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Croatian Association for Construction Management

University of Zagreb, Faculty of Civil Engineering

13TH INTERNATIONAL CONFERENCE

ORGANIZATION, TECHNOLOGY AND MANAGEMENT IN CONSTRUCTION

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HRVATSKA UDRUGA ZA ORGANIZACIJU GRAĐENJA
CROATIAN ASSOCIATION FOR CONSTRUCTION MANAGEMENT

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SVEUČILIŠTE U ZAGREBU GRAĐEVINSKI FAKULTET
UNIVERSITY OF ZAGREB FACULTY OF CIVIL ENGINEERING

University of Zagreb, Faculty of Civil Engineering

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Foreword

Dear Colleagues, dear Friends,

On behalf of the Organising Committee, it is my great pleasure to welcome you to the 13th OTMC, International Conference. The Conference has been designed to provide the overview of the actual research in the field of organisation, technology and management in construction, but also to host the meeting of IPMA Megaprojects Special Interest Group. We believe that combination of two related topics will contribute to the quality of meeting and its reaches.

Many distinguished academics and practitioners have joined the Conference. We have 6 highly interesting keynote speakers and more than 120 authors of papers from 21 countries and five continents who will be presenting during plenary and parallel sessions. The parallel program of IPMA Megaproject Special Interest Group with participation of numerous top class experts in different aspects of all the kinds of megaprojects will be available for all participants.

As a part of the Conference it will be organised the Research workshop on project management, aimed to bring together young and experienced researchers to discuss the actual topics of research, research methodologies and many other to improve the future of project and construction project management.

Beside the scientific and academic content of the Conference we traditionally organise the round tables and discussion panels on actual professional topics. This time there are two round tables, the first one is on the development of the national guidelines for implementation of BIM, and the second one on experiences and criticism of application of the existing regulation for managing construction projects.

We would like to express our thanks to patrons of the Conference same as to sponsors and all the partners for their generous support to make this Conference successful.

We hope that you will enjoy the Conference and that your interaction with your colleagues from many different countries will stimulate a creative exchange of ideas and will be personally rewarding. We also hope and trust that you will enjoy your visit to the very beautiful Croatian coast and the city of Poreč.

Yours sincerely,

Prof. Ivica Završki, Ph.D.

Chair of Organizing Committee

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PAPERS IN CROATIAN LANGUAGE

General Management and Economics in Construction

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Construction and Project Management Issues

Project Implementation Units of EU co-financed Water Projects

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Abstract:

Management of public projects in the Republic of Croatia is an actual topic from professional, scientific and legal point of view. Due to the changes in the system of management and control of EU funds in Croatia, changes in the national law, as well as larger growth of professional interest and need for project management knowledge and skills acquisition, it is useful and interesting to explain genesis, structure and role of Project Implementation Units. Project Implementation Units are project organizations responsible for management of implementation of EU co-financed water projects in Croatia. This article shows their mission, role, composition and organizational scheme, as well as their relationship with parent organization and Croatian Water as an Intermediate Body of Level 2. Examples of created Units are given, as well as practical guidelines for their future development. The purpose of the article is explanation of project management and Project Management Units' importance in terms of EU co-financed public water projects, as well as creation of guidelines for future praxes. Findings from five different case studies are interesting and useful for institutional system of management and control of EU funds in Croatia, national water management, utility companies, end users of water projects and civil engineers occupied on water and other public projects. These findings are important in terms of familiarization with new praxes and regulations, learning and continuous improvement on the field of construction management and economy.

Keywords: *project management; water sector; European Union; Project Implementation Unit*

1. Introduction

Project management is the application of knowledge, skills, tools, and techniques to project activities in order to meet the project requirements (PMI, 2013). The usefulness of successful project management in achieving project success is undoubtedly shown through large scale of different studies (Mir and Pinnington, 2014; Papke-Shields et al., 2010; Han et al., 2012). These findings have special importance when it comes to public construction projects, due to the fact that they have a larger set of goals to fulfil in contrast to private ones. According to Project Cycle Management Guidelines (European Commission, 2004), project is a series of activities aimed at bringing about clearly specified objectives within a defined time-period and with a defined budget. In the context of the Logical Framework Matrix, a project is defined in terms of a hierarchy of objectives (inputs, activities, results, purpose and overall objective) plus a set of defined assumptions and a framework for monitoring and evaluating project achievements

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(indicators and sources of verification). For instance, public good, satisfaction of end users and larger society with the final product, environmental and energy efficiency, preservation of health and safety, as well as accordance of the project outputs and impacts with distinct policies (national, EU, institutional etc.) come ahead of traditional measures of project success in terms of schedule, budget and quality. That is the main reason why it is vitally important to educate, disseminate, apply, implement and continuously improve project management knowledge, skills, standards, methods, techniques, tools and praxes.

This message has already been recognized by the European Union as well as national legislator in the Republic of Croatia. Namely, Croatian Act on Physical Planning and Building Tasks and Activities (Official Gazette 78/15) defines activities of construction management and obligation of public investor to appoint project manager for investments in construction of infrastructural and other structures with total investment value larger than 10.000.000,00 HRK (approx. 1,3 mil EUR) excluding VAT, as well as investments in construction of buildings with total investment value larger than 50.000.000,00 HRK (approx. 6,7 mil EUR) excluding VAT. The Law also defines conditions that project manager must satisfy. This is applicable to all public projects in the Republic of Croatia, which is also member state of the European Union. That means that for all EU co-financed projects in Croatia, additional set of rules must be taken into consideration. When it comes to project management, EU has ramified guidelines, directives, forms and documents that should be applied to co-financed projects.

This article will explain the main project management principles through management of EU co-financed projects in water sector in Croatia, mainly focusing on Project Implementation Units (PIUs), with a purpose of contribution to knowledge and praxes of public projects' management and creation of useful guidelines for future development. In order to achieve this purpose, article is divided into three parts. In the first part, general regulation regarding project management and Project Implementation Units is given. In the second part, three case studies of water projects are explained in order to show how PIUs work in everyday operational and managerial sense. In the last part, guidelines for PIUs' development are given. These guidelines can be useful for all participants involved in institutional system of management and control of EU funds in Croatia and/or national water management, personnel of utility companies, end users of water projects, civil engineers occupied on water and other public projects, as well as other professionals dedicated to the various area of project management.

2. Project management of EU co-financed projects

Project management is relevant topic for the European Union. In 1992 the European Commission (EC) adopted "Project Cycle Management" (PCM) as its primary set of project design and management tools (based on the Logical Framework Approach), and a first PCM manual was produced in 1993. The manual was subsequently updated in 2001 and 2004, and it provides:

• A description of the policy framework within which EC development assistance is provided, and the role of the project in relation to other aid delivery modalities;
• An operational framework within which staff of the RELEX family (EuropeAID, DG Development and DG External Relations) and other stakeholders can make effective and timely decisions related to Project Cycle Management;

• A description of key tasks, quality assessment criteria, documented information requirements and decision options at each stage of the cycle;
• A description of key tools that support effective PCM; and
• A resource to support training in PCM (European Commission, 2004).

Establishment of special unit in charge of project management is not novelty when it comes to projects, especially those of more complex structure and organization. The need for implementation of special unit, besides common and classical reasons defined in numerous manuals, is even more expressed in complex environment of EU co-financed projects.

Therefore, Project Implementation Units have been developed in water sector in order to contribute to smooth application of these and other general main principals and politics given in:

• EU Regulation No 1303/2013 of the European parliament and of the Council of 17 December 2013 laying down common provisions on the European Regional Development Fund, the European Social Fund, the cohesion Fund, the European Agricultural Fund for Rural Development and the European Maritime and Fisheries Fund and laying down general provisions on the European Regional Development Fund, the European Social Fund, the Cohesion Fund and the European Maritime and Fisheries Fund and repealing Council Regulation No 1083/2006,
• Financial Regulation applicable to the general budget of the Union and its rules of application (EC, 2013)
• Guide to Cost-benefit analysis of investment projects – Tool for economical assessment of cohesion policy 2014-2020 (EC, 2015)
• Reforming Technical Cooperation and Project Implementation Units for External Aid provided by the European Commission - A Backbone Strategy (EC, 2008)
• etc.

These documents underline the importance of economical and efficient use of EU grants. To do this, successful management is necessity, especially in the part of project implementation, where most of project expanses are made, spent and verified. Manual on PCM defines five phases in EU co-financed project (Figure 1) as: programming, identification, formulation, implementation and evaluation and audit. The phase that will be in focus of this article is therefore the implementation phase, in which Project Implementation Units find their purpose and application.

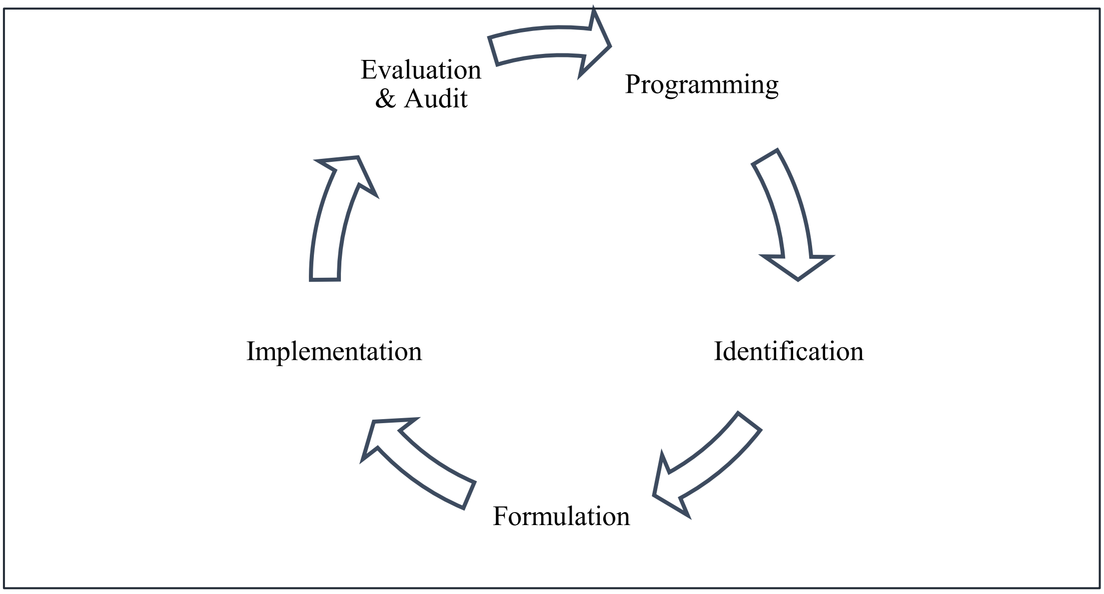

Figure 1. Project cycle (source: European Commission, 2004)

The importance of effective project management is also reflected in the increased focus on project management in the new EU financial regulation 2014-2020. Experience in the implementation of projects in financial perspective 2007-2013 showed insufficient emphasis on the importance of quality project management, resulting in difficulties in the implementation, as well as failures in achieving project goals. European Commission recognized proper project management as one of the key elements of project success, when defining the legislative framework for using EU funds and developing rules and regulations for financial perspective 2014 – 2020.

When requesting EU assistance for his project, beneficiary needs to demonstrate his capacity to implement the project, as well as to secure project short and long term sustainability.

It is necessary for a project beneficiary to explain technical, legal, financial and administrative capacity of its organization in project application forms of European fund for Regional Development / Cohesion fund: "Investment in infrastructure / A manufacturing investment" - part A.4. "Capacity of the body responsible for project implementation". At exactly this point PIUs became inevitable. When speaking in water sector terms, beneficiary (that is, utility company) must demonstrate its organizational capacity to manage the project successfully, in order to receive grants for its project. If the beneficiary is not capable to do so with its internal resources, they should consider their need for technical assistance. Beneficiaries should bring up institutional mechanisms and organizational structure like Project Implementation Units, which shall demonstrate their capability to carry out planned activities and to achieve specific project goals. Project management cost is acceptable for EU funding, irrespective of whether funds are used to pay for internal resource costs or engagement in external technical assistance.

3. Project Implementation Units: guidelines

Project Implementation Units (commonly referred to as project management units, project management consultants, project management offices, project coordination offices, etc.) are dedicated management units designed to support the implementation and administration of projects or programmes (European Commission, 2008). According to A Backbone Strategy on Reforming Technical Cooperation and Project Implementation Units for External Aid provided by the EC (2008), PIUs are typically required to perform tasks regard to the implementation of a project or programme: monitoring and reporting on technical and/or financial progress, accounting, procurement of works, goods and services, drawing-up terms of reference, contract supervision, detailed design or equipment specification.

Project Implementation Units are not exclusively brainchild of European Union. Namely, World Bank, Asian Development Bank and many other global, regional and local institutions implement those in order to speed up efficiency of project management. World Bank for instance, has had PIUs as a usual praxes on their projects for a quiet of time. But, although Bank found PIUs useful, they stress the fact that the degree of PIUs integration into existing institutions is positively correlated with the projects' contribution to capacity development of the implementing agencies (World Bank, 2005; Asian Development Bank, 2005). That is the main reason why it is important to strengthen internal capacities of managing projects on every level, especially beneficiaries' level.

Beneficiaries of EU funds are utility companies in the Republic of Croatia. Croatian communal sector is quite fragmented with 150 utility companies, many of which are unable to independently manage these complex projects, which by their size even exceed the size of budget of their owners or units of local self-government.

The consolidation of utilities sector is a part of the water management strategy and is one of the key prerequisites for more rational management of public water utility systems.

Based on that, establishment of effective project management system thought dedicated PIUs becomes even more important. A greater number of smaller utility companies with similar organization, allows certain standardization in establishing PIUs and defining their roles and responsibilities.

However, there are already examples of good practices for consolidating utilities (e.g. Vodovod i odvodnja Zagrebačke županije d.o.o. as a consolidated company created by merging five utility companies, which allows them to successfully apply for large EU funded project, with investment value greater than 70 million EUR, as well as several smaller projects). Such consolidated utility companies will be able to organize their project management structure differently, with more complex forms of project management then described in this article, but, for majority of cases, PIUs as described here will serve their purposes.

In water sector, PIUs have task to prepare project's execution and manage project's performance regarding modern project management methods' application in order to fulfill planned implementation goals of a project, especially those related to planned costs, given deadline, specified quality, compliance with laws, regulations and rules of profession (both Croatian and European), with efficient work of all participants and client's satisfaction. PIU has special task to carry out an execution of a project on a way that will be verified by Intermediate body of Level 2 (Croatian Water, Sector for EU co-financed projects in Croatian Water), for parts of specific goals under priority axes "Climate changes and risk management" and "Environment protection and resource sustainability" in management structure of Operational Programme "Competitiveness and Cohesion 2014-2020".

In the following parts PIUs' elements will be explained, based on Guidelines for forming Project Implementation Units for implementation of EU co-financed projects: for projects financed through Operational Programme Competitiveness and Cohesion 2014-2020. (Croatian Water, 2017).

Guidelines for forming Project Implementation Units for implementation of EU co-financed projects (Croatian Water, 2017) define a large scale of areas:

- definition of PIU's tasks
- procedures of competencies verification and PIU's work results check
- definition of competencies needed in PIU
- definition of PIU's activities
- definition of PIU's composition
- organizational structure representation: quantitative and qualitative members' determination inside PIU, regarding project complexity
- guidelines on PIU costs calculation
- advisory on procedures which PIU are obligatory to apply during project execution management
- advisory on communication inside PIU and other project participants
- link between PIU and parent organization
- use of ICT tools for project execution management.

In Section 3, only the most important and interesting parts will be shortly explained, and then tested on five case studies, results of which are shown in Section 4.

3.1 Required competencies in PIU

Competencies of PIUs' members must be in accordance with international standards, because EU co-financed projects are occurring within international context, in which the highest standards and results are required.

Project manager within PIU should obligatory have these competences:

- Project management – knowledge and practice in accordance to international standards
- Technical knowledge and practice from an area in which project is being executed
- Capability to work with people and organization

PIU team members should have these competencies:

- Project management – knowledge and practice in accordance to international standards on a level of project assistant
- Specialist knowledge and practice from an area that they cover within PIU

3.2 PIU tasks

PIU carries out entrusted task given goals' achievement in project implementation phase, mostly by competent project management, with a respect to given frames of project delivery due to technical documentation, laws, regulations and standards (both national and EU). Tasks that PIU will carry out should be documented through "Project management manual", which should include:

- General project information

- Project scope according to the WBS structure (deliveries' components)
- Project goals (project delivery) and project management goals (regarding time, budget, quality and other specific goals)
- Analysis of project stakeholders
- Organizational structure of project execution
- PIU composition with roles and responsibilities
- Project implementation schedule
- Project costs and financing plan
- Analysis of key risks and constraints for project implementation
- Communication while implementing the project and the way of project information distribution
- Administration and document management procedures
- Other, if necessary.

This document should be checked at the beginning and during the implementation, as well as revised at the end of a project, in order to evaluate goals, risks, changes and constraints that occurred on project, and to document lessons learned.

3.3 PIU composition and organisation structure

PIU composition depends on project complexity. PIU members can be permanent or temporary. Permanent members are 100% involved on project and they do not perform other tasks. Permanent PIU members should be project manager and different number of team members based on complexity and size of each particular project. Main competencies, roles and responsibilities of PIU member regardless permanent or temporary can be seen in table 1.

Table 1. Competencies, roles and responsibilities of PIUs' members (Croatian Water, 2017)

Role	Competence	Profession	Responsibilities
Project manager – PIU leader	Project management, knowledge on EU projects	- Technical (construction)	- Managing project implementation - Fulfilling project goals and performance goals, with a respect to law and iron triangle - Making of Project management manual - Leading of project team - Organization and communication - Decision making regarding contractors and suppliers - Establishment of motivating working atmosphere, conflict management - Timely and correct reviews
Project manager deputy	Project management	- Preferably technical (construction)	- Assistance in managing all project issues - Analytical planning - Monitoring of financial plan and schedule - Monitoring of project regarding "Project management manual"

			- Efficient working procedures - Reporting on all aspects of project - Monitoring and control of all aspects of project implementation
(Certified) civil engineer	Project management associate	- Technical (construction)	- Assistance in managing, monitoring and control - Controlling of execution in accordance to technical documentation, laws and regulations - Leading of operative meetings with contractors and subcontractors - Leading project's administration tasks
Project manager associate	Project management associate	- Any: economical, law, technical, administrative, etc.	- Assistance in managing all project performance questions - Dealing with remaining issues

Roles visible in table 1 are those that should always be engaged in PIU. In wider composition, PIU can also consist of other employees necessary during some temporary amount of time or due to some specific expertise that is temporary necessary. They work inside their parent organization and work only part-time on project. They can be:

- Specialists (for different project specific tasks, e.g. lawyers, technologist, etc.)
- Consultants (for different project specific tasks, e.g. claim expert, EU regulation expert)
- Supporting and administrative stuff.

Organizational scheme of PIU is quite simple (Figure 2). PIU consists of PIU's leader, his/her deputy and three sub-teams.

PIU's leader is a key role regarding competencies, position and responsibility for project implementation. Leader's deputy is oriented on all project aspects, and manages project with project manager. PIU's members who have technical profession manage all technical aspects of project execution, with a respect to project management support. PIU's members who support management of the project are responsible for all performance issues assigned to them by project manager. They work inside their specialties (economical, administrative, law, technological, etc.), but as well have project management competence, and work beyond their narrow specialty, having broader set of project goals always on mind.

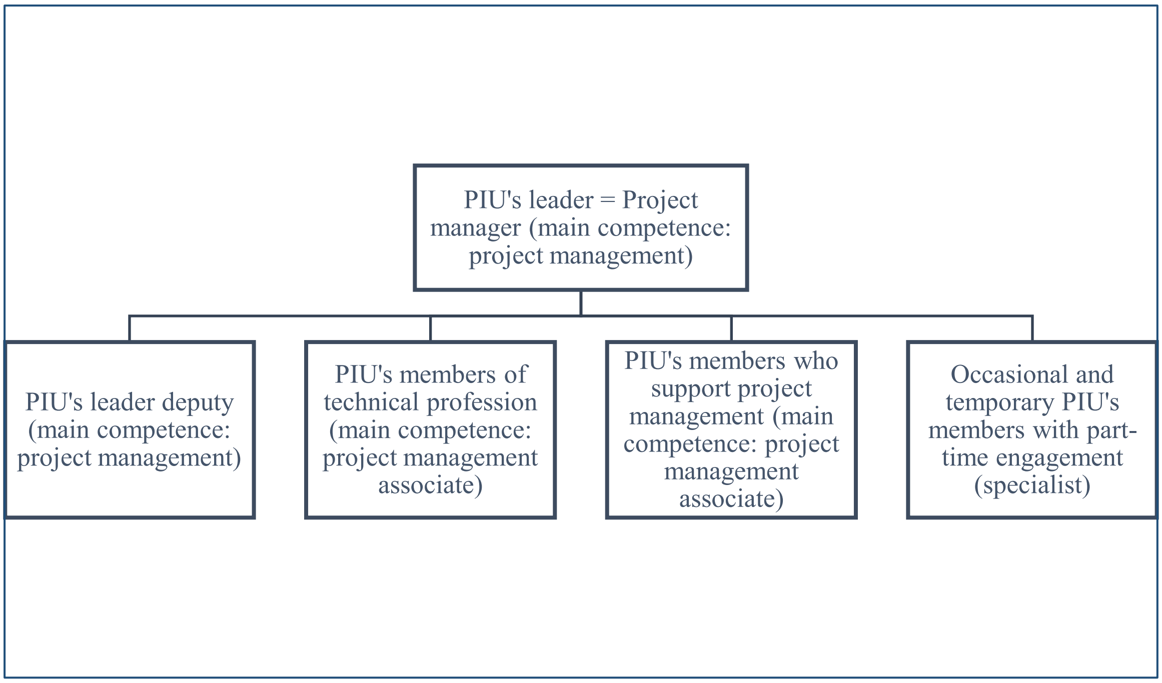

Figure 2. PIU organizational scheme (Croatian Water, 2017)

Number of permanent PIU members should be between 1 to 5, depending on project size and complexity (Table 2).

Table 2. Number of PIU's members (Croatian Water, 2017)

Project according to management complexity	Number of permanent PIU's members	Number of temporary PIU's members
Complex project	3-5	2-4
Medium complex project	2-3	1-2
Simple project	1-2	1-2

Project complexity can be defined according to total project cost and number of stakeholders. Proposal of such projects' classification is given in Table 3. It is important to note that project's complexity is defined according to each of requirements. For final management complexity, the highest rank according to two conditions is applicable (i.e. project complexity class is function of max (total project cost; stakeholders number)).

Stakeholders groups are all those groups who may affect, be affected by, or perceive itself to be affected by a decision, activity, or outcome of a project (Project Management Institute, 2013).

Division of project based only on project cost and number of stakeholder is based on nature of project in water sector which are almost identical to its purpose and planned activities, namely construction of water supply and sewerage network, and construction of waste water treatment plant(s).

Table 3. Proposal of projects' classification regarding management complexity (Croatian Water, 2017)

Projects classification regarding management complexity	Total project cost (mil. EUR)	Number of stakeholders (groups)
Complex project	≥ 50	≥ 20
Medium complex project	10 -50	≥ 10
Simple project	< 10	< 10

3.4 Relationship between PIU and parent organization

Parent organizations of PIUs are utility companies, which are also beneficiaries of project deliverables and beneficiaries of EU grants. Relationship between PIU and parent organization depends on project complexity and size of utility company.

Large company / beneficiary has praxes of project performance management, capability of understanding of EU project implementation procedures, and functional organizational structure with specialized departments or units. Number of employees exceeds number 50, and has 5 to 10 highly qualified employees. But, in Croatian praxes, even the large beneficiaries have problems in managing projects and project performance management, in spite the fact they have some relevant experience on that field.

Small company / beneficiary does not have developed organizational structure and has less than 50 employees, from which up to five of them are highly educated. There are no praxes of permanent or temporal project performance and there is no experience in managing EU projects' implementation.

According to combination of project complexity and utility company size, two types of structure is possible: deepened structure and expanded structure (Table 4; Figures 3 and 4).

Table 4. Relationship between company size, project complexity and PIU - parent organization structure (Croatian Water, 2017)

Utility company size	Project complexity	PIU – parent organization type of structure
Large company / beneficiary	Simple project	Deepened structure
	Medium complex project	Deepened structure
	Complex project	Expanded structure
Small company / beneficiary	Simple project	Expanded structure
	Medium complex project	Expanded structure
	Complex project	Expanded structure

Deepened structure, applicable for large beneficiaries implementing simple or medium complex projects, can be seen on Figure 3. PIU is under supervision of project sponsor i.e. head of some specific department, who is responsible to company's board.

On the other hand, extended structure, applicable for small beneficiaries and complex projects, establishes project sponsor or project committee outside of functional departments, lining it between board and PIU (Figure 4). For small beneficiaries and simple projects, it is possible to form expanded structure without project sponsor, because all relevant decisions are directly communicated between PIU and board.

Project sponsor or project committee should be responsible for strategic governance of project goals, and support PIU in project implementation.

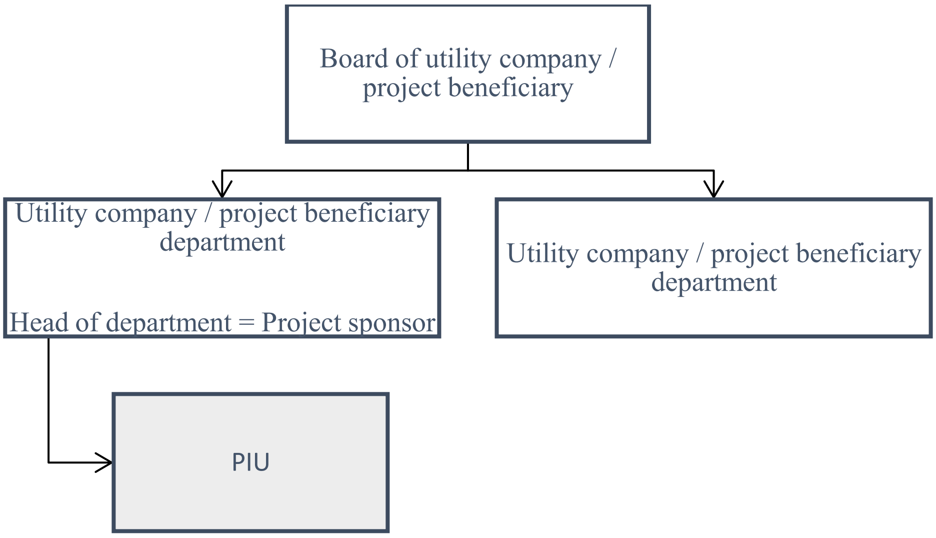

Figure 3. PIU and parent organization: Deepened structure (Croatian Water, 2017)

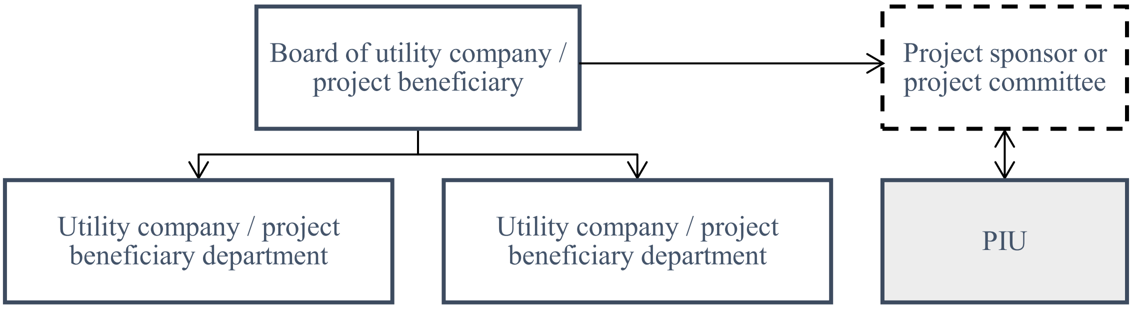

Figure 4. PIU and parent organization: Extended structure (Croatian Water, 2017)

3.5 Communication between PIU and project participants

Communication is one of the most important factors influencing project success, as well as one of the greatest causes of problems and conflicts on projects. Communication task is to satisfy project participants' need for information, where information are only those facts that have special importance for their receivers.

Communication can be developed in two directions:

- Internal communication: communication of direct participants that participate in project implementation.
- External communication: communication with stakeholder groups that influence on project execution or have a specific interest for project.

PIU should be responsible for development of project communication plan, which has to answer these questions:

- Who needs which information?
- When will the information be delivered?
- By which mean will the information be delivered?
- Which information should be archived and how?

PIU has a special task to communicate all project information related with project implementation with: parent organization, contractors and suppliers, Intermediate Body of Level 2 and external stakeholders. Basic scheme of communication processes is given on Figure 5.

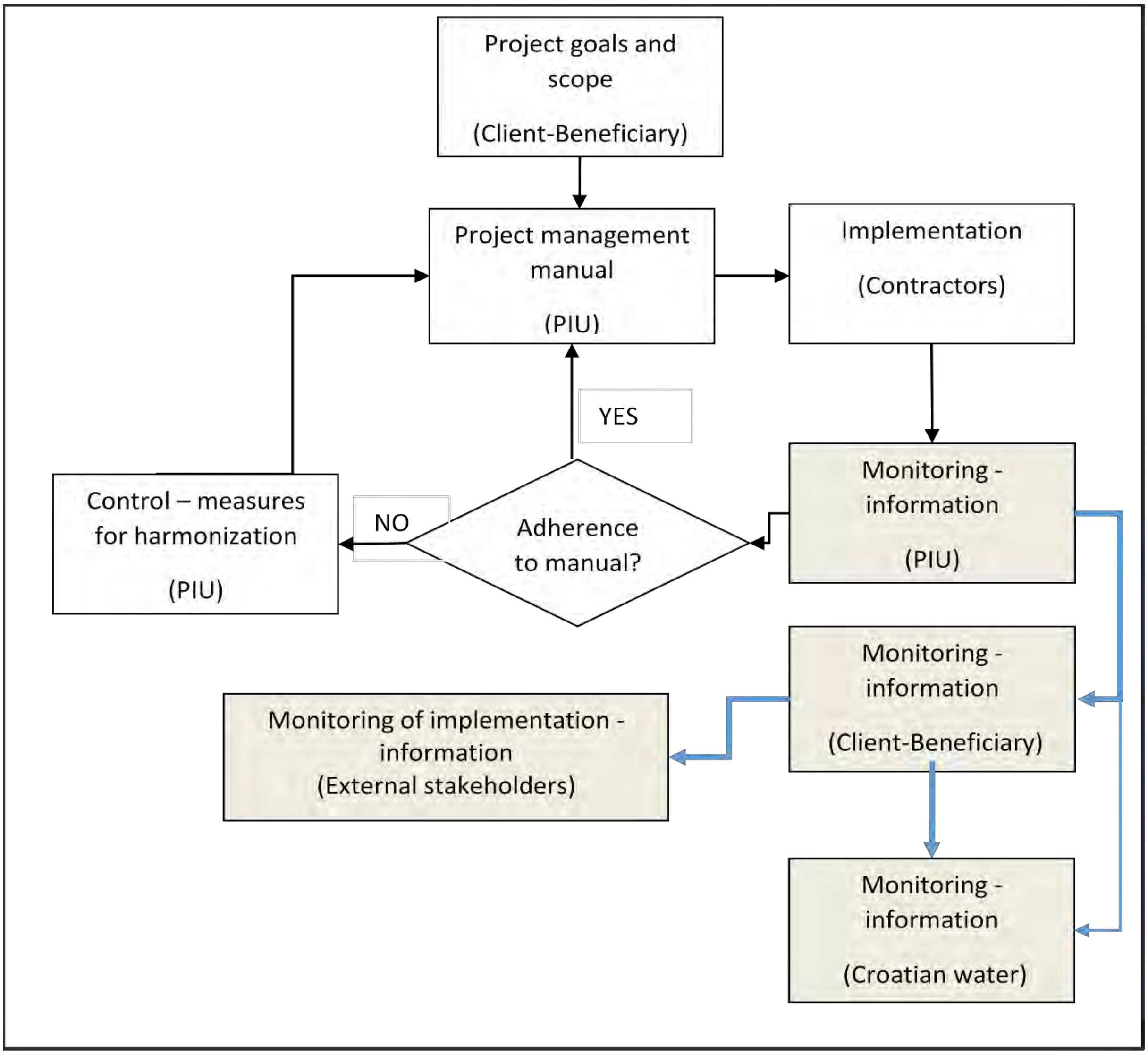

Figure 5. Basic scheme of implementation monitoring process and communication flow (Croatian Water, 2017)

4. Project Implementation Units: case studies

This part of the article will explore to which extend do actual Project Implementation Units follow guidelines brought out in previous chapter. Namely, explanation of PIUs' competencies, tasks, composition and structures, relationship with parent organization and communication plans represent good praxes and planned elements of PIUs in water sector. However, few PIUs have already been implemented due to the changes in project application procedure and forms explained before. The aim of this part is therefore to see how do these, implemented PIUs function on EU co-financed projects, and bring clear directions on future development. Up to this point, PIUs exist on five EU co-financed water projects. All characteristics explained before are tested on these projects.

4.1. PIUs' analysis

Five different EU co-financed water project are analyzed. Results of this analysis is given in tables 5-7.

Table 5. EU co-financed water projects with PIUs: characteristics – part 1

Project label	Total cost category (mil. EUR)	Number of stakeholders	Complexity	Number of PIU members		Company size	PIU structure
				Permanent	Temporary		
A	10-50	13	Medium complex	5	Outsourcing, if necessary	Small (11)	Simple extended structure, project sponsor is company's director
B	≥ 50	12	Complex	11	Outsourcing, if necessary (3)	Big (69)	Simple extended structure, project sponsor is company's director
C	10-50	14	Medium complex	5	Outsourcing, if necessary (2)	Big (129)	Simple extended structure, project sponsor is company's director
D	10-50	14	Medium complex	3	Outsourcing, if necessary	Small (42)	PIU is outside of the company
E	10-50	17	Medium complex	8	Outsourcing, if necessary	Big (356)	Simple extended structure, project sponsor is company's director

After collection of information on project costs, number of stakeholders, number of PIU members and company size, further analysis is made on projects' complexity and PIU structures implemented on them. It is important to note here that stakeholders have been defined as: consultants in charge for feasibility studies, designers, contractors, supervising engineers, and co-financiers (Ministry as Intermediate Body of Level 1, Croatian Water as Intermediate Body of Level 2, beneficiaries, cities/municipalities and counties).

It can be seen that 4 out of 5 projects are medium complex, and one of them is complex. However, all projects have simple extended PIUs, which is convenient in case of very simple project and/or small beneficiary. This can be explained only in case A, even in case D some sort of project sponsor is required due to the fact that complete PIU is outsourced.

Table 6. EU co-financed water projects with PIUs: characteristics – part 2

Project label	Communication plan	PM document	PIU tasks	Composition and PIU member label

A	No official plan	- No official PM document - Dynamical plan of PIU members' engagement - Obligations of each PIU member	- Project implementation monitoring - Public procurement - Cash flow monitoring - Takeover - Supervision of WWTP work in guarantee period	- Project manager (A1) - Project manager deputy (A2) - Legal expert (A3) - Financial expert (A4) - Administrator (A5)
B	No official plan	- No official PM document - Dynamical plan of PIU members' engagement - PM part of feasibility study	- Project implementation preparation - Project implementation monitoring	- Project manager (B1) - Project manager deputy (B2) - 5 engineers / technical experts (B3, B4, B5, B6, B7) - Administrator (B8) - 3 assistants (B9, B10, B11) - 3 outsourced experts; if necessary: legal expert, financial expert and technical expert (B12, B13, B14)
C	No official plan	- No official PM document - Dynamical plan of PIU members' engagement - PM part of feasibility study - Obligations of each PIU member	- Project implementation monitoring - Public procurement - Cash flow monitoring - Takeover - Supervision of WWTP work in guarantee period	- Project manager (C1) - Project manager deputy (C2) - Legal expert (C3) - Financial expert (C4) - Administrator (C5) - 2 outsourced experts; if necessary: lawyer, and technical expert – engineer (C6, C7)
D	No official plan	- No official PM document - Outsourcing planned through feasibility study	- Project implementation monitoring	- Project manager, outsourced (D1) - Project manager deputy, outsourced (D2) - Technical expert (D3)
E	No official plan	- No official PM document - Dynamical plan of PIU members' engagement - PM part of feasibility study	- Project implementation monitoring - Public procurement - Cash flow monitoring - Takeover - Supervision of WWTP work in guarantee period	- Project manager (E1) - 2 project manager deputies (E2, E3) - Public procurement expert (E4) - Financial expert (E5) - Assistant (E6) - 2 technical experts – engineers (E7, E8)

From information given in Table 6, it can be stated that no PIU has official communication plan. Even more important, they have no official document on project management – Project management manual. PIUs' tasks are mostly defined through feasibility studies or decisions on PIUs' formation, as well as PIUs' member tasks and responsibilities given in table 7.

Table 7. EU co-financed water projects with PIUs: characteristics (2)

PIU member role	PIU member labels	PIU member tasks and responsibilities
Project manager	A1, B1, C1, D1, E1	- Execution of all beneficiary obligations due to the Grant contract - Monitoring of Contract realization and secondary contracts implementation - Communication with FIDIC engineer - Construction site supervision - Project coordination - Photo documentation of works - Meetings with FIDIC engineer and/or Contractor - Keeping project diary - Monitoring of supervisor engineer, FIDIC engineer and Contractor - Monitoring of physical project realization - Preparation of Requests for reimbursement and all accompanying documentation for IB2 - Reporting on project status - Coordination of PIU members - Decision making
Project manager deputy	A2, B2, C3, D2, E2, E3	- Monitoring of secondary contracts implementation - Construction site supervision - Project coordination - Photo documentation of works - Irregularities management - Monitoring of supervisor engineer and Contractor - Monitoring of physical project realization - Preparation of Requests for reimbursement and all accompanying documentation for IB2 - Reporting on project status - Procurement bids evaluation - Other tasks from project manager
Legal expert	A3, B12*, C3	- Tender preparation - Procurement bids evaluation - Complaints management - Contract management - Preparation of ex-ante and ex-post procurement control documentation for IB2 - Dealing with all law and regulative aspects of project - Other tasks from project manager
Public procurement expert	E4	Not defined.
Financial expert	A4, B13*, C4, E5	- Execution of all payment procedures - Calculation control of construction situations - Assure financial funds for contractors' payment - Procurement bids evaluation - Dealing with all financial aspects of project - Other tasks from project manager
Technical expert – engineer	B3, B4, B5, B6, B7, B14*, C7*, D3, E7, E8	- Monitoring of construction and construction sites - Photo documentation of works - Irregularities management - Monitoring of supervisor engineer and Contractor - Monitoring of physical project realization
Administrator	A5, B8, C5	- Correspondence (post, fax, e-mail, phone) as a central person for information flow - Receiving, sending and archiving of all documentation according to ISO 9011

		- Organization and archiving of all project documentation - Internal tracking of project documentation - Other tasks from project manager
Assistant	B9, B10, B11, E6	Not defined.
Lawyer	C6*	Not defined.

4.2. Recommendation based on PIUs' analysis

What can be seen from information given in previous part of the article is that PIUs are implemented on five different EU co-financed water project. With a further look in facts brought up in tables 5 – 7, following observations can be made:

- Official project management document does not exist as a result of integrated PIUs' activities. Some parts of PIUs' activities are given through other documents, such as: feasibility studies, application forms, internal beneficiaries' decisions on consisting PIUs, addendum to PIU members' working contracts, schedule and financing plans from Applications for Reimbursement. Although project goals, project management goals, organizational breakdown structure, PIU's composition and roles and responsibilities, schedule and cost / financing plan do exist in some forms, those information are scattered. General recommendation is to make Project management manual as a paper that integrates all these information at the same place. On that way, it would be possible to effectively monitor and control all main project aspects and extract information necessary for different kind of project reviews, and consequently, improve project implementation.
- All PIUs except PIU on project D, are constituted within beneficiaries organizations. This indicates a strong wish to keep project decision-making "in house", which is not a problem if project interest is in the forefront and if beneficiaries have adequate competencies to manage their project successfully. Critical and objective measures of organizational capacity is needed before bringing final decision on who would manage project. Beneficiaries should search for quality personnel which can suit to predefined competence on project management, in number defined through project complexity. If such personnel is not available internally, it should be outsourced. No matter if PIU is mostly internal or outsourced, it is very important to define project management responsibilities and liabilities, mostly through special decisions or contracts.
- In addition, it is interesting to see how PIUs work in their relation to parent organizations. No project has deepened nor fully expended structure, as it was initially planned. They just work as an additional department of utility companies, with project manager on head of them. Other members mostly work only part-time on project, and the rest on their regular places within parent organization, which is an example of matrix organization. But, the most important thing is that there is no project sponsor (or project committee) in official sense. This committee would solve many problems with decision-making and communication between beneficiary's board, project manager, contractor and engineer, as well Croatian Water as Intermediate Body of Level 2. It is very important to communicate with all stakeholders and project participants in timely and correct manner, but also to take care of project governance from more strategic point of view. Project sponsor or committee could improve this area of project strategic management.
- When it comes to roles and responsibilities of PIUs' members, they can be divided in four main groups: project manager, project manager deputy, stuff that support project

management and other temporal members. There are legal and financial experts on most projects, which is not a problem if they are capable to manage some parts of project beyond their initial specialties. From the description of their tasks it can be seen that they work only within their narrow specialties. Those tasks are undoubtedly important, but, what is even more important is an accent on project management. PIU permanent members should be those who are capable to manage a project as a whole, regardless of their specialty. Specialists or consultants can then always be outsourced if necessary. This is why it is crucial to educate people in field of project management knowledge and praxes, so they can broaden their view from technical to more contextual and behavioristic point of project view.

- No official risk management or stakeholders' management is being made within PIUs. These procedures are extremely important in managing infrastructure projects with large number of different stakeholders, and never sleeping risks, constraints and changes. If there were no risks, constraints or changes, project management would be quite easy, which is not the case (Radujković and Sjekavica, 2017). Implementation of those procedures would highly help PIUs in carrying out their tasks.
- As it has been stressed before, it is vitally important to educate, strengthen capacity and disseminate project management knowledge, standards and best praxes. Only by the means of education, real, measurable improvement in praxes can be made.

Based on these observations authors' recommendations on PIUs' implementation are:

- Make Project management manual as a basic document that integrates all project management information at the same place.
- Define the need for project management stuff based on project complexity. If quality personnel for managing project cannot be found within the parent company, outsource it.
- Form project sponsor or committee in order to communicate with stakeholders and improve project strategic governance.
- Implement risk management and stakeholders' management in PIU procedures.
- Educate people within project management field, so they can be capable to broaden their view from their narrow specialties to the comprehensive project view.
- Strengthen project management field by the means of education and learning on project management competences.

5. Conclusion

Project management has become ineluctable lever in achieving project success, which is especially important on public projects, such as are those in water sector. Project Implementation Units can highly help in implementation of physical, financial, time and resource management in central project parts. PIUs were implemented on five EU co-financed projects. Those cases are put in context of requirements and recommendations given in Guidelines for forming Project Implementation Units for implementation of EU co-financed projects (Croatian Water, 2017). Analysis of PIUs is made in order to improve present praxes, and general recommendations for improvement are drawn up.

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References

Act on Physical Planning and Building Tasks and Activities, Official Gazette 78/15.

Asian Development Bank (2005), The Role of Project Implementation Units.

Croatian Water (2017), Guidelines for forming Project Implementation Units for implementation of EU co-financed projects: for projects financed through Operational Programme Competitiveness and Cohesion 2014.-2020., Zagreb.

European Commission (2004), Project Cycle Management Guidelines, EuropeAid Cooperation Office, Brussels.

European Commission (2008), Reforming Technical Cooperation and Project Implementation Units for External Aid provided by the European Commission: A Backbone Strategy, Publications Office of the European Union, Luxembourg.

European Commission Directorate-General for Regional and Urban policy (2015), Guide to Cost-benefit analysis of investment projects – Tool for economical assessment of cohesion policy 2014-2020, Publications Office of the European Union, Luxembourg.

European Union (2013), Financial Regulation applicable to the general budget of the Union and its rules of application: Synoptic presentation and a selection of legal texts relevant to the budget, Publications Office of the European Union, Luxembourg.

Han, W.S., Yusof, A.Md., Ismail, S., Aun, N.C. (2012), Reviewing the Notions of Construction Project Success, International Journal of Business and Management, Vol. 7, No.1, pp. 90-101.

Mir, F.A., Pinnington, A. (2014), Exploring the value of project management: Linking Project Management Performance and Project Success, International Journal of Project Management, No. 32, pp. 202-217.

Papke-Shields, K.E., Beise, C., Quan, J. (2010), Do project managers practice what they preach, and does it matter to project success?, International Journal of Project Management, Vol. 28, No. 7, pp. 650-662.

Project Management Institute (2013), A Guide to the Project Management Body of Knowledge (PMBOK® Guide)—Fifth Edition, Project Management Institute, Philadelphia.

Radujković, M., Sjekavica, M. (2017), Razvoj modela za poboljšanje uspješnosti upravljanja projektom analizirajući rizike, promjene i ograničenja, Građevinar, Vol. 69, No. 2, pp. 105 -120.

Regulation (EU) No 1303/2013 of the European Parliament and of the Council of 17 December 2013 laying down common provisions on the European Regional Development Fund, the European Social Fund, the Cohesion Fund, the European Agricultural Fund for Rural Development and the European Maritime and Fisheries Fund and laying down general provisions on the European Regional Development Fund, the European Social Fund, the Cohesion Fund and the European Maritime and Fisheries Fund and repealing Council Regulation (EC) No 1083/2006, Official Journal of the European Union, L 347, pp. 320-469.

World Bank (2005), Guidance Note for Project Management Strengthening Institutional Capacity during Project Implementation.

The Impact of Risk on Bid Price and Project Budget for Contractors

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Abstract:

Estimate of risk is an essential process in management of all business systems, especially those which deal with execution of construction works, and it significantly affects their competitiveness and operation stability. Business decision-making requires identification of potential risks and estimation of their impact on projects and the whole system.

This paper presents results of research of estimation of risk impact to the formation of contractor's bid price and budget for construction projects. The presented results identify and estimate project risk impact to the contractor's budget during the tender phase for execution of construction projects which are implemented by calculation method "of applying unit prices according to really executed works calculated in accordance with the BoQ".

During creation of bid price, risk project impacts apply to the total cost of labor, materials, other's services, machinery, equipment, and general indirect costs of construction site. Impact estimation of other business risks to the project budget is conducted through the impact estimation of business risks to the total indirect intermediary costs of business system which is transmitted to project budget. Negative risk impact is introduced to all components of bid price and project budget as well as the entire business system. Using this model it is possible to estimate the risk reserves for execution of construction project in tender phase, which can be monitored during potential realization of projects. This risk estimation forms the basis for more accurate budget and total cost of the execution of construction project and more stable business of entire organization.

Keywords: *risk management, bid price, project budget, contractor, business system*

1. Introduction

This paper analyzes the execution of construction projects (hereinafter "projects") by contractors from cost risk aspects in the contract (bid) price. The construction business system (mainly construction, hereinafter referred to as the "business system") takes over the project by forming a project system for the realization of such a project. The business system takes over projects, supports project systems and ensures their financial stability and long-term profitability in the interests of the entire business system. The project system defined by the business system under given pricing, deadline and quality conditions realizes the construction project supported by the business system (of the original organization). At the beginning of

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each project there is a large amount of cost risk arising from uncertainty about the way the project will be run (*Smith et al., 2006*). The amount of risk also depends on the general business environment in which the project is realized.

The risk represents uncertainty in the outcome of expected events in the future, namely, it is a situation where we are uncertain of what will happen and it reflects the probability of possible outcomes related to some expected value. Here, the expected value is the average result of unpredictable situations frequently repeated (*Srića, 2011*). The cost of the business system taken over by the project and the cost of the project system interact with each other. If necessary, the business system with its support function can improve cost-effectiveness of a project but also the project system with its cost performance during realization affects the cost and performance of the business system. The effects can be both positive and/or negative. Positive influences are welcome and they will not be discussed in this paper. Indeed, a brief review of the literature on impact of risk on the bid price of the contractor will be made first. The following is an overview of the model of bid price formation by contractors for projects where the contract is concluded with the contractor who offers the lowest price with a technically satisfactory offer based on the bill of quantities and pro-forma invoice. Through the results of the research we will also analyze the impact of the project's characteristics on the occurrence of risk sources and the impact of the risk sources on the increase of the appropriate share of the price when forming a bid for the project execution or the potential project budget of the contractor. It will also show the results of the study of impacts of the risk occurrence probability of a business system on the business success structure of the whole system and the impact of business risk drivers on the probability of starting business risks. This paper will therefore present and analyze the results of the research of the impact of the risk on the contractor's bid price, all with the purpose of forming a quantitative model for the calculation of the bid price for for construction works contractors, which would adequately contain the possible negative effects of the risk on certain parts of the price during a project execution.

2. Literature review

Construction, as well as many other industries, is exposed to greater intensity of risk impact due to the unique features and complexity of construction projects such as long running times, complex processes, inaccessible environments, financial intensity and dynamic organizational structures (*Flanagan and Norman, 1993, Akintoye and MacLeod, 1997, Smith, 2003*). Consequently, the proper definition of the impact of the risk on the cost of the execution of the projects represents an indispensable part of successful construction projects for the contractor of construction works. Contracators have traditionally used high premiums to cover possible risks when conducting works, but as competition became more powerful, this approach could no longer be effective (*Baloi and Price, 2003*). It is accepted as a standard in the professional literature, that contractors usually include a hidden risk premium in their bid prices (*Hackett et al., 2007*). Previous research has shown that risk premiums make up about 0-5% of the tenderers' bid price for carrying out construction works (*Neufville and King, 1991; Shash, 1993; Smith and Bohn, 1999*).

A significant number of formal and analytical models of price risk impacts has been formed, which can be used by contractors in cost-pricing procedures when preparing a bid for works (eg. Fuzzy set model by Zenga et al., 2007; Fuzzy logic-based Artificial neural network mode by Liu and Ling, 2005, Fuzzy set model by Paek et al., 1993, a fuzzy set model formed by Taha et al., 1993, and techniques based on the Al-Bahar and Crandall influence diagram, 1990) (*Larye and Hughes, 2011*). However, the way in which contractors actually calculate the impact of risk on the formation of a bid price is not clearly articulated in construction literature (*Larye and Hughes, 2008*). Several empirical studies carried out by construction contractors have also shown that these models are rarely used in practice.

3. Forming a bid price

Below, the unit price formation will be shown when forming a bidding offer for construction works, which will include risk impacts on unit price amounts.

The research analyzes projects that a contractor obtains through a procurement process in tenderering procedures according to the lowest price criterion and technically satisfactory bids, which is most common in our construction works market. Therefore, too large provisioning for project cost risks and business system costs can cause failure in the tendering process and the absence of a contract, whereas too small provisioning for risks will, as a rule, lead to losses in accepted contracts from the project budget, which is largely consequently transmitted to the business system endangering it by the time. The same can happen with business system risks that can endanger project budgets by not providing adequate “support” in terms of funds, money, logistics, and resources.

Most of today's bids for construction works are based on bill of quantities and pro-forma invoice. Consequently, we can conclude that the revenues of construction contractors are mostly realized according to such contracts. This implies that the value of execution is calculated as the sum of the multiplication of the individual quantities of items in the bill of quantities $k_{i,j}$ (quantity of 'i'-item of a project 'j'-bill of quantities), and the most comprehensive unit price $c_{i,j}$ for an individual project 'j' (*Đukan, 1986*) (1):

$$c_{pr,j} = \sum_i k_{i,j} * c_{i,j} \qquad (1)$$

The business system revenue for all projects in a portfolio is the sum of "j" of such prior project combinations of quantities and prices:

$$\sum_i c_{pr,j} = \sum_i \sum_j k_{i,j} * c_{i,j}$$

Items of bill of quantities are neither the plan activities, nor the cost breakdown structures. As such, they cannot even be used to form a risk breakdown structure of the costs of the contractor's project.

The contractual (bid) price for such projects is expressed as $c_{pr,j} = \sum_i k_{i,j} * c_{i,j}$, although essentially it consists of the budget of the $BP_{p,j}$ project (Project system costs) to which it is necessary to add a part of the indirect cost of the business system $\Delta IC_{tr,j,pos}$, which executes the project (General Overhead) (transferring the business system potentials to the contract price for project realization).

$$c_{pr,j} = BP_{p,j} + \Delta IC_{tr,j,pos} = \sum_i k_{i,j} + c_{i,j}$$

It is important to distinguish the negative impact of the risk on the cost of the project and business system so that this impact would not generally be treated as a "lump sum". For a construction organization, it is very important to be able to distinguish the risk of negative impacts on project costs from the risk of negative impacts on the cost of the business system (organization) so that it is possible to identify the responsibilities and risk carriers, because they are not the same in the project and business systems.

The following analysis will show one of the ways of identifying general analyzed structures of project system and business system costs, which could serve to reflect their mutual influence as well as the impact of both of them to the bid (contractual) price. The project revenue described above is realized as follows (2).

$$U_{pp} = \sum_i c_{p,j} = \sum_j \sum_i k_{i,j} * c_{i,j} = \sum_j \sum_i BP_{p,j} + IC_{p,j} \tag{2}$$

$$IC_{tr,pos} = \sum_j \Delta IC_{tr,j,pos}$$

The budget of the project "j" consists of the direct costs $Dt_{i,j}$ (work, materials, services of others, machines of individual execution of the item "i" of the project's bill of quantities and pro-forma invoice "j") (3) and the general costs of the construction site / the project "j" ($GC_{tr,gr,j}$).

$$BP_j = (Dt_{i,j}) + (CG_{tr,gr,j})$$

$$Dt_{i,j} = \sum_i k_{j,i} * r_{j,i} + \sum_i k_{j,i} * m_{j,i} + \sum_i k_{j,i} * u_{j,i} + \sum_i k_{j,i} * s_{j,i} \tag{3}$$

$$Dt_{j,i} = \sum_i k_{j,i} * (r_{j,i} + m_{j,i} + u_{j,i} + s_{j,i}) \tag{3}$$

The business requirement is that revenues are higher than the costs (4):

$$U_{pp} \geq \sum_i c_{p,j} \geq \sum_i BP_{p,j} + IC_{tr,pos} \tag{4}$$

$$\sum_i c_{p,j} = \sum_j \sum_i k_{i,j} * c_{i,j} \geq \sum_j BP_{p,j} + IC_{tr,pos}$$

In the case of construction works, the quantities are usually measurable and the prices are fixed, thus the income, namely revenues $U_{pp} = \sum_i c_{p,j} = \sum_j \sum_i k_{i,j} * c_{i,j}$ are largely certain and reliable, whereas costs and expenditures are uncertain and unreliable due to risk-based burdens. Thus, we come to the basic question that is addressed in this paper, which is the implementation of the risk impact in the contract price, all in order to achieve the basic business requirement.

$$\sum_j \sum_i k_{i,j} * c_{i,j} = (Dt_{i,j}) + (GC_{tr,gr,j})$$

$$Dt_{j,i} = \sum_i k_{j,i} * (r_{j,i} + m_{j,i} + u_{j,i} + s_{j,i})$$

Bidding and contractual amounts $\sum_j \sum_i k_{i,j} * c_{i,j} + (GC_{tr,gr,j})$ are estimated at the time of bidding and before contracting whereas the real costs $Dt_{j,i} = \sum_i k_{j,i} * (r_{j,i} + m_{j,i} + u_{j,i} + s_{j,i})$ and $GC_{tr,gr,j}$ occur at a later time that may be different than the planned by several years.

In this risk-based study, we are not talking about risk cases that can be "compensated" in any way, that is, the risks that the contractor is naturally entitled to claim if so agreed. We therefore analyze the risks that in no event will be indemnified, compensated, and in any case have to be included in the price.

The following section presents and identifies related risk analysis, cost breakdown structure, resource breakdown structure and risk breakdown structure. The following are the terms for identified project costs and total business system costs:

From the term for total business system revenue (2), we come up to the term for identified project costs (5).

$$U_{pp} = \sum_j c_{p,j} = \sum_j BP_{p,j} + IC_{tr,pos} \tag{2}$$

$$\sum_j cp_j * \left(1 - \frac{IC_{tr,pos}}{U_{pp}}\right) = \sum_j BP_{p,j}$$

$$\left[\sum_j \left(\sum_i k_{i,j} * c_{i,j}\right)\right] * \left(1 - \frac{IC_{tr,pos}}{U_{pp}}\right) = \sum_j BP_{p,j}$$

$$c_{p,j} * \left(1 - \frac{IC_{tr,pos}}{U_{pp}}\right) = BP_{p,j}$$

$$\left(\sum_i k_{i,j} * c_{i,j}\right) * \left(1 - \frac{IC_{tr,pos}}{U_{pp}}\right) = BP_{p,j}$$

$$c_{p,j} = BP_{p,j} * \left[\frac{1}{\left(1 - \frac{IC_{tr,pos}}{U_{pp}}\right)}\right]$$

$$c_{p,j} = \left(\sum_i k_{i,j} * c_{i,j}\right) = BP_{p,j} * \left[\frac{1}{\left(1 - \frac{IC_{tr,pos}}{U_{pp}}\right)}\right] \tag{5}$$

By further analyzing the terms shown, we come to terms for total business system costs (6)

$$\left(\sum_i k_{i,j} * c_{i,j}\right) + \Delta IC_{tr,j,pos} = BP_{p,j} * \left[\frac{1}{\left(1 - \frac{IC_{tr,pos}}{U_{pp}}\right)}\right]$$

$$\Delta IC_{tr,j,pos} = BP_{p,j} * \left\{\left[\frac{1}{\left(\frac{U_{pp} - IC_{tr,pos}}{U_{pp}}\right)}\right] - 1\right\}$$

$$\Delta IC_{tr,j,pos} = BP_{p,j} * \left\{\left[\frac{1}{\left(U_{pp} - IC_{tr,pos}\right)}\right] - \left(\frac{U_{pp} - IC_{tr,pos}}{U_{pp} - IC_{tr,pos}}\right)\right\}$$

$$\Delta IC_{tr,j,pos} = BP_{p,j} * \frac{IC_{tr,pos}}{U_{pp} - IC_{tr,pos}} = BP_{p,j} * \frac{1}{\left[\left(\frac{U_{pp}}{IC_{tr,pos}}\right) - 1\right]}$$

$$\sum_j \Delta IC_{tr,j,pos} = \left(\sum_j BP_{p,j}\right) * \frac{IC_{tr,pos}}{U_{pp} - IC_{tr,pos}} = \left(\sum_j BP_{p,j}\right) * \frac{1}{\left[\left(\frac{U_{pp}}{IC_{tr,pos}}\right) - 1\right]}$$

$$IC_{tr,j,pos} = \sum_j \varDelta IC_{tr,j,pos} = \left(\sum_j BP_{p,j}\right) * \frac{IC_{tr,pos}}{U_{pp}-IC_{tr,pos}} = \left(\sum_j BP_{p,j}\right) * \frac{1}{\left[\left(\frac{U_{pp}}{IC_{tr,pos}}\right)-1\right]}$$

$$\sum_i c_{p,j} = \sum_j BP_{p,j} + IC_{tr,pos}$$

$$\sum_i c_{p,j} = \sum_j BP_{p,j} + \left(\sum_j BP_{p,j}\right) * \frac{1}{\left[\left(\frac{U_{pp}}{IC_{tr,pos}}\right)-1\right]}$$

$$\sum_i c_{p,j} = \sum_j BP_{p,j} * \left\{1 + \frac{1}{\left[\left(\frac{U_{pp}}{IC_{tr,pos}}\right)-1\right]}\right\}$$

$$\sum_i c_{p,j} = \sum_j BP_{p,j} * \left\{\frac{\left[\left(\frac{U_{pp}}{IC_{tr,pos}}\right)-1\right]}{\left[\left(\frac{U_{pp}}{IC_{tr,pos}}\right)-1\right]} + \frac{1}{\left[\left(\frac{U_{pp}}{IC_{tr,pos}}\right)-1\right]}\right\}$$

$$\sum_j c_{p,j} = \sum_j BP_{p,j} * \left\{\frac{1}{\left[1-\frac{1}{\left(\frac{U_{pp}}{IC_{tr,pos}}\right)}\right]}\right\} = \sum_j BP_{p,j} * \frac{U_{pp}}{U_{pp}-IC_{tr,pos}}$$

$$\sum_j c_{p,j} = \sum_j BP_{p,j} * \frac{1}{1-\frac{IC_{tr,pos}}{U_{pp}}} \qquad (6)$$

$$c_{p,j} = BP_{p,j} * \left[\frac{1}{1-\left(\frac{IC_{tr,pos}}{U_{pp}}\right)}\right]$$

$$BP_j = \left(Dt_{i,j}\right) + \left(CG_{tr,gr,j}\right)$$

$$Dt_{i,j} = \left(\sum_i k_{j,i} * r_{j,i} + \sum_i k_{j,i} * m_{j,i} + \sum_i k_{j,i} * u_{j,i} + \sum_i k_{j,i} * s_{j,i}\right)$$

$$Dt_{i,j} = \sum_i k_{j,i} * dt_{j,i}$$

$$dt_{j,i} = \left(r_{j,i} + m_{j,i} + u_{j,i} + s_{j,i}\right)$$

$$Dt_{i,j} = \sum_i k_{j,i} * \left(r_{j,i} + m_{j,i} + u_{j,i} + s_{j,i}\right)$$

As we have already mentioned, a contractor forms the budget of any project according to unit prices and quantities of work.

The budget of the contractor's project is usually formed as a sum of the cost of labor (R_j), cost of material (M_j), others' services (U_j), machinery and equipment (S_j) and general project or site cost (GC_j). Each project has its own general indirect costs of the construction site/project.

$$B_{p,j} = \left\{\left[\left(R_j\right) + \left(M_j\right) + \left(U_j\right) + \left(S_j\right)\right] + \left(GC_j\right)\right\} \qquad (7)$$

$$c_{p,j} = \left(\sum_i k_{i,j} * c_{i,j}\right) = B_{p,j} * \left[\frac{1}{\left(1-\frac{IC_{tr,pos}}{U_{pp}}\right)}\right]$$

$$(R_j) = \sum_i k_{j,i} * r_{j,i}$$

$$(M_j) = \sum_i k_{j,i} * m_{j,i}$$

$$(U_j) = \sum_i k_{j,i} * u_{j,i}$$

$$(S_j) = \sum_i k_{j,i} * s_{j,i}$$

The term for calculation project costs (9) or business system costs (8) can also be formed from the expression for the project budget.

$$\left(\sum_i k_{i,j} * c_{i,j}\right) = \left\{\left[(R_j) + (M_j) + (U_j) + (S_j)\right] + (GC_j)\right\} * \left[\frac{1}{\left(1 - \frac{IC_{tr,pos}}{U_{pp}}\right)}\right]$$

$$U_{pp} - IC_{tr,pos} = \sum_J c_{p,j} - IC_{tr,pos} = \sum_j BP_{p,j}$$

$$U_{pp} * \left(1 - \frac{IC_{tr,pos}}{U_{pp}}\right) = \sum_j c_{p,j} * \left(1 - \frac{IC_{tr,pos}}{\sum_j c_{p,j}}\right) = \sum_j BP_{p,j}$$

$$\sum_j c_{p,j} = \left(\frac{1}{\left(1 - \frac{IC_{tr,pos}}{\sum_j c_{p,j}}\right)}\right) * \sum_j BP_{p,j}$$

$$\left(\sum_i k_{i,j} * c_{i,j}\right) = \left\{\left[(R_j) + (M_j) + (U_j) + (S_j)\right] + (GC_j)\right\} * \left[\frac{1}{\left(1 - \frac{IC_{tr,pos}}{U_{pp}}\right)}\right]$$

$$\sum_j c_{p,j} = \left(\frac{1}{\left(1 - \frac{IC_{tr,pos}}{\sum_j c_{p,j}}\right)}\right) * \sum_j BP_{p,j}$$

$$\sum_j c_{p,j} = \left(\sum_i k_{i,j} * c_{i,j}\right) = \left(\sum_i k_{i,j} * dt_{i,j}\right) * f_{GC,tr,gr,j} * f_{IC,tr,pos} \quad (8)$$

$$c_{i,j} = dt_{i,j} * f_{GC,tr,gr,j} * f_{IC,tr,pos} \quad (9)$$

$f_{GC,tr,gr,j}$ (10) represents the coefficient of general site/project cost of an individual project, which multiplies direct project costs in order to include the general costs of the construction site/project into the price indirectly. It is specifically calculated for each project.

$f_{IC,tr,pos}$ (11) represents the coefficient of the business system indirect cost, which multiplies project budgets in order to include the business system potentials (indirect costs) into the price indirectly. It is mostly unique for entire business system.

As we have already stated, in most construction contracts, they are realized according to bill of quantities and pro-forma invoice, as the sum of the product "$k_{i,j}$" - quantities of „i“ item of the project "j" (bill of quantities, BoQ) and the comprehensive unit price"$c_{i,j}$" is for each individual project "j", the calculation and implementation of the overall cost of the project/site and the indirect costs of the business system into unit prices are as follows:

$$c_{pr,j} = \sum_i k_{i,j} * c_{i,j}$$

$$c_{i,j} = dt_{i,j} * f_{GC,tr,gr,j} * f_{IC,tr,pos}$$

$$c_{pr,j} = f_{GC,tr,gr,j} * f_{IC,tr,pos} * \sum_i dt_{i,j}$$

$$BP_{p,j} = f_{GC,tr,gr,j} * \sum_i dt_{i,j}$$

$$f_{GC,tr,gr,j} * \sum_i dt_{i,j} = \left(Dt_{i,j}\right) + \left(GC_{tr,gr,j}\right)$$

$$Dt_{i,j} = \left(\sum_i k_{j,i} * r_{j,i} + \sum_i k_{j,i} * m_{j,i} + \sum_i k_{j,i} * u_{j,i} + \sum_i k_{j,i} * s_{j,i}\right)$$

$$f_{GC,tr,gr,j} = 1 + \frac{\left(GC_{tr,gr,j}\right)}{\left(\sum_i k_{j,i} * r_{j,i} + \sum_i k_{j,i} * m_{j,i} + \sum_i k_{j,i} * u_{j,i} + \sum_i k_{j,i} * s_{j,i}\right)}$$

$$f_{GC,tr,gr,j} = 1 + \frac{\left(GC_{tr,gr,j}\right)}{\left(R_j + M_j + U_j + S_j\right)} \tag{10}$$

$$f_{GC,tr,gr,j} = 1 + \frac{\left(GC_{tr,gr,j}\right)}{\sum_i k_{j,i} * (r_{j,i} + m_{i,j} + u_{i,j} + s_{i,j}}$$

$$f_{IC,tr,gr,j} = \left[\frac{1}{\left(1 - \frac{IC_{tr,pos}}{U_{pp}}\right)}\right] \tag{11}$$

As the business system's indirect costs (12) are calculated as a sum of investment in basic fixed assets (SS), business system costs (HP), investment in working capital (OS) and the profit, the coefficient of the business system's indirect cost is then defined by the following term (13). In the end, we come up with the term for forming the contract bid price based on the project budget and the coefficient of business system indirect costs (14).

$$IC_{tr,pos} = SS + HP + OS + Profit \tag{12}$$

$$f_{IC,tr,pos} = \frac{1}{\left\{1 - \left[\frac{SS + HP + OS + Profit}{U_{pp}}\right]\right\}} \tag{13}$$

$$BP_{p,j} = \left(\sum_i k_{i,j} * dt_{i,j}\right) * f_{GC,tr,gr,j}$$

$$BP_{p,j} + \Delta IC_{tr,j,pos} = BP_{p,j} * f_{IC,tr,pos}$$

$$\Delta IC_{tr,j,pos} = BP_{p,j} * \left(f_{IC,tr,pos} - 1\right)$$

$$c_{p,j} = BP_{p,j} + BP_{p,j} * \left(f_{IC,tr,pos} - 1\right) \tag{14}$$

Concerning the standard term for project budgeting (7), it is obvious that it does not contain impact of potential risks, which may arise during the project execution for individual prices and thus for the entire project budget of the contractor.

Risk-based increases in the value of individual parts of the project cost are percentage increases of the basic price, minimum, and in fact they are random variables with some distribution, or simpler random variables with beta pert distribution. The impact of project features and project environment on the causes of certain risks ultimately affects the project budget components. The impact of the risk leads to an increase in the cost of labor, materials, machinery and equipment, others' services, general costs of the construction site and the project, and they are calculated in the following way:

R+Rr	labor + risk impact to labor price
M+Mr	material + risk impact to the price of material
U+Ur	others' services + risk impact to the price of others' services
S+Sr	equipment and machinery + risk impact to the price of equipment and machinery
GC+GCr	general construction site cost + risk impact to general construction site cost

The analysis of the risk impact on a project budget or risk impact implemenatation provides a term for the creation of a contractor's project budget, which includes risk-impact on individual parts of the project cost (15):

$$BP_{r,j} = \{[(R + R_r) + (M + M_r) + (U + U_r) + (S + S_r)] + (GC + GC_r)\} \quad (15)$$

4. Research methodology

A review of the literature found a lack of a model for incorporating the impact of risk into the formation of the bid price of the project by the contractors of construction works. For this reason, a survey has been formed and conducted among construction organizations whose results will serve to form a model of unit price calculation that will have negative risks included. The results were obtained on the basis of a survey conducted among 40 construction organizations for construction projects. The methodology of data analysis as well as the methodology of establishing the results will be explained for each of the individual parts of the research.

5. Analysis of research results

Generally, the budget of a project should be based on the realistic performance of the work, taking into account the budget of resources, productivity, time-related costs and risks (*Smith et al., 2006*).

The results of the research are presented for the question of the most common share of individual cost components in the work of construction organizations that were covered by the research.

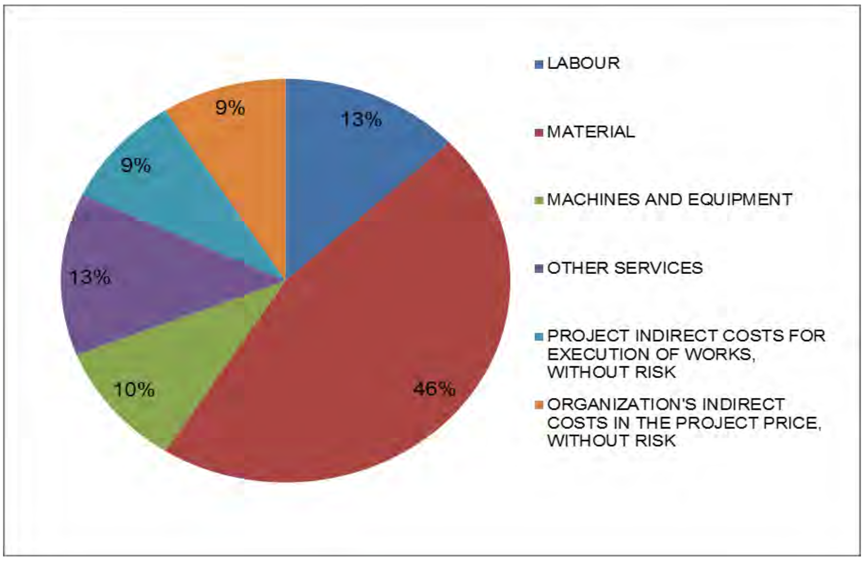

Figure 1. The share of individual cost components in the work of construction organizations involved in the research

The results show that the cost of material has the largest influence in price formation in the works of the surveyed organizations. Thus, we can conclude that the features of the project that have the greatest impact on increasing the probability of risk-related material costs have the greatest impact on the price increase or project budget for the surveyed contractors.

The research has ordered the risks of completing the works within the planned time, the costs within the budget and within the scope of the project with the requested quality by the frequency of the occurrence from 1 to 3. 1 represents the most frequent and 3 the least frequent risk during the execution of the works.

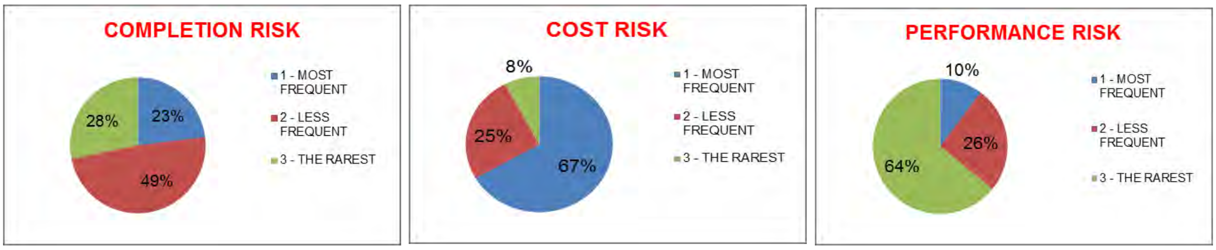

Figure 2. Frequency of occurrence of risk in project execution

From the results of the research we can see that the contractors rated that the most frequent cost risk was 67%, indicating the need for a more detailed account of the risks and their impact on the costs, i.e. on the budget of contractors.

5.1 Impact of project features on probability of occurrence of risk sources

The research has analyzed the impact of project features on the probability of the occurrence of risk sources which can later result in changes of the execution cost or the contractor's budget.

Each risk has its cause. Each cause of the risk has a certain probability of its occurrence. The research will determine how much the project features and project environment affect the probability of occurrence of external or internal risk sources. External risk sources are classified as legal, political, economic, social and natural, while internal risk sources are classified as management, technical documentation, human factor, supply and logistics, and contracting (*Radujković, 1997)*.

Table 1. External and internal risk sources

External risk sources				
Legal	***Political***	***Economic***	***Social***	***Natural***
Local regulations	Change in politics	Economic politics	Education, culture	Climate
Permits	Elections	Prices, taxes	Seasonal work	Soil
Approvals	War	Terms of financing	Strike	Fire
Changes to the law Standards	Agreements	Currency exchange rate	Fluctuation of people	Earthquakes, flooding
Internal risk sources				
Management	***Technical documentation***	***Human factor***	***Supply and logistics***	***Contracting***
Unreal goals	Incompleteness	Productivity	Shortages	Contract types
Bad controling	Inaccuracy	Sick leave	Deliveries	Short deadlines
Organizational technology	Incompletion	Motivation	Reliability of machines	Unreasonable price
	New solutions	Omissions	Lack of people	Relationships of participants

In this section, the results of the research show what percentage certain project features have on probability of risk source to occur. Within the project features and the project environment, the following issues were analyzed: intensity of technology impact, deadlines, sub-contractors' potentials, resource conflicts, security, environment, participation of government regulation, political interests, number of key collaborators, complexity of projects, resources and labor force, number of works locations, financing and impact on project costs, size and type of construction from the point of view of environmental protection and occupational safety, quality requirements, public participation and project implementation programs. Risk study investigated the amount of impact that individual project features have on the occurrence of the risks on a scale of 1 to 10. 1 represents the least and 10 the greatest impact on the probability of occurrence of a risk event. The mode value for each of the studied causes is the level of impact or the belonging probability of the occurrence of the risk source. Impact intensity is divided into 5 classes.

Table 2. Intensity classes of the project features' impact on risk sources

Impact intensity	Expectations of theoretic distribution	Mode	Risk occurrence probability
Very low impact VNU	0-2	0-2	0-20 %
Low impact NU	2-4	2-4	20 - 40 %
Moderate impact UU	4-6	4-6	40 - 60 %
High impact VU	6-8	6-8	60 - 80 %
Very high impact VVU	8-10	8-10	80 - 100 %

The results for each of the listed project features and the project environment are presented and analyzed separately. The results were classified into the classes of impact intensity of project features on each project source.

PROJECT CHARACTERISTICS - CAUSES	EXTERNAL					INTERNAL				
	LEGAL	POLITICAL	ECONOMIC	SOCIAL	NATURAL	MANAGEMENT	TECHNICAL DOCUMENTATION	HUMAN FACTOR	SUPLLY AND LOGISTIC	CONTRACTING
TECHNOLOGY	8 VVU	9 VVU	5 UU	3 NU	4 UU	7 VU	5 UU	4 UU	10 VVU	7 VU
DEADLINES	10 VVU	10 VVU	1 VNU	10 VVU	5 UU	6 VU	9 VVU	9 VVU	3 NU	4 UU
SUBCONTRACTORS COMPETENCE	7 VU	10 VVU	1 VNU	4 UU	6 VU	2 NU	7 VU	9 VVU	3 NU	10 VVU
CONFRONTING REQUIREMENTS	4 UU	1 VNU	7 VU	9 VVU	10 VVU	4 UU	3 NU	1 VNU	10 VVU	3 NU
SAFETY	1 VNU	2 NU	4 UU	7 VU	1 VNU	3 NU	5 UU	10 VVU	9 VVU	10 VVU
ENVIRONMENT	10 VVU	2 NU	7 VU	4 UU	5 UU	5 UU	7 VU	9 VVU	3 NU	5 UU
STATE REGULATIONS PARTICIPATION	1 VNU	10 VVU	8 VVU	4 UU	5 UU	3 NU	7 VU	8 VVU	9 VVU	5 UU
POLITICAL ASPECT	2 NU	1 VNU	3 NU	4 UU	5 UU	6 VU	6 VU	3 NU	9 VVU	10 VVU
NUMBER OF KEY STAKEHOLDERS	5 UU	10 VVU	2 NU	9 VVU	10 VVU	6 VU	7 VU	7 VU	5 VU	10 VVU
PROJECT COMPLEXITY	8 VVU	9 VVU	6 VU	6 VU	2 NU	4 UU	1 VNU	3 NU	4 UU	5 UU
RESOURCES/ WORK FORCE/PRODUCTIVITY	7 VU	2 NU	3 NU	6 VU	2 NU	6 VU	5 UU	1 VNU	5 UU	8 VVU
NUMBER OF SITE LOCATIONS	10 VVU	10 VVU	6 VU	9 VVU	4 UU	7 VU	5 UU	6 UU	2 NU	7 VU
FINNACING/COST IMPACT	8 VVU	10 VVU	3 NU	2 NU	10 VVU	3 NU	7 VU	5 UU	8 VVU	6 VU
ENVIRONMENT PROTECTION	10 VVU	9 VVU	5 UU	2 NU	1 VNU	5 UU	4 UU	3 NU	9 VVU	10 VVU
QUALITY REQUIREMENT	10 VVU	10 VVU	8 VVU	3 NU	4 UU	1 VNU	3 NU	2 NU	8 VVU	7 VU
PUBLIC INVOLVEMENT	3 NU	2 NU	2 NU	7 VU	10 VVU	5 UU	5 UU	3 NU	3 NU	8 VVU
RUNNING SCHEDULE	3 NU	2 NU	2 NU	9 VVU	6 VU	4 UU	5 UU	1 VNU	4 UU	6 VU

Figure 3 - Impact intensity of project characteristics to the probability of risk sources occurrence

According to the results of the research, project characteristcs that involve changes in technology have a low impact on the occurrence of social risk sources. Technology-related features have the greatest impact on the supply and logistics risk source, as any change in technology can lead to increased project or budget costs due to workforce procurement or procurement of equipment for performing such a project.

The research results related to project characteristics associated with deadlines show that such features of a project have very low and low impact on the occurrence of economic sources of risk and sources of supply and logistics risks although theoretically the extension of deadlines or delay in execution can strongly influence the occurrence of risk sources due to a change in the exchange rate of the currency in which the performance was contracted or because of the lack of workforce needed for other projects.

Expected results of the research are such that project characteristics associated with the capabilities of subcontractors of the construction project features being performed have a high impact on the probabillity of occurrence of management risk and supply and logistics risks due to possible bad control, lack of adequate equipment and machinery on the part of subcontractors or possible lack of people due to unrealistic goals the subcontractor undertook.

From the results of the research we can conclude that the impact of security as a project characteristic on average has a low impact on external risk sources and a great influence on the probability of occurrence of internal risk sources as expected because safety at execution is mainly controlled from within the organization itself.

The displayed research results show that the environmental related project characteristics on average have a moderate impact on the likelihood of occurrence of both internal and external sources of risk events. Additional environmental requirements imply a higher likelihood of occurrence of risk events due to the need for additional approvals and permissions, and can lead to possible productivity reductions, frequent illnesses in the workforce or omissions due to strict environmental protection requirements.

According to the results of the research, the participation of government regulations on average has a high impact on the probability of occurrence of risk events during project execution. The result of a very high impact of the participation of state regulations on the likelihood of occurrence of human factor and supply and logistics risk factors was not expected, but we can conclude that the contractors had frequent unexpected negative experiences related to such causes and sources of risk events that resulted into increase of the budget when executing the works.

According to the research results, the project characteristics related to the number of key stakeholders have a high impact on the likelihood of risk sources events in a project and as such they have a high impact on the price increase and thus on the project budget of the contractors executing the project with such features.

According to the research results, the project complexity on average has moderate impact on the probability of occurrence of risk sources events during project execution. However, when considered separately, the complexity of a project has a high impact on external sources and low impact on internal sources of risk events.

According to research findings, the project feature related to resources and labor force productivity have moderate impact on the probability of occurrence of risk sources on average. These project features are expected to have a low impact on the probability of external risk sources because these features are mainly related to the workforce and the internal issues of an organization.

The project characteristics associated with the number of work locations have a generally high impact on the likelihood of risk occurrence. Such research results obtained by examining construction organizations that execute works are not expected because it is theoretically difficult to understand why such project features have a very high impact on social or political risk sources.

According to the research results, project features related to the size and type of construction from the point of view of environmental protection and waste disposal have the lowest or very low impact on management related risk sources. High quality demands increase the possibility of increased costs due to some special delivery of materials, lack of high quality people, and due to the lack of reliable equipment to perform the works in accordance with the required quality levels.

According to the results of the research, the project features related to the needs of quality have the greatest impact on the probability of occurrence of natural risk sources. Such project features also have a very high impact on the risks involved in contracting.

The research results show that the public involvement project features generally have a low or moderate impact on the probability of occurrence of sources of risk events during a project implementation.

5.2 Impact of risk sources on the occurrence of completion, costs and performance risks

After the research has established the impact of project characteristics on the probability of occurrence of risk sources, an assessment has been made to determine the consequences of the occurrence of certain risk sources, ie the impact of a certain risk source on the completion of works, costs and performance risks within the set limits. Impact levels were determined through a survey among construction organizations. Impact levels were divided into three classes from 1 to 3 where 1 represents the highest and 3 the lowest impact on the risks of completion, cost and performance. The results of the surveyed organizations are shown in percentages for each impact level.

RISK SOURCE	IMPACT DEGREE	COMPLETION RISK (%)	COST RISK (%)	PERFORMANCE RISK (%)
LEGAL	1	37,50	22,50	20,00
	2	25,00	37,50	20,00
	3	37,50	40,00	60,00
POLITICAL	1	27,50	30,00	25,00
	2	25,00	27,50	27,50
	3	47,50	42,50	47,50
ECONOMIC	1	32,50	53,50	20,00
	2	35,00	27,50	42,50
	3	32,50	20,00	37,50
SOCIAL	1	30,00	37,50	27,50
	2	22,50	37,50	20,00
	3	47,50	25,00	52,50
NATURAL	1	45,00	17,50	30,00
	2	42,50	35,00	32,50
	3	12,50	47,50	37,50
MANAGEMENT	1	30,00	25,00	40,00
	2	35,00	47,50	25,00
	3	25,00	27,50	35,00
TECHNICAL DOCUMENTATION	1	30,00	25,00	47,50
	2	40,00	32,50	22,50
	3	30,00	42,50	30,00
HUMAN FACTOR	1	47,50	32,50	40,00
	2	35,00	50,00	25,00
	3	17,50	17,50	35,00
SUPLLY AND LOGISTIC	1	47,50	42,50	15,00
	2	27,50	40,00	45,00
	3	25,00	17,50	40,00
CONTRACTING	1	47,50	27,50	37,50
	2	22,50	52,50	30,00
	3	30,00	20,00	32,50

Figure 4. Impact levels of risk sources on the occurrence of risk of completion, cost and performance

According to the research results, legal, natural, management, human resources, contracting, supply and logistics risks have the greatest impact on the uncertainty of completing the construction project. Political risks have the least impact on the uncertainty of completing a construction project in the planned time, according to the research results.

Political, economic and social risks have the greatest impact on the uncertainty of realizing the costs within the budget in executing construction projects, whereas 47,50% and 42,50% of respondents believe that natural and technical documentation risks have the least impact on the costs.

Risks having the greatest impact on the uncertainty of realizing the scope of the project in the required quality are management risks , as considered by 40% of the contractors, and the risks of the technical documentation as considered by 47,50% of the contractors. Legal, political, economic, social, human, supply and logistics, contracting and management risks have the least impact on the uncertainty of the project realization in the required quality.

5.3 Impact of risk sources on the increase of certain parts of the cost during the preparation of a bid for the project execution

The research presented the data about the extent in which the percentage of the individual previously mentioned risk sources increase the corresponding part of the cost of construction works during the bid preparation phase. As a relevant data in the research results, we took the mean of all 40 responses of the surveyed contractors. Surveyed organizations have mentioned reservations based on past experiences due to the impact of the risk sources for individual parts of the project execution cost. The results of the reservation are shown in percentages per a portion of the cost.

RISK SOURCE	DIRECT COSTS				PROJECT AND SITE INDIRECT COSTS FOR EXECUTION OF WORKS
	LABOUR	MATERIAL	MACHINES AND EQUIPMENT	OTHER SERVICES	
LEGAL	2,50%	1,88%	1,92%	2,40%	2,23%
POLITICAL	1,73%	1,43%	1,33%	1,33%	1,98%
ECONOMIC	4,68%	4,48%	4,28%	3,90%	4,05%
SOCIAL	3,23%	2,38%	2,30%	2,35%	2,18%
NATURAL	2,50%	1,82%	1,98%	1,55%	2,28%
MANAGEMENT	2,95%	3,18%	3,15%	2,00%	3,50%
TECHNICAL DOCUMENTATION	2,93%	3,38%	2,53%	2,83%	2,85%
HUMAN FACTOR	4,35%	3,83%	3,28%	3,33%	3,18%
SUPLLY AND LOGISTIC	3,73%	3,73%	4,25%	3,48%	4,20%

Figure 5. Impact of risk sources on the increase of a certain part of the price

Legal risk sources have the greatest impact on the increase in the part of the project cost associated with labor cost (2.50%) and others' services, whereas it has the lowest impact on the increase in the cost price related to the cost of material (1.88%), machinery and assets.

Political risk sources have the greatest impact on the increase of part of the project cost related to the indirect costs of the project and the construction site, which is 1.98%, and the lowest impact to the increase of the cost is related to the direct costs of machinery and others' services (1.33%). On average, according to research results, legal risk sources have the lowest impact on increasing the construction cost of a construction project.

Economic risk sources have the greatest impact on the increase in the share of labor cost (4.68%) and material (4.48%), and to the lowest extent they affect the increase of part of the cost related to the services of others, namely 3.80%. Looking at the overall results of the research we can conclude that the economic risk sources on average have the greatest impact on both the increase of the parts and the total cost of the project.

Social risk sources have an equal greatest impact on the increase in each of the parts of the project cost, but the greatest impact is on increasing the share of labor-related costs and the least on the indirect costs of the project and the construction site.

Considering overall research results, natural risk sources also have an average low impact on the increase in project cost. The lowest impact is on the increase in the share of cost related to others' services, and this is 1.55%.

Management related risk sources have the greatest impact on the increase in costs related to the indirect costs of the project and the construction site (3.50%) and the lowest impact on others' services (2.00%)

Risk sources related to technical documentation have the greatest impact on the increase of a part of the cost of the project related to direct costs of material (3.38%) and the lowest impact to the cost of machinery and construction works (2.53%).

Human resources related risk sources, on average, have the third-largest impact on parts of the cost of the project immediately after economic and supply and logistics risk sources. They have the greatest impact on the increase of a part of the project cost associated with the labor and this is 4.35%.

Risk sources of supply and logistics, as we have already mentioned, have intensity impact on the increase in the cost of the project immediately after the economic risk sources. They have the greatest impact on the increase in the cost of machinery and equipment (4.25%) and the lowest on others' services (3.48%).

5.4 *Impact of risk sources on the increase of the corresponding part of the cost during the project realization phase*

The research results of the percentage increase of an individual share of the price as a consequence of the above mentioned risks in the project realization phase were created on the basis of the records of individual contractors. Based on previous experience, surveyed organizations have indicated price increases due to the impact of risk sources for individual parts of the project execution cost in the project implementation stage. Only in the absence of evidence the contractors gave their estimates. The results of the reservation are shown in percentages per part of the price.

RISK SOURCE	DIRECT COSTS				PROJECT AND SITE INDIRECT COSTS FOR EXECUTION OF WORKS
	LABOUR	MATERIAL	MACHINES AND EQUIPMENT	OTHER SERVICES	
LEGAL	2,43%	1,88%	2,40%	2,33%	2,63%
POLITICAL	1,21%	0,85%	1,00%	1,08%	1,43%
ECONOMIC	3,60%	4,05%	3,85%	3,90%	3,38%
SOCIAL	2,10%	1,40%	2,30%	3,40%	1,43%
NATURAL	1,80%	1,53%	1,55%	1,53%	1,98%
MANAGEMENT	2,98%	3,13%	2,73%	2,80%	2,68%
TECHNICAL DOCUMENTATION	2,93%	2,75%	2,55%	2,68%	2,48%
HUMAN FACTOR	3,85%	3,23%	2,55%	3,15%	2,95%
SUPLLY AND LOGISTIC	2,95%	3,40%	3,00%	3,25%	3,10%
CONTRACTING	2,90%	3,28%	2,50%	2,70%	2,38%

Figure 6. Impact of risk sources to the increase of an individual part of the price during project realization

In the stage of realization, economic risks (3.60%) and risks related to the human factor (3.85%) have the highest percentage of increase in part of the cost related to the labor costs, while natural risks (1.80%) and political risk sources (1.21%) have the lowest impact on a share of labor cost.

The highest percentage increases in the part of the cost associated with material costs is caused by economic risk sources (4.05%) and by the sources of supply and logistics risks (3.40%). The smallest percentage increase in the total cost related to materials costs is caused by social (1.40%) and political risk sources (0.85%) out of the mentioned risk sources.

Concerning the part of the price related to the costs of machinery and assets during the implementation stage, the highest percentage of increase is caused by economic (3.85%) and legal risk sources (3.00%), while the lowest percentage increase is caused by natural (1.55% and political risk sources (1.00%) out of all mentioned risk sources.

The increase of a part related to the subcontractors' costs is mostly caused by economic (3.90%) and supply and logistics risk sources (3.25%), while the lowest increase percentage is caused by natural resources (1.53%) and political risk sources, 08%).

Regarding the part of the price related to the general costs of the project and construction site, the highest increase percentage is caused by economic (3.38%) and supply and logistics risk sources (3.10%), while the lowest increase percentage is caused by social and political risk sources in the amount of 1.43%, out of all mentioned risk sources.

5.5 Impact of business system risk on the structure of business success and the state of business system

The probability of occurrence of a risk event depends on the business environment and business system features. The occurrence of a risk event influences the changes in the business system and thus it affects the changes in the project system. By investigating risk events, it was examined what impact the intensity of the the risks of the business system has on the structure of business success and on the state of the business system. Impact intensity is divided into five classes, namely very high, high, moderate, low, and very low impact, ranging from 15 as the highest possible to 0 as the lowest possible impact. The class of intensity impacts is determined according to the intensity class table.

Table 3. Intensity classes of impact of cost system risks on business system

Impact intensity	**Mean value**	**Mode**
Very low impact VNU	0-3	0-3
Low impact NU	3-6 3-9	3-6 0-3
Moderate impact UU	6-9 6-9	3-6 6-9
High impact VU	6-9 6-9	9-12 >12
Very high impact VVU	>9	>12

The impact results of all cost system risks on business system costs and thus on its success are presented and analyzed. The impacts of business system risks on the structure of business success are introduced and classified into intensity classes.

	INVESTMENT IN BASIC ASSETS (SS)		OPERATING COSTS OF BUSINESS SYSTEM (HP)		INVESTMENT IN WORKING CAPITAL (OS)		GROSS PROFIT		TOTAL REVENUE	
BUSINESS SYSTEM RISKS	MEAN	MODE	MEAN	MODE	MEAN	MODE	MEAN	MODE	MEAN	MODE
changes in legislation and regulations	7,45	10	8,20	5	8,15	5	7,64	10	8,03	4
	HIGH IMPACT		MODERATE IMPACT		MODERATE IMPACT		HIGH IMPACT		MODERATE IMPACT	
the ability to access credits	8,90	10	7,15	10	8,44	10	6,64	5	7,40	5
	HIGH IMPACT		HIGH IMPACT		HIGH IMPACT		MODERATE IMPACT		LOW IMPACT	
slow recovery, double effect of recesion, double after a short recovery	9,75	15	8,43	10	9,5	10	9,3	10	9,37	15
	VERY HIGH IMPACT		HIGH IMPACT		HIGH IMPACT		HIGH IMPACT		VERY HIGH IMPACT	
Problems in talent management, fluctuation, education, training	7,18	9	7,18	10	6,97	5	6,58	5	6,24	5
	HIGH IMPACT		HIGH IMPACT		MODERATE IMPACT		MODERATE IMPACT		MODERATE IMPACT	
Emerging markets, transition	9,42	10	8,48	5	7,9	5	7,85	5	8,19	15
	HIGH IMPACT		MODERATE IMPACT		MODERATE IMPACT		MODERATE IMPACT		HIGH IMPACT	
activities on cost cutting	7,18	5	7,19	10	6,62	10	6,83	10	6,67	5
	MODERATE IMPACT		HIGH IMPACT		HIGH IMPACT		HIGH IMPACT		MODERATE IMPACT	
New non-traditional partners, new business models	6,74	5	7,51	10	7,03	8	7,2	7	6,72	6
	MODERATE IMPACT		HIGH IMPACT		MODERATE IMPACT		MODERATE IMPACT		MODERATE IMPACT	
ecology, energy efficiency, control of environmental protection	5,13	2	5,63	2	5,26	5	6,08	3	5,67	5
	LOW IMPACT		LOW IMPACT		LOW IMPACT		MODERATE IMPACT		LOW IMPACT	
trend of socially acceptable and socially responsible business	6,19	5	7,66	5	7,27	5	7,62	3	7,27	10
	MODERATE IMPACT		MODERATE IMPACT		MODERATE IMPACT		MODERATE IMPACT		HIGH IMPACT	
mergers, investments and acquisitions	6,12	10	6,31	1	5,97	1	6,68	10	7,15	8
	HIGH IMPACT		MODERATE IMPACT		VERY LOW IMPACT		HIGH IMPACT		MODERATE IMPACT	
Inability to innovate, innovation	7,88	11	7,66	10	7,11	1	7,17	10	7,69	7
	HIGH IMPACT		HIGH IMPACT		MODERATE IMPACT		HIGH IMPACT		MODERATE IMPACT	
Changes in maintenance of infrastructure, changes to investment in infrastructure	8,70	10	8,32	10	7,86	10	8,13	10	7,84	10
	HIGH IMPACT		HIGH IMPACT		HIGH IMPACT		HIGH IMPACT		HIGH IMPACT	
the risk of new technologies, how introduction of new technologies can affect the business	8,70	10	7,77	10	7,90	10	7,00	10	6,85	10
	HIGH IMPACT		HIGH IMPACT		HIGH IMPACT		HIGH IMPACT		HIGH IMPACT	
tax risk, risk of change in tax policy	8,18	5	8,00	3	7,63	5	9,14	10	8,44	10
	MODERATE IMPACT		MODERATE IMPACT		MODERATE IMPACT		HIGH IMPACT		HIGH IMPACT	
price pressure - decrease of prices due to various causes	8,92	15	9,43	15	9,73	15	9,92	15	9,58	15
	HIGH IMPACT		VERY HIGH IMPACT		VERY HIGH IMPACT		VERY HIGH IMPACT		VERY HIGH IMPACT	

Figure 7. Impact of business system cost risk on the business success structure and the state of business system

The analysis of the results of the survey shows that changes in legislation and regulations as a business system risk have a high impact on investment in basic assets and on gross profit, whereas they have the lowest impact intensity on the overall business system revenues, namely, moderate impact. On average, the highest impact on the business system success is made by business system risks along with price pressure or decrease of prices due to various causes. The impact intensity of this business risk is very high for the cost of operating a business system, investment in working capital, gross profit and total revenues. These business risks also have a high intensity impact on investment in basic working capital. On average, the lowest impact on the business system is made by business system risks related to ecology, energy efficiency, and environmental regulation. According to research results, their impact intensity is low on investment in working capital, operating system costs, investment in working capital and total income.

5.6 Impact of business system risk on increase of the corresponding part of business system costs

This part of the study analyzes the impact of the risk source on a part of the business system. The results show the mean values for contractors who believe that some of the business system risk sources are affecting the business system. For business system resources that affect the business system costs by more than 1%, we say they have a significant impact on costs, while for those below 1% we say that they only affect the business system costs. For the impact results with an average value below 0, we consider them not to affect the operating costs of a business system.

BUSINESS SYSTEM RISKS	INVESTMENT IN BASIC ASSETS (SS)	OPERATING COSTS OF BUSINESS SYSTEM (HP)	INVESTMENT IN WORKING CAPITAL (OS)	GROSS PROFIT	TOTAL REVENUE
changes in legislation and regulations	1,95%	2,63%	2,42%	1,13%	1,26%
the ability to access credits	0,87%	0,28%	1,26%	-0,30%	0,10%
slow recovery, double effect of recesion, double after a short recovery	1,14%	2,78%	1,64%	0,58%	-7,08%
Problems in talent management, fluctuation, education, training	0,08%	0,28%	0,05%	-0,13%	-0,13%
Emerging markets, transition	2,08%	0,38%	1,08%	0,56%	0,82%
activities on cost cutting	0,26%	0,70%	0,00%	0,10%	-0,21%
New non-traditional partners, new business models	0,87%	1,13%	1,10%	0,38%	0,85%
ecology, energy efficiency, control of environmental protection	0,64%	0,90%	0,90%	0,50%	0,60%
trend of socially acceptable and socially responsible business	0,49%	1,03%	0,55%	0,55%	0,35%
mergers, investments and acquisitions	0,56%	0,00%	0,18%	0,00%	0,05%
Inability to innovate, innovation	1,36%	1,13%	0,74%	-0,13%	-0,15%
Changes in maintenance of infrastructure, changes to investment in infrastructure	1,23%	1,08%	0,18%	-0,13%	-0,69%
the risk of new technologies, how introduction of new technologies can affect the business	1,28%	1,74%	0,77%	0,63%	-0,16%
tax risk, risk of change in tax policy	2,48%	1,64%	1,90%	1,51%	1,26%
price pressure - decrease of prices due to various causes	3,18%	3,13%	2,92%	1,50%	1,34%

Figure 8. Impact of business system cost risk on the increase of a part of business system costs

Significant impact on investment in basic working capital as a business risk source is made by the changes in legislation, slow recovery from recession, emerging and transition markets, inability to innovate, changes of government investment in infrastructure, the risk of new technologies, tax risk, and the highest impact of 3.08% is made by price pressures or price drops due to various causes.

Changes in legislation, slow recovery from recession, new non-traditional collaborators, a trend of socially acceptable and socially responsible business, the inability to innovate, the change of government investment in infrastructure, the risk of new technologies, the tax risk, and price pressure or price drop have a significant impact on the business system costs. Price pressures also have high impact on costs of operating the business system (3.13%), whereas they are not impacted by merger, investment and acquisitions (0.00%).

Changes in legislation, access to credit, slow recovery, emerging markets, new non-traditional partners, tax risk and price pressures have a significant impact on investment in working capital. The minimum intensity of the impact on investment in working capital is posed by problems in managing talents and this is 0.05%, while the greatest impact is related to price pressure risks - 2.92%.

Significant impact on gross profit is made by business system risk sources related with changes in legislation, tax risks and price pressure or price drop risks due to various causes. The highest impact on gross profit is made by tax risks (1.51%) and respondents believe that gross profit is not affected by business risks related to the possible access to credits, talent management problems, and inability to innovate and the change of government investment in infrastructure.

The overall revenue of the business system is significantly impacted by the risk sources related to changes in legislation and regulations, tax risks as well as price pressures or price drops due to various causes.

This part of the research can serve as a recommendation for identifying the size of the impact that the source of the risk poses to a certain part of the business system state of affairs. It is certainly necessary to take into account the choice of a risk source by the intensity of the link of identified risk as well as the probability of occurrence of the observed risk.

5.7 Impact of business risk initiators on probability of initiating business risks

This part of the paper analyzes the research results of the phenomena that initiates the business risk from the passive to the active state. The impacts of initiators on a particular risk source are classified into five impact intensities.

Table 4. Classes of the intensity of initiators impact to individual risk sources

Impact intensity		Respondents' attitude
Very low impact	VNU	0-20 %
Low impact	NU	20 - 40 %
Moderate impact	UU	40 - 60 %
High impact	VU	60 - 80 %
Very high impact	VVU	80 - 100 %

A risk initiator is considered as relevant if at least 20% of the surveyed organizations estimate that initiator as able to initiate a risk from the passive to the active state.

BUSINESS SYSTEM RISKS	FALL OF REVENUE	INCREASE OF NUMBER OF COURT SETTLEMENT	FLUCTUATIONS OF KEY PERSONNEL	LOSS OF CUSTOMERS	LOSS OF TENDERS	INSOLVENCY	LOSS OF PARTNERS	CANCELLATION OF SUPPLIERS	LACK OF BANK SUPPORT
changes in legislation and regulations	55,00% MODERATE	47,50% MODERATE	15,00%	7,50%	17,50%	27,50% LOW	10,00%	5,00%	10,00%
the ability to access credits	27,50% LOW	12,50%	10,00%	15,00%	30,00% LOW	52,50% MODERATE	22,50% LOW	20,00% LOW	40,00% MODERATE
slow recovery, double effect of recesion, double after a short recovery	67,50% HIGH	20,00% LOW	20,00% LOW	40,00% MODERATE	20,00% LOW	30,00% LOW	15,00%	20,00% LOW	10,00%
Problems in talent management, fluctuation, education, training	35,00% LOW	7,50%	45,00% MODERATE	10,00%	2,50%	7,50%	5,00%	10,00%	10,00%
Emerging markets, transition	37,50% LOW	5,00%	22,50% LOW	10,00%	12,50%	10,00%	12,50%	15,00%	10,00%
activities on cost cutting	22,50% LOW	10,00%	25,00% LOW	7,50%	7,50%	17,50%	10,00%	12,50%	12,50%
New non-traditional partners, new business models	12,50%	17,50%	12,50%	10,00%	15,00%	12,50%	10,00%	17,50%	20,00% LOW
ecology, energy efficiency, control of environmental protection	25,00% LOW	25,00% LOW	10,00%	7,50%	12,50%	5,00%	2,50%	5,00%	2,50%
trend of socially acceptable and socially responsible business	27,50% LOW	15,00%	22,50% LOW	2,50%	17,50%	15,00%	7,50%	10,00%	10,00%
mergers, investments and acquisitions	27,50% LOW	5,00%	7,50%	2,50%	15,00%	12,50%	12,50%	5,00%	5,00%
Inability to innovate, innovation	25,00% LOW	7,50%	12,50%	20,00% LOW	15,00%	15,00%	12,50%	10,00%	22,50% LOW
Changes in maintenance of infrastructure, changes to investment in infrastructure	35,00% LOW	22,50% LOW	15,00%	15,00%	15,00%	5,00%	7,50%	10,00%	10,00%
the risk of new technologies, how introduction of new technologies can affect the business	15,00%	10,00%	15,00%	15,00%	15,00%	5,00%	7,50%	10,00%	10,00%
tax risk, risk of change in tax policy	62,50% HIGH	27,50% LOW	12,50%	15,00%	7,50%	27,50% LOW	15,00%	15,00%	12,50%
price pressure - decrease of prices due to various causes	67,50% HIGH	12,50%	30,00% LOW	10,00%	22,50% LOW	22,50% LOW	17,50%	37,50% LOW	10,00%

Figure 9. Impact of risk initiators on individual risk source

According to the research results we can conclude that all business risk initiators other than new non-traditional collaborators and the risk of new technologies may lead to initiating the income drop risk from passive into active state. High impact on the income drop risk is made by a slow recovery from recession, tax risk and price pressures.

According to the research, the most common risk initiator that can lead to risk initiation from passive to active state is the risk initiator related to slow recovery from recession and the least risk-driving initiator is the initiator related to new non-traditional collaborators and the risk of new technologies. Initiating the risk of losing customers and losing partners is very rare according to the respondents. Only the initiators of risk related to slow recovery from recession and the inability to innovate affect the initiation of customer loss, whereas risk initiators associated with credit access impact the activation of loss of partner risk with low intensity

5.8 Results of revenues research and of provisions for risks in total business system revenues

The study investigated the most common amount of business risk provisions covered by the company's indirect costs in the total cost of the project. The respondents most commonly answered that they reserve 1% for business risks in the prices of their projects. According to Pert distribution with an 80% probability, the adoption of an amount of 2.53% of the cost for business risks could be considered.

The survey also investigated by what percentage the business systems usually plan to increase revenues over the next year or period relative to the revenues in the previous year or period. The most common respondents' answer was that they plan 10% higher revenues over the next period compared to the previous one. According to Pert distribution with an 80% probability, 12.83% of planned revenue growth could be considered as compared to the previous period.

The results of the revenues percentage for the next year or the period that had already been provided at the time of developing the plan were also analyzed. The most commonly respondents answered that only 30% of revenues was provided at the time of the plan's adoption. According to Pert distribution with an 80% probability, an adoption of 44.80% for insured revenues at the time the business plan was created could be considered.

6. Contributions of research and future research

As a review of the literature found a lack of a model for incorporating the risk impact when a contractor of construction works forms the project bid price, a questionnaire was developed to investigate the impact of risk on the bid price and the contractor’s project budget. The research results were analyzed in the paper. The interdependence of the results of certain parts of the research has not been analyzed here, nor is the way of applying these results addressed. These research results will be used to form the model of bid price and project budgets that will adequately include all project and business system risk impacts. By comparing the results and establishing the interdependence of results with regard to the impact of risk on project and business systems, the results will be prepared for application in the future model. By applying this model, the contractor will avoid excessive risk provisions in its bid price, thereby increasing the possibility to be awarded a contract and to increase the revenues of the business system. By the application of such model, the contractor will also avoid too scarce reservations for the risks that could cause disasterous consequences for the project as well as for the entire business system during the project implementation. In the follow up to this research, the formation of this model will be introduced and potential further research conducted in order to create a more detailed model. Also, the application and verification of the formed model on a number of projects will be ensured.

7. Literature

Akintoye, A. S. and MacLeod, M. J. (1997); Risk analysis and management in construction. International Journal of Project Management, 15(1), 31-38.

Baloi, D. and Price, A. D. F. (2003); Modelling global risk factors affecting construction cost Performance. International Journal of Project Management, 21, 261-269.

Đukan, P. (1986); Standardna kalkulacija, Građevinar, Zagreb.

Flanagan, R. and Norman, G. (1993); Risk Management and Construction, Blackwell Science Ltd, London.

Laryea, S. and Hughes, W. (2008); How contractors price risk in bids: theory and practice, Construction Management and Economics, 26(9), 911-924.

Laryea, S., & Hughes, W. (2011); Risk and Price in the Bidding Process of Contractors. Journal of Construction Engineering & Management, 137(4), 248-258.

Neufville, R. and King, D. (1991); Risk and need-for-work premiums in contractor bidding, Journal of Construction Engineering and Management, 117(4), 659-73.

Radujkovic, M. (1997); Risk Sources and Drivers in Construction Projects. In: Kähkönen, K. and Artto, KA (Ed.), International Symposium PRM'97- International Association for Project Management, E&FN SPON, 275-284.

Shash, A. A. (1993); Factors considered in tendering decisions by top UK contractors, Construction Management and Economics, 11, 111-118.

Smith, N. et al. (2006); Managing Risk in Construction Projects 2nd Edition, Blackwell Publishing Ltd, 9600 Garsington Road, Oxford OX4 2DQ, UK.

Smith, N. J. (2003); Appraisal, Risk and Uncertainty (Construction Management Series), London: Thomas Telford Ltd, UK.

Smith, G. R. and Bohn, M. C. (1999); Small to medium contractor contingency and assumption of risk, Journal of Construction Engineering and Management, ASCE, 125(2), 101-108.

Srića, V. (2011); Menadžment rizika, Collegium Sibenicense Polytechnic of Šibenik, Šibenik.

Cost Optimal Time Scheduling Integrating Spreadsheet and Project Management Software

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Abstract:

Time scheduling represents an important phase in project management. In its implementation, durations and costs of project activities should be considered in such manner to obtain a cost-effective time schedule. Therefore, the basic aim of this paper is to introduce an approach to cost optimization of project time schedules which combines a spreadsheet application and data transfer to project management software. At this point, the project scheduling problem is modelled using Microsoft Excel and optimally solved with Solver while organization of data is handled by macros. Afterwards, Microsoft Project is employed to further manage and demonstrate the attained optimal scheduling results. An example is presented in the paper to show the advantages of the proposed approach.

Keywords: *optimization; project scheduling; spreadsheet application; project management software;*

1. Introduction

Practical relevance of cost effective time scheduling in project management was recognised by numerous researchers. Every project activity requires employment of certain resources and direct cost. Activity acceleration usually requires additional resources and associated direct cost is consequently increased. Project duration is also in pair with indirect costs which are decreased by its acceleration. Critical success factor can be often identified as keeping the project budget within boundaries and not to exceed the project deadline. At this point, a cost effective project schedule is traditionally achieved in a cost-duration analysis among various feasible alternatives.

Over the years, researchers have applied different methods for cost optimization of project schedules. In this way, research works focused on optimal project scheduling using classical approximate heuristic methods can be found in literature. For example, models for optimization of project schedules using genetic algorithm (GA) were proposed by Zheng et al. (2004), Senouci and Eldin (2004) and others. Simulated annealing (SA) optimization model for optimal scheduling was proposed by Azaron et al. (2007) while neural network (NN) model formulation was developed by Adeli and Karim (1997). A model for project scheduling that is based on the ant colony optimization approach was introduced by Xiong and Kuang (2008) and the particle

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swarm optimization (PSO) model was set by Yang (2007). Certainly, there exist many further extensions of mentioned techniques that are available in literature.

In search of high quality solutions, different exact methods for cost optimization of project schedules have been also proposed alongside mentioned heuristic methods and their extensions. There are roughly two branches of mathematical models that were frequently suggested to be used with exact methods. On one side, there are models with linear problem formulations, like those proposed by Achuthan and Hardjawidjaja (2001), Möhring et al. (2001), Vanhoucke et al. (2002), Sakellaropoulos and Chassiakos (2004) and others. On the other hand, there also exist models that may contain non-linearities, like those introduced by Deckro and Hebert (2003), Turnquist and Nozick (2004), Klanšek and Pšunder (2010), etc.

Usage of commercial software packages is often needed to optimally solve project scheduling models in practice. Core of software packages are solver engines with different algorithms capable of solving only a certain class or a number of different classes of optimization models. For example, some of the most widely used software packages in this field are (Sarker and Newton 2007): LINDO, LINGO, XPRESS, CPLEX, MINOS and Excel Solver. The latter one is a part of the Microsoft Office Excel, a powerful spreadsheet tool with VBA robust programming capabilities. Application of Solver in mentioned area was proposed by various researchers like Filho et al. (2010), Trautmann and Gnagi (2015) among others.

Project management software has been often considered for graphical representation and control of time schedules. In this context, Microsoft Project was frequently recognized as a very useful project management software (Kostalova and Tetrevova 2014) and its successful applications were documented in many articles (Kazovic and Valencic 2013; Von Laszewski and Dilmanian 2008).

The main aim of this paper is to introduce an approach to cost optimization of project time schedules which combines a spreadsheet application and data transfer to project management software. At this point, the project scheduling problem is modelled using Microsoft Excel and optimally solved with Solver while organization of data is handled by macros. Afterwards, Microsoft Project is employed to further manage and demonstrate the attained optimal scheduling results. An example is presented in the paper to show the advantages of the proposed approach.

2. Modelling and solving optimization problem with spreadsheets

Advantages of spreadsheets have been recognised among users quite some time ago and these kinds of tools are nowadays widely extended into many fields of human activities. The reason behind their success is their intuitive cell based structure and simple interface. Features incorporated in application, such as data entry and manipulation, functions, charts, word processing capabilities, workgroup sharing, programmability options and a number of add-in programs, make them one off the essential and frequently used tools by numerous computer users who have to process and handle a large number of information. With their wide use, spreadsheets have been used as tools for developing mathematical models in many different branches. In this paper, a spreadsheet program, Microsoft Excel 2016 is used to model the optimization problem for time scheduling.

Excel contains add-in tool called Solver that can be used for purposes of mathematical optimization model solving. Solver tool is basically software program where solver engines containing more algorithms for solving a certain mathematical model are nested and was developed by Frontline Systems (Frontline Systems 2017). Simplex LP engine is used here to resolve time scheduling optimization problem presented as example in continuation of this paper. Engine is capable of solving smooth linear optimization problems and is one of three engines that are part of the Solver software, others being GRG Nonlinear engine, for solving smooth nonlinear optimization problems, and Evolutionary engine, for non-smooth problems.

When project schedule is determined by optimization process, data need to be processed by project management software in which their graphical representation and control during the project duration can be done. Software is capable of importing spreadsheets but only in certain data arrangement. Excel programming capabilities, called Visual Basic for Applications (VBA) are suggested as very powerful additional feature at that phase.

VBA is an implementation of Microsoft´s event-driven programming language Visual Basic and enables building of automated processes. It is used to automate the process of creating spreadsheet form, recognised by project management software, from optimized time schedule data in Microsoft Excel file.

3. Project management software

Project management software were developed to support planning, organizing and managing resource tools in project management. They can manage estimation, scheduling, budget management, resource allocation, collaboration, communication, decision-making, quality management, and administration systems. Numerous project management software solutions are currently available at the market. To manage example project schedule in this particular paper, Microsoft Project is implemented. It is aimed for planning, monitoring and control of project realization, and is one of the most widely used software packages for project management.

It is important that all planned activities are carried out within a deadline, that the financial plan is levelled with the estimated budget and that the project beneficiaries are satisfied with implementation of the project including benefits derived from it (Biafore 2013; Harris 2016). With MS Project following can be achieved (Marmel 2013):

- monitoring of all gathered information about the project,
- visualization and presentation of the project schedule,
- efficient allocation of tasks and resources,
- exchange of information on the project within the project team,
- communication with involved parties in the project, etc.

Program is used here in the context of graphical presentation of optimal project schedule for the example taken from the literature. In the beginning, basic information about the project are entered in Project options dialog e.g. calendar type, currency, start date, work days, hours of work per day, etc. as shown in Figure 1.

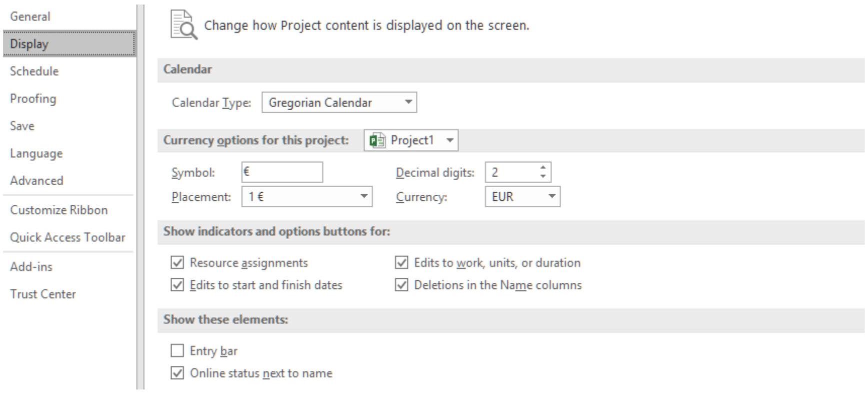

Figure 1: Project options

Project information about project activities, durations, costs and precedence relationships needs to be inputted into the project management software. Since all information are already existing in MS Excel, macro written in VBA programming language is executed to form a new spreadsheet recognised by MS Project. New spreadsheet needs columns with following information about activities for input recognition: ID, name, duration, predecessors and costs. Import wizard needs to be executed for data transfer when all the data are nested in new spreadsheet, see Figure 2.

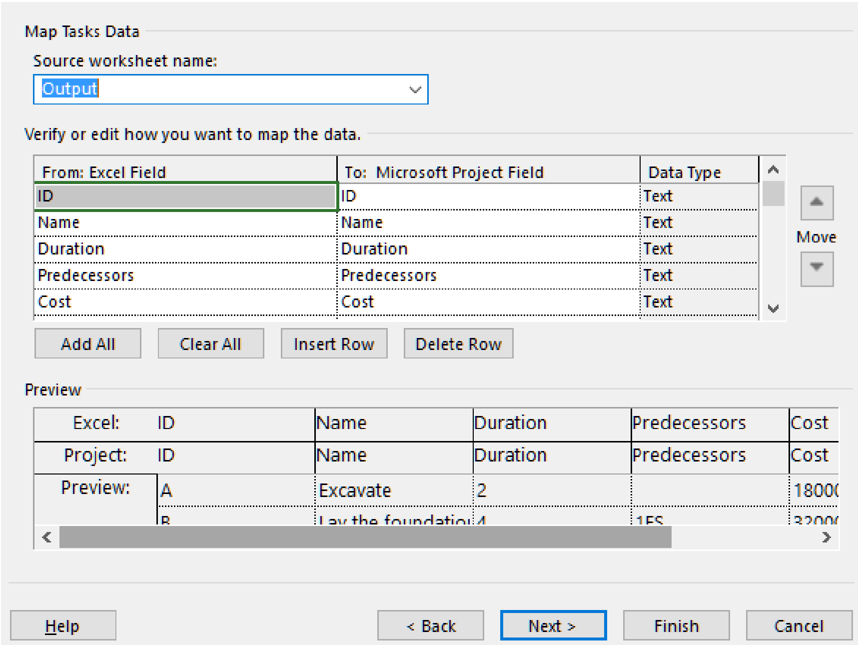

Figure 2: Import wizard

Visualization of the optimal time schedule is achieved in MS Project where Gantt chart tool is used for illustration of time schedule. Gantt chart enables simpler determination of starting and finishing times for activities on a time line.

4. Example from the literature

To show the advantages of solving cost optimization problems in field of project scheduling using Solver and data transfer from Microsoft Excel to Microsoft Project, a modified example project, originally presented by (Hillier and Lieberman 2014) is considered here. Project consists of 14 activities. Project activities and their predecessors are given as:

- A excavate,
- B lay the foundations, preceding activity: A,
- C put up the rough wall, preceding activity: B,
- D put up the roof, preceding activity: C,
- E install the exterior plumbing, preceding activity: C,
- F install the interior plumbing, preceding activity: E,
- G put up the exterior siding, preceding activity: D,
- H do the exterior painting, preceding activities: E, G,
- I do the electrical work, preceding activity: C,
- J put up the wallboard, preceding activity: F, I,
- K install the flooring, preceding activity: J,
- L do the interior painting, preceding activity: J,
- M install the exterior fixtures, preceding activity: H,
- N install the interior fixtures, preceding activities: K, L.

The alternative cost-duration options and the direct cost-duration functions for the project activities are presented in Table 1. Linear approximation of the direct cost-duration functions is developed for project activities based on the alternative cost-duration options. First option represents crashed activity duration while second option is representation of normal activity duration.

Table 1: Duration and direct costs of activities

Activity ID	Duration [weeks]		Direct cost		Direct cost-duration function
	Option 1	Option 2	Option 1	Option 2	
A	1	2	280000	180000	$(380\text{-}100T_A) \times 10^3$
B	2	4	420000	320000	$(520\text{-}50T_B) \times 10^3$
C	7	10	860000	620000	$(1420\text{-}80T_C) \times 10^3$
D	4	6	340000	260000	$(500\text{-}40T_D) \times 10^3$
E	3	4	570000	410000	$(1050\text{-}160T_E) \times 10^3$
F	3	5	260000	180000	$(380\text{-}40T_F) \times 10^3$
G	4	7	1020000	900000	$(1180\text{-}40T_G) \times 10^3$
H	6	9	380000	200000	$(740\text{-}60T_H) \times 10^3$
I	5	7	270000	210000	$(420\text{-}8300T_L) \times 10^3$
J	6	8	490000	430000	$(670\text{-}30T_J) \times 10^3$
K	3	4	200000	160000	$(320\text{-}40T_K) \times 10^3$
L	3	5	350000	250000	$(500\text{-}50T_L) \times 10^3$
M	1	2	200000	100000	$(300\text{-}100T_M) \times 10^3$
N	3	6	510000	330000	$(690\text{-}60T_N) \times 10^3$

The targeted project duration is fixed at 47 weeks and indirect project cost is 31.000 € per week. The objective of optimization was to find the project time schedule with optimal durations and start times of activities at minimal total project costs. The LP optimization model formulation was set and Excel, a spreadsheet application from Microsoft, was used for modelling for the data inputs/outputs. Excel Solver was enabled to perform the cost optimization of example project time schedule using the developed model. The considered optimization problem was solved by personal computer, Intel Core2 Duo P8600, 2.40 GHz, 4GB RAM DDR3 and 250 GB SSD disc. Note here that the optimization problem formulation for the example project can be found in reference (Hillier and Lieberman 2014).

The LP approach applied on the project scheduling problem represents continuous optimization technique where optimal values of continuous variables were calculated inside their upper and lower bounds. Spreadsheet application Excel from Microsoft was employed for modelling and for data inputs/outputs. Input data for the example project are presented in Figure 3.

Activity		
ID	Description	Preceding activities
A	*Excavate*	-
B	*Lay the foundations*	A
C	*Put up the rough wall*	B
D	*Put up the roof*	C
E	*Install the exterior plumbing*	C
F	*Install the interior plumbing*	E
G	*Put up the exterior siding*	D
H	*Do the exterior painting*	E, G
I	*Do the electrical work*	C
J	*Put up the wallboard*	F, I
K	*Install the flooring*	J
L	*Do the interior painting*	J
M	*Install the exterior fixtures*	H
N	*Install the interior fixtures*	K, L

Targeted project duration [weeks]
47

Indirect project cost [€/week]
31000

Activity	Duration [weeks]		Direct cost [€]		Direct cost-duration function
ID	Option 1	Option 2	Option 1	Option 2	[× 1000 €]
A	1	2	280000	180000	$380\text{-}100T_A$
B	2	4	420000	320000	$520\text{-}50T_B$
C	7	10	860000	620000	$1420\text{-}80T_C$
D	4	6	340000	260000	$500\text{-}40T_D$
E	3	4	570000	410000	$1050\text{-}160T_E$
F	3	5	260000	180000	$380\text{-}40T_F$
G	4	7	1020000	900000	$1180\text{-}40T_G$
H	6	9	380000	200000	$740\text{-}60T_H$
I	5	7	270000	210000	$420\text{-}8300T_L$
J	6	8	490000	430000	$670\text{-}30T_J$
K	3	4	200000	160000	$320\text{-}40T_K$
L	3	5	350000	250000	$500\text{-}50T_L$
M	1	2	200000	100000	$300\text{-}100T_M$
N	3	6	510000	330000	$690\text{-}60T_N$

Figure 3: Input data in MS Excel

First spreadsheet defines input data of the addressed example like project activities IDs, activities descriptions, preceding activities, durations and direct costs of activities with normal and crashed durations, direct cost-duration functions, targeted project duration and indirect project cost.

For further data manipulation array of preceding and succeeding activities was created. Preceding activities were presented as columns and succeeding activities were presented as rows of the array. When finish-to-start relation between activities was established, value of the intersecting element was 1. Array was defined in second spreadsheet as presented in Figure 4.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
1	Suc\Pre	A	B	C	D	E	F	G	H	I	J	K	L	M	N	
2	A															
3	B	1														
4	C		1													
5	D			1												
6	E			1												
7	F					1										
8	G				1											
9	H					1		1								
10	I			1												
11	J						1			1						
12	K										1					
13	L										1					
14	M								1							
15	N											1	1			
16																
17																

Figure 4: Array of activities

The cost optimization of the project time schedule was performed with Solver which is an integral part of Microsoft Office Excel. Durations and start times of activities were defined as changing cells in third spreadsheet as presented in Figure 5.**Error! Reference source not found.** Objective function and (in)equality constrains were included into model as well.

	A	B	C	D	E	F
2		Activity ID	Activity duration [weeks]	Activity start time [week]	Direct cost [€]	
3		A	2	0	=(380-100*C3)*1000	
4		B	4	2	=(520-50*C4)*1000	
5		C	10	6	=(1420-80*C5)*1000	
6		D	6	18	=(500-40*C6)*1000	
7		E	4	16	=(1050-160*C7)*1000	
8		F	5	20	=(380-40*C8)*1000	
9		G	7	24	=(1180-40*C9)*1000	
10		H	9	31	=(740-60*C10)*1000	
11		I	7	16	=(420-30*C11)*1000	
12		J	6	25	=(670-30*C12)*1000	
13		K	4	31	=(320-40*C13)*1000	
14		L	5	31	=(500-50*C14)*1000	
15		M	2	40	=(300-100*C15)*1000	
16		N	6	36	=(690-60*C16)*1000	
17		Project	42	0	=SUM(E3:E16)+Input!B24*C17	<--- Optimization function
18						
19		FS precedence relationship		Project duration constrains		
20		Nr.	Equation	Nr.	Equation	
21		1	=C3+D3-D4	1	=D15+C15-D3	
22		2	=C4+D4-D5	2	=C16+D16-D3	
23		3	=C5+D5-D6			
24		4	=C5+D5-D7			
25		5	=C5+D5-D11			
26		6	=C6+D6-D9			
27		7	=C7+D7-D8			
28		8	=C7+D7-D10			
29		9	=C8+D8-D12			
30		10	=C9+D9-D10	Create output file		
31		11	=C10+D10-D15			
32		12	=C11+D11-D12			
33		13	=C12+D12-D13			
34		14	=C12+D12-D14			
35		15	=C13+D13-D16			
36		16	=C14+D14-D16			

Figure 5: Changing cells

Solver parameters had to be selected in Microsoft Office Excel Solver as described in Figure 6. Objective was apointed, where minimal value was desired and changing variable cells were described. Objective function was subjected to seven blocs of constrains and Simplex LP was used to solve the optimization problem.

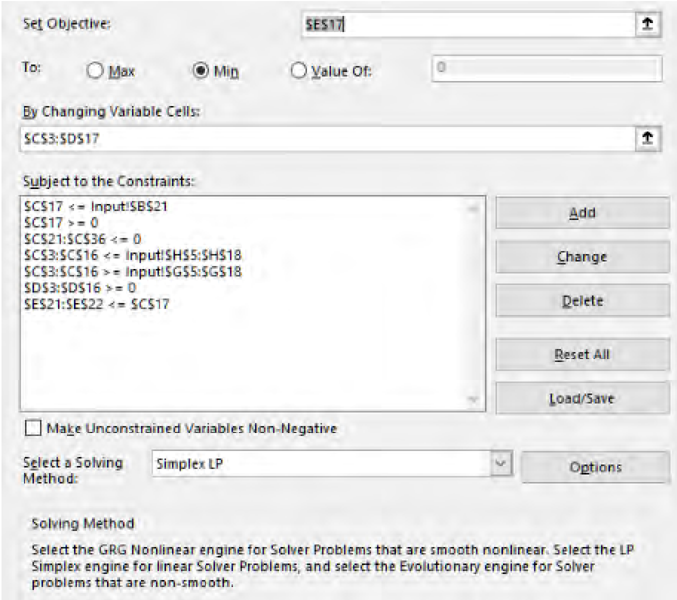

Figure 6: Solver

The minimal cost for the example project time schedule, found by selected solving method was 5.912.000 € and optimal duration of the project was 42 weeks. Direct costs of the project were 4.610.000 € and indirect costs represented 1.302.000 €. Optimal durations and direct costs of the activities are presented in Figure 7.

When the optimization process was carried out and optimal solution for the example project time schedule was obtained, macro written in VBA (Visual Basic for Applications) was used to create new output file. With the activation of the command button labelled "Create output file" shown in Figure 5, macro was executed.

Output file incorporated spreadsheet where array of project data was arranged as displayed in Figure 7. Macro transferred activities input data from first spreadsheet presented in Figure 3 to first two columns of the array. Duration of activities was rearranged from spreadsheet containing optimization variables shown in Figure 5 to third column of the new array. Similar is done to activities cost values which are presented in the fifth column.

	A	B	C	D	E	F
1	ID	Name	Duration	Predecessors	Cost	
2	A	Excavate	2		180000	
3	B	Lay the foundations	4	1FS	320000	
4	C	Put up the rough wall	10	2FS	620000	
5	D	Put up the roof	6	3FS	260000	
6	E	Install the exterior plumbing	4	3FS	410000	
7	F	Install the interior plumbing	5	5FS	180000	
8	G	Put up the exterior siding	7	4FS	900000	
9	H	Do the exterior painting	9	7FS,5FS	200000	
10	I	Do the electrical work	7	3FS	210000	
11	J	Put up the wallboard	6	9FS,6FS	490000	
12	K	Install the flooring	4	10FS	160000	
13	L	Do the interior painting	5	10FS	250000	
14	M	Install the exterior fixtures	2	8FS	100000	
15	N	Install the interior fixtures	6	12FS,11FS	330000	

Figure 7: Output file

Precedence relationships between example project activities were defined as finish-to-start ones and, therefore, predecessors in the fourth column were labeled with the number of preceding activity and FS abbreviation. Precedence relationships are rearranged from array of activities shown in Figure 4. Created output file was then used to import optimized data into Microsoft Office Project where further data management was possible. Creation of graphical presentation of optimal project time schedule, presented in Figure 8, was generated applying the Gantt chart tool.

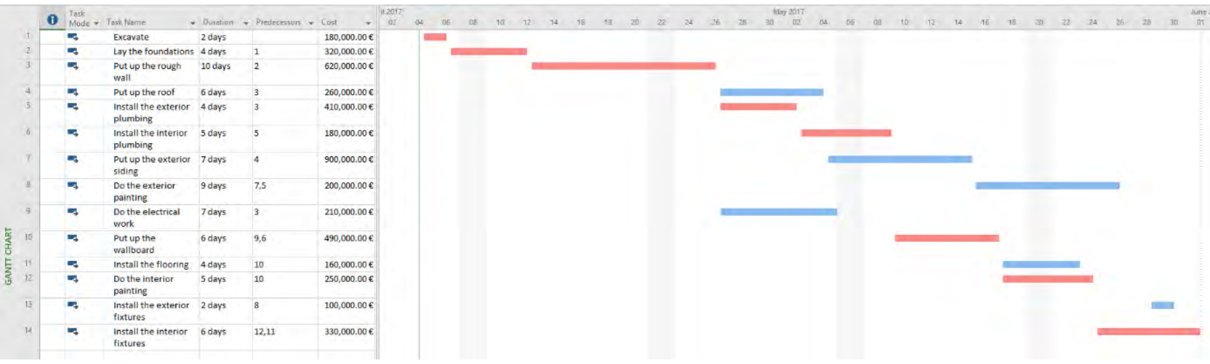

Figure 8: Optimal schedule of the example project

Critical activities were labelled with red colour in the Gantt chart and composed the critical path of the optimized project schedule. As well known, their duration can directly affect the duration of the project and its costs. When duration of those activities is crashed, the direct costs are increased but indirect cost of the project is reduced since duration of the project is also reduced. Acceleration of non-critical activities, labelled with blue colour, does not have the same effect since it does not affect the duration of the project and can only raise the direct costs.

5. Conclusion

Construction projects are often recognised as complex tasks where many activities must be executed in certain order before production is completed. Resources such as manpower, machinery, materials and equipment are utilized in construction activities. Moreover, resources can be allocated to different activities in such a manner that activity durations are crashed or delayed and, therefore, time schedule is very significant for cost effective execution of the construction project.

Importance of tools for project management was recognised by many experts in construction business since its use enables more efficient time scheduling. With rise of computers many software programs have arrived and allow faster and easier implementation of management tools to workflow. Contemporary project management software is nowadays used for monitoring and visualization of the tasks, exchange of information on the project within the project team, communication with parties involved in project, etc. Cost optimization of time schedule, on the other hand, is usually accomplished with specialized software for solving mathematical models and information flow to project management programs is needed.

In this paper, flow of information from Microsoft Office Excel, where optimization of the time schedule was accomplished, to Microsoft Project, a project management software, was shown. Programs were selected because Microsoft Office suite is widely used across construction companies and it contains tools needed for the process.

The example demonstrated that the project modeled and optimized in Microsoft Office Excel can be easily transferred to Microsoft Project, where visualization and further treatment of the information can be performed. Data flow between programs is automated and chance of error occurrence in the process is minimized.

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References

Achuthan, N.R. and Hardjawidjaja, A. (2001), "Project Scheduling under Time Dependent Costs – A Branch and Bound Algorithm", Annals of Operations Research, Vol. 108, No. 4, pp. 55–74.

Adeli, H. and Karim, A. (1997), "Scheduling/Cost Optimization and Neural Dynamics Model for Construction", Journal of Construction Engineering and Management, Vol. 123 No. 4, pp. 450–458.

Azaron, A., Sakawa, M., Tavakkoli-Moghaddam, R., and Safaei, N. (2007), "A discrete-time approximation technique for the time-cost trade-off in PERT networks", RAIRO - Operations Research, Vol. 41 No. 1, pp. 61–81.

Biafore, B. (2013), Microsoft Project 2013 : the missing manual, O'Reilly Media, Sebastopol, CA.

Deckro, R.F. and Hebert, J.E. (2003), "Modeling diminishing returns in project resource planning", Computers & Industrial Engineering, Vol. 44 No. 1, pp. 19–33.

Filho, O.S.S., Cezarino, W. and Ratto, J. (2010), "Aggregate production planning: Modeling and solution via Excel spreadsheet and solver", in IFAC Proceedings Volumes, Elsevier, Vol. 43 No. 17, pp.89–94 .

Frontline Systems, (2017), "Frontline Solvers Optimization and Simulation User Guide", available at: https://www.solver.com/user-guides-frontline-systems-excel-solvers/ (accessed 10 April 2017).

Harris, P.E. (2016), Planning and control using Microsoft Project 2013 and 2016, Eastwood Harris Pty Ltd, Doncaster Heights, Victoria.

Hillier, F.S. and Lieberman, G.J. (2014), Introduction to operations research 10th ed., McGraw-Hill Higher Education, New York, NY.

Kazovic, D. and Valencic, D. (2013), "Using Microsoft Project for project management in non-governmental organisations", in Information & Communication Technology Electronics & Microelectronics (MIPRO), 2013 36th International Convention, IEEE, pp. 681–684.

Klanšek, U. and Pšunder, M. (2010), "Cost Optimization of Time Schedules for Project Management", Economic Research-Ekonomska Istraživanja, Vol. 23 No. 4, pp. 22–36.

Kostalova, J. and Tetrevova, L. (2014) "Project Management and its Tools in Practice in the Czech Republic", Procedia - Social and Behavioral Sciences, Vol. 150, pp.678–689.

Von Laszewski, G. and Dilmanian, L.E. (2008), "E-science project and experiment management with microsoft project", Proceedings of the Grid Computing Environments (GCE) workshop, held at the austin Civic Center: Austin, Texas, GCE, Austin, Texas.

Marmel, E. (2013), Project 2010 bible, John Wiley & Sons, Indianapolis, Indiana

Möhring, R.H., Schulz, A.S., Stork, F. and Uetz, M. (2001), "On project scheduling with irregular starting time costs", Operations Research Letters, Vol. 28 No. 4, pp. 149–154.

Sakellaropoulos, S. and Chassiakos, A.P. (2004), "Project time–cost analysis under generalised precedence relations", Advances in Engineering Software, Vol. 35 No. 10, pp. 715–724.

Sarker, R.A., Newton, C.S. and Charles S. (2007), Optimization modelling : a practical approach, CRC Press, Boca

Raton, FL.

Senouci, A.B. and Eldin, N.N. (2004), "Use of Genetic Algorithms in Resource Scheduling of Construction Projects", Journal of Construction Engineering and Management, Vol. 130 No. 6, pp. 869–877.

Trautmann, N. and Gnagi, M. (2015), "On an application of Microsoft Excel's evolutionary solver to the resource-constrained project scheduling problem RCPSP", In 2015 IEEE International Conference on Industrial Engineering and Engineering Management (IEEM). IEEE, pp. 646–650.

Turnquist, M.A. and Nozick, L.K. (2004), "A Nonlinear Optimization Model of Time and Resource Allocation Decisions in Projects With Uncertainty", Engineering Management Journal, Vol. 16 No. 1, pp. 40–49.

Vanhoucke, M., Demeulemeester, E. and Herroelen, W. (2002), "Discrete time/cost trade-offs in project scheduling with time-switch constraints", Journal of the Operational Research Society, Vol. 53 No. 7, pp. 741–751.

Xiong, Y. and Kuang, Y. (2008), "Applying an Ant Colony Optimization Algorithm-Based Multiobjective Approach for Time–Cost Trade-Off", Journal of Construction Engineering and Management, Vol. 134 No. 2, pp. 153–156.

Yang, I.-T. (2007), "Using Elitist Particle Swarm Optimization to Facilitate Bicriterion Time-Cost Trade-Off Analysis", Journal of Construction Engineering and Management, Vol. 133 No. 7, pp. 498–505.

Zheng, D.X.M., Ng, S.T. and Kumaraswamy, M.M. (2004), "Applying a Genetic Algorithm-Based Multiobjective Approach for Time-Cost Optimization", Journal of Construction Engineering and Management, Vol. 130 No. 2, pp. 168–176.

Application of ERP Systems within Construction Industry and Probable Directions of Further Research

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Abstract:

On the one hand, the construction industry is project-oriented with a focus on Project Planning, Project Management, Project Execution and Project Control. Furthermore, construction projects are transient in nature, variable in duration and costs, and require different internal or external resources. On the other hand, the construction industry is inefficient in making successful organizational changes (e.g. reengineering of processes or accepting new technologies). Regardless of the resistance to new technologies, e.g. Information Technologies (IT), Enterprise Resource Planning (ERP) systems have been used within construction companies to improve resource efficiency and eliminate waste. As ERP systems are process-oriented tools which are not initially developed for construction industry, nowadays different applications for the construction industry are being developed, e.g. construction ERP (CERP) software. Introducing an ERP system to a construction organization demands organizational change and re-engineering of business processes. Therefore, this research investigates the current development of CERP systems as well as their successful integration with the current business setting. Finally, further research involves exploring information exchange between construction ERP modules but also information integration of ERP system and other existing information systems (BIM modules, Project Management modules) within a construction company. At the end, this study proposes a framework for future research.

Keywords: *ERP; Construction Industry; Complexity; CERP; Integration*

1. Introduction

Enterprise Resource Planning (ERP) is an information model of enterprise management. This is never-ending process of effective planning and controlling all resources needed, with the main task to integrate all the functions and business processes of the organization. Therefore, ERP concept is not software package but ERP system is computer application, which enable efficient resource planning, or ERP (Vuković *et al*., 2007; Rashid *et al*., 2002).

1.1. ERP Evolution

Through the history, products on the marketplace was less diverse and was delivered from stock of warehouse while manual approaches were used for stock management. As marketplace

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became more complex and demanding there was need of Information Technology (IT) implementation in material management. Development of ERP systems started in 1950s when inventory control systems were designed and implemented in organizations. Material Requirement Planning (MRP) systems were developed in 1970s as better method for planning the supply, material ordering or production of material, because MPR system has recognized connection of usage between some part of final product (e.g. nuts and bolts). MRP evolved into closed loop MRP which has kept deadlines and changes in the production of enterprise. Further development, through the Manufacturing Resource Planning (MRP II) concept, has meant optimization of production processes to coordinate the supply of required material and the needs of production. To achieve effective production using MRP II concept it was very important to unify and harmonize material, information and cost flow. First ERP systems appeared in the late 1980s and have represented software solutions which have supported information integration to coordinate all functions through organization and have automated all business processes. Different ERP vendors are specialized for different industries, but the basic modules for successful ERP implementation could be condensed to listed: module for accounting, financial, manufacturing, production, transportation, sales & distribution and human resource management (Rashid *et al*., 2002). During 2000s extended ERP systems were developed which started integration with external modules such as supply chain management (SCM), customer relationship management (CRM) and E-Business, advanced planning and scheduling, sales force automation and many other newer approaches. Moreover, the number of ERP vendors had rapidly increased. Thus today there is a multitude of ERP systems on the marketplace with similar functions and features (Vuković, *et al*., 2007, Rashid *et al*., 2002). To conclude, evolution of ERP brought development of centralized systems and processes where the data was maintained at a central location and shared with various functions of the same enterprise. Such systems overcame problems with the lack of real-time information which have caused unnecessary cost and time overruns (Tatari *et al., 2008*). Furthermore, usual organization of ERP systems is 3-tiered architecture that includes the user interface tier, the application tier and the database tier (Santos, 2009; Szitas, 2004).

1.2. ERP as a Complex Project

ERP systems have been developed in a modular approach (Luo, Strong, 2004) and they connect interrelated participants from various hierarchic rang but also interrelated data from various sources. The ERP life cycle can be studied in three phases which are investment, implementation and usage (Tatari *et al.*, 2008). Thus, introduction of ERP system in business of some company could be considered as a complex project (Ghos, Skibniewski, 2011). Due to multiple complexity, introduction of ERP concept should be included in project management and project governance activities or, in other words, it needs to be considered from strategic, tactical and operational perspective (Al-Mashari, Zairi, 2000). Moreover, the implementation of such comprehensive system is high cost and risk investment why many authors research critical success factors of ERP implementation, but also key ERP risk factors (Moon, 2007; Ghos, Skibniewski, 2011; Aloini, 2007; Ghos, Skibniewski, 2011). Examples of critical success factors are: top management support and commitment; project management and evaluation; business process reengineering and minimum customization; ERP team composition, competence and compensation; change management process; user training and evaluation; business plan and vision; enterprise wide communication and cooperation (Moon, 2007; Ghos, Skibniewski, 2011). The key risk factors are: inadequate selection of application; ineffective strategic thinking and planning strategic; ineffective project management techniques and bad managerial conduction; inadequate change management; inadequate training (Aloini, 2007; Ghos, Skibniewski, 2011). Testing ERP system in specific enterprise environment is important step to determine if system modules fit to exist (or changed) company's processes. In case the implementation is not carried out through incremental steps, failure of ERP introduction could be expected (Potosky, Olshan, 2008).

1.3. Organization and ERP System Adaptation

According to Luo and Strong (2004), four ERP characteristic cause ERP implementation issues. First, ERP is a complex system which requires the integration between data, processes and operations through the enterprise. Moreover, ERP systems are packaged software developed on the base of the best industry practices and a rarely custom to specific organization setting. Technical customization could be accomplished through three types of customization which are: module selection, table configuration and code modification (Luo, Strong, 2004). As most ERP software are developed in a modular approach, choosing certain modules that fit to company's business is the best option. In doing so, little technical customizations are possible, which are low in cost and risk. Other options (table configuration and code modification) are more flexible to adapting them to specific organization, but could be very complex and high in cost and risk. On the other hand, fit can be achieve by process customization, which is classified into three categories: no change (changes only in tasks and resources), incremental change (changes in tasks and resources; changes in relationship among tasks but also between tasks and resources) and radical change (fundamental rethinking and radical redesign of the elements in a business process). Due to many researches and practitioners, the easier and lower cost option is process customization rather than system customization. In favour of mentioned going the fact that old organization and new technology should resulted with expensive old organization. Thus, reengineering of old organization is crucial for successful ERP implementation. The exact level of each customization (system or organization) depends on specific case and requires detail analyses (Luo, Strong, 2004). To conclude, ERP systems are good vehicles for business process reengineering and introduction of IT systems.

1.4. Problem description

The type of applied ERP modules and decrease of customization implemented ERP system depends on business processes of organization, which relate to the type of industry. However, ERP vendors recognize specific business processes of certain industries, and required modules or customization. In this study, we focused on ERP customization directed towards the needs of construction industry which affects the ability of ERP system to produce process of cost estimation, project planning, construction monitoring, etc. To overcome mentioned problems many researchers suggested development of Construction Enterprise Resource Planning (CERP) systems with focus on the project (Tatari *et al.,* 2008), while other propose integration with external Information Systems related with construction (Mêda, Sousa, 2012). In this study the both aspect of further ERP development will be investigated. The aim of this paper is to explore the environment of ERP evolution and implementation within construction industry but also the possible problems of ERP implementation as well as the future directions of development. Furthermore, after the detailed literature review the next step of this research will be to explore ERP search engines. The result will be a table with listed search engines which enable custom search. Further, comparison of listed search engines will be done, to select exactly one which can help in choosing ERP system intended for usage in construction industry. Filtered ERP software will be sorted by popularity, number of reviews and given average user rating. Finally, conclusion about ERP introduction within construction market will be made.

2. Usage Enterprise Resource Planning System within Construction Industry

2.1. Construction Industry Specifics from the ERP Perspective

Construction industry is project-oriented where the business goal is to accomplish balance between production capabilities and real work of enterprise as well as achieve maximum usage of internal resources within the company (e.g. rent out owned equipment or manpower when there is absence of work, rent outside equipment or manpower when there is more work, bid lower prices to get new job, etc.). Furthermore, construction projects are transient in nature, variable in duration and costs, but also require different internal or external resources (Shi, Halpin, 2003). As such, construction industry is resistant to change and has lack of investment in new technologies (Mêda, Sousa, 2012), but to achieve progress in business and keep an important place on the market it is necessary to permit entry of Information Technology (IT). Proper IT application could give support to construction firms where business processes are very interlocked and complex. ERP systems have been used within construction companies to improve efficiency and eliminate waste, but this can be realized only with successful ERP implementation (Chung *et al.,* 2008). Thus, ERP systems should be customized to cover all company's necessary business functions where all participants should use it because they want and not because they are forced. Furthermore, ERP systems should be user friendly to increase popularity among users. Moreover, company should be focused on output quality and positive results of ERP implementation at development phase of implementation strategy, but also in later phases of implementation (Chung *et al*., 2008; Chung *et al*., 2009).

ERP systems were not initially developed for construction industry neither for small and medium companies while more than 90% of constructions firms are small to medium size (Shi, Halpin, 2003). Moreover, as ERP implementation represents expensive investment as well as involvement of human and technical resources, it is hard to expect from small enterprises to invest all their potential in mega-system, which maybe fail. According to Ahmet *et al.* (2003) little number of ERP software have been specially developed for construction industry and this is one more reason of slow ERP entry in construction industry (Ahmed *et al.*, 2003). Furthermore, Sheu *et al.* (2004) noticed that language, culture, politics, government regulations, management style, and labour skills affect various ERP implementation practices at different countries, which can affect successful ERP implementation. To prevent ERP failure, early identification of the relationship between ERP implementation and mentioned national difference variables is necessary (Sheu *et al.,* 2004).

2.2. Development of Construction Enterprise Resource Planning (CERP) Systems

According to Shi and Halpin (2003) CERP should be: project oriented (all construction business is operated around projects whose profit and progress affect performance of enterprise); integrated (construction companies has many two front-office functions and back-offices); paralleled and distributed (in the same organization and at the same time various participant need information from one database); open and expandable (participant use various applications and ERP modules which can be added or removed through time); scalable (IS has to be able to follow economic expansions and downturns which are not rare in construction industry); remotely accessible (many construction sites are distant from head office); transparent (construction industry is resistant to new technologies and IS system should have obvious positive results); reliable and robust (IS in construction firms are frequently decision-supporting systems). CERP systems with mentioned characteristics will enable information sharing which is very important because of large number of participants involved in project. Moreover, they will improve transparency of management responsibilities and management efficiency (Shi, Halpin, 2003). In addition, during 2000s, the major ERP vendors (e.g. SAP, Oracle) have tried to tailor their standard systems for construction market (Skibniewski, Ghos, 2009). On the contrary, per Yang *et al*. (2007) CERP system is still unrealistic for successful and quick ERP implementation because only mature commercial ERP systems entail long term technical support and custom service, which most construction companies demand before contracting (Yang *et al.*, 2007). Thus, development of specific construction ERP systems could be possibility for small ERP vendors to find their customer.

2.3.Data, Processes and Participants Integration through CERP

Although ERP systems are primarily designed to automate managerial accounting business processes (Skibniewski, Ghosh, 2009) different modules have been developed to expand ERP system usage. By Ozorhon and Cinar (2015) CERP were developed to combine and partly computerize business processes such as construction site planning, financial management, human resource management (HRM), customer relationship management (CRM), warehouse management, procurement and tendering (Ozorhon, Cinar, 2015). By Tatari *et al*. (2008) ERP systems are intended to integrate data, information and project participants and thus have similarities with Computer Integrated Construction (CIC). CIC is usual term for information technology application researches in the construction domain (Boddy *et al.,* 2007). In CERP systems data integration is achieved through one centralized database where each data enters the system only once and is visible through whole project life cycle. Processes integration is realized through one integrated information system for entire project life cycle. In such system, all business processes are interrelated and project participants integrated. CERP system consist of the following modules designed for construction industry (figure 1): Workforce Management, Bidding/Marketing, Project Control, Subcontractor Management, Design/Engineering, Finances/Accounting, Materials Management, Estimating, Scheduling/Planning, Equipment Management, Workforce Management (Tatari *et al.,* 2008).

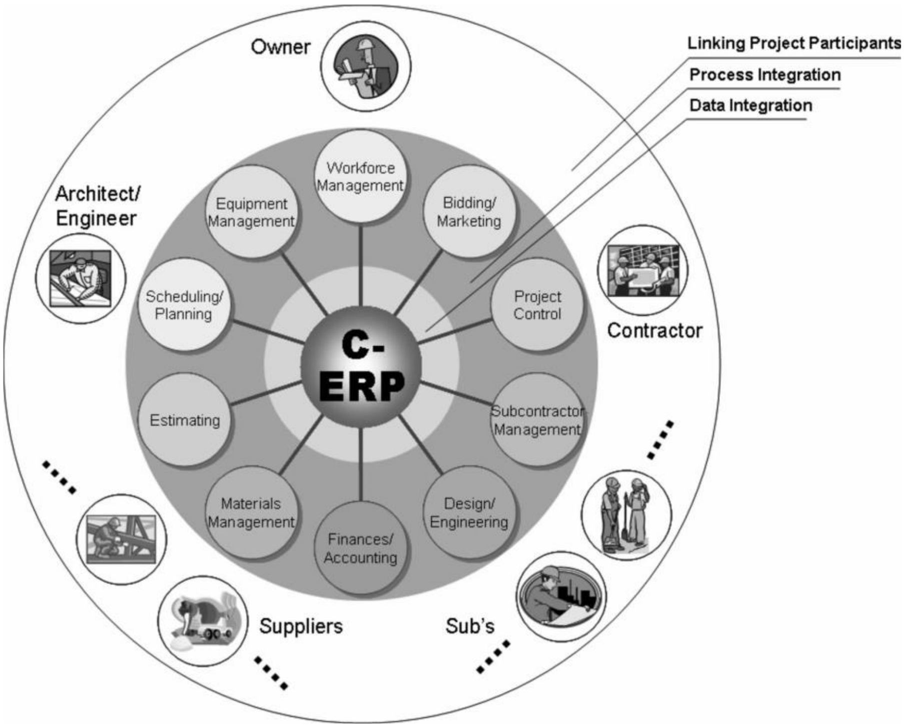

Figure 1. CERP system contributions toward objectives of CIC (adopted from Tatari *et al.,* 2008)

Although, the standard CERP modules have been developed, strict standardization of these modules have not been fully implemented yet on the market. Below are listed classifications of construction ERP modules according to selected sources:

- Purchase, Contractors Management, Inventory Management, Material Management, Vendor Management, Taxes and Statutory Year End Financial, Human Resource Management, Reports and Dashboard (Capterra, 2017)
- Purchase Module, Inventory Module, HR and payroll Module, Tools and plants module, Tender and bid module, Sub-contractor payment module, Financial Module, Engineering Module, Admin Module (Quora, 2017)
- Supplier relationship management (SRM), Customer relationship management (CRM), Project Management (PM) are modules which are used to grow construction business (ERPfocus, 2017)

2.4. Selection of ERP System in Construction Environment

Before selecting an ERP system, it is necessary to achieve alignment of the proposed IT system with the organizational structure and processes. Thus, conservative companies which hope to minimize the changes in own business processes as well as customization of ERP system, will probably experience downsides of ERP implementation. Besides, if a well-developed ERP system is not designed for the construction industry it is very expensive and complicated to customize all the needed functionalities. Therefore, reengineering of existing business processes is the first step. After reengineering was completed, possible customization of ERP system may follow. Regardless of the further customization cost, ERP vendors do not have needed support and should put more effort to custom possible solutions for construction industry (e.g. coding system, language, localized properties, etc.) and extend ERP systems with new functionalities (Yang *et al*., 2007).

ERP implementation processes (reengineering, selecting and implementing ERP system) should have the support of all levels managers and other participants involved in such a complex project. This support is crucial for the successful ERP implementation. Consultant role is very important in process of selecting and implementing ERP systems to reach the balance between clients and vendors. To achieve benefits of ERP, it is important that ERP systems are considered by all participants in supply chain, regardless of the IT competence amongst subcontractors and material vendors (Yang *et al*., 2007). Further, five characteristics of ERP systems are crucial when selecting the appropriate ERP system for construction industry: job estimation, flexible accounting, granular payroll capabilities, material and equipment handling and comprehensive financial reporting (ERPfocus1, 2017).

2.5. ERP and External Information Systems Integration in Context of Construction

Construction industry is project-oriented so the business processes of construction companies are project-based. Furthermore, every project is unique with multiple stakeholders involved (e.g. owners, general contractor, architects, engineers, subcontractors, material suppliers). Moreover, different entities follow different business processes within their companies and have different corporate goals. Such environment causes the occurrence of multitude time-sensitive and disintegrated information, which make construction projects complex to manage (Skibniewski, Ghos, 2009). Therefore, the problem is in how to transfer much data among different modules in one ERP system, between different ERP systems but also between ERP system and other existing systems inside or outside of company.

ERP systems are robust system which manages and integrates important parts of enterprise. In such environment the problem is how to determine where are borders and boundaries of further ERP development. As project is minor part of enterprise it is very courageously to expect of ERP systems to integrate all the project information. To deal with mentioned, Mêda and Sousa (2012) propose connection with Integrated Construction Information System (ICIS). ICIS are system used to manage construction projects and as such link all stakeholders during whole life cycle of project. Moreover, they are used to manage the construction projects in aspect of e.g. Finance Management, Material Management, Contract Management, etc. (Mêda, Sousa, 2012). Furthermore, ERP systems currently do not provide sustainable solutions for project planning and scheduling so integration with project planning systems like Primavera or Microsoft Project are referred to as a proposed solution (Gulliksen, 2012; Weston, 2001).

Further development of external application used in construction industry (e.g. scheduling, cost estimating, material takeoff, etc.) indicates growth of Building Information Modeling (BIM) concept (Gulliksen, 2012; Mêda, Sousa, 2012; Santos, 2009). BIM supported project activities and provides technical representation of information throughout the project, which ensures precise resource planning (e.g. material takeoff, cost estimation, scheduling, etc.) and thus more efficient procurement. Finally, BIM and ERP are two different information systems whose application in today’s construction industry is highly increasing. Their connection is seemingly not applicable because each of them monitors different organizational aspects. The integration of these two concepts would thus enable construction companies to connect the organizational procurement processes with project management. However, there is still vast scarcity of knowledge in bringing these two concepts together. Currently the biggest problem is how to exchange the information from one system to another while the exchange has no bad impact on the execution of processes within each system (Santos, 2009). While integrating such different systems and much data, the attention should be paid to the gap between construction and IT companies (Lee, Lee, 2017).

3. Results of Software Review and Discussion

3.1. ERP Search Engine Features

Below are described founded search engines which satisfy set conditions while filters and sort options of each are sown in table 1.

- Accounting-software is independent review platform for business–to–business (B2B), software as a service (SaaS) and financial solutions. Platform provides software search by many categories while ERP software is subcategory of Accounting and Finance Software. Moreover, it allows comparison of founded software but small adjustments options limit the analysis (Accounting-software, 2017).
- Capterra is a free service with comprehensive list of software to help business entities to find right software. ERP software is one of the offered software categories which could be analysed. Capterra gives very detailed analysis of most popular software (e.g. number of customers, users, reviews, likes, followers on social network, etc.) (Capterra2, 2017).
- ERPfocus provides knowledge and evaluation resources to navigate the ERP market. It enables comprehensive comparison and features of every ERP vendor in North America and Canada (ERPfocus2, 2017).
- ERPsoftwareinsider is software site that uses Graphiq's semantic technology to deliver software analysis via articles, visualizations and research tools. ERP systems are defined like one of categories of logistic software. Through website many software information are available to users (product overview, features, pricing, reviews, ratings, specifications, company, available demo version) (ERPsoftverinsider, 2017).
- Software Advice is a part of Gartner, company for information technology research and advisor. Website gives reviews and research of thousands software applications where ERP software is one of offered categories (Software Advice, 2017).
- Technology Advice is website to educating, advising and connecting buyers and sellers of business technology. ERP is one of listed software categories which could be analysed through product overview, details about specific software, reviews and comparison with other selected software (Technology Advice, 2017).
- Top10ERP indexes and compares the highest Manufacturing ERP software solutions from top rated vendors in United States and Canada. Search engine enables comprehensive comparison of ERP software solutions but also gives many white papers and case study of ERP implementation (Top10ERP, 2017).

Table 1. Search engines features

Name of search engine	Filters options	Sort options
Accounting-software	customer types, pricing model, language support, devices supported, deployment	newest, our score, price, user satisfaction
Capterra	product rating, number of users, deployment, features	
ERPfocus	business sectors, industry, ERP software features, system hosting	popularity, name (A-Z), name (Z-A)
ERPsoftwareinsider	platform, business size, industry, admin, logistic, production, customer	popularity, average user rating, number of reviews, admin score, logistics score, production score, customer score, swa sort
Software Advice	industry, size, price, ratings, deployment, platform	
Technology Advice	average user review, pricing, size of company for best work, integration	most reviewed, alphabetic (A-Z), alphabetic (Z-A), average rating (high to low), average rating (low to high)
Top10ERP	industry, manufacturing (MFG) mode, technology platform	newest, our score, price, user satisfaction

The results show that four search engines have option to filter ERP software by industry (ERPfocus, ERPsoftvareinsider, Software Advice, Top10ERP) while three of them have construction industry as an option (ERPsoftvareinsider, ERPfocus, Software Advice). Furthermore, most search engines have option to sort filtered software due to selected sort option. As popularity is required option, only two search engines (ERPsoftvareinsider, ERPfocus) fulfil second condition. Software Advice do not have sort option but have multiplied filter option (filtered software by one criteria can be further filtered by some offered software option). Moreover, as Software Advice give information about number of reviews and ratings, listed software could be manual filtered by popularity. Due to analyses only three software engines satisfy both set conditions which are: ERPsoftvareinsider, ERPfocus and Software Advice.

3.2. ERP Systems for Construction Industry

To get 10 most popular ERP software used in construction industry, ERP software base of selected search engines (ERPsoftvareinsider, ERPfocus and Software Advice) was filtered by construction industry and then sorted by popularity. Only the first ten ERP software will be observed. Results of comparison are shown in table 2. The date of search was set to the 6th of July 2017.

Table 2. Top 10 most popular construction ERP software obtained by different search engine

Search engine	Filter	Total number of listed software	Sort	Results (top 10)
ERP Softwareinsider	Construction	77	Popularity	MasterTools Standard ERP Epricor ERP Openbravo ePROMIS EZ Business System CANIAS ERP PENTA Construction ERP Software Blue Link ERP SYSPRO
ERPfocus	Construction	62	Popularity	Glovia G2 Infor CloudSuite Industrial IFS Application FinancialForce ERP SAP S/4HANA Microsoft Dynamics SL PearlChain Dynamics 365 for Operations Intacct Odoo Online
Software Advice	Construction and Engineering	2	Popularity (manual sort)	PENTA Construction ERP Software ABIS Adjutant

Due to results (table 2), two search engines in their ERP software base recognized much more software specialized for construction industry (ERPsoftvareinsider recognized 77 software while ERPfocus 62) than search engine Software Advice (recognized only 2 software). The reason was that ERPsoftvareinsider and ERPfocus were specialized search engines for ERP software while for Software Advice it cannot be said (offers search of other software categories). Moreover, the results show that only PENTA Construction ERP software appears on the software list twice.

3.3. Discussion

In this study we have found that ERP software search engines offer construction industry as one of the filter options, which confirms the fact that ERP vendors have recognized the need of ERP software specificity within construction market application. Although complexity of construction market has been recognized, the term CERP is not yet widespread at ERP vendors. Moreover, standard ERP construction modules do not exist. ERP vendors offer connection with construction management external software as well as integration with BIM tools (e.g. Vista Contractor Management Software, SAP). Thus, the need of ERP software and specialized construction tools integration has been recognized too, while the framework of integration is not yet strictly defined.

Further, search engines are tools which provide basic information about ERP software to ERP customers. Reached information about each ERP software could be useful when doing ERP implementation strategy. In later stages of ERP implementation, available information on search engines are not enough to define the best ERP software option. Thus, consultant engagement and detail software and business processes analysis is necessary.

Limitations of this software review was that the search engines are focused on specific market but also the fact that information about each of listed software is not equally represented. Thus, search engines largely represent a marketing tool and conclusion about most popular ERP software within construction industry could not be made.

4. Conclusion and future work

On one hand, construction industry is manly operating in the project-oriented mode, practicing project management processes, e.g.: planning, controlling, organizing, monitoring etc. Moreover, construction projects are transient in nature, variable in duration and costs, and require different internal and external resources which make industry much more complex. Regardless of the orientation on projects, construction industry is resistant to change, and doing successful organizational changes (e.g. reengineering or implementation of new technologies) still represents challenge to practitioners. On the other hand, ERP software are process-oriented tools which are not initially developed for construction industry neither for small and medium companies (which mainly construction organizations are). Thus, little number of ERP software were specially adapted for application within construction industry. Besides, language, culture, politics, government regulations, management style, and labour skills affect various ERP implementation practices at different countries. Despite the differences, ERP systems have been used within construction companies to improve efficiency and eliminate waste.

Implementation of ERP system in organizations demands further system adaptation. Therefore, before selecting an ERP system, it is necessary that business processes fit to new system's functionalities. Thus, further reengineering of existing business processes should be performed before or even during ERP implementation. Besides, reengineering, selecting and implementing ERP system should have support of all levels managers, consultants and other participants.

Within CERP, data integration is achieved through one centralized database. The processes integration is realized through one integrated information system while participants are connected through integrated project information which are available to all of them. Moreover, standard CERP modules have been limited to: Workforce Management, Bidding/Marketing, Project Control, Subcontractor Management, Design/Engineering, Finances/Accounting, Materials Management, Estimating, Scheduling/Planning, Equipment Management, Workforce Management (Tatari *et al.,* 2008). As projects are distant from permanent organization in enterprise, ERP systems need to interrelate with the project information. Therefore, further development refers to integration with modern information systems in construction, e.g. project management software application and Building Information Modeling (BIM). Finally, further research involves exploring:

1. Information exchange between ERP modules (existing and developed) designed for the construction

2. Information connections of ERP system and other existing information systems within a construction company
3. Integration of CERP and BIM modules
4. Integration of CERP and project management modules

References

Accounting-software (2017), https://accounting-software.financesonline.com/ (accessed 6 July 2017).

Ahmed, Syed M., et al. (2003). "Implementation of enterprise resource planning (ERP) systems in the construction industry." Construction Research Congress: Wind of Change: Integration and Innovation.

Al-Mashari, M., Zairi, M. (2000). "Supply-chain re-engineering using enterprise resource planning (ERP) systems: an analysis of a SAP R/3 implementation case." International Journal of Physical Distribution & Logistics Management 30.3/4 (2000): 296-313.

Aloini, D., Dulmin, R., Mininno, V. (2007). "Risk management in ERP project introduction: Review of the literature." Information & Management44.6 (2007): 547-567.

Boddy, S., Rezgui, Y., Cooper, G., Wetherill, M. (2007). "Computer integrated construction: A review and proposals for future direction." Advances in Engineering Software 38.10 (2007): 677-687.

Capterra (2017), http://blog.capterra.com/comparison-of-5-construction-erp-software-options/ (accessed 6 July 2017).

Capterra2 (2017), http://www.capterra.com/ (accessed 6 July 2017).

Chung, B, Skibniewski, M.J., Kwak, Y.H., Developing ERP systems success model for the construction industry, Journal of Construction Engineering and Management 135 (3) (2009) 207–216.

Chung, B. Y., Skibniewski, M. J., Lucas, H. C., Kwak, Y. H., "Analyzing enterprise resource planning system implementation success factors in the engineering-construction industry", *J. Comput. Civ. Eng.*, vol. 22, no. 6, pp. 373-382, Nov./Dec. 2008.

ERPfocus (2017), http://www.erpfocus.com/construction-erp-modules-business-growth-4055.html (accessed 6 July 2017).

ERPfocus1 (2017), http://www.erpfocus.com/construction-erp-must-haves.html (accessed 6 July 2017).

ERPfocus2 (2017), http://www.erpfocus.com/ (accessed 6 July 2017).

ERPsoftverinsider (2017), available at: http://erp.softwareinsider.com/ (accessed 6 July 2017).

Ghosh, S., Skibniewski, M.J. (2010). Enterprise resource planning systems implementation as a complex project: A conceptual framework, Journal of Business Economics and Management, 11:4, 533-549

Gulliksen, T. (2012). Interoperability between ERP System and Project Planning System. MS thesis. Institutt for bygg, anlegg og transport, 2012.

Lee, C., Lee, C. (2017). "Method to reduce the gap between construction and IT companies to improve suitability before selecting an enterprise system." Computers in Industry 85 (2017): 23-30.

Luo, W. H., Strong, D. M. (2004). "A Framework for Evaluating ERP Implementation Choices," IEEE Transaction on Engineering Management, Vol. 51, No. 3, 2004, pp. 322-333.

Mêda, P., Sousa, H. (2012). Towards Software Integration in the Construction Industry - ERP and ICIS Case Study, Proceedings of the CIB W78 2012: 29th International Conference –Beirut, Lebanon, 17-19 October

Moon, Y. B. (2007). Enterprise Resource Planning (ERP): a review of the literature. Int. J. Management and Enterprise Development, Vol. 4, No. 3.

Ozorhon, B., and Cinar, E. (2015). “Critical success factors of enterprise resource planning implementation in construction: Case of Turkey.” J. Manage. Eng., 10.1061/(ASCE)ME.1943-5479.0000370, 04015014.

Potosky, D., Olshan, B. (2008). "The secret success of a global ERP champion: Everything changed and nothing happened."Enterprise Resource Planning for Global Economies: Managerial Issues and Challenges. IGI Global, 2008. 94-107.

Quora (2017), https://www.quora.com/What-are-the-modules-of-Construction-ERP (accessed 6 July 2017).

Rashid, M.A., Hossain, L., Patrick, J.D., (2002). The evolution of ERP Systems: A historical perspective in Enterprise Resource Planning: Global Opportunities and Challenges, Idea Group Publishing, 2002, pp. 1-16

Santos, E.T. (2009). "BIM and ERP: finding similarities on two distinct concepts." 5th CIB W102 Conference: Deconstructing Babel: Sharing Global Construction Knowledge, Rio de Janeiro. 2009.

Sheu, C., Bongsug, C., Chen-Lung, Y. (2004). "National differences and ERP implementation: issues and challenges." Omega 32.5 (2004): 361-371.

Shi, J.J., Halpin, D.W. (2003). Enterprise resource planning for construction business management, Journal of Construction Engineering and Management 129 (2) (2003) 214–221.

Skibniewski, M. J. & Ghosh, S. (2009). Determination of Key Performance Indicators with Enterprise Resource Planning Systems in Engineering Construction Firms. Journal of Construction Engineering and Management, 135 (10), 965-978. http://dx.doi.org/10.1061/(ASCE)0733- 9364(2009)135:10(965)

Software Advice (2017). http://www.softwareadvice.com/ (accessed 6 July 2017).

Szitas, Z. "Technical requirements in enterprise resource planning systems." Electronics Technology: Meeting the Challenges of Electronics Technology Progress, 2004. 27th International Spring Seminar on. Vol. 3. IEEE, 2004.

Tatari, O., Castro-Lacouture, D., Skibniewski, M. J. (2008). “Performance evaluation of construction enterprise resource planning systems..” J. Manage. Eng., 24(4), 198–206.

Technology advice (2017), http://technologyadvice.com/ (accessed 6 July 2017).

Top10ERP (2017), available at: http://www.top10erp.org/ (accessed 6 July 2017).

Vuković, A., Džambas, I., Blažević, D. (2007). "Development of ERP concept and ERP system." Engineering Review 27.2 (2007): 37-45.

Weston, F. (2001). ERP implementation and project management. Production and Inventory Management Journal, 42 (3/4) (2001), pp. 75-80

Yang, J.B., Wu, C.T., Tsai, C.-H., (2007). Selection of an ERP system for a construction firm in Taiwan: a case study, Automation in Construction 16 (6) (2007) 787–796.

Unit Price Ranges in Building Construction

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Abstract:

The tender price is usually the main criterion in the procurement process. As only about 5–10 % of the provided tenders get accepted (Čadež, 2014a) there is an ongoing intensive price competition in the construction industry. Thereby some contractors submit tenders with speculative unit prices with the aim to gain an additional profit in case of claims. These claims are one of the main reasons for conflicts between project parties.

To prevent speculative unit prices in the procurement the paper "Unit Price Ranges In Building Construction" suggests a range of "common" unit prices and further recommendations. The study is based on four standard items in building construction. The combination and variation of the influencing factors of the unit price determination leads to minimum and maximum unit prices for each item.

In conclusion, common unit prices for standard items in building construction may deviate within a range of +/- 30–50 % of the common unit price. In the tender assessment clients should examine unit prices carefully. Especially items with high quantities, high unit prices, high total prices or items with a high probability of modification should be examined with particular attention. If the offered unit prices in comparison to the common unit prices deviate more than 30–50 %, clients should be warned and e.g. require a written explanation from the contractor. In the case that the contractor cannot explain the deviations of the unit prices reasonable, the tenderer may be excluded from the competition.

Keywords: *Unit price contract; Price speculation; Direct costs; Indirect costs; Tender assessment; Procurement process*

1. Introduction

In the public procurement process in Germany the tender price is usually the main assessment criterion which forces an intensive price competition in the construction sector. Due to the price competition, the calculated profit varies commonly between 0–4 % of the production costs. This insufficient profit buffer is a main reason that failures in the construction process lead to losses for contractors. Hence, some contractors decide to calculate their tenders in a strategical or even speculative way. Thereby contractors change one or more unit prices while the tender price remains constant or is just amended slightly to stay competitive. During the construction phase contractors expect changes in the specifications (e.g. change of scope, extension of time or increase in quantity), which lead to claims calculated on the basis of the

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tender calculation. Therefore items with speculative unit prices may generate an additional profit for the contractor (Schulze-Hagen, 2007). The amount of claims for changed specifications is evaluated with 4–25 % of the construction sum (Kattenbusch, 2002).

All this shows that price speculations contain a significant potential to gain additional profit for contractors. However, speculations also have a risk of profit loss, if the speculation does not work the way the contractor expected it. In contrast clients have a risk of unplanned additional costs by speculative prices if the speculation tallies.

Based on a judgement in 2008, which has set boundaries for unit prices in the invoicing of construction contracts for the first time, an ongoing discussion in science, practice and jurisdiction has been emerged. Especially the boundaries and the correct calculation of “common unit prices” have been discussed intensively. The Federal Court of Justice (Bundesgerichtshof, BGH) defines the common unit price as the price which is at the time of the conclusion of the contract the price of the general understanding for works of the same type, quality and dimension at the place of the construction site (Bundesgerichtshof, 2001). This general definition has led to the scientific discussion in construction management and construction law concerning different methods of calculating common unit prices (see chapter 2).

As the boundaries set by the jurisdiction are only case-by-case decisions and the public sector has no justification for its boundary, a general boundary for common unit prices in building construction is nonexistent. This led to the study of “ranges” for common unit price in building construction which is shown in this paper. The results of the common unit prices shall provide clients an assistance for the assessment and determination of unit prices during the procurement process. The described research background and process is shown in figure 1.

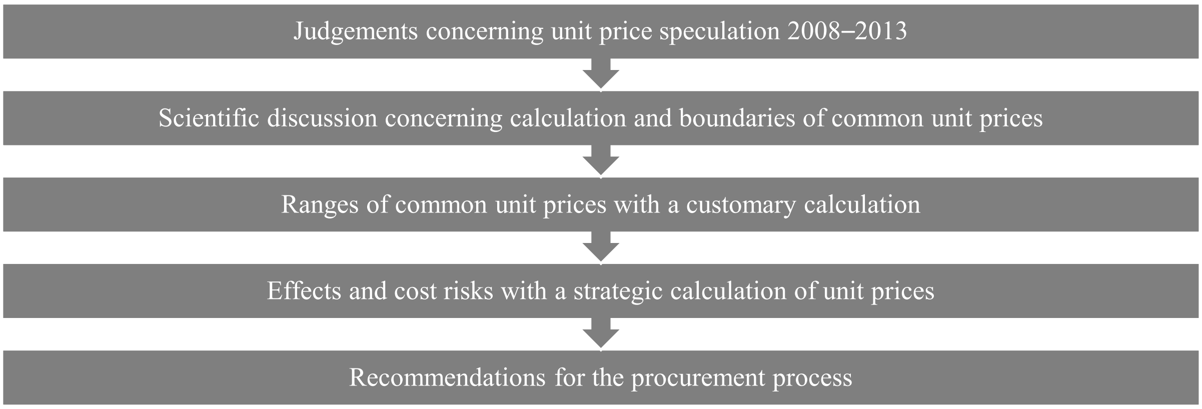

Figure 1. Research process

Following to the research background the influencing factors and their impact on the height of unit prices will be determined (chapter 3). The impact of the influencing factors is determined by an example calculation (chapter 4) and may differ slightly depending on the construction project. Therefore the influencing factors are assessed qualitatively.

The study is based on a unit price contract with standard items in building construction according to the German Construction Contract Procedures (Vergabe- und Vertragsordnung für Bauleistungen, VOB). To determine the common ranges of unit prices in building construction the influencing factors will be varied and combined to obtain the highest possible ranges by an accurate and customary calculation. Altogether twelve cases have been examined per item (48 in total). The average unit price of the twelve determined unit prices per item is defined as the "common unit price". Relating to the common unit price defined by the jurisdiction of the BGH, the average unit price is close to the common unit price. The defined common unit price may be appropriate for the assessment of unit prices during the procurement process (chapter 4).

To show the cost risks for clients as well as the chances to increase the profit for contractors an example will be depicted. In particular it shows the significant cost difference in the invoicing between unit prices based on the specifications and unit prices based on strategic reasons, if the claim does occur as the contractor expected it (chapter 5). Finally the results of the study and their impact on the unit price examination in the procurement process will be summarized (chapter 6).

2. Judgements and scientific discussion concerning speculative unit prices

The scientific discussion about unit price speculation has been heating up due to a judgement in 2008 about a more than 800 times heightened unit price compared to the common unit price. The client and the contractor could not agree on the 800 times heightened unit price for a claim of an item with an increased quantity. The BGH called the unit price unconscionable which led to the nullification of the unit price for the excess quantity. In conclusion the excess quantity had to be invoiced as the common unit price (Bundesgerichtshof, 2009). Following the decisive judgement in 2008 the jurisdiction about speculative unit prices has been specified. As of today an eight times heightened unit price is unconscionable, if on the one hand the total amount of the additional compensation is substantial and on the other hand the amount of the compensation is significant in comparison to the tender price (Bundesgerichtshof, 2013). The presumption of unconscionableness may be disproved by the contractor, if he is able to explain why the determination of the unit price is reasonable (Bundesgerichtshof, 2009).

Beside the judicial boundaries, the public sector also limited the variation of unit prices. According to the procurement and contract manual of the federal government (Vergabe- und Vertragshandbuch für die Baumaßnahmen des Bundes, VHB) unit prices may be unconscionable if the unit price is five times heightened. In the wording of the VHB it remains unclear, which unit price serves as a benchmark and which consequences can be expected if a unit price is heightened (Bundesministerium für Umwelt, Naturschutz, Bau und Reaktorsicherheit, 2016).

Furthermore there is an ongoing discussion about the specific calculation of common unit prices. Franz and Kues suggest to calculate common unit prices for claims based on the actual costs plus the calculated profit or loss of the related item. In the case of claims based on an increase of quantity unit prices need to be updated as provided in the contract (Franz and Kues, 2010).

Büchner et al. recommend to take common unit prices from construction price databases. These unit prices may differ in a certain range and beyond that, the certainty of the determination depends on the quality and quantity of the database (Büchner et al., 2010).

Oberhauser pleads for a price update with "common market prices". In her opinion the calculation of the common market price depends on how the contractor would have calculated, if the specifications would have been correct in the first place. The profit should remain as provided in the contract (Oberhauser, 2011).

Duve and Richter distinguish between two cases in the calculation of common unit prices. If the contract parties have worked together several times, they have a similar understanding of a common price which can be taken from previous contracts. In the second case the parties have no similar understanding of common unit prices why these need to be calculated with a "customary calculation". This implies that the calculation needs to be done e.g. considering official wage scales, the Register of Construction Equipment and "common" surcharges for overhead and profit (Duve and Richter, 2013). The advantages of this approach are that nearly every item might be calculated this way and that there is a common understanding of this type of calculation in the construction management sector. Accordingly this approach is the basis for the following study to determine common unit price ranges.

3. Influencing factors on the height of unit prices

For the calculation of the common unit price the common direct costs, consisting of labor costs, equipment costs, material costs and other costs need to be determined first. The labor costs are the product of the average wage and the performance factor. The average wage is subdivided into

- "A", employee's wage,
- "AS", average wage "A" + social costs,
- "ASL", average wage "AS" + non-wage labor costs and
- "ASLP", average wage "ASL" + foreman's wage.

The disposition of the employees in official wage scales depending on the classification and qualification of the employees results in the average wage "A" which remains constant in this study. Further the social costs need to be added to the average wage. Depending on the assumptions the social costs vary between 78–88 %. Especially the number of the absence days due to illness and bad weather are decisive for the height of the percentage. The determined percentage needs to be multiplied by the average wage "A". Next the non-wage labor costs need to be added which vary depending on the location of the construction site. The average wage "ASLP" needs to be calculated, if the foreman is embedded in the labor costs. Otherwise the foreman needs to be allocated to the on-site overhead. In total the difference between the maximum and the minimum average wage is about 25 % related to the minimum average wage. Due to individual project-conditions or different assumptions the average wage may differ even more.

The performance factor varies significantly depending on the item due to the number of influencing factors e.g. qualification as well as the experience of the employee's or construction site conditions. The variation of the performance factor is analyzed by a literature review. Thereby the highest deviation can be encountered for the performance factor of the item "shuttering of concrete walls" as the maximum performance factor is increased by the factor 2.33 compared to the lowest performance factor. The variances of the performance factors for the items "delivering and laying of filigree ceilings" (2.24) and "concrete for ceilings" (2.13) are similarly high. Just the item "laying of concrete wire fabric" has a low deviation with 1.32 times the minimum performance factor.

The material is bought at the place of the construction site during the construction phase. Depending on that the material costs may be determined with a direct query at the location of the construction site. In this study the material costs are determined with a construction costs handbook and remain constant.

The equipment costs are calculated with the consideration of the average replacement value of the Register of Construction Equipment (Baugeräteliste, 2015). It is assumed that the average replacement value differs between 100 % for the maximum and 50 % for the minimum replacement costs. The assumption is based on the knowledge that the depreciation time is often considerably higher than indicated in the Register of Construction Equipment. The depreciation for wear and tear and interest differ in the same range because they depend on the amount of the average replacement value. Other costs are mainly shuttering costs, which are calculated the same way as the equipment costs.

The on-site overhead is constant, except the consideration of the foreman in the labor costs or the on-site overhead. The surcharge for overhead and profit is fixed with 10 % of the production costs.

In the unit price determination the assigned amount of the indirect costs and profit on the direct costs have a significant impact on the deviation of the unit price. Also the percental allocation of the direct costs of each item (e.g. 70 % labor costs; 30 % equipment costs) and the cost type's percental distribution of the total direct costs are decisive for the unit price ranges (Čadež, 2014b).

The higher the percental amount of the labor costs, the higher is the deviation of the unit prices. On the contrary equipment costs and other costs have, due to their small amount of the direct costs, a substantial smaller influence on the deviation of the unit prices. The main influencing factors and their impact on the unit price variation are shown in table 1.

Table 1. Influencing factors on the range of common unit prices

Influencing factor	**Adjustment possibilities**	**Impact**

Labor costs	• Average wage
	  ▪ Qualification and experience of the employees
	  ▪ Additional labor costs
	  ▪ Calculation of the foreman in the labor costs or the on-site overhead
	• Performance factor
		+

Material costs	• Material costs remain unchanged (assumption)	-

Equipment costs	• Equipment dimensioning
	• Fixing of replacement value
	  ▪ Depreciation for wear and tear and interest
	  ▪ Repair costs
		o

Other costs	• Shuttering costs (analogue equipment costs)	o
On-site overhead	• Calculation of the foreman in the on-site overhead or the labor costs • Other on-site overhead unchanged	-
Overhead and profit	• Unchanged percentage (assumption)	-
Assigned amount of the indirect costs and profit	• 0 % on direct costs without labor costs and the remaining contribution margin on the labor costs • 10 % on direct costs without labor costs and the remaining contribution margin on the labor costs • 100 % on direct costs without labor costs and the remaining contribution margin on the labor costs	+
Percental distribution of the cost types	• Percental distribution of the cost types of the direct costs in the items • Impact depends on the distribution of the overheads and profit	+

Legend: major impact: +; minor impact: o; no impact: -

4. Ranges of unit prices due to customary calculation

The determination of the common unit price ranges is based on framing works for an office building in skeleton structure. Four items of the specifications will be exemplary determined:

- Delivering and laying of filigree ceilings,
- Laying of concrete wire fabric,
- Concrete for ceilings and
- Shuttering of concrete walls.

Altogether twelve cases for each item will be considered. The main influencing factors on the unit prices (see table 1) will be varied and combined to create minimum and maximum common unit prices for each item. The average unit price of the twelve cases is defined as the common unit price (see chapter 1).

The result of the customary calculation is a useful suggestion about the range of common unit prices which is not generally valid at this point because of the small number of examined cases. Nevertheless recommendations for action during the procurement process are applicable.

By the use of the minimum, maximum and common unit price, three different ratios can be depicted and are helpful for the comprehension of the price ranges. To illustrate the maximum range of the unit price the ratio of the maximum compared to the minimum unit price needs to be determined. Clients should determine common unit prices as shown in this paper or adopt them from already processed construction contracts. The common unit price needs to be compared to the offered unit prices to proof the reasonableness of the unit price deviations. The ranges of the four considered items are depicted in table 2.

Table 2. Summary of unit price ranges

Item / Ratio	**maximum/ common**	**minimum/ common**	**maximum/ minimum**
1. Delivering and laying of filigree ceilings [m²]	47 %	42 %	155 %
2. Laying of concrete wire fabric [to]	26 %	28 %	76 %
3. Concrete for ceilings [m³]	39 %	36 %	118 %
4. Shuttering of concrete walls [m²]	38 %	38 %	124 %

In conclusion, common unit prices in building construction may differ, based on a customary calculation, in the range of 76–155 % of the minimum unit price. The range related to the common unit price is 26–47 %. The calculated deviations are considerably smaller than the determined eight times enhancement by the jurisdiction and the five times enhancement by the VHB. What do those common unit price ranges imply and which recommendations can be given for further action in the procurement process?

In the procurement process standard items with a deviation of more than 25–50 % related to the common unit prices need to be examined with particular attention. Especially labor costs and the related performance factors need to be assessed. Further the percentage and the height of the indirect costs of the particular item should be examined because of their major impact on the height of unit prices. Besides strategic and speculative reasons for high unit price deviations, non-speculative reasons for the deviation may occur such as misunderstood specifications, calculation mistakes or the chosen calculation method (e.g. generalized predetermined unit prices). Speculative unit prices can also indicate to failures or gaps in the tendering. The more specific and detailed the tendering is, the less risks the contractor has to take in his calculation of the tender price and the less is the potential of price speculations. In addition to that it is proven, that the lower the percental amount of the indirect costs and profit of the tender price is, the lower the effects of a strategical pricing are (Equally, Kurbos, 2014). Especially non-standard items (e.g. façade works, building services) and items in civil engineering (e.g. earthworks) may force higher ranges of unit prices.

5. Example of a strategic calculation

The revealed ranges of unit prices resulting from customary calculation may be used by contractors to submit tenders with strategic unit prices in some items. These strategic unit prices might result in significant additional profits for contractors as well as additional costs for clients. To prevent this, clients should require a written explanation of the unit price before the contract closing if the deviation is substantial.

In the following example a calculation of a construction project with four items is considered. For reasons of simplification it is assumed that there are no indirect costs calculated in this project. In total the direct costs of the four items in the base case are 4 500 units and the profit margin is declared with 4 % thus the profit is 180 units. Altogether the calculated tender price is 4 680 units. However, if the contractor decides to calculate in a strategic way the tender price needs to remain constant, otherwise the contractor minimizes his chances to win the contract.

In case of a strategic calculation the contractor varies the direct costs within a range of 30 % (see columns + 30 %; - 30 %) because of the common ranges of unit prices (see chapter 4). As the contractor expects an increase of quantity in item 2 during the construction process, he decides to choose the highest possible direct costs for item 2. The other three items need to be adjusted to assure that the tender price remains constant. Especially the performance factor and the resulting labor costs are convenient for those adjustments which implies that clients need to check the performance factor carefully in the procurement process.

Table 3. Strategic calculation of the tender price

		Base Case		+ 30 %		- 30 %		Strategic calculation	
Item	Quantity	Direct costs	Sum	Direct costs	Sum	Direct costs	Sum	Direct costs	Sum
1	10	50	500	65	650	35	350	35	350
2	20	100	2 000	130	2 600	70	1 400	130	2 600
3	50	20	1 000	26	1 300	14	700	15	750
4	100	10	1 000	13	1 300	7	700	8	800
Sum			4 500		5 850		3 150		4 500
Profit (4 %)			180						180
Tender price			4 680						4 680

To show the effects of a strategic calculation it is assumed that the client orders an excess quantity of 50 % for item 2 (claim due to: § 1 Abs. 4 VOB/B i.c.w. § 2 Abs. 6 VOB/B). In the base case the contractor has to update the item with the calculated 100 units of direct costs. This results in extra direct costs of 1 000 units (10 * 100 units). Multiplied by the profit margin

(4 %), the contractor receives 40 units of additional profit. In Total the profit due to the base case and claim would have been 220 units (see table 4).

If the contractor calculates in a strategic way as shown in table 3 and a claim in item 2 does occur, the speculation tallies. In this case the contractor is able to update item 2 with 130 units per unit of quantity which is 30 units of additional profit per unit of quantity. Multiplied by 10 units of quantity the claim forces 300 units of additional profit due to the additional direct costs. This leads to an enormous leverage effect on the profit because the profit in the direct costs of the claim is about 23 % (300/1 300) which is 5.75 times (23 %/4 %) the calculated profit in the contract. Furthermore the profit margin needs to be added whereby an additional profit of 12 units is resulting. In total the profit increases by 312 units due to the claim. Altogether the profit which would have occurred by the base case plus the profit due to the claim increases the profit of the construction project to 532 units. Compared to the profit in the case of a claim based on the base case calculation the profit increases by 242 % (532/220). Just the additional profit of 312 units is even higher than the profit due to the base case which is about 142 % (312/220) of additional profit. Nevertheless, it should be noted that the described effects have such remarkable impact on the profit in this example because of the structure with only 4 items and no overheads. The effects of the strategic calculation are shown in table 4.

Table 4. Effects of the strategic calculation in case of claims

		Base Case		Strategic calculation		Difference
Item	Quantity	Direct costs	Sum	Direct costs	Sum	
2	20	100	2 000	130	2 600	
Claim	10	100	1 000	130	1 300	300
Sum			3 000		3 900	
Calculated profit in the contract						180
Additional profit due to claim (Base Case; 4 % by 1 000 units)						40
Sum						220
Effects of the strategic calculation						
Additional profit due to additional direct costs						300
Additional profit due to profit on the additional direct costs						12
Additional profit (sum)						312
Additional profit by comparison to the base case (312/220)						142 %

If the actual direct costs are added up, the costs for the contractor in this example are 5 500 units (4 500 + 1 000). However, the invoice total is 6 032 units which consist of 5 500 units of direct costs and 532 units of profit. So the total profit of the contract due to the claim and the strategic calculation is 9.7 % (532/5 500). In other words, it is more profit than the contractor could draw with two (!) construction projects of that size. Certainly it should be pointed out that the strategic calculation also may force significant profit losses, if items which are calculated below the actual cost are involved in claims.

6. Summary

The main influencing factors on the height of unit prices at standard items in building construction are the height of labor costs and equipment costs as well as the percental distribution of direct costs of the related item and the project-specific distribution of indirect costs and profit. Due to the variation and combination of the main influencing factors a range for the height of standard unit prices is determined. The maximum deviation of the considered items is about 26–47 % of the common unit prices. Even if those results are not generally valid, recommendations for action in the procurement process can be given.

Recommendations for clients refer to the project phase before the conclusion of the contract. As speculations are always based on the specifications, the best way to prevent speculative prices are accurate specifications. Especially the quantity of the items need to been calculated exactly as well as the specifications need to be completed before the procurement.

During the procurement process clients should calculate or determine common unit prices for standard items to compare them to the offered unit prices of the contractors. If the offered unit prices of standard items deviate more than 25–50 % related to the common unit prices clients should be warned and examine those items with special attention. It is also advisable to obtain a written explanation about the reasonableness of the deviated unit price by the contractor. If the contractor cannot explain his unit price reasonable, the tender may be excluded from the competition.

As demonstrated in the example above, even a strategic calculation within the ranges of common unit prices may force significant cost risks for clients as well as profit benefits for contractors. Depending on the item and the claim even a 30 % heightened unit price can increase the profit significantly.

In conclusion, especially items with high quantities, high unit prices, high total prices or items with a high probability of modification should be examined carefully. Beyond that it needs to be differentiated between items in building construction and civil engineering as well as standard and non-standard items. Need for research is especially given in the field of civil engineering and non-standard items in terms of speculative as well as common unit prices.

References

Baugeräteliste (2016), "Baugeräteliste 2015", available at: HTTP://WWW.BGL-ONLINE.INFO (accessed 22 March 2017).

Bundesgerichtshof (2001), "Zur Üblichkeit der Vergütung i.S. von § 632 Absatz 2 BGB", Zeitschrift für Baurecht, Vol. 24, No. 2, p. 104.

Bundesgerichtshof (2009), "Unwirksamkeit einer Preisvereinbarung für Mehrmengen wegen Sittenwidrigkeit der Preisbildungsgrundlage", Zeitschrift für Baurecht, Vol. 32, No. 4, pp. 341–346.

Bundesgerichtshof (2013), "Sittenwidrigkeit einer Vergütungsvereinbarung nach § 2 Nr. 6 Abs. 2 VOB/B", Zeitschrift für Baurecht, Vol. 36, No. 5, pp. 456–459.

Bundesministerium für Umwelt, Naturschutz, Bau und Reaktorsicherheit (2016), "Vergabe- und Vertragshandbuch für die Baumaßnahmen des Bundes", Issue 2008, Effective April 2016 available at: HTTP://WWW.FIB-BUND.DE/INHALT/VERGABE/VHB/LESEFASSUNG_AUSTAUSCHSEITEN_APRIL_2016.PDF (accessed 22 March 2017).

Büchner, S., Gralla, M., Kattenbusch, M., and Sundermeier, M. (2010), "Alternativmodelle zur Nachtragspreisermittlung aus der Vertragskalkulation", BauR – Zeitschrift für das gesamte öffentliche und zivile Baurecht, Vol. 41, No. 5, pp. 688–697.

Čadež, I. (2014a), "Neue Verfahren zur Ermittlung der Höhe der Allgemeinen Geschäftskosten in der Angebotskalkulation", Bautechnik, Vol. 91, No. 2, pp. 139–144.

Čadež, I. (2014b), "Kosteneinfluss- und Kostenzuordnungsfaktoren von AGK bei Mehrvergütungsansprüchen", Bautechnik, Vol. 91, No. 4, pp. 274–279.

Duve, H., Richter, R. (2013), "Die übliche Vergütung nach § 632 – Was ist das?", BauR – Zeitschrift für das gesamte öffentliche und zivile Baurecht, Vol. 44, No. 6, pp. 831–838.

Franz, B., Kues, J.-H. (2010), "Guter Preis bleibt guter Preis – Rechtfertigt die Faustformel Korbions ein Vertragspreisniveau?", BauR – Zeitschrift für das gesamte öffentliche und zivile Baurecht, Vol. 41, No. 5, pp. 678–687.

Kattenbusch, M. (2002), "Nachtragsbearbeitung in Bauunternehmen", Baumarkt+Bauwirtschaft, No. 4, pp. 42 f.

Kurbos, R. (2014), "Spekulation mit Zuschlägen!?", in Heck, D. and Lechner, H. (Ed.), 5. Grazer Baubetriebs- und Baurechtsseminar – Die Bedeutung der Kalkulation in der Vertragsabwicklung, Verlag der Technischen Universität Graz, Graz, pp. 113–137.

Oberhauser, I. (2011), "Preisfortschreibung als Vergütungsmodell für geänderte und zusätzliche Leistungen – sieht die VOB/B das wirklich vor?", BauR – Zeitschrift für das gesamte öffentliche und zivile Baurecht, Vol. 42, No. 10, pp. 1547–1562.

Schulze-Hagen, A. (2007), "Wertung von Spekulationsangeboten", in Jochem, R. (Ed.), Rechtshandbuch des ganzheitlichen Bauens – Festschrift für Hans Ganten, Vieweg, Wiesbaden, pp. 309–320.

Risk Management of the Complex Construction Project – The New Cruise and Ferry Port of Zadar

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Abstract:

From the Croatian construction and economical perspectives the NCFPZ project is having a very particular significance as projects of this magnitude and complexities have rarely been developed locally. There are often high levels of uncertainty in construction projects. Systematic risk management helps you quantify that uncertainty. Therefore, it was relatively easy to conclude that the special attention should be drawn, as part of the project management for the NCFPZ, to the risk management.

For the identification and categorization of risks and risk analysis for the NCFPZ project, taking into account the best known practice, as well as specific experience gained in managing a number of large port infrastructure projects, it was decided that a hybrid approach will be used, a variant which will categorize risks per phases of the project's life cycle. The categorization of risks is shown throughout the stages from the start of the project and design, obtaining all permits and approvals, construction and preparation for engagement of the future operator of the project.

The example of this complex infrastructure project risk assessment and analysis showed that the greatest impacts of the project risks came from a group of administrative and political risks where is the greatest imbalance of more than 300% up to 400% from the initially quantified risks in relation to their appearance during implementation.

This can be explained in part by the fact that the project took place in a time and environment of extremely "busy" legal regulatory activities of conforming to the European directives during the process of accession of the Republic of Croatia to the EU.

Keywords: *Project Management, Risk Management, Complex Construction Project, Cruise and Ferry Port, European Union*

1. Introduction

The Croatian Government assessed the project of relocating the ferry port of Zadar in the area of commercial port Gaženica, 3.5 km south of Zadar's Old Town, as a priority project. Croatian Government was represented by the Ministry of Sea, Tourism, Transport and Development (MSTTD), further represented by the Port of Zadar Authority (PZA). PZA has been in charge

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of implementing the New Cruise and Ferry Port of Zadar (NCFPZ), planned to last from 2008 to 2017, and funded by international financial institutions (IFIs); European Investment Bank (EIB) and KfW Bankengruppe (KfW). The project was being funded through two separate financial agreements. The EIB provided the amount of 100 million euros and KfW ensured a loan in the amount of 120 million euros. PZA secured additional 16 million euros from its own resources. PZA´s responsibilities included: procurement, financial management, contract management, monitoring and evaluation of projects and programs, and reporting. These activities were the responsibility of two project implementation units (PIU) established within the existing PZA. Complete technical documentation was developed by the Institute IGH with partners; DHI, Rijeka project and Marina project. Supervision services over the entire construction are carried out by the IGH Institute. Consultants selected for this job; EGIS International SA, conducted services of the overall project management for the NCFPZ. Various transport and transportation needs determined the functions of the NCFPZ. Therefore, the new port consists of ferry terminals for local and international traffic, home-port and cruise terminal and fishing port. The total area of the NCFPZ of about 13.5 hectares, includes areas for berths and piers, roads (roads, lanes for waiting, boarding and unloading, pedestrian zones), and area of the central terminal building. Maritime part of the port consists of 12 berths with a total length of 1,851 meters, draft of 5-13 meters. This individually divided by different traffic terminals includes: the terminal for international traffic (cruise ships and ferries) with 5 berths total length of 1146 m, with the draft from 10 to 13 meters, the terminal for local traffic (ferries, boats and speed boats) consisting of 7 berths with a total length of 705 m, and draft from 5 to 10 meters. The role of the central terminal building is providing logistic support to the international and local ferry traffic, as well as to the home-port for cruise traffic. The building also includes ancillary facilities such as waiting rooms, areas for ticket offices, toilets, luggage depos, customs and police areas, arrival and departure halls and the associated coffee shops and restaurants.

The realization of the NCFPZ project will have a very significant impact on the development of the city of Zadar and Zadar County, inter alia, through the promotion of employment, new opportunities for the development of tourism which is dominant industry in the county and the region. According to the international standards, the NCFPZ project represents the so-called "Major Infrastructure Project", or a large infrastructure project. From the standpoint of local construction practices in the Republic of Croatia, the mentioned project certainly represents a lot more, bearing in mind that projects of this type, vocationally and technically very demanding port infrastructure project, have not been carried out not only in Croatia but also in the wider area as well.

Due to the all of the mentioned, it was relatively easy to conclude that, as a part of the NCFPZ project management the special attention will need to be paid to the risk management. During the realization of construction projects there are often high levels of uncertainty. Each feasibility study necessarily contains many assumptions about the future. Systematic risk management helps quantify such uncertainty (Bing, 1999). Risk management has traditionally been applied instinctively, where risks remain implicit and controlled by common sense and reported experientially. Systematic approach makes risks clearer, making them easier to control. In other words, systematic risk management is a management tool which requires practical experience and training in the use of the techniques (Mills, 2001). Elements of the risks associated with construction projects are affecting time, cost and quality of the project. Risk management is an ongoing activity in the development of the project from the beginning and throughout the life of the project (Akintoye, 1997). Due to these specificities of the project it was decided to pay special attention to the methodological approach to the assessment and categorization of risks.

2. Methodology for risk categorization and assessment

Risk management in the construction industry requires complementary, interdisciplinary, flexible approach that allows registering the variable character risk factors (qualitative and quantitative) as it requires a precise description and explanation of the mechanisms involved in the organization of construction production. In the process of developing the model of risk assessment in construction projects the compilation of tools should be enabled, starting with those already known and frequently used to those which as new and original are just being made available, thus facilitating the application of the so-called hybrid approach. Risk identification is the first and main step in the risk management process (Rutkauskas, 2008). It describes the conditions for competitiveness, clarifies risks and factors of uncertainty, identifies potential sources of risk and defines the responsibilities for uncertainty (Zayed et al., 2008). In the process of identification of risk, a key question to be asked is: Which are the discrete features of projects (sources of risk) that may cause such mistake? (Godfrey, 1996). Furthermore, according to the same authors, the project risks can be divided into three groups: external, design, internal. External risks are those risks which are beyond the control of the project management team. External risks are further divided into: political risk, economic risk, social risk, weather risk. Political risks presume changes in national laws and regulations, political changes and changes in system administration, etc. (Li and Liao, 2007). Economic risks include instability of the economy in the country, the system of payments, inflation and financing. Furthermore, Tvaronavičienė and Grybai (Tvaronavičienė and Grybai, 2007) have analyzed the Lithuanian economic activities in the construction industry. The economic disaster, as used herein, refers to periodical economic crises of such proportion that impede the proper assessment of the contract, their occurrence or their impact on costs. Social risks have a rising significance when working on the allocation of risk. This is an area in which there are political and social pressures from parties that have little interest in the project itself, but have a huge impact on the project outcomes. The risk of bad weather; except in extremely abnormal weather conditions, this is a risk the contractor should assume, and it should be evaluated as an impact of the construction methods applied by the contractor. Internal risks can be divided according to the party that could be the initiator of the risk events, such as project stakeholders, designer, contractors, etc.

According to Hayes (Hayes et al., 1986) risks and uncertainties are part of all construction work, no matter the size of the project. Other risk factors that bear the risk are: complexity, speed of construction, the position of the project, as well as knowledge of the methodology of work. When serious risks appear on the projects, the consequences can be very harmful. In extreme cases, exceeding deadlines and cost overruns can turn a potentially profitable project to project failure. The studies have shown that time and cost goals often fail due to unforeseen events that even an experienced project manager cannot predict. Although these events are known in advance, their scope is often not quantifiable. It is also recommended to group the risks in accordance with simple measures of their probability and likelihood of impact, focusing on what is important, with action controlling the risk. Williams (Williams, 1995) found that the identification of each risk is an essential first step in risk management and it's also probably the most difficult. Identification of each source of risk and components enables the separation of that element from the others. Consideration of each influential factor will simplify the analysis and risk management (Bajaj, 1997).

Risk assessment is achieved by assessing the likelihood and severity of the impact of risk. More detailed information that is available throughout the building process can be effectively used for traditional risk management systems, such as risk control (Han et al., 2008). The risk management process can be described as a process of five stages: Identification, Analysis, Assessment, Response, Monitoring (Zavadskas et al., 2010).

The likelihood of the adverse event is usually expressed in the number of such events that are expected to occur during the year (Godfrey, 1996). The consequence of the adverse event, sometimes known as damage, is often expressed in financial terms. Godfrey (Godfrey, 1996) and Hayes (Hayes et al., 1986) found that the greatest degree of uncertainty is encountered in the early phase of the life cycle of projects. The decision taken during the earliest stages of the project can have a very big impact on the final price and duration. Change is inevitable in any of the major capital projects, but its extent is often underestimated in these early stages. Williams (Williams, 1995) defines the quantification of risk as the size and frequency or time frame of each event. Each event can be a single incident or a collection of more incidents.

The construction industry is 'contaminated' with risks, but they are not always adequately treated which often resulted in poor performance with an increase in costs and significant delays. In addition, construction projects became increasingly complex and dynamic in its nature. Risk assessment is a complex issue that is determined by a number of factors. Many techniques for risk assessment of construction projects that are currently used are elaborated tools. However, in many cases, the use of these tools cannot give satisfactory results due to the incomplete information about the risks or the high levels of uncertainty involved in the available data. It was therefore essential to develop new / original methods of risk analysis, to identify the main factors and assess the associated risks in an acceptable manner in different environments where the existing tools cannot be efficiently and effectively applied (Zeng et al, 2007). For the very implementation of the identification and categorization of risk and risk analysis for the NCFPZ project, taking into account the quoted texts and recommendations, as well as special and specific experience gained in managing risks on a large number of similar large port infrastructure projects, it was decided that a hybrid variant would be used where the risks would be categorized within the phases of the project's lifecycle. In this case, the categorization of risk will be shown through the stages divided into: the launch of a project or design, obtaining of all permits and approvals, construction and preparation for the use of project results, that is, the preparation for engagement of the future operator of the project described under phase operation, as shown in Table 1:

Table 1. Risk Categories

1. Design	**2. Permits**	**3. Construction**	**4. Business**
a) Legislation & Admin procedures	a) Legislation	a) Procurement	a) Sponsor / Employer business model decisions /changes
b) Design (technical documentation)	b) Admin delays	b) Tender process	b) Political changes
Technical specification		c) Political changes	c) Legislation & Administrative changes
Technical solutions		d) Geotechnical design changes	

Costs estimations	e) Detail design changes
Re-Design	f) Contractor's time delays
Design delay	g) Sponsor's / Employer's changes of scope
	h) Procurement

The values from the following table were used for the display of the probability of occurrence of certain types of risks with impact measuring.

Table 2. Display of likelihood of certain types of risks with impact measuring

Impact		**1**	**2**	**3**	**4**	**5**
Probability		0-0,050	0,050-0,500	0,500-2,0	2,0-5,0	5,0-20,0
1	0-5 %	Low	Low	Low	Medium	High
2	5-40%	Low	Low	Medium	Medium	High
3	40-70%	Low	Low	Medium	High	High
4	70-80%	Low	Medium	Medium	High	High
5	80-100%	Low	Medium	High	High	High

3. Findings

The subject of the research are project assumptions and risks that give answers to the following questions: what are the assumptions and risks that affect the performance of the contract; list of the appropriate measures that would help in the realization of project assumptions and ways to avoid the effects of risk incorporated into the project strategy. The ultimate goal of the research is to identify exactly those risks which considerably deviate from the usual practice of the initial risk assessment on similar projects in the world in relation to the environment in which this project takes place.

3.1 Identification of Project Assumptions

Assumptions are factors on which the project cannot directly influence. In order to contribute to the achieving of these assumptions, the conditions necessary for achieving the objectives on each level have been set, and the appropriate management strategies formulated. The intention was to implement all the mechanisms necessary to ensure effective and responsible management of not only the project activities, but also the assumptions in order to ensure their validity throughout the project cycle. The applied methodology that was followed had to be flexible enough to allow for the best possible changes to existing and / or adaptation of new assumptions, due to possible changes in the project needs or changes in the external environment of the project. Active cooperation and support of the team of experts at the user level is set as the main support for managing the assumptions. List of key assumptions, together with management strategies that were supposed to allow their implementation is shown in Table 3.

Table 3. List of main project assumptions

No	**Assumptions**	**Management strategy**

Assumptions on the level of the overall project objectives (developed during 2008 -2009)		
1	Croatia will not be significantly affected by the global economic crisis	Implementation of the project will increase the competitiveness of Croatian maritime transport sector and boost transport links with the rest of the world. The current global economic crisis will affect the described policy.
2	All existing ferry traffic, local and international, as well as the cruiser traffic will be relocated from the historic center of the city of Zadar	The historical core of Zadar will be freed from the ferry traffic
3	The concept of management of the NCFPZ will be in accordance with the concepts defined in the approved feasibility study	The project implementation process will strictly adhere to the guidelines set in the feasibility study, approved and accepted by the Government of the Republic of Croatia and international financial and monetary credit institutions.
The assumptions on the level of project purpose		
4	The consultant has obtained all necessary documentation and support for the effective fulfilment of their obligations.	The consultant will work closely with the PZA and the MMATI and actively involve the staff of the users and stakeholders in the implementation of the project.
5	Procurement and contracting are carried out smoothly and without significant backsets	The consultant will make sure that all public procurement procedures and contracting are carried out smoothly and without major delays by ensuring that all necessary documents are issued on time and with all necessary details, so that there are no additional administrative barriers (appeals and annulments) that could jeopardize the project objectives .
6	There is a strong commitment and coordination between the MMATI and the PZA in the project implementation	The consultant will provide continuous interaction with all project stakeholders to ensure the synergy of all parties that have a significant share in the success of the project.
7	Presentation of the project to all stakeholders and the general public with ensuring the transparency	The consultant will create a communications strategy that will be based on proactive information exchange.
8	Implementation of the project will be realized through two project implementation units (PIU); 1. PIU for construction 2. PIU for PPP management	The consultant will coordinate and manage the exchange of information.
Assumptions on the results' level		
9	Project documentation and studies prepared in accordance with the laws and regulations in force, in a way that the license is issued in due time	The issuing of licenses is a process that usually creates delays and extensions of deadlines. Because of the frequent changes in laws and regulations there is a certain level of non-compliance that creates difficulties to the administrative bodies in the final issuance of the permits, with the risk that the drafters of the technical documents will fail to fully anticipate all needed procedures and consents that need to be obtained, which may lead to further delays.

3.2 Identification of Project Risks

Identification of project risks before the start of the project will give answers to the following questions: which risks endanger the efficient implementation of the contract, what is their probability of occurrence and their impact, and which should be the appropriate mitigation measures? The list of risks was carried out during the preparatory phase of the project in the course of 2008 and 2009.

Based on the chosen methodology for the categorization of risk the "risk matrix" was made taking into account the selected method of risk assessment: the product of probability of occurrence and amount of potential financial losses is expressed in accordance with the adopted scales, taking into account identification and quantification of risk on the basis of experiences gained in similar large infrastructural maritime facilities.

The table below shows the initial assessment and risk evaluation with their expected effects and the measures for their suppression or mitigation.

Table 4. Assessment and evaluation of the risks with their expected effects and suppression measures

	Risk assessment

No.	Risk Category	Reason / Cause	Effect	Time impact (mons)	Probability %	Impact 000.000 (€)	Level of risk	Risk response strategy
1	**Design**							
a.	Legislation & Admin procedures	Changes of legislation	Delay of most project activities	6	0-5	0,500	L	Early notes, time extension
b.	Design documentation							
	Technical documentation	Changes of scope	Delays of designing	6	5-40	2,000	M	Time delays, contingency
	Technical solutions	Adjustments of scope	Disturbed designing	3	5-40	0,500	L	Control of the design work
	Cost estimations	Underestimated costs	Higher cost of construction	3	5-40	0,500	L	Time delays, contingency
	Re-Design	Optimizing of scope	Delay of designing & construction	3	0-5	0,500	L	Time delays, contingency
	Designer	Delay of design	Postponed construction	6	5-15	0,500	L	Extension of time
2	**Permits**							
a.	Legislation	Changes of legislation	Delay of most project activities	6	5-40	2,000	M	Early notes, time extension
b.	Administrative delays	New admin procedures	Postponed construction	9	40-70	2,00	H	Extension of time
3	**Construction**							
a.	Procurement	Delay of tenders	Postponed contract awards	3	5-15	0,500	L	EIB & KfW procurement
b.	Tender process	Delay of tender	Delays of contract awards	3	5-15	0,500	L	EIB & KfW procurement
c.	Political changes	Public admin changes	Delay of all project activities	6	5-15	0.050	L	Anticipation of possible problems
d.	Geotechnical design changes	Insufficient geotech. probes	Higher construction costs	3	5-25	5,000	M	Time delays, contingency
e.	Detailed design changes	Detailed designs adjustments	Delay of construction, costs increase	3	5-40	2,000	M	Time delays, contingency
f.	Contractor's time delays	Contractors defaults	Works handover delays	6	10-20	2,000	M	Contract administration
g.	Sponsor's / Employer's changes of scope	Detailed designs changes	Higher costs of construction	3	5-15	0,500	M	Time delays, contingency
4	**Business**							
a.	Sponsor / Employer business model decisions /changes	Changes of strategy	Delay of operations	6	5-15	0,500	L	Comparative analysis
b.	Political changes	Public admin changes	Delay of operations	6	5-15	0,050	L	Anticipation of problems
c.	Legislation & Administrative changes	Changes of legislation	Delay of operations	3	5-40	0,500	M	Early diagnosis of problems

3.3 Results of Risk Analysis

The majority of the assumptions defined at the beginning of the project were realized. Several project assumptions were realized, but with bigger or smaller corrections. So we have: for the assumption no. 5 "Procurement and contracting are carried out smoothly and without significant backsets" - the assumption is mostly realized with certain adjustments; one tender was canceled and repeated due to the price exceeding the foreseen budget. Furthermore, the assumption no. 9 "The project documentation and studies prepared in accordance with laws and regulations in force, in a way that the license is issued in due time" - a precondition realized with significant difficulties in the process of obtaining permits or with delays significantly greater than assumed.

Following (Table 5.) is the analysis of the initial risk identification prior to the start of the project and a comparison with the actually realized risks during the implementation of the NCFPZ project, categorized according to the proposed categorization from Chapter 2.

Table 5. Detailed descriptions of the realized risks per groups of project activities

No.	Risk Category	Foreseen risk	Actual risk; reasons for occurring	Risk Variance - %
1	**Design**			
a.	Legislation & Admin procedures	Changes of legislation; anticipated delays approx. 6 months	Amendment to the law caused The total delay of about 6 months	**0%** (6m/6m - in accordance with the initial assumption)
b.	Design documentation			
	Technical documentation	Changes of scope; 6 months possible extension of time, project contingency of 15%	The delay for works from Lot 2 & 3a of 15 months, Cost of the work within the agreed sum, implemented optimization	**250%** (15 m/6m - Achieved risk is 2.5 times higher) 0% for the price of works
	Technical solutions	Adjustments of scope; anticipated delay up to 3 months	The risk that was not achieved except in separately described cases	**0%**
	Cost estimations	Increase of costs; Project's estimated budget plus 15% contingency, anticipated delay up to 3 months	Estimate of 42.5 million €, best offer from an international tender was 50.00 million €.	**118%** (50/42,5 – best offer higher for 118% of the available Project Budget)
	Re-Design	Increase of costs for anticipated re-design but not evaluated, anticipated delay up to 3 months,	Review of the functional program for Lot 3 b and redesigning	Repeated tender gave price of 25 mil €.
	Designer	Delay of design; anticipated total delay for whole design works up to 6 months	Delay of the new project for Lot 3 b due to the corrections of tender documentation conditioned by the creditor KfW	**0%** (6m/6m - in accordance with the initial assumption)
2	**Permits**			
a.	Legislation	Changes of legislation; anticipated delays up to 6 months	Amendments to the law (in 2008).; redesigning in Preliminary design	**0%** (6m/6m - in accordance with the initial assumption)
b.	Administrative delays	Complicated procedures; anticipated delays up to 9 months for whole NPZ project elements	Terms of the reviewers changed the main project in relation to the project from the tender	**166%** (15m/9m - Produced a total shift in the program of 15 months)
3	**Construction**			
a.	Procurement	Delay of tenders; anticipated minor delays up to 3 months	Initial delay in the consultancy services tender due to harmonizing of local practices with the requirements of the creditor.	**200%** (6 m/3m - delay of 6 months for all activities)
b.	Tender process	Delay of tenders; anticipated minor delays up to 3 months	Use of the EBRD forms and KfW's guidelines for procurement of services provided direct contracting of redesigning works for Lot 2 & 3b (time saving of approx. 4 + 4 months)	**56%** (Saving of time for approx. 4 months + 4, from the total of 9 + 9 final time was 5 + 5)
c.	Political changes	Changes of public administration; anticipated up to 10% of total time or 6 months	Lot 3b: a delay in the start of works on the port terminal building due to changes in the financing concept; 18 months deadlock	**300%** (18m/6m - Suspensions of Lot 3b for 18 months)
d.	Geotechnical design changes	Insufficient geotech. probes; cost anticipated project contingencies, minor delays up to 3 months	Lot 1: insufficient initial geotechnical testing, Budget overrun of approx. 10% and 6 months extension.	**200%**(works realized in 18 instead of 12 months, 10% of the design reserves)
e.	Detailed design changes	Detailed designs changes; anticipated from contingencies, time delay up to 3 months	Successful monitoring of variations, requests and claims on the contract for works from Lot 2 & 3a.	**0%** - Changes within the stipulated timeframe and budget
f.	Contractor's time delays	Contractors defaults; 10% of total time – 6 months, to be managed contractually	Works performed in the contracted deadlines	**0%**- Changes within the stipulated time
g.	Sponsor's / Employer's changes of scope	Detailed designs adjustments; from project contingencies; time extension up to 3 months	Lot 2: ramp adjustments on the ferry berths, delays in the start of works for 6 months, the value of additional work from approximately 0.5 mil €.	**200%** (6m/3m- The delay of 6 months, the value of work 0.5 million € from the contracted project reserve)
4	**Business**			
a.	Sponsor / Employer business model decisions /changes	Changes of Sponsor's/Employer's strategy, anticipated delays of up to 3 months	Changes of the business model (one or more concessions for the building) Tendering extended for approx. 9 months	**300%** (9m/3m – Changing the tender for the concession, an extension of 9 months)
b.	Political changes	Changes of public administration; anticipated delays up to 10% of total time or 6 months	Change of the building construction concept (Lot 3b) conditioned by the state authorities, instead of financing from KfW's loan, funding by DBOT	**400%** (24m/6m - Delay of all activities from Lot 3b for approx. 24 months)

c.	Legislation & Administrative changes	Changes of legislation; anticipated delays up to 3 months	Amendments and supplements to the relevant laws (concession on maritime domain, public procurement, etc.)	**133%** (4m/3m – additional extension of 4 months due to adjustment to new laws)

The presented approach to the management of project risks has proven to be extremely important for this complex project because the sponsors and the main stakeholders of the project were familiar with the elaborate list of possible risks at an early stage of project preparation.

Should be point out here that the very successful parts in risk management were: activities on managing the implementation of the redesign on part of the maritime buildings (lot 2), or revising the initially functional program for the terminal building (Lot 3b) which allowed bringing the project to its final phase within the planned budget by phases without changes of the originally conceived project purpose, even though with significant delays compared to the originally set deadlines. Monitoring of variations, requests and claims on the contract for works from Lot 2 & 3a was also very successful, as well as management of comparative analysis of business models for NCFPZ.

It is important to be noted that the mentioned risks from group of administrative and political risks appeared in much greater intensity and scope than the previously planned. So the listed political risks generated significant delays in the project realization due to the attempts to change the financing model for certain elements of the NCFPZ project (Lot 3b). Anachronistic building regulations, through certain administrative legal proceedings, allowed for a further significant delay of the realization of Lot 2 & 3 a (negative statements on the main design by the originally hired project reviewers, additional design requirements by the aforesaid group resulting with a significant increase in the works price, and ultimately acceptance of the original technical solutions for main design issued later on by another group of reviewers). In addition to risks from the previously mentioned group, some of the decisions in the project management proved to be extremely risky (decision on the implementation of the tender for works from Lot 2 & 3a on the basis of the non-audited main design), or deficiencies in retaining the necessary dynamics of the project realization (reluctances in making of the decisions to change the selected business model for the management of the NCFPZ central terminal building).

4. Conclusion

The example of this complex infrastructure project showed that the biggest negative influence had risks from the group of administrative and political risks, even though they were initially identified and quantified. This can be explained in part by the fact that the project took place in a time and environment of extremely "busy" legal regulatory activities of conforming to the European directives during the process of accession of the Republic of Croatia to the EU. However, part of the political risks must certainly be pointed out here (we have such disproportion of even 300% up to 400% for some individual categories of initially quantified risks and those measured by the risk analysis) which manifested themselves on this project especially during and after the changes of state administration and resulted almost in complete standstill of some project activities. Then the cases from the scope of administrative risks, where there were created almost insuperable obstacles for the project (disproportion of 166% up to 250% for some individual categories of initially quantified risk and those measured by the risk analysis) in certain activities caused in part by the anachronistic administrative legal proceedings from building regulations.

In the end, it is also necessary to mention the possible potentials for improving the management of this project. Firstly, it would be necessary to carry out in a more precise and detailed manner the elaboration of the initial review of the project risks with more elaborated countermeasures. Moreover, the possibility for sufficiently frequent reviews of the risk matrix and countermeasures should be provided for. Also, the efforts on improving the process for obtaining the necessary permits should be made, that is, these processes should be made significantly more efficient. And finally, but of particular importance, it would be necessary to increase the autonomy of the project in relation to the so-called political and administrative legal risks.

5. Review of abbreviations

PZA	Port of Zadar Authority
NCFPZ	New Cruise and Ferry Port of Zadar
KfW	Kreditanstalt für Wiederaufbau
EIB	European Investment Bank
MSTTD	Ministry of Sea, Tourism, Transport and Development
IFI	International Financing Iinstitutions
MMATI	Ministry of Maritime Affairs, Transport and Infrastructure
MoF	Ministry of Finance
FS & CBA	Feasibility Study and Cost Benefit Analyses
EU	European Union
RC	Republic of Croatia

6. References

Akintoye, A.S. and MacLeod, M.J. (1997) “Risk analysis and management in construction”, International Journal of Project Management Vol. 15, No. 1, pp. 31-38.

Baccarini, D. and Archer, R. (2001) The risk ranking of projects: a methodology; International Journal of Project Management 19, pp.139-145

Bajaj, J. (1997), "Analysis of contractors’ approaches to risk identification in New South Wales, Australia", Construction Management and Economics, Vol. 15, No.4, pp.363-369

Bing, L. (1999), "Risk management in international construction joint ventures", Journal of Construction Engineering and Management, pp. 277-284.

Dziadosza, A. and Rejmentb, M. (2015), “Risk analysis in construction project - chosen methods”, Procedia Engineering 122, pp. 258-265

Godfrey, P. (1996), Control of Risk: A Guide to the Systematic Management of Risk from Construction, Construction Industry Research and Information Association, London

Han, S.H.; Kim, D. Y.; Kim, H.; Jang, W.S. (2008), “A web-based integrated system for international project risk management”, Automation in Construction Vol. 17, No. 3, pp. 342–356

Hayes, R., Perry, J., Thompson, J. (1986), Risk Management in Engineering Construction: A Guide to Project Risk Analysis and Risk Management., Thomas Telford, London,1986

Li, Y.; Liao, X. (2007), “Decision support for risk analysis on dynamic alliance”, Decision Support Systems Vol. 42, No. 4, pp. 2043-2059

Mills, A. (2001), “A systematic approach to risk management for construction”, Structural survey, Vol. 19, No. 5, pp. 245-252

Rutkauskas, A. V. (2008), “On the sustainability of regional competitiveness development considering risk”, Technological and Economic Development of Economy Vol. 14, No. 1, pp. 89-99

Tvaronavičienė, M. and Grybaitė, V. (2007), “Impact of FDI on Lithuanian economy: insight into development of main economic activities”, Journal of Business Economics and Management Vol. 8, No. 4, pp. 285–290

Williams, P. (1995), "A regulation evaluation system: a decision support system for the Building Code of Australia", Construction Management and Economics, Vol. 13 pp.197- 208

Zavadskas, E.K., Turskis, Z., Tamošaitiene, J. (2010) “Risk assessment of construction projects”, Journal of Civil Engineering and Management, Vol. 16, No. 1, 33-46

Zayed, T., Amer, M.; Pan, J. (2008), “Assessing risk and uncertainty inherent in Chinese highway projects using AHP”, International Journal of Project Management Vol. 26, No. 4, pp. 408-419

Zenh, J., An, M., Smith, N. J., (2007), “Application of a fuzzy based decision making methodology to construction project risk assessment”, International Journal of Project Management Vol. 25, pp. 589–600

Client and Contractor Perspectives of the Role of Performance Feedback on Process Performance

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Abstract:

The purpose of this study is to examine the role of performance feedback on construction process performance. Data were collected from client and contractors. A total of 2175 usable responses were retained representing 579 clients and 1596 contractors. A structural equation modeling approach was used to test the proposed model on clients and contractors. The proposed model was first validated across the two subsamples using confirmatory factor analysis. Subsequently structural paths were tested across both groups. The results suggest a significant positive direct impact of the performance feedback on construction process performance. The results further suggest that performance feedback mediates (i.e., strengthens) the effect of learning and collaboration on performance. The study proposes that the effects of performance feedback have a significant role in explaining processes in which the involvement of key stakeholders affects the likelihood of meeting agreed goals.

***Keywords: Construction industries, Performance, Feedback, Collaboration, Learning, SEM*.**

1. Introduction

Many studies in various countries have found that cost and time overruns are common in construction projects, causing major problems for clients and their end-users (e.g., Iyer and Jha, 2005; Assaf & Al-Hejji, 2006; Cantarelli et al., 2012; Shehu et. Al., 2014; Palmquist & Wennberg, 2016). Hence, there is a need for improved efficiency and productivity in construction projects to reduce these overruns. Construction work involves multi-actor projects in which clients and contractors are the main stakeholders (Manley & Chen, 2015) that often have differing or even opposing views. These two major parties have a number of similarities and differences that influence their perceived process outcomes. When outcomes do not match and deviate substantially we often see conflicts and significant cost overruns. Often, simply having more frequent and concrete meetings with feedback may solve inaccuracies in budgets and time schedules and reduce differences in views stemming from misunderstandings. It also seems that performance feedback increases the likelihood of success in short-term rather than long-term projects in construction industries (Ruuska & Vartiainen, 2005; Wong et. al., 2012). Jashapara (2003) noted that contractors have sophisticated schemes for identifying long and short-term effects of learning (i.e., single and double loop learning) from performance evaluation to avoid unexpected costs and increase the chances of success. Offering direction to current clients through performance evaluation is therefore highly valued because acquiring new knowledge and new partners is a lot more costly than processing the same work with known partners and existing knowledge (Wong, Cheung and Leung, 2008). As these ideas need to be shared between contractors and clients, they also tend to be heuristic in nature, involving

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various trial-and-error processes. Much of learning, and learning to do something better, is an iterative process (Wong et al., 2014) keeping records (Wong et al., 2012) of what works and what does not. Meaningful performance feedback is assumed to visualize current issues on the basis of earlier positive and negative learning experiences (Van de Ven & Polley, 1992) that fit both sides of the agreement.

Early studies on inertia suggest that performance feedback is best supported with consistent repetitive behavior, since it significantly increases the likelihood of success and decrease resistance against change (Hannan & Freeman, 1989). Thus understanding of resistance or inertia is the simple notion that repeated and past behavior predicts future behavior. Yet, this also becomes more difficult when recognizing both sides of the contract, that is, a client and contractor. Against this background of experience in learning, we know that feedback (Chinowsky, Molenaar & Realph, 2007; Harvey, Waterson & Dainty, 2016), controls (Zadeh, et al., 2016) ultimately explains performance (Luo, 2001), role performance (Praxmarer-Carus, 2014) and process performance (Marosszeky et al., 2004). As the reciprocal recognition tends to become more complex, increased, improved and repeated feedback is assumed be positive for process performance. More follow up increases the chances that both feel recognized. To this end it is known that supporting activities not only evaluate previous activities but also emphasize preferred future activities (Greve, 2003a-b, Burney & Widener, 2013; Miller & Cockrell, 2015; Van der Kolk & Schokker, 2016). However, to our knowledge it is not clear how temporal projects handle more processes and when learning outcomes are expected.

Project management has identified that certain characteristics to control temporal projects (Ling & Wong, 2016; Larsson et al., 2014). Within this literature, a number of survey studies have found explanations at a country level (Aitken & Crawford, 2008) of project managers (Ling & Loo, 2015) and different representatives in concurrent client contractor projects (Chan et al. , 2009). These studies clearly indicated that respondents tend to display significant differences in their judgments and behavior, without clearly addressing issues of client and contractor interests simultaneously. For example, it is well known that they rank issues differently (Chan et al., 2009), that they tend to be less satisfied if their values deviate from those of their focal organization (Ling & Loo, 2015). To this end, and given that processes not only differ but also affect evaluation of these processes, more research is needed on how process performance are perceived in light of feedback when multiple stakeholders are present (Haponava & Al-Jibouri, 2009, 2010).

Albeit the substantial amount in project management the literature has not addressed a validation of these concepts by doing comparing clients and contractors. The lack of such validation makes it difficult to establish a solid understanding and discuss implications of these concepts at a detailed level. In practical terms, since project management remains an important topic for temporal organizations, there is a lack of precision about how to specify these from the perspective of clients and contractors. More knowledge at the conceptual level may enrich discussion and lead to more detailed process outcomes, specifically in terms of ways that support processes to develop strategies to overcome duality issues in contracts.

While it is commonly argued that there are differences between clients and contractors, most studies investigate either side of the contract, that looking at the contractor's view (e.g., Ng et al., 2002; Akintoye & Main, 2007; Mason, 2007) or the client's view (Eriksson et al., 2008; Frödell et al., 2008; Pesämaa et al., 2009). Accordingly, there is a lack of studies that first establish equivalence at the conceptual construct level before testing the relationships among constructs in the model. The purpose of this paper is twofold: first, we establish equivalence at the conceptual construct level, to ensure that clients and contractors perceive and understand our key concepts in a similar way. Second, we test if the relationships understanding of key concepts differs between clients and contractors. The study is executed using structural equation modeling. A comprehensive review of the project management literature in construction industry is provided in the next section. The research design further explains what methodological assumptions guided this study. Thereafter, findings of the study are presented. Finally, we suggest a number of theoretical implications for researchers and managerial implications for practitioners.

2. Literature Review

2.1 Process performance

Much of literature assigns performance goals such as key performance indicators to reflect overarching goals (Kärnä et al., 2016; Chan & Chan, A2004). In a study of building designers, Lin and Gerber (2014) recognize the need for feedback and performance feedback loops to achieve a process that everyone can find meaningful. The latter perspective is also more known in the literature process performance (Marosszeky et al., 2004). Process performance literature (Kagioglou, Cooper & Aouad, 2001) is much directional and recognizes loops of learning with multiple reference points (Locke & Latham, 2002). This literature is derived from behavioral theories assuming that feedback has multiple functions, such as recognizing the most relevant activities and the overall objectives to which these are directed (Locke & Latham, 2002). Process performance is strongly related to performance feedback as it supports individuals or teams of individuals to stay on track and also decide what efforts or activities are less prioritized. Feedback and process performance are therefore often understood simultaneously with different roles (Locke & Latham, 2002).

2.2 Feedback in behavioral theory

"Feedback is the degree to which an individual is able to obtain direct and clear information about the effectiveness of his work performance from the job itself" (Ling & Wong, 2016:53). Feedback is found to increase job satisfaction (Chen, 2008) and performance (Locke and Latham, 2002). Feedback is one of the most commonly employed behavioral constructs in project (Ling & Loo, 2015) and construction management literature (Zadeh et al. , 2016). Behavioral impact is an important notion here, but its meaning is often vague or not defined at all. Behavioral means that individuals change their actions or consider a change (Cyert & March, 1963; Ajzen, 1985). Behavioral theory (Cyert & March, 1963) is the origin of performance feedback theory changes such as learning (Greve, 2003a, 2003b), selling (Berl, Powell & Williamson, 1984), or procurement (Joseph, Klingebiel & Wilson, 2016). Yet many authors carelessly use concepts such as knowledge as behavioral when it at bottom they actually reflect learning outcomes.

2.3 Collaboration

Much of achieving meaningful outcomes defined by processes involve multiple interests. Collaboration is an essential ingredient to collect multiple reference points to one point. Behavioral theories assume that individuals in managerial positions use multiple reference points (Blettner et al., 2015) to direct targeted and specific messages of performance feedback (Joseph, Klingebiel & Wilson, 2016) on processes. As construction projects are often achieved in teams, the processes tend to become complex and demand multiple perspectives. To this end, many projects need to be jointly defined and, given that performance feedback is specific, it also leads to more meaningful process performance outcomes. While collaborative processes (Xue et al., 2017) are not linear, it is known that more specific feedback may enhance the effects of collaboration on process (Locke & Latham, 2002). Therefore:

H_1: Collaboration has a positive relationship with performance feedback.

2.4 Learning

Learning is also tied to behavior theory and performance feedback (Argote & Greve, 2007) with subsequent consequences. It is conceptually interactive and evolves in a process of iterative loops. Behaviors such as collaboration and learning are difficult to observe directly. Yet both of these occur on purpose and have often undergone considerable points of selection. Any goals are also directional, pointing at an activity or a behavior (Locke & Latham, 2002). These loops allow mechanisms such as feedback to question fundamentals (Locke & Latham, 2002) and give direction for further action. In such processes of feedback, the human reactions take problems forward or sometimes one step backward. Meaningful feedback (or absence of it) is therefore assumed to foster both productive (Aitken & Crawford, 2008) and less productive outcomes (Chan et al. , 2009). Therefore:

H_2: Learning has a positive relationship towards performance feedback.

In the construction industry, these behaviors occur simultaneously and often between contractors and clients. Many of these are interpersonal and often unique. Some ingredients of it may have similar properties. Also, in line with earlier theory performance feedback, it is assumed to affect process performance in a positive way (Blettner et al., 2015; Locke & Latham, 2002). Therefore:

H_3: Performance feedback has a positive relationship towards process performance.

2.5 Hypothesized model

Based on the preceding discussion, this study proposes and tests that clients and contractors have the same ideas on feedback on process performance (Figure 1).

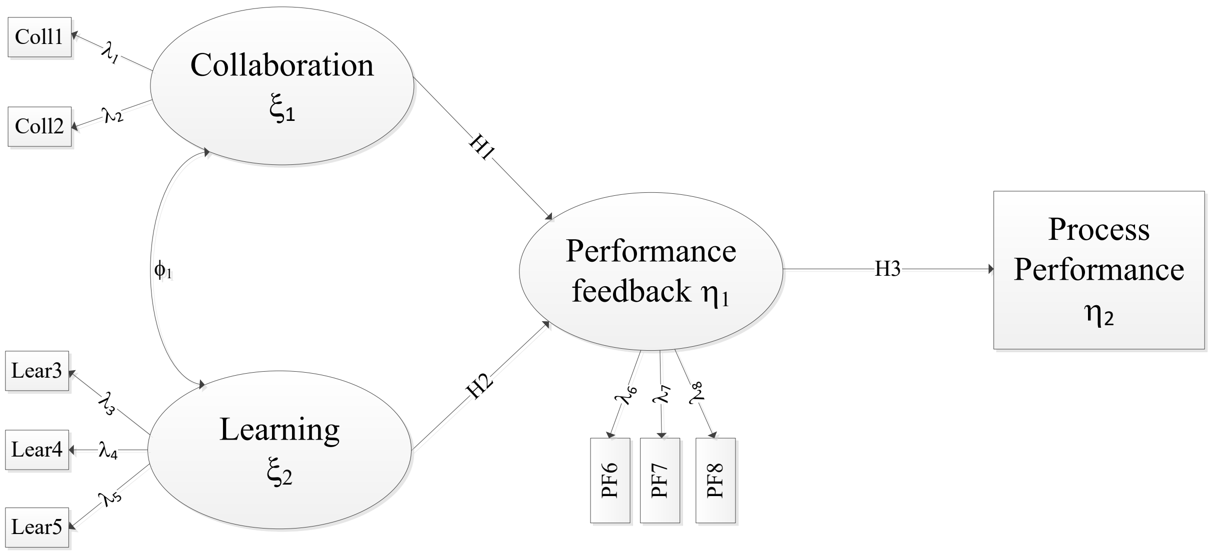


Figure 1. Theoretical Model

3. Research Design

3.1 Sample and data collection

Data from a company working with construction process measurement was utilized to test the proposed model. The construction process measurement includes a questionnaire survey based on prior research but developed by the company. At the time of this analysis, data from approximately 250 projects has been collected over the previous five years including respondents from all involved stakeholders and those in different roles in the projects. However, based on the purpose of the study, only data from clients and contractors are used during the tests. Further, some projects include extensive missing values for test variables and these projects were therefore excluded from the data sample. A sample of a total of 2175 responses from 109 different construction projects was finally used during the study. Table 1 displays a summary of the sample, including both product types, distribution of stakeholders' and respondents' roles in the project team. It was assumed that differences exist if the respondent was a contractor or client due to diverse project expectations. The idea was therefore to test different perceptions about various process outcomes. In total 579 clients and 1596 contractors were identified and subsequently assumed to represent two independent samples. It was therefore essential to run a multi-group analysis instead of a pooled sample

Table 1. Profile of the projects and respondents

	Projects	Stakeholders			Roles				
Product type	No.	Client	Contr.	No.	Managers	Experts	Designer	Workers	No.
Other civil	3	11	11	22	15	5		2	22
Other building	17	94	256	350	238	18	3	91	350
Residential	3	19	31	50	16	19	1	14	50
Office	10	27	500	527	273	41	12	201	527
Industry	1	2	16	18	11	2		5	18
Railway	21	124	122	246	88	126	1	31	246
Commercial	6	16	140	156	77	29	1	49	156
Earthwork	1	1	5	6	1	1		4	6
Hospital	11	64	90	154	48	67	8	31	154
Underground	1	1	1	2		1		1	2
Healthcare	4	13	57	70	44	3		23	70
Road	31	207	367	574	284	134	30	126	574
Summary	109	579	1596	2175	1095	446	56	578	2175

2.3 *Measurement scale*

The measurement model includes three latent constructs with a total of eight variables and one single item scale. The model is validated based on clients and contractors to test if they perceive these processes in the same way. The questions that assessed these processes were measures on an 11-point Likert scale anchored by 0 = strongly disagree and 10 = strongly agree. The latent constructs are as follows:

Collaboration was measured with two observables. These are: (1) Collaboration within the project organization works successfully; and (2) Collaboration between partner organizations works successfully. These measures thus reflect collaboration within the own focal organization and between one's own and the partner.

Learning was measured with three observables. These are: (1) I am free to express my opinions and ideas in the project; (2) In the project organization "we" work actively to find more efficient work processes; and (3) Within the project team "we" value experience from this and other projects. The measures thus reflect openness and interaction of experiences to fulfill expected tasks.

Feedback was measured with three observables. These are: (1) The managers in the project lead by good example and inspire me to do my very best; (2) I get valuable support and constructive feedback in my daily work in the project; and (3) I have access to necessary information to perform satisfactorily in the project. The measures thus reflect direction of feedback and access of information to improve performance.

Finally process performance was reflected by a single item scale measuring the extent “the project works well in terms of well-functioning processes that run efficiently against established goals.”

2.4 Data analysis

A structural equation modeling approach was used to test the proposed model on the clients and contractors samples, using the maximum likelihood (ML) method of estimation (AMOS 22.0). A two-stage approach was employed. A confirmatory measurement model was tested first, followed by the structural model, for both samples simultaneously. Several statistics were examined to determine how well the model fitted the data, including the chi-square statistics with associated p values and other fit indices such as the Comparative Fit Index (CFI), and Root Mean Square Error of Approximation (RMSEA). Studies suggest that the CFI should exceed .90, and SRMR and RMSEA should be lower than .08 (Xiong, Skitmore & Xia, 2015; Bentler, 1990; Marsh, Balla & Hau, 1996).

3. Results

3.1 Correlations

Table 2 presents the descriptive statistics, including means and standard deviations and raw correlations for the two independent samples respectively.

Table 2a: Correlations client (N=579)

	Mean	StDev	N	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9
Q1	8.09	1.71	579									
Q2	7.11	1.86	579	**.62****								
Q3	8.77	1.45	579	.63**	.46**							
Q4	7.85	1.72	579	.60**	.58**	**.60****						
Q5	7.81	1.84	579	.60**	.49**	**.57****	**.67****					
Q6	8.12	1.66	579	.67**	.57**	.66**	.64**	.63**				
Q7	7.37	1.92	579	.67**	.52**	.60**	.57**	.58**	**.69****			
Q8	7.86	1.64	579	.57**	.55**	.55**	.57**	.56**	**.59****	**.61****		
Q9	7.93	1.54	579	.72**	.64**	.63**	.68**	.64**	.78**	.64**	.67**	

*p<0.05, **p<0.01

Table 2b: Correlations contractors (N=1596)

	Mean	StDev	N	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9
Q1	7.84	1.87	1596									
Q2	7.00	2.01	1596	**.55****								
Q3	8.21	1.91	1596	.56**	.48**							
Q4	7.70	2.03	1596	.50**	.51**	**.67****						
Q5	7.62	2.01	1596	.51**	.55**	**.61****	**.73****					
Q6	7.47	2.01	1596	.61**	.60**	.63**	.62**	.63**				
Q7	6.96	2.11	1596	.61**	.55**	.62**	.58**	.56**	**.73****			
Q8	7.44	2.00	1596	.50**	.50**	.58**	.54**	.53**	**.58****	**.58****		
Q9	7.40	1.94	1596	.60**	.64**	.62**	.68**	.66**	.73**	.65**	.63**	

*p<0.05, **p<0.01

Within-correlation coefficients were examined to identify multi-collinearity issues. As expected, all within-correlation coefficients (marked in bold) were found to be significant and robust. Following guidelines from Shook et al. (2004), these matrixes also enable the replication of the results.

3.2 Measurement invariance testing

For the purpose of the study, respondents were divided into two groups based on their role as contractors or clients. A multi-group analysis in SEM was used to examine the differences across the two groups. A prerequisite to conduct multiple group comparison was to establish measurement invariance across groups. The following sequence of tests was conducted following the suggestion by Vandenberg and Lance (2000).

Firstly, to examine the equivalency of the factor structure between the clients and contractors group, parameters for both groups are estimated simultaneously. The tenability of the proposed factor structure rests on the overall goodness-of-fit for the two-group model (Byrne, 2013). The overall unconstrained fit of the two-group model (Table 3: Model 1) was: χ^2= 358.367; df=44; p-value = .000; χ^2/DF=8.145; CFI=.976; RMSEA=.057. Review of the fit statistics suggested that the hypothesized factor structure was equivalent across the two independent groups (configural invariance).

3.3 Measurement model testing

Once the measurement invariance was confirmed, the proposed measurement models for both independent samples were tested simultaneously to assess the measurement properties. Two types of validity measures, convergent and discriminant validity, were examined. Convergent validity was determined by the following tests (Anderson & Gerbing, 1988). First we ran a full model including all three constructs, with the single item measure on process performance. Results are reported in Table 4. In Table 4 all t-values associated with each completely standardized factor loading for each indicator were significant at 0.05 level, confirming the posited relationships between indicators and assigned theoretical constructs. The average variance extracted (AVE) values were calculated for each latent construct. All AVE values exceeded 0.55, indicating that most of the variance in each construct was explained by the common underlying factor (Table 4). In addition, construct reliability for each latent construct with more than three items was calculated and the scores ranged from 0.61 to 0.67 (Table 4), exceeding the ideal cutting off value of 0.70. Measurement properties of collaboration were reflected by the fact that two items had a strong inter-correlation, ranging from .55-.62 (Table 4). Therefore convergent validity of the full measurement model was established.

Table 3: Goodness-of-fit and model comparison across contractors and clients

	Goodness-of-Fit all three models						Model comparison		
Model	χ^2	D.F	P	χ^2/D.F	CFI	RMSEA	Δ df	$\Delta\chi^2$	p-value
Unconstrained	358.367	44	0.000	8.145	0.976	0.057			
Model 2: loadings constrained	370.861	49	0.000	7.569	0.975	0.055	5	12.494	0.029
Model 3: Loadings and intercorrelations constrained.	511.548	59	0.000	8.67	0.965	0.059	15	153.181	0.000

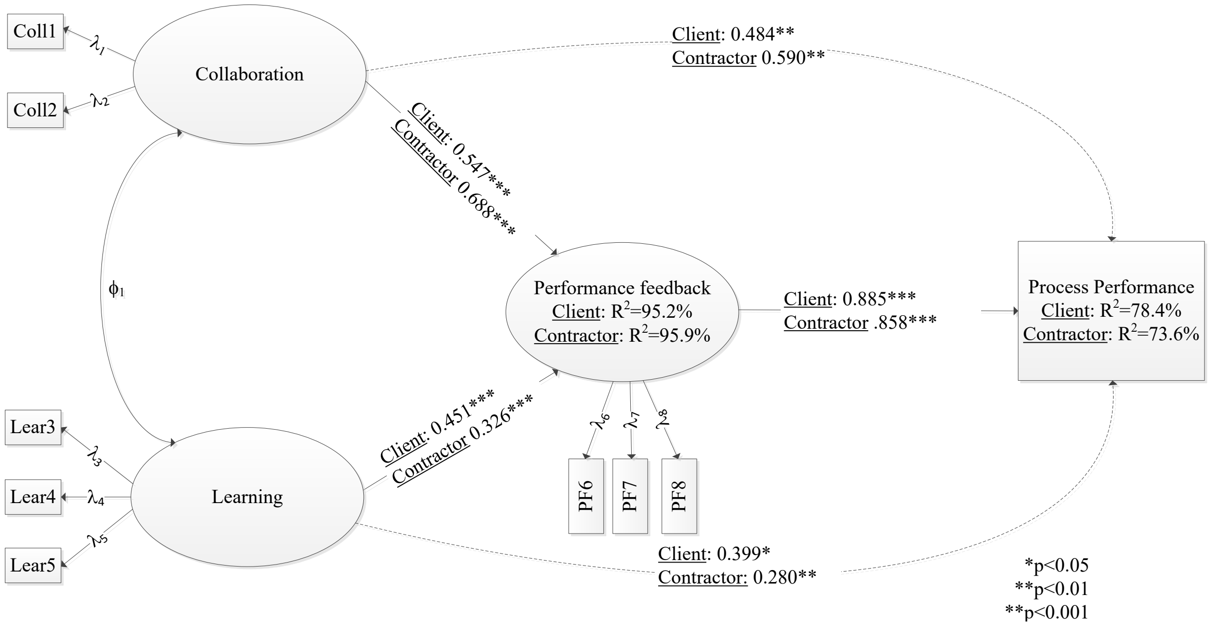
Table 4: Factor loadings

	Contractor	Client
Collaboration		
Coll1	0,743	0,845
Coll2	0,741	0,727
Reliability inter-correlation (*r*)	.55	.62
AVE	55%	62%
Learning		
Lear1	0,783	0,766
Lear2	0,851	0,807
Lear3	0,825	0,779
Composite reliability	.81	.75
AVE	67%	61%
Feedback		
PF1	0,863	0,856
PF2	0,814	0,778
PF3	0,712	0,736
Composite reliability	.64	.63
AVE	77%	76%

Next, the equivalency of the pattern of factor loadings was tested (metric invariance). Metric invariance was examined by constraining all loadings to be equal across both samples (i.e., client and contractors). The $\chi2$ difference test of Model 2 in Table 3 with constrained loadings equal was marginally rejecting $\chi2$ differences ($\Delta\chi2$ (df) =12.494 (6); p-value =.029). Loadings can thus be considered equal and adequate comparison (with loadings) across groups can be performed. Next Model 3 included loadings and inter-correlations. Model 3 was then compared to Model 2 and the $\chi2$ difference test reported ($\Delta\chi2$ (df) =153.181 (15); p-value =.000) significant differences (Xiong, Skitmore & Xia, 2015). Regression with relationships between construct is thus assumed to differ between the samples.

3.4 Structural model testing

After establishing the measurement models, structural models for both samples were tested simultaneously. The structural model involves three hypotheses, in which theoretical arguments support substantial relationships between feedback and process performance (Locke & Latham, 2002) and further a proposed mediating meaning that feedback mediates the effects of collaboration and learning on process performance. First, findings indicated that the theoretical structural model is well reflected by the observed data based on an acceptable model fit: Goodness-of-Fit: χ^2= 384.576; df=48; p-value = .000; χ^2/DF=8.012; CFI=.974; RMSEA=.057. The proposed model explained 95.2-95.9% of the variance in performance feedback and 73.6-78.4% of process performance Thus, variation between client and contractors was found to be relatively small.



Goodness-of-Fit: χ^2= 384.576; df=48; p-value = .000; χ^2/DF=8.012; CFI=.974; RMSEA=.057.

Figure 2. Test and results theoretical model

In Figure 2 findings indicated no significant relationship between collaboration and performance feedback for both groups (H_1) (Client β =0.547, p<0.001 vs Contractor β =0.688, p<0.001). Hypothesis 1 was thus supported for both groups. Significant relationship was identified between learning and performance feedback for both groups (H_2) (Client β =0.451, p<0.001 vs Contractor β =0.326, p<0.001), which provided support for Hypothesis 2. Hypothesis 3 proposed a significant relationship between performance feedback and process performance, which was also supported by the findings for both groups (H_3) (Client β =0.885, p<0.001 vs Contractor β =0.858, p<0.001). Dashed lines in Figure 2 also report strong indirect effects of all proposed relationships. Performance feedback is thus a fundamental mediator for these processes.

4. Discussion

4.1 Theoretical implications

This study confirms four dimensions that reflect a process performance model. The model proposed examines the relationship between collaboration, learning, performance feedback and process performance. It presents a complex structure of nine variables distributed on three latent indirect dimensions on one direct measure of process performance. It is found that the model has an acceptable goodness-of-fit. The comparisons made between the clients and contractors resulted in both similarities and differences. The measures were found to measure the same thing but inter-correlations imply that it is appropriate to examine the two samples separately.

The findings from H1 suggest that collaboration is strongly significant and affects performance feedback for both clients and contractors. As the measures to some extent reflect a core activity that needs to be present in construction industry (Eriksson, 2015), this is not surprising. The study, however, offers a measure that is the same across these samples although more nuanced measures on the same thing may find differences. We stress that this is a first step towards a way of seeing how client and contractors experience the same behaviors in the same way.

In line with theoretical backing, Hypothesis 2, which proposed a significant positive direct impact of learning on performance feedback, is also supported for both groups. This finding is consistent with those of the previous studies (Argote & Greve, 2007). Again it is emphasized that this is a core activity that is reflected to be the same across both groups.

Hypothesis 3 proposed that performance feedback has a significant impact on process performance, which is supported for both groups. This result concurs with those of Locke and Latham (2002), as well as of Blettner et al. (2015). As for the difference, these results are also extremely similar.

The findings derived from H_{2-3} indicate that performance feedback strongly meditates the effect of collaboration and learning on process performance for both clients and contractors.

4.2 Managerial implications

The role of performance feedback is here discussed and tested as central for meaningful process performance outcomes. Theoretically we framed the study from a behavioral approach, using performance literature to stress directional outcomes. The model shows that these directions, given proper attention, may strengthen effects beyond feedback. The mediation in the model was framed to show that feedback is necessary and conditional to learning and collaborative behaviors assumed to be critical for any construction project. As the paper recognized, these at an abstract level were both processes were experienced in the same way it opens up for slightly more nuanced measures.

5. Conclusion and limitations

Drawing data from clients and contractors in the construction industry, this study explains different antecedents leading to meaningful process performance, including collaboration, learning and performance feedback. A conceptual model was developed and tested using SEM. The findings supported the significant role that performance feedback has on process performance.

As the study is based on a relatively large sample size for this type of complicated model (i.e., two independent samples), the results are believed to be important. The relatively large sample may strengthen the results of the study. Further studies may allow segmentation of clients and contractors on a more nuanced but smaller sample.

6. References

Aitken, A. & Crawford, L. (2008). Senior management perceptions of effective project manager behaviour: an exploration of a core set of behaviours for superior project managers. PMI Research Conference, 2008.

Ajzen, I. (1985). From intentions to actions: A theory of planned behavior. In *Action control*. Springer Berlin Heidelberg, pp. 11-39.

Akintoye, A. & Main, J. (2007). Collaborative Relationships in Construction: The UK Contractors' Perception. *Engineering, Construction and Architectural Management*. 14 (6), 597-617.

Anderson, J.C. & Gerbing, D.W. (1988), Structural equation modelling in practice: a review and recommended two-step approach. *Psychological Bulletin*. 103 (3), 411-423.

Argote, L., & Greve, H. R. (2007). A behavioral theory of the firm—40 years and counting: Introduction and impact. *Organization Science*, 18 (3), 337-349.

Assaf, S. & Al-Hejji, S. (2006). Causes of delay in large construction projects. *International Journal of Project Management*. 24 (4), 349-57.

Bentler, P. M. (1990). Comparative fit indexes in structural models. *Psychological Bulletin.*.107 (2), 238–246.

Berl, R., Powell, T., & Williamson, N. C. (1984). Industrial salesforce satisfaction and performance with Herzberg's theory. *Industrial Marketing Management*. 13 (1), 11-19.

Blettner, D. P., He, Z. L., Hu, S., & Bettis, R. A. (2015). Adaptive aspirations and performance heterogeneity: Attention allocation among multiple reference points. *Strategic Management Journal*.36 (7), 987-1005.

Burney, L. L., & Widener, S. K. (2013). Behavioral work outcomes of a strategic performance measurement system-based incentive plan. *Behavioral Research in Accounting.* 25 (2), 115–143.

Byrne, B. M. (2013). *Structural Equation Modeling with AMOS: Basic Concepts, Applications and Programming*. New York: Routledge.

Cantarelli, C., van Wee, B., Molina, E. J. E., & Flyvbjerg, B. (2012). Different cost performance: Different determinants? The case of cost overruns in Dutch transport infrastructure projects. *Transport Policy*. 22 (July), 88-95.

Chan, A. P., & Chan, A. P. (2004). Key performance indicators for measuring construction success. *Benchmarking: an International Journal*. 11 (2), 203-221.

Chan, A. P., Lam, P. T., Chan, D. W., Cheung, E., & Ke, Y. (2009). Potential obstacles to successful implementation of public-private partnerships in Beijing and the Hong Kong special administrative region. *Journal of Management in Engineering*. 26 (1), 30-40.

Chen, L. H. (2008). Job satisfaction among information system (IS) personnel. *Computers in Human Behavior*. 24 (1), 105-118.

Chinowsky,P Molenaar, K. & Realph, A. (2007). Learning organizations in construction. J. Manage. Eng., 23,27–34.

Cyert, R. M., & March, J. G. (1963). *A Behavioral Theory of the Firm*. Malden, MA: Blackwell.

Eriksson, P. E., Nilsson, T., & Atkin, B. (2008). Client perceptions of barriers to partnering. *Engineering, Construction and Architectural Management*. 15(6), 527-39.

Eriksson, P. E. (2015). Partnering in engineering projects: Four dimensions of supply chain integration. *Journal of Purchasing & Supply Management*. 21 (1), 38-50.

Frödell, M., Josephson, P.-E., & Lindahl, G. (2008). Swedish construction clients' views on project success and measuring performance. *Journal of Engineering, Design and Technology*. 6 (1), 21-32.

Greve, H. R. (2003a). *Organizational Learning from Performance Feedback*. Cambridge: Cambridge University Press.

Greve, H. R. (2003b). A behavioral theory of R&D expenditures and innovations: Evidence from shipbuilding. *Academy of Management Journal.* 46, 682–702.

Haponava, T., & Al-Jibouri, S. (2009). Identifying key performance indicators for use in control of pre-project stage process in construction. *International Journal of Productivity and Performance Management*. 58 (2), 160-173.

Haponava, T., & Al-Jibouri, S. (2010). Influence of process performance during the construction stage on achieving end-project goals. *Construction Management and Economics*. 28 (8), 853-869.

Harvey, E. J., Waterson, P., & Dainty, A. R. (2016). Applying HRO and resilience engineering to construction: Barriers and opportunities. *Safety Science*. In press.

Iyer, K. & Jha, K. (2005). Factors affecting cost performance: Evidence from Indian construction projects. *International Journal of Project Management*. 23 (4), 283-95.

Jashapara, A. (2003). Cognition, culture and competition: an empirical test of the learning organization. *The Learning Organization*. 10 (1), 31–50.

Joseph, J., Klingebiel, R., & Wilson, A. J. (2016). Organizational structure and performance feedback: Centralization, aspirations, and termination decisions. *Organization Science*. *27* (5), 1065-1083.

Kagioglou, M., Cooper, R., & Aouad, G. (2001). Performance management in construction: a conceptual framework. *Construction management and economics*. 19 (1), 85-95.

Kärnä, S., Kärnä, S., Junnonen, J. M., & Junnonen, J. M. (2016). Benchmarking construction industry, company and project performance by participants' evaluation. *Benchmarking: An International Journal*. 23 (7), 2092-2108.

Larsson, J., Eriksson, P. E., Olofsson, T., & Simonsson, P. (2014). Leadership in civil engineering: Effects of project managers' leadership styles on project performance. *Journal of Management in Engineering*. 31(6), 1-11.

Lin, S. H., & Gerber, D. J. (2014). Evolutionary energy performance feedback for design: Multidisciplinary design optimization and performance boundaries for design decision support. *Energy and Buildings*. 84, 426-441.

Ling, F. Y. Y., & Loo, C. M. (2015). Characteristics of jobs and jobholders that affect job satisfaction and work performance of project managers. *Journal of Management in Engineering*. 31 (3), 1-10.

Ling, F. Y., & Wong, D. M. (2016). Redesigning facility management operatives' jobs to increase work outcomes. *Journal of Facilities Management*. 14 (1), 50-68.

Locke, E. A., & Latham, G. P. (2002). Building a practically useful theory of goal setting and task motivation: A 35-year odyssey. *American Psychologist*. 57 (9), 705.

Luo, Y. (2001), Antecedents and consequences of personal attachment in cross-cultural cooperative ventures, *Administrative Science Quarterly*. 46 (2), 177-201.

Manley, K., & Chen, L. (2015). Collaborative learning model of infrastructure construction: a capability perspective. *Construction Innovation*. 15 (3), 355-377.

Marosszeky, M., Karim, K., Davis, S. & Naik, N. (2004). Lessons learnt in developing effective performance measures for construction safety management. Paper presented at the 12th Annual Conference on Lean Construction, Elsinore, Denmark, 10–11 August.

Marsh, H. W., Balla, J. R. and Hau, K. (1996), An evaluation of incremental fit indices: a clarification of mathematical and empirical properties. In: Marcoulides, G.A. & Schumacker, R.E. (eds.) *Structural Equation Modeling: Issues and Techniques*. Erlbaum, Mahwah, NJ, pp. 315–353.

Mason, J. (2007). The views and experiences of specialist contractors on partnering in the UK. *Construction Management and Economics*. 25 (5), 519-27.

Miller, T. C., & Cockrell, R. C. (2015). Discussion of workplace culture mediates performance appraisal effectiveness and employee outcomes: A study in a retail setting. *Journal of Management Accounting Research*. 27 (2), 35–38.

Ng, T., Rose, T., Mak, M., & Chen, S. E. (2002). Problematic issues associated with project partnering - The contractor perspective. *International Journal of Project Management*. 20(6), 437-49.

Pesämaa, O., Eriksson, P. E., & Hair, J. (2009). Validating a model of cooperative procurement in the Swedish construction industry. *International Journal of Project Management*. 27(6), 552-59.

Palmquist, J., & Wennberg, A. (2016). Norra länken–A case study. Candidate Thesis. (KTH: Stockholm).

Praxmarer-Carus, S. (2014), Why the proposal of a complex contract may harm or foster a partner's trust, *Journal of Business Research*. 67 (7), 1421-1429.

Ruuska, I. & Vartiainen, M. (2005). Characteristics of knowledge sharing communities in project organizations. *International Journal of Project Management*. 23 (5), 374–379.

Shehu, Z., Endut, I. R., Akintoye, A., & Holt, G. D. (2014). Cost overrun in the Malaysian construction industry projects: A deeper insight. *International Journal of Project Management*. 32 (8), 1471-1480.

Shook, C. L., Ketchen, D. J., Hult, G. T. M., & Kacmar, K. M. (2004), An assessment of the use of structural equation modeling in strategic management research. *Strategic Management Journal*. 25 (4), 397-404.

Vandenberg, R. J., & Lance, C. E. (2000), A review and synthesis of the measurement invariance literature: Suggestions, practices, and recommendations for organizational research. *Organizational Research Methods.* 3, 4-69.

Van der Kolk, B., & Schokker, T. (2016). Strategy implementation through hierarchical couplings in a management control package: An explorative case study. *Journal of Management Control.,* 27 (2–3), 129–154.

Van de Ven, A. H., & Polley, D. (1992). Learning while innovating. *Organization Science*. 3 (1), 92-116.

Wong, P. S. P., Cheung, S. O., & Leung, K. Y. (2008). Moderating effect of organizational learning type on performance improvement. *Journal of Management in Engineering*. 24 (3), 162-172.

Wong, P. S., Cheung, S. O., Yiu, R. L., & Hardie, M. (2012). The unlearning dimension of organizational learning in construction projects. *International Journal of Project Management*. 30 (1), 94-104.

Wong, P. S., Demertjis, M., Hardie, M., & Lo, C. Y. (2014). The effect of unlearning on organisational learning behaviour and performance in construction contracting organisations. *International Journal of Project Organisation and Management*. 6 (3), 197-214.

Xiong, B., Skitmore, M., & Xia, B. (2015). A critical review of structural equation modeling applications in construction research. *Automation in Construction*. 49, 59-70.

Xue, X., Zhang, X., Wang, L., Skitmore, M., & Wang, Q. (2017). Analyzing collaborative relationships among industrialized construction technology innovation organizations: a combined SNA and SEM approach. *Journal of Cleaner Production*. In Press.

Zadeh, M. T., Dehghan, R., Ruwanpura, J. Y., & Jergeas, G. (2016). An index to assess project management competencies in managing design changes. *International Journal of Construction Engineering and Management*. 5(1), 11-24.

Application of S-curve in EVA Method

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Abstract:

This paper gives an overview of Earned Value Analysis (EVA) and its application in managing and controlling construction projects. EVA is a method for measuring the progress and success of the project through costs, time, and technical and physical implementation of project. EVA method compares project progress i.e. amount of profit in relation to actual project costs at the moment of monitoring. It is based on the three basic variables: planned project cost, actual project cost and earned project value. Indicated variables are shown through separate S-curves that present flow of selected variables in time. This paper presents the way these curves are used in the mentioned method.

Keywords: *EVA method, S-curve, project management and control*

1. Introduction

The primary purpose of construction project management is to complete the project on time, within the budget and in accordance with the given technical requirements (Pewdum et al., 2009 as cited in De Marco and Narbaev, 2013). The biggest problem in the construction sector is the failure to fulfill these management objectives, that is, overruns in the planned costs and time. The problem of overruns of time and cost in construction projects is considered a global phenomenon (Sambasivan and Soon, 2007), both in developed and developing countries. In order to reduce overruns and delays, project managers should use effective tools and techniques to monitor project status during the construction stage (Fleming and Koppelman, 2006 as cited in Abdul-Rahman et al., 2011). Effective control of project progress is very important for later successful delivery of construction project (Hegazy, 2002 as cited in Turkan et al., 2013). No matter how good a project design is, if there is no regular and timely control during project execution, it is impossible to evaluate project progress and effectiveness of the plan (Cleland and Ireland, 2007 as cited in De Marco and Narbaev, 2013). Feedback enables project managers to identify issues in early stage and make the necessary adjustments, which is crucial to later project success.

The traditional way of project control involves comparing the planned and realized values, which does not always have to be an accurate project performance indicator. If the project takes place according to the schedule, it does not have to mean that the project costs are within the planned budget. In order to establish a comprehensive project performance control, all volume, time and cost indicators need to be integrated and calculated as

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interdependent sizes (Katić and Duspara, 2014).

The process, which is believed to be effective in this area, is called Earned Value Analysis (EVA). Unlike traditional project monitoring, this method integrates three types of data: planned costs - value of execution - actual costs, and provides a much better analytical basis for performance evaluation of the project (Radujković et al., 2012). According to Fleming and Koppelman (2002) EVA is the best indicator of the project's future results, where it is possible to predict cost and/or time deviations by using project trend data in the early stages of construction (as cited in Abdul-Rahman et al., 2011). The EVA method uses S-curves as a tool for integrated time and cost management of project. The S-curve, clearly and accurately represents the state of the cost within the schedule of the project.

The aim of this paper is to show how the mentioned S-curves are used in the EVA method.

2. S-curve

The S-curve represents the cumulative growth of the selected variable or amount of work over a given time period. The name was given because of similarity to the letter "S" (less work is done and less money is accumulated in the earlier and later stages of the project than in the mid-stage of the project). S-curves are widely applied in project management and it is interesting that the records about their application date back to 90 years ago, more precisely, they date from 1928 (Martyniak, 2002 as cited in Czarnigowska et al., 2011).

In project management, S-curves are used to graphically display cumulative progress of work, expressed in units of costs, labor of hours, percentage of progress, etc., in relation to time (PMI, 2008, Narbaev and De Marco, 2014). With regard to the topic of work, the S-curve can be precisely defined as a graph of cumulative cash flow over a given period, where the abscissa shows the time and ordinate shows the costs (Figure 1) (Ostojić-Škomrlj and Radujković, 2012).

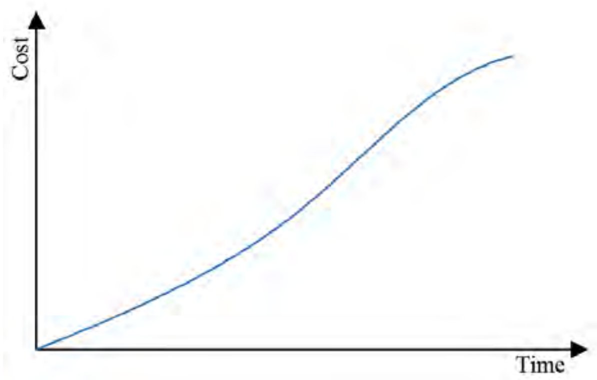


Figure 1. S-curve

The S-curve is obtained through the planning process in several steps which include creation of project work breakdown structure, cost estimate and Gantt chart. When constructing the curve by points, time intervals are applied to the horizontal axis and the associated cost value, counted from the beginning to this very moment, to the vertical one (Tijanić et al., 2016).

The S-curve showing the relationship "costs - time" has several types (Figure 2).

- Baseline S-curve – Prior to project commencement, the schedule represents the proposed allocation of the resources and the time needed to complete the project. This schedule is referred to as the baseline schedule and from this schedule, a baseline S-curve is generated. This S-curve reflects the planned progress of the project. If the project requirements change prior to commencement (e.g. change of scope, delayed start) the baseline schedule then requires changes in accordance with the new terms.
- Target S-curve – After the project commencement, it is usually necessary to modify the baseline schedule. Changes are continually made to the schedule, and such schedule reflects the actual progress of the project to date. From this schedule, a target S-curve can be generated. In ideal conditions, the target S-curve will meet the baseline S-curve at the end of the project (on time, on budget) or finish below and to the left of the baseline S-curve (early, under budget). In reality, it is not uncommon for the target S-curve to finish above and to the right of the baseline S-curve (late, over budget).
- Actual S-curve - The work schedule is updated on a regular basis throughout the project. These updates include an insight into the percentage of execution of each task. Using this information, an actual S-curve can be generated. This S-curve reflects the actual progress of the project to date of observation, and can be compared with the baseline and target S-curves to determine how the project is progressing. At the end of the project, the actual S-curve will meet the target S-curve (Garland, 2009).

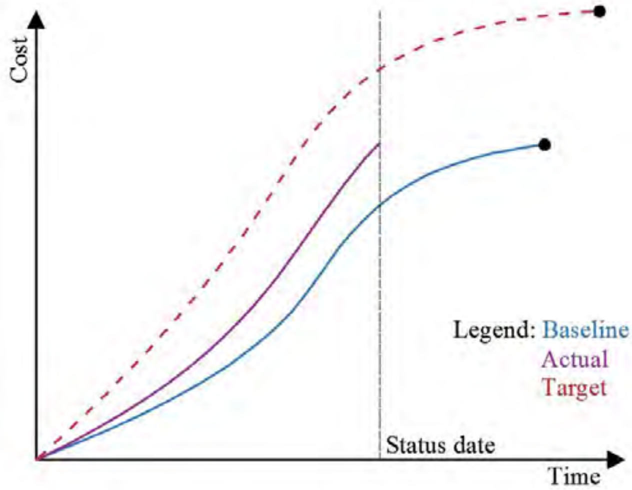


Figure 2. Different types of S-curves (Garland, 2009)

The shape of the S-curve can provide significant information about the nature of the project. Curves that start with a high inclination and then align can point to "front loading", which could be projects that require little or no planning time, repair of disaster damage, or they could indicate a schedule that has been accelerated since beginning. S-curves that start out with a lower pitch and then go steep to the end could indicate a large planning or design time in the beginning and a reduced construction time (Goodman, 2010). For larger projects, the curve usually has a slight pitch at the beginning (the allocation of staff and materials is limited at the beginning of the project). During the middle period, the slope of the curve is increasing because of the higher activity and generally the higher cost growth rate.

Large number of authors who have studied S-curves application can be listed. Boussabaine (1982) dealt with the analysis of the cash flow in projects, Miskawi (1989) developed the S-curve equation for project control, Radujković and Izetbegović (1999) studied the selection of functional connections while conducting the research on S-curve trend (as cited in Tijanić et al., 2016). Standardized curves were studied by Balkau (1979), Bromilow (1978), Drake (1978), Hudson (1978), Tucker and Rahilly (1988), Singh and Phua (1984), Kenley and Wilson (1986), Kaka and Price (1991) (as cited in Ostojić-Škomrlj and Radujković, 2012), and according to them Ostojić-Škomrlj developed an S-curve prediction model in early construction project stages (Ostojić-Škomrlj and Radujković, 2012), and so on.

S-curves are a very useful tool for effective project control and taking corrective measures when the actual performance differs from the planned one. However, in the interpretation of the S-curve, it is necessary to go with the level of precautionary. Interpreting them with no regard to the relationships between project tasks and reasons for deviations may lead to wrong decisions. In spite of this, S-curves do not lose on popularity in project management, and one of their most common applications is in the EVA method – a method designed to provide reliable measures of project performance and to allow the project manager to make inferences on the final effect of the project (PMI, 2005, Czarnigowska et al., 2011). The EVA method involves displaying three types of data, so we differentiate three different types of S-curves: curve of planned project cost, curve of actual project cost and curve of project earned value. This type of view can be very effective for a quick overview of overall task performance, account control, or project status. It is possible to identify potential project budget overruns, possible risks and errors that could affect the project's performance.

3. Earned Value Analysis

Earned Value Analysis is a tool for measuring project performance by comparing the planned amount of work with the actual amount of work and actual costs. It is the most commonly used cost and time control method because it integrates project technical performance data, time performance data, and cost data within one frame (El-Omari and Moselhi, 2011, Sumara and Goodpasture, 1996 as cited in Turkan et al., 2013). Based on the three types of data, it is possible to compare the planned value (PV) of planned work with the earned value (EV) of the completed work and the actual cost (AC) of the actual work done. Based on the presentation of these three data, deviations in costs that affect the time schedule can be identified, and vice versa, the project lagging behind the time schedule will probably have increased costs compared to planned costs.

The use of EVA helps the project manager in determining the current project status by answering questions such as: Is it project on schedule? Is it project on cost? Do the costs reflect the true accomplishments? What are and how big are variances (Kerby and Counts, 2017)?

As a project management tool, EVA brings a number of advantages. One of the main advantages is that it is a relatively simple reporting system on project progress that includes all interested project participants, regardless of their position, ensuring that everyone remains focused on their individual and global responsibilities to ensure timely delivery of the project. EVA enables precise metering of project efficiency, and identifies areas where an error can occur with the emergence of the plan. Based on its use in the project implementation phase, EVA also provides early warning signs of possible delays and overruns, and it forecasts how it will affect the eventual completion of the project. EVA helps the project manager by providing data and reports highlighting the problem areas developed within the actual project implementation, and people responsible for solving these problems are timely informed. The project is trying to return to its original goals, if it possible. On the other side, EVA also shows where the project is above expectations, thus providing information on potential reserve funds or costs that could help to cover potential future project problems (https://www.ukessays.com/essays/project-management/earned-value-analysis-advantagesand.php, accessed 21 April 2017).

The EVA method originally pulls roots from the USA where it has been introduced more than hundred years ago. It was first used in commercial industrial production plant for the production cost management. The basic concept of the EVA method was also accepted in the USA air force, and by 1967, the USA Defense Ministry officially approved the use of the EVA method in all major procurement systems (Fleming and Kopellman, 1999 as cited in Dissanayake, 2010). The basic concept of the EVA method has not changed since then (Christensen, 1999 as cited in Dissanayake, 2010).

EVA research are numerous. Lipke (1999) developed cost and schedule ratios to manage cost and schedule reserves in projects. Lipke (2003) introduced the earned schedule. Lipke (2004) developed project cost and time performance probabilities. Lipke et al. (2009) provided a reliable forecasting method of the final cost and duration to improve the capability of project managers for making informed decisions. Anbari (2003) enhanced the effectiveness of earned value implementation (Najafi and Azimi, 2015). Kim et al. (2003) studied the implementation of earned value in different types of projects and organizations (as cited in Najafi and Azimi, 2015). Vandevoorde and Vanhoucke (2005) concluded that the best and the most reliable method to estimate time at completion is the earned schedule method (Najafi and Azimi, 2015). Cioffi (2005) proposed an S-curve to analyze project progress and cost that can be defined using two basic parameter values, and he concluded that curves with favorable goodnessof-fit can then be incorporated into EVA (Nai-Chieh et al., 2016). Cioffi (2006) also proposed a new notation for the earned value analysis to make EVA mathematics more transparent and flexible (as cited in Najafi and Azimi, 2015). Pajares and López-Paredes (2011) introduced two new metrics for integrating EVA and project risk management methodologies: cost control and schedule control indices. These two indices compare the EVA measures with the maximum values that a project should exhibit if the project was running under the risk analysis hypothesis (as cited in Najafi and Azimi, 2015). Acebes et al. (2013) proposed a graphical framework for EVA to integrate the dimensions of project cost and schedule with risk management (Najafi and Azimi, 2015). Czempik (2014) applies EV management to control construction projects (Najafi and Azimi, 2015). Recently, new studies have been published that deal with other aspects of EV management.

It is important to note that EV management alone does not solve problems, but it helps to identify it before it reaches its full potential. By applying the EVA method on a monthly basis, meeting project goals (on time, on budget) is no longer unimaginable. With proper planning and efficient management tools, project managers are better informed about the state of the project, and can make appropriate project management decisions (Kerby and Counts, 2017).

3.1 S-curve within the EVA method

Using the S-curve, it is possible to show the planned state, the current state and the prognosis of the future state of the project, and it is gladly used to control the cost of the project using the EVA method which compares the progress of the project based on actual costs at the time of observation (Čulo, 2010).

The idea of the earned value is the preparation of the baseline plan to measure the actual progress of the project. The baseline schedule is the budgeted cost of work scheduled (BCWS), that is, S-curve of planned costs in planned time of the project (Figure 3).

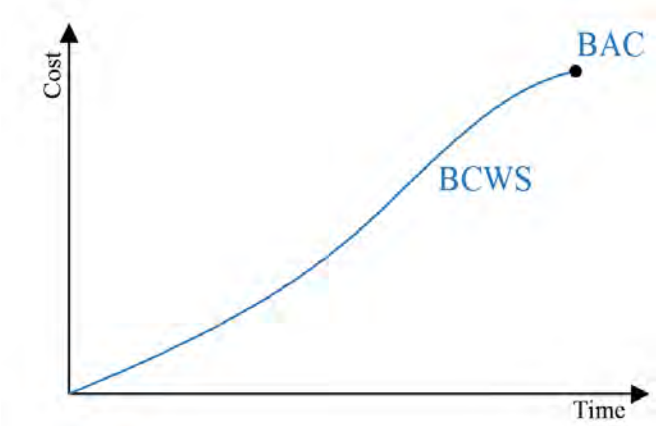


Figure 3. S-curve of planned costs of the project (Anbari, 2003)

The BCWS curve represents the cumulative flow of planned cost of project, that is, approved budget for project completion. BCWS is the baseline cost schedule and serves as a basis for comparison with other types of costs. At the end of execution time, the BCWS value is equal to the total planned cost of the entire project, that is, budget at completion (BAC).

When the project starts, the task of the manager is to regularly monitor the actual progress and costs, so two more S-curves were designed (PMI, 2005, Czarnigowska et al., 2011).

- ACWP – Actual cost of work performed. It represents cumulative actual costs incurred on the project to the point of observation. Based on this curve from a certain point of observation, the costs for the remaining time of the project can be estimated (FCST), and total costs at project completion (EAC) (Figure 4).

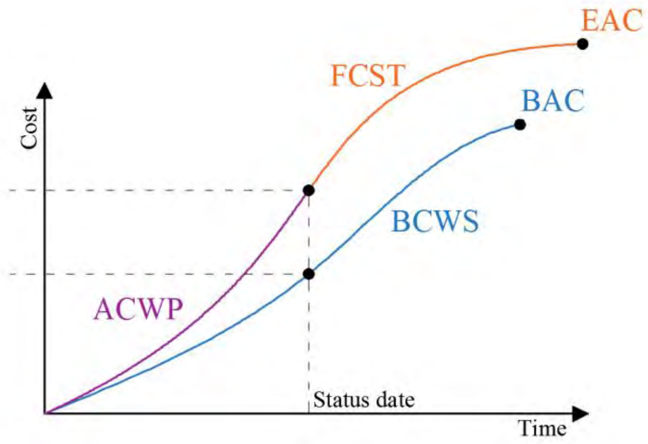


Figure 4. S-curves of planned and actual project costs (Anbari, 2003)

- BCWP – Budgeted cost of work performed. It represents the amount budgeted for performing the work that was accomplished by given point in time (Anbari, 2003). BCWP for a specific task is obtained as a product of the planned cost and percentage of completion of that task.

BCWS, ACWP and BCWP are expressed in units of costs or in hours or days of work. BCWS, ACWP and BCWP can be calculated for any element of the work to determine its progress (Figure 5).

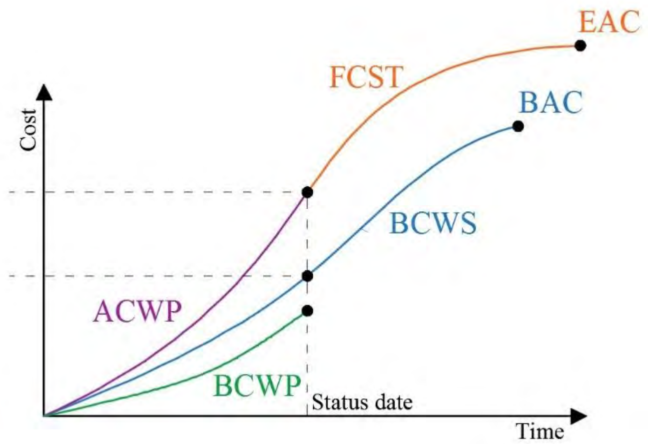


Figure 5. S-curves of EVA method (BCWS, ACWP, BCWP) (Anbari, 2003)

Once the curves for the planned, actual and earned value are generated, the project manager can use them to analyze the current state of the project and forecast what the project will do in the future. Using these three S-curves, the variances and coefficients listed in Table 1 are determined. Based on the variances and the coefficients, it is possible to give an assessment of the current progress and estimation of the future state of the project.

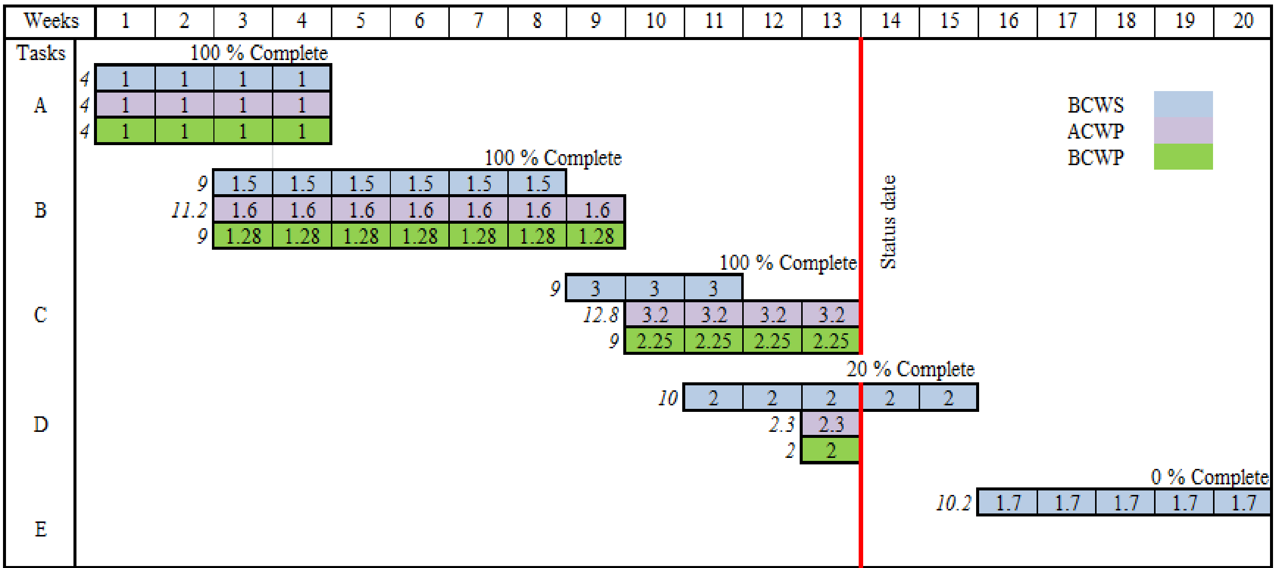
Table 1. Parameters of EVA method (Prasanth, Raja, 2014)

Parameter	**Project Management Questions**	**Formula**	**Interpretation**	
Cost variance (CV)	Is it project under or over budget?	BCWP-ACWP	Positive	Negative
			Project under budger	Project over budget
Schedule variance (SV)	Is it project ahead or behind of schedule?	BCWP-BCWS	Positive	Negative
			Project ahead of schedule	Project behind of schedule
Cost Performace Index (CPI)	Are resources used efficiently?	$\frac{BCWP}{ACWP}$	>1	<1
			Good performance	Poor performance
Schedule Performance Index (SPI)	Is time used efficiently?	$\frac{BCWP}{BCWS}$	>1	<1
			Good performance	Poor performance
Time Estimate At Completion (EACt)	When is work likely to finish?	$\frac{(BAC/SPI)}{(BAC/WEEKS)}$	With the continuation of current trend of performing, the project will end up in the resulting week	
Estimate At Completion (EAC)	What is the project likely to cost?	BAC/CPI	With the continuation of the current trend of performing, the project will cost as the amount earned	
Variance At Completion (VAC)	What project is under or over budget?	BAC-EAC	With the continuation of the current trend of performing, the project will be under or over the budget for the amount earned	
Estimate To Complete (ETC)	What will be the remaining work cost?	(BAC-BCWP)/CPI	With the continuation of the current trend of performing, the rest of the project will cost as the amount earned	

The application of the EVA method is shown in the following example.

The project consists of 5 activities that are planned to last for 20 weeks, and the planned total costs are 40.5 money units. The project is currently at the end of the 13th week and it is decided to check its performance, that is, to check how it progresses in relation to the planned cost and time values. Activity A was performed within the deadline and at planned costs. With activity B there are problems, it lasted a week more than planned, and its actual costs were higher than planned. Activity C due to the previous activity begins later and also lasts for a week longer, as a result of which it has increased costs. Activity D is 2 weeks late and it so far 20% complete. On the day of the project status check it is noticeable that the project greatly overran the planned deadline of completion and budget.

To obtain S-curves of the EVA method, it is necessary to show the flow of three types of costs in the Gantt chart (Figure 6), based on which cumulative cost values are obtained. By using cumulative cost values, the S-curves of EVA method are generated, that is, BCWS, ACWP, BCWP and FCST curves shown in Figure 7. Using these curves, i.e. cumulative cost values, the EVA method parameters are calculated. The FCST curve was obtained by calculating the costs at the end of the project (EAC), and then estimating the cost from the observation point to the EAC.



Weeks	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
BCWS	1	1	2.5	2.5	1.5	1.5	1.5	1.5	3	3	5	2	2	2	2	1.7	1.7	1.7	1.7	1.7
cum.	1	2	4.5	7	8.5	10	11.5	13	16	19	24	26	28	30	32	33.7	35.4	37.1	38.8	40.5
ACWP	1	1	2.6	2.6	1.6	1.6	1.6	1.6	1.6	3.2	3.2	3.2	5.5							
cum.	1	2	4.6	7.2	8.8	10.4	12.0	13.6	15.2	18.4	21.6	24.8	30.3							
BCWP	1	1	2.3	2.3	1.3	1.3	1.3	1.3	1.3	2.3	2.3	2.3	4.3							
cum.	1	2	4.3	6.6	7.8	9.1	10.4	11.7	13.0	15.2	17.5	19.7	24.0							

Figure 6. Gantt chart showing flow of the planned, actual and earned costs in project

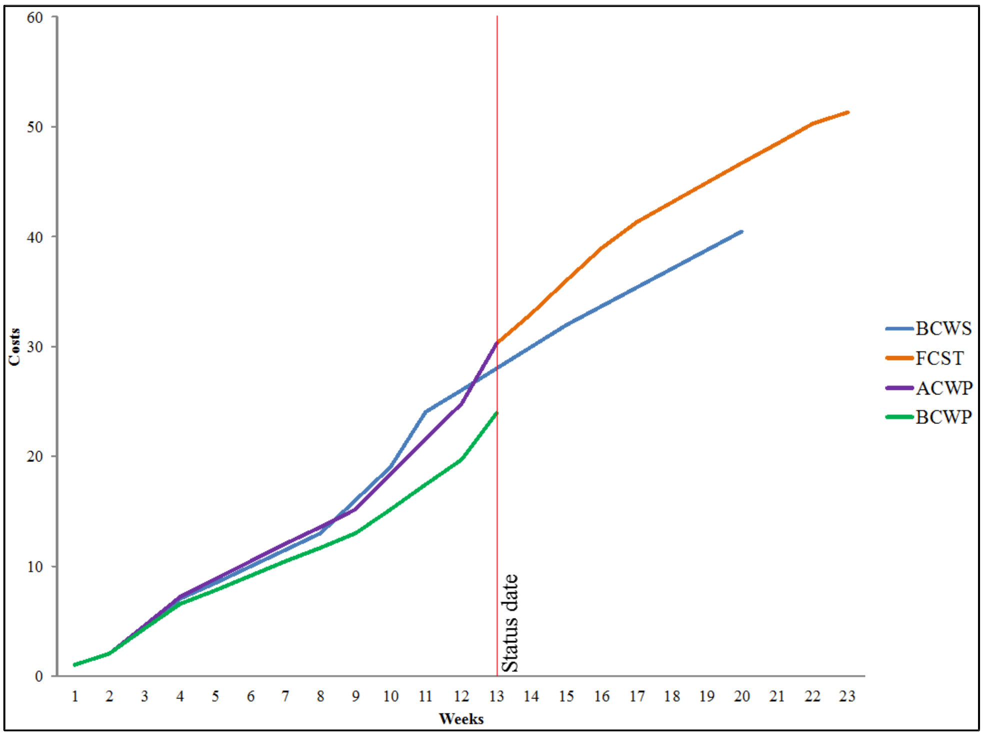


Figure 7. S-curves of EVA method for the example shown

From Figure 7 it is apparent that the curve of earned value is below the curve of the planned value, which indicates that the work was not realized at the planned value. It is also clear that the curve of earned value is below the actual value curve, which indicates that work is being carried out at overpayment costs.

The performance indicators of the project presented in Table 2 are calculated according to the BCWS, ACWP and BCWP flow of costs.

Table 2. Project performance indicators for the example shown

Parameter	Value	Interpretation
Schedule analysis and forecasting		
SV	- 4.0	Behind schedule
SPI	0.86	Behind schedule, poor performance
EACt	23.3	Not on schedule
Cost analysis & forecasting		
CV	-6.3	Over budget
CPI	0.79	Over budget, poor performance
EAC	51.3	Assumption: current performance trends continue
VAC	-10.8	Over budget
ETC	20.9	Assumption: current performance trends continue

Based on these results you can see how much the planned budget will overrun and how much additional funds must be provided to complete the project if no steps are taken to bring the project into the planned costs and planned time frame.

The project has an unfavorable schedule variance of – 4.0 which means that the project is behind schedule. The SPI is 0.86 and it is telling that the project is progressing at 86 % of the rate originally planned. SPI shows the rate at which the project is progressing. The planned

completion time of the project is 20 weeks. Here we found that if work continues at the current rate the project will take 3.3 weeks longer than what was originally planned; as time estimate for completion is now 23.3 weeks. The project has an unfavorable cost variance of -

6.3 that means the project is over budget. The CPI of 0.79 would tell that the project is currently running over budget by 21 %. The EAC shows that the expected project costs at completion are 51.3 money units. Variance at completion shows the variance of the total cost of the work and expected cost. In this case it amounts to - 10.8, that means at this status date the project is over budget by 10.8 money units. ETC shows the expected cost required for finishing all the remaining work, here it is 20.9 and this amount is needed to complete the work.

4. Conclusion

Project execution monitoring through the EVA method provides an effective approach to managing costs and time in construction projects. The calculation of EVA parameters allows examining current and future project costs. With the EVA method, it is possible to monitor and forecast cash flows and point out the overruns of costs that may occur during the project cycle. All deviations are best monitored via graphical S-curves. The S-curve shows the flow of cost in the project duration time. With a graphical view, the curves of planned costs, actual costs and earned value can be compared. Looking at these three curves, the project manager can tell in what state is his project currently. Therefore, this approach provides early warning signs for any deviation from the initial plan and helps the project team determine the strategy of successful completion of the project.

References

Abdul-Rahman, H., Wang, C., Binti Muhammad, N. (2011), "Project performance monitoring methods used in Malaysia and perspectives of introducing EVA as a standard approach", Journal of Civil Engineering and Management, Vol. 17 No. 3, pp. 445-455.

Acebes, F., Pajares, J., Galán, J.P., López-Paredes, A. (2013), "Beyond Earned Value Management: A Graphical Framework for Integrated Cost, Schedule and Risk Monitoring", in Procedia - Social and Behavioral Sciences proceedings of 26th IPMA World Congres, Crete, Greece, 2012, pp. 181-189.

Anbari, F. (2003), "Earned value project management method and extensions", Project Management Journal, Vol. 34 No. 4, pp. 12-23.

Cioffi, D. F. (2005), "A tool for managing projects: an analytic parameterization of the S-curve", International Journal of Project Management, Vol. 23 No. 3, pp. 215-222.

Cioffi, D.F. (2006), "Designing project management: a scientific notation and an improved formalism for earned value calculations", International Journal of Project Management, Vol. 24 No. 2, pp. 136-144.

Czarnigowska, A., Jaskowski, P., Biruk, S. (2011), "Project Performance reporting and Prediction: Extensions of Earned Value Management", International Journal of Business and Management Studies, Vol 3. No. 1, pp. 11-20.

Czemplik, A. (2014), "Application of Earned Value Method to Progress Control of Construction Project", in Procedia Engineering proceedings of XXIII R-S-P seminar, Theoretical Foundation of Civil Engineering (23RSP), pp. 424-428.

Čulo, K. (2010), Ekonomika investicijskih projekata, Sveučilište Josipa Jurja Strossmayera u Osijeku, Gradevinski fakultet, Osijek.

De Marco, A., Narbaev, T. (2013), "Earned value-based performance monitoring of facility construction projects", Journal of Facilities Management, Vol. 11 No. 1, pp. 69-80.

Dissanayake, P.B.G. (2010), "Earned Value Management System as a Project Management Tool for major multi-disciplinary Projects", in International Conference on Sustainable Built Environment proceedings of the international conference in Kandy, Sri Lanka, 2010, pp. 14-19.

Garland, D. (2009), "The Mysterious S-curve", available at: http://www.maxwideman.com/guests/s-curve/progress.htm (accesed 20 April 2017).

Goodman, J. (2010), "Analyzing S-curves", available at: http://www.aacei.org/toc/toc_55r-09.pdf (accessed 18 April 2017).

Katić, D., Duspara, A. (2014), "Metoda ostvarene vrijednosti", available at: http://gf.sve-mo.ba/e-zbornik/e_zbornik_07_06.pdf (accessed 18 April 2017).

Kerby, J.G., Counts, S. M., "The Benefits of Earned Value Management from a Project Manager's Perspective", available at: https://www.nasa.gov/pdf/293270main_63777main_kerby_counts_forum9.pdf (accessed 27 March 2017).

Lipke, W. (1999), "Applying management reserve to software project management", Defense Software Engineering, Vol. 12 No. 3, pp. 17–21.

Lipke, W. (2003), "Schedule is different", available at: http://www.earnedschedule.com/Docs/Schedule%20is%20Different.pdf (accessed 18 April 2017). Lipke, W. (2004), "The probability of success", available at: https://www.researchgate.net/profile/Walt_Lipke/publication/284789097_The_probability_of_success/links/56e983c108ae95bddc29e795.pdf (accessed at 18 April 2017)

Lipke, W., Zwikael, O., Henderson, K., Anbari, F. (2009), "Prediction of project outcome. The application of statistical methods to earned value management and earned schedule performance indexes", International Journal of Project Management, Vol. 27 No. 4, pp. 400–407.

Nai-Chieh, W., Chiao-Ping, B., Shuan-Yuan, Y., Pao-Sheng, W. (2016), "Earned Value Management Views on improving Performance of Engineering Project Management", The International Journal of organizational Innovation, Vol. 8 No. 4, pp. 93-111.

Najafi, A., Azimi, F. (2016), "An extension of the earned value management to improve the accuracy of schedule analysis results", Iranian Journal of Management Studies, Vol. 9 No. 1, pp. 63-75.

Narbaev, T., De Marco, A. (2014), "An Earned Schedule-based regression model to improve cost estimate at completion", International Journal of Project Management, Vol. 32 No. 6, pp. 1007-1018.

Ostojić-Škomrlj, N., Radujković, M. (2012), "Model prognoziranja S-krivulja u ranim fazama gradevinskih projekata", Gradevinar, Vol. 64 No. 8, pp. 647-654.

Prasanth, A., Raja, T. (2014), " Project Performance Evaluation By Earned Value Method", in International Conference on Engineering Technology and Science proceedings of the international conference in Tamilnadu, India, 2014, pp. 73-81.

Project Management Institute (PMI) (2005), Practice Standard for Earned Value Management, Newtown Square, PA.

Project Management Institute (PMI) (2008), A guide to the project management body of knowledge, 4th Edition, Newtown Square, PA.

Radujković, M. et al. (2012), Planiranje i kontrola projekata, Sveučilište u Zagrebu, Gradevinski fakultet, Zagreb.

Sambasivan, M., Soon, Y. W. (2007), " Causes and effects of delays in Malaysian construction industry", International Journal of Project Management, Vol. 25 No. 5, pp. 517-526.

Tijanić. K., Car-Pušić, D., Marović, I. (2016), "Managing cost and time in projects of public-use facilities by using the S-curve", in People, Buildings and Environment 2016 proceedings of the international scientific conference in Luhačovice, Czech Republic, 2016, pp. 185-196.

Turkan, Y. et al. (2013), "Toward Automated Earned Value Tracking Using 3D Imaging Tools", Journal of Construction Engineering and Management, Vol. 139 No. 4, pp. 423-433.

Vandevoorde, S. and Vanhoucke, M. (2005), "A comparison of different project duration forecasting methods using earned value metrics”. International Journal of Project Management, Vol. 24 No.4, pp. 289–302.

Challenges in Implementing Systemic Innovation in Transport Infrastructure Projects

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Abstract:

Innovation and productivity improvements are essential ingredients to reduce lead times, costs and environmental impact and improve value for money in the transport infrastructure sector. Transport infrastructure projects are inter-organizational and innovations are often of systemic nature. Prior research indicates that implementation of systemic innovation is difficult in inter-organizational projects. The purpose of this study is therefore to identify differences between prospective opportunities (given by the client) and challenges (perceived by the contractor) that affect the implementation of systemic innovations in infrastructure projects. A multiple case-study of six infrastructure projects, which the Swedish Transport Administration has classified (ex ante) as innovation friendly, have been conducted. The selected projects may be viewed as favorable critical cases; if innovations are not successfully implemented in projects that have been classified as innovation friendly, innovation implementation will be even more difficult to manage in other types of projects. The empirical data is collected through semi-structured interviews with relevant stakeholders from both the client and contractor in the project organizations. Tentative findings reveal multiple implementation challenges throughout the projects. Challenges are often related to the fact that even small innovations become systemic and therefore affect multiple stakeholders. Moreover, it is evident that client and contractors often have different views on these challenges and to what extent the clients' procurement strategies and project management practices have given opportunities for innovation. The findings extend current knowledge of managing innovation within the public transport infrastructure sector.

Keywords: *Innovation management; Construction innovation; Procurement strategies; Project management.*

1. Introduction

Like those in other industries, firms in the construction industry are exposed to increasing competition and customer demands, and hence must be innovative in order to improve productivity and competitive advantage (Winch, 2003; Panuwatwanich et al., 2009). This could be highly significant because many governmental reports and research publications highlight that low productivity is a problem facing the construction industry in many countries, including Great Britain and the US (e.g. Egan 1998; Teichholz et al., 2001). In Sweden there is also an urgent need to raise productivity and client satisfaction in the construction industry (including

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both building and infrastructure sector), which has triggered a number of government investigations (SOU, 2002; 2012).

Measures to increase the productivity of the transport infrastructure sector are particularly important from a societal perspective, since significant amounts of public funds are invested in a sector that is crucial for national development and economic growth (Caerteling et al., 2011). Previous research has found that productivity is a key challenge in this sector, and that many transport infrastructure projects suffer from cost and schedule overruns (Flyvbjerg et al. 2004; Cantarelli et al., 2012). However, introducing extensive innovations, which could lead to increased productivity over time, has been particularly difficult in the transport infrastructure sector. Frequently mentioned reasons for this include the industry's project-based, engineer-to-order, fragmented and strongly institutionalized characteristics (e.g. Kadefors, 1995; Fairclough, 2002). Due to the highlighted characteristics of the industry, the most common innovations in construction are incremental and arise to solve problems within construction projects (Winch, 1998; Taylor and Levitt, 2004). These incremental innovations seldom leads to systemic changes but remains project-specific.

Innovations in the project-based transport infrastructure sector are always implemented within inter-organizational transport infrastructure projects rather than, as in more traditional manufacturing industries, within the organizations developing the innovations (Winch, 1998). This has profound consequences for the implementation of (especially) systemic innovations (Colvin et al., 2014) since not only the developing company is affected, but rather a number of stakeholders throughout the supply chain. Innovations may be developed inside or outside a transport infrastructure project by stakeholders, such as contractors or suppliers, but the public client must, as a "system integrator", initiate and manage any subsequent implementation (Segerstedt and Olofsson, 2010). The strong influence of the client with its accompanying norms, regulations and procurement strategies have previously been stressed as barriers hampering the implementation of systemic innovations (Larsson et al., 2014). Thus, owing to the inter-organizational and project-based nature of the transport infrastructure sector, the procurement strategies of the client have the ability to strongly affect the rate of systemic innovations.

The importance of the client has been recognized by the Swedish Transport Administration (STA). STA is the major public client of transport infrastructure in Sweden and consequently the influence of their procedures cannot be ignored. STA has recognized the need to increase rates of innovation, both by initiating an innovation program and by increasing the rate of design-build (DB) contracts, to resolve the issue of low productivity. In prior research, DB contracts and early contractor involvement have been suggested to increase the opportunities for contractors to innovate (Eriksson et al., 2014) and improve cost and/or time performance (Hale et al., 2009; Song et al., 2009; Shrestha et al., 2012). However, recent studies pinpoint that the extent of specification in the contracts, the reward system, and other aspects related to the client's procurement strategies also affect the contractors' possibilities and incentives for innovation (Ahola et al., 2008; Eriksson, 2017).

Due to the inter-organizational nature of transport infrastructure projects and systemic innovations, it is critical to increase the knowledge of how the client's procurement strategies affect the contractors' perceived opportunities and incentives for innovation. The purpose of this study is therefore to identify differences between prospective opportunities (given by the client) and challenges (perceived by the contractor), affecting the implementation of systemic innovations in transport infrastructure projects. The empirical data is acquired from a multiple case study of six public transport infrastructure projects. The findings from the multiple case study extend current knowledge of the management of systemic innovations within the public transport infrastructure sector.

2. Systemic innovation in transport infrastructure projects

Organizations in the project-based transport infrastructure sector are often fluidly structured to deliver unique and complex solutions for their clients in specific business projects (Gann and Salter, 2000). Transport infrastructure projects, as business projects in the transport infrastructure sector, usually offer unique solutions to each client in an arrangement bounded by contractual agreements (Keegan and Turner, 2002). The client normally initiates projects, defines their specifications, provides financial resources, and benefits from the end delivery (Keegan and Turner, 2002). Owing to the project-based setting, innovative approaches and performance aimed at the successful execution – in terms of budget, schedule, quality, and (hence) short-term efficiency – of individual transport infrastructure projects, have been emphasized in construction management literature (Winch, 1998; Egan, 1998). Therefore, innovation implementation usually occurs during daily design and production in individual business projects. There is however another possibility for achieving innovations where stakeholders develop the innovations in separated development projects followed by implementation in business projects (Blindenbach-Driessen and Van Den Ende, 2006). Stakeholders throughout the supply-chain (e.g. contractors, consultants and material suppliers) therefore handle two distinct types of projects: business projects and development projects. Thus, innovation may arise via either of two paths: via problem-solving in business projects or through development projects in firms followed by implementation in inter-organizational business projects (Winch, 1998; Eriksson, 2013). Furthermore, due to the inter-organizational nature of business projects most innovations, whether they are small or large, affect multiple stakeholders throughout the supply-chain and hence become systemic.

Successful realization of systemic innovations often require coordinated changes by multiple stakeholders throughout the supply-chain (Taylor and Levitt, 2004; Kähkönen, 2015). The new knowledge needed for these systemic innovations often needs inter-organizational knowledge, hence the approach to innovation must become more open. However, a more systemic approach to innovation, which requires collaborative approaches, has scarcely been reported in construction management to date. Control focused project management practices based on planning and control have instead been emphasized as important aspects of business projects to minimize deviations from the pre-determined goals (Crawford and Pollack, 2004; Geraldi, 2009; Karrbom Gustavsson and Hallin, 2014). Most prior studies on construction management therefore promote control focused project management practices to facilitate efforts to minimize change and promote satisfactory performance of individual projects (Dvir and Lechler, 2004; Menches et al., 2008; Giezen, 2012). Furthermore, project managers are generally reluctant to develop innovations within business projects and, if developed, the success of such innovations is limited by the project control systems (Keegan and Turner, 2002). These procedures based on extensive planning and control especially affect the implementation of systemic innovations since they require changes throughout the supply-chain, regardless of the origin of the innovations.

The early stages of development in business projects involve high levels of uncertainty among stakeholders (Widén et al., 2013), which are gradually replaced by knowledge acquired through various activities. At the end of the development (if successful), the solution can be implemented into its intended context. These processes pose fundamental challenges to project management, and managers (who oversee this development) must maintain sufficient perspective to handle the constant shifts in knowledge, aims, and other issues associated with the project. An understanding of the intricate and dynamic phase of implementation is essential for the introduction of new products, services or processes, but innovation implementation is a difficult and uncertain task. The major steps in the implementation phase of business projects are: providing suitable resources, supplying tenders and planning inputs, and gaining experience and widespread acceptance (Tatum, 1987). Stakeholders play a vital role in implementation of systemic innovations and those who are overlooked will be disengaged and unable to contribute to success (Widén et al., 2013). In fact, the absence of stakeholders in early key decisions/gates could have a devastating effect on the process. The client that manage the process must therefore act as an integrator (rather than as a delegate for stakeholders) who engages stakeholders at the right time and maintains their motivation and focus. These aspects are highly dependent on the client's procurement strategies that affect key stakeholders' opportunities and incentives for innovation (Ahola et al., 2008). Eriksson (2017) argue that the delivery system affect the opportunities for innovation by deciding both the timing and degree of involvement in development work. Furthermore, the reward system and the partner selection procedure affect the contractor's incentives to innovate (Eriksson, 2017). The last component of any procurement strategy, i.e. the collaboration model, affects both opportunities and incentives, especially for systemic innovation where inter-organizational collaboration is critical (Eriksson, 2015).

3. Method

Case studies are beneficial in fields that are still in an exploratory stage, since they can provide rich data, give insights into complex behaviour, and identify new aspects and phenomena (Yin, 2013). Thus, a multiple case study approach seemed the most suitable for the study of challenges for implementing systemic innovation in public transport infrastructure projects.

3.1 Sample

The empirical data used in this study concern six public transport infrastructure projects, with some differences in characteristics and procurement strategies. However, similarities are that all six projects are managed by Swedish Transport Administration (STA) and are rated (ex ante) by the client as innovation friendly. Criteria for selecting cases were therefore based mainly on *critical cases* to achieve data that permits logical conclusions, but to some extent also *maximum variation cases* to be able to detect similarities and differences between projects with different characteristics (Flyvbjerg, 2006). STA provided a list that contained projects that they has rated as innovation friendly. This classification was based on that the client had taken sufficient proactive action (e.g. early market dialogue, external review of tender documents, tender documents based on functional requirements) to promote development and innovations in each project. Table 1 summarizes information about the studied transport infrastructure projects and their respective focus for the identified components in the procurement strategy.

Table 1 Information about the studied transport infrastructure projects

Proj.	Description	Delivery system	Reward system	Bid Invitation	Bid Evaluation	Collaboration model
1	New railway bridge	DB	Fixed price	Open	Lowest price	Basic
2	New and reconstruction of a highway	DB	Fixed price	Open	Lowest price	Basic
3	Strengthening of existing road	DB	Fixed price	Open	Lowest price	Basic
4	Maintenance of existing road	DB	Fixed price with incentives	Open	Lowest price	Medium
5	New railway and road	ECI	Target cost	Selective	Multiple criteria	High
6	New and reconstruction of a highway	ECI	Target cost with incentives	Open	Multiple criteria	Medium

3.2 Data collection

Data for the study were gathered through multiple methods (interviews and secondary data collection). However, most information was collected through semi-structured interviews with respondents playing key roles such as project manager (PM) in each project (Table 2). The interviews were conducted to obtain rich insights regarding procurement related opportunities and challenges for implementing innovations.

Table 3 Roles of interviewees in each of the projects and length (in minutes) of each interview

Project	No.	Respondent	Length
Project 1	1	PM client	63
	2	PM contractor	42
Project 2	3	Procurer client	40
	4	PM client	32
	5	PM contractor	40
Project 3	6	Procurer client	22
	7	PM client	32
	8	PM contractor	51
Project 4	9	Procurer client	31
	10	PM client	38
	11	PM contractor	61
Project 5	12	Procurer client	36
	13	PM client	38
	14	PM contractor	27
Project 6	15	Procurer client	55
	16	PM client	59
	17	PM contractor	38

An interview guide was developed and used to maintain coherence in the data collection and also to facilitate the following analysis. The interview guide (in addition to items regarding background information) included themes such as innovation rate, specific implemented innovations, and perceived barriers, opportunities and drivers for innovation. Departure from the questions included in the interview guide was permitted, to pursue interesting and particularly relevant insights that emerged during interviews. All interviews were audio-recorded and transcribed to enable investigator triangulation (Patton, 2002). Secondary data about the projects was obtained from internal project documents and from publicly available sources. The multiple source approach enabled data triangulation, which helps strengthen the construct validity of case studies (Patton, 2002).

3.3 Analytical procedure

The analysis follows the steps for qualitative research proposed by Miles & Huberman (1994): data reduction, data display, and conclusion drawing and verification. In the data reduction step, interview responses were first summarized and transferred into a database to focus and organize the data. This was followed by a thematic analysis where the empirical data were coded into categories, based on opportunities and challenges related to innovation, to make the data more manageable and meaningful. The coded data were then displayed in a table to facilitate interpretation. During the data analysis, iterations between emerging results, theory, and empirical data related to the projects were performed to consolidate the developing conclusions (Yin, 2013).

4. Findings

4.1 Project 1

Project 1 involves construction of a new railway bridge located in a very challenging terrain requiring adaptation of traditional production methods. The most challenging task is not the actual construction of the bridge but the logistical task of transporting building materials to the site. The difficult site conditions led the client to invite each potential bidder to a guided site visit. The project also encompasses a rather tight time schedule since the bridge is to be opened for traffic before a certain large sport event. Due to this issue, the procurement have run parallel to the process of establishing the required plan of the project scope, which contains information about where the road/railway is to be built in terms of a road corridor with fixed height and width. The usual procedure is to have this scope plan approved before the procurement of the contractor since this simplifies the process of establishing certain requirements and demands in procurement documents.

The client was of the general opinion that they had created significant opportunities for the contractor to innovate. First, even though the position of the rails are fixed, all other requirements of the structures beneath the rails are based on functionality, which should increase the freedom for the contractor to select suitable types of structures and construction processes. The other action that is conducted to facilitate for innovation is that the project has been provided with a larger terrestrial access around the site than what is traditionally provided. This should, according to the client, increase the possibility to use more innovative logistical solutions for the contractor during construction. The positive view of opportunities for innovation is not shared by the contractor in any of the above aspects. The contractor instead means that their entrance point in the project should have been in an earlier stage to enhance their opportunities for innovation. The PM of the contractor meant that when they got involved in the project: *"everything was already decided except quantities"*. Further, the contractor meant that the client's reason for using DB instead of DBB contract is to put more responsibility on the contractor since the project involves an extensive amount of complexity linked to the extreme site conditions.

4.2 Project 2

Project 2 is one part of a larger megaproject that aims to renovate and increase the capacity of one of the large highway routes in Sweden. The studied subproject is a traditional road project that contains widening the road and building four new bridges. The corridor for the road was fixed before the contractor entered the project and least possible land area needed for constructing the road was provided.

The client's procurement manager stated that "*this is a genuine DB contract that gives the contractor large degrees of freedom and opportunities to choose other solutions*". The aim of choosing a DB contract was to facilitate innovative thinking in early stages. However, the procurement manager also pinpointed the importance of promoting innovation after the contractor had been procured and that this depends on personal interests of project participants. Whereas the client believe that most of the procurement documents involved functional requirements, the contractor argued that the degrees of freedom were slim, not least regarding the bridges. The PM of the contractor said: *"This project is very controlled and constricted; there are so many specified technical solutions, which describe how things should be"*. This difference in perception was highlighted already at the start-up meeting when the contractor emphasized that the client had exceptionally many technical requirements in the specifications. Not only the procurement documents were perceived as a limitation for innovation, but also the tight time schedule and the narrow road corridor contribute to low degree of innovation.

4.3 Project 3

Project 3 involves reconstruction and strengthening of an existing road with rather low traffic load. This project is characterized by the client as rather standardized but the contract includes incentives for the contractor to both maintain high quality of the temporary gravel road as well as conducting the project in an efficient manner, contributing to an earlier opening of the reconstructed road.

The client has tried to define functional requirements instead of technical solutions but in reality the procurement documents contained a mix of both. Some of the expressed technical solutions are due to safety issues of both workers and road users during the time of construction. A suggestion from the client regarding production planning that could lead to increased quality of the end product is also included in the procurement documents. In this project the client's PM however realizes that the opportunity for innovations are limited mainly to production processes and the choice of material in the coating. This is also confirmed by the contractor that express the lack of freedom due to fixed road corridor and "too" high demands on certain quality aspects. The client further point out that by using a DB contract the warranty is ten years which increased the risk for the contractor. The contractor confirms this by saying that the demand and risk that are transferred from the client to the contractor in a DB contract lead to less tendency of testing innovations. The communication and collaboration between stakeholders during the detailed design stage has however been positive, which is emphasized by both client and contractor, meaning that many issues have been easily solved. This positive climate is according to the contractor due to the choice of DB contract where they are given a certain amount of opportunity to discuss and implement their production experience better than in a DBB contract.

4.4 Project 4

Project 4 includes a road maintenance contract that extends over 15 years. The agreement contains coating work and road marking of a specific highway section. This is a DB contract with functional responsibility for the contractor. The functional responsibility means that the client demand a certain quality of the road but the contractor can decide when, what and how the required actions to maintain the quality are to be performed. The client has included a penalty into the contract to ensure that the contractor delivers the requested quality of the product.

Both stakeholders were rather satisfied with how the procurement strategy works and especially the contractor was satisfied with the long-term contract since that gives opportunities and incentives to increase the rate of innovations and efficiency. The contract invites the contractor to choose from a variety of production methods, types of asphalt, when the actions are to be conducted, etc. The client's PM believes that this freedom contributes to innovation: *"I think we've opened up very well for innovation"*. This is the first time the client has procured road maintenance by functionality and the client's PM points out that there exists an internal uncertainty about this approach: *"It is with some internal concern and uncertainty, how dare you do it and how will it go?"* Those who are skeptical means that the contractor will do minimum actions to maintain the required quality, especially in the end of the contract: *"They will not do more than what is required. The last few years, they will probably not do anything at all"* (the client's PM). However, the contractor points out that the long-term contract allows them to invest in innovation and efficiency improvements in terms of machinery and equipment. However, the contractor stresses that it is a lack of incentives for the contractor to deliver a better solution than what is required, and that such incentives would promote even more innovations.

4.5 Project 5

Project 5 is one part of a larger megaproject that involves upgrading of the railway network in a metropolitan region. This subproject contains new construction of railway, road and several bridges. The complexity is rather high since the construction has to be integrated into the current transport infrastructure network that comprises several of the busiest roads and railway connections in Sweden. The high complexity lead the client to choose an early contractor involvement (ECI) approach with two stages, where the aim is to utilize the contractor's production knowledge in the early design stage. The first stage contains an 18 months period where the client, the contractor, and two different consultant firms are located together in a joint project office to design technical solutions, plan the construction work, and generate a target cost for the subsequent production. In the first stage, the contractor and consultants are engaged through a consultancy contract. After this target cost has been agreed and approved by the client, the actors enter the second stage, which contains production based on a DB contract.

The client has, due to the complexity and uncertainty in early stages, put emphasis on a high degree of cooperation and quality during the bid evaluation. Hence, the traditional focus on lowest price has been of less importance when selecting the contractor before the first ECI-stage. However, despite the ECI-approach, the railway and road corridors were fixed before the contractor entered the project, which arguably puts limits on the degrees of freedom and possibilities for innovation. Nevertheless, the contractor describes that high degree of cooperation and the joint project office facilitates innovation since a large amount of knowledge and experience is collected under the same roof in an effort to achieve a joint goal in the best way. High degree of cooperation and the work with many parallel project processes also cause some difficulties. Since the stakeholders have different organizational goals and internal processes, the contractor emphasizes that it has been a struggle to get everyone into the same boat. The parallel processes conducted during the early stages increase the intertwining between certain tasks, sometimes leading to long waiting times. However, both the client and the contractor emphasize that this type of complex project would have been difficult to accomplish with a more traditional contract. The contractor's PM pinpoints that *"Looking at the complexity of what we are going to construct, I find it hard to see a different arrangement or another type of delivery system for this project…"*.

4.6 Project 6

Project 6 is another subproject within the abovementioned megaproject that aims to renovate and increase the capacity of one of the large highway routes in Sweden. The client conducted an early market dialogue with the aim to increase the interest for the project. This aim succeeded according to the contractor that won the contract. The contractor highlighted that this market dialogue triggers the organization to start discussing the project internally. The project is based on a two stage ECI-approach. The first stage contains a design and planning stage where the stakeholders together develop the scope plan in terms of the road corridor and subsequently design technical solutions and plan the construction work. During this stage the contractor also generates a target cost for the project which will then be discussed and approved by the client before the project enters the second stage, containing the construction work.

This ECI contract was procured in a very early stage when even the road corridor was still not fixed. Such an early procurement is unique for STA and thus this is considered a pilot project. The contractor that won the contract was involved in the deciding road corridors that suited efficient production. The involvement of the contractor in early stages is expressed by both stakeholders as a contributing factor for high rate of innovation. The client's PM states that *"When the contractor is involved in the design, they can take care of constructability issues and consider where it is good or bad to construct the road when choosing corridor. In this way, we are confident that we will have a better road to a more optimal price and a faster (construction) process. We avoid trouble when we start building"*. This is also confirmed by the contractor's PM: *"In this project we work together and decide on solutions together, the contractor participates and influences constructability"*. The difficulty for the contractor has been to perform calculations and produce an accurate tender since the procurement documents mostly consist of functional requirements. This is the first ECI contract managed by STA that is procured before the road corridor is fixed. Both the contractor and client stress the importance that the process will become even better if this pilot project is followed by others, since the approach demands a new mindset for both stakeholders. Collaboration between stakeholders in early stages has therefore been necessary and both stress the importance of joint goals and team spirit. The contractor's PM expresses that this is a really good opportunity and that *"STA has completely opened for novel solutions, because we do this together, nothing is fixed, there is total freedom, it is the dream for us"*.

5. Discussion

The discussion is divided into two separate parts where the six studied transport infrastructure project are divided into two groups based upon their procurement strategy. This separation allow a comparison of opportunities and perceived challenges between procurement strategies and other project procedures. The first group of projects (projects 1-3) consists of design-build (DB) projects with conventional procurement strategies that are based more on competition, whereas the second group of projects (projects 4-6) have procurement strategies focusing more on collaboration , either through early contractor involvement (ECI) or long-term contracts.

5.1 Competitive procurement strategies based on design-build contracts

The case study shows that the procurement strategies in these projects focus more on competition than on collaboration to achieve satisfactory project outcomes. The applied project management approach severely hamper intended innovative purposes in several ways. First, all these projects have a clear cost focus where the reward system is based on a fixed price and the contractors are procured entirely based on lowest price. This conventional competitive tendering approach has been found to hinder innovation in DB contracts (Ahola et al., 2008; Eriksson, 2017). Further, to secure a certain level of quality and minimize the risk of cost overruns the specifications and tendering documents comprise many technical solutions. Hence, the needed freedom for the contractors to choose other solutions and achieve innovations is lacking. These practices based on monitoring, extensive planning, and constraints are typically found within the control focused project management paradigm, which is the most common in construction (Karrbom Gustavsson and Hallin, 2014). The control based project management paradigm is most efficient when projects are rather simple and straight forward, making it possible to calculate costs, reduce uncertainty, and execute projects according to plans and pre-determined goals, while it is less suitable for complex and uncertain projects requiring collaboration and innovation (Crawford and Pollack, 2004; Geraldi, 2009; Karrbom Gustavsson and Hallin, 2014).

Findings reveal that all contractors agree that the late entering point and the lack of early joint development and problem solving pose a challenge for realizing systemic innovations. Hence, the vital sense of solidarity to do their utmost in the project is missing. This issue has been found to hinder innovation since disregarded stakeholders often becomes disengaged and unable to contribute to success (Widén et al., 2013). The empirical findings also show that more conflicts arise within this group of projects and that these are more difficult to solve due to the rather competitive climate and low degree of collaboration, which is created by the applied management practices and procurement strategy.

It was evident that the clients and contractors within this group of projects had different or even opposing views of the opportunities for and challenges of innovation. The clients seem to put a lot of hope and anticipation that the DB contract in itself will provide contractors with opportunities for innovation. Indeed, the aim of using DB contracts instead of DBB contracts is to improve efficiency and innovation. The contractors are of a different opinion. Since the contractors are involved when most important design parameters are already decided and fixed, the project becomes control focused and competition between stakeholders is evident for all projects in this group. Hence, the contractors perceive that everything is controlled and constrained by the client from the start, which complicates the implementation of systemic innovations. Accordingly, it seems that the clients are not aware of that they have adopted a control focused project management approach that hamper innovation.

5.2 Collaborative procurement strategies based on ECI or long-term contracts

The case study shows that the procurement strategies in these projects focus more on collaboration to achieve satisfactory project outcomes. ECI and long-term contracts spanning several years (15 years in Project 4) are important strategies to make the duration of collaboration longer, which is especially important in projects facing high complexity and uncertainty (Eriksson, 2015). Collaboration and knowledge integration among key stakeholders are critical aspects for managing complexity and uncertainty through flexibility and adaptation. These elements are central in the flexibility focused project management paradigm, which focuses on facilitating learning, innovation and development by embracing and dealing with complexity and uncertainty rather than reducing and controlling them (Crawford and Pollack, 2004; Geraldi, 2009; Karrbom Gustavsson and Hallin, 2014). Accordingly, the procurement strategies adopted in these projects seem appropriate to facilitate collaboration and adaptation in these complex projects with long durations.

The early joint development and problem solving by key stakeholders are stressed in all three projects as an important component to create a foundation for an innovative climate. These proactive discussions are most effective when important design parameters are not yet fixed and when the client is willing to listen to the contractor and change already established parameters to increase the innovation space. The motivation and collaborative climate are found to be better in all projects in this group. These project procedures integrate vital construction knowledge into early design decisions, which have long been recognized as important for achieving satisfactory performance in construction projects (Song et al., 2009).

It was evident that the client and contractors within this group of projects had similar views and anticipations of the opportunities and challenges for innovation. Both clients and contractors were very optimistic about their projects and all interviewees highlighted that the procurement strategies had set the stage for collaborative development efforts and joint problem solving. Because the systemic innovations that are common in this empirical context require inter-organizational collaboration and knowledge integration (Taylor and Levitt, 2004; Kähkönen, 2015), it seems that the flexibility focused project management approach adopted within these projects is suitable and that the stakeholders' common and positive opinion about the approach taken is justified.

6. Conclusions

The comparison of clients' and contractors' opinions about the opportunities and incentives for innovation in the six studied projects resulted in several interesting and relevant findings and contributions. First, we contribute to the procurement literature within the construction management field by highlighting the importance of choosing a suitable delivery system for the project at hand. Although some studies have found that DB contracts enhance project performance (Hale et al., 2009; Shrestha et al., 2012), we argue that that the choice of delivery system is not foremost about the type of contract. Instead, our findings suggest that the timing of contractor involvement, the length of the contract, and the extent of specification in the contract, have a stronger effect on contractors' performances in general and their possibilities and incentives for innovation in particular.

Second, we contribute to the project management literature by discussing how clients' procurement strategies are related to the two main project management paradigms, based on either control or flexibility. Our findings indicate that clients in the Swedish transport infrastructure sector believe that DB contracts procured by competitive tendering strategies provide contractors with opportunities for innovation. These clients do not seem to be aware of that such procurement strategies are related to a control focused project management paradigm that hampers innovation. Accordingly, to adopt a flexibility focused project management approach is not mainly about the type of contract (DB or DBB); it requires a more collaborative procurement strategy based on early contractor involvement and/or long-term contracts with less restricted specifications.

Third, we contribute to the construction innovation literature by discussing how systemic innovations can be enhanced in the transport infrastructure sector by adopting a flexibility focused project management approach based on collaborative procurement procedures. Prior research have found that systemic innovations require collaboration and knowledge integration among key stakeholders with different knowledge sets (Taylor and Levitt, 2004; Kähkönen, 2015). Hence, it is important to highlight that DB contracts procured through traditional competitive tendering procedures are not a strong basis for systemic innovations. Instead, our findings indicate that a flexibility focused project management approach based on early contractor involvement and/or long-term contracts may enhance contractors' opportunities to participate in innovative work and joint development efforts.

This multiple case study has some limitations that may spur further research on this topic. The sample is limited to six Swedish infrastructure projects procured by one public client. It would therefore be interesting to conduct a similar study in other empirical contexts, involving other construction and engineering sectors (e.g. housing and commercial buildings), both private and public clients, and projects in other countries. Furthermore, due to the small sample our findings are indicative and testable, rather than verified and valid. Hence, it would be relevant to make a large-scale quantitative study to investigate how different procurement strategies (competitive vs collaborative) and project management approaches (control focused vs flexibility focused) affect innovation and project performance in a large sample of projects with different characteristics.

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References

Winch, G. M. (2003), "How innovative is construction? Comparing aggregated data on construction innovation and other sectors–a case of apples and pears", Construction Management and Economics, Vol. 21 No. 6, pp. 651-654.

Panuwatwanich, K., Stewart, R.A. and Mohamed, S. (2009), "Validation of an Empirical Model for Innovation Diffusion in Australian Design Firms", Construction Innovation, Vol. 9 No. 4, pp. 449-467.

Egan, J. (1998), Rethinking Construction (the Egan Report), London: Department of the Environment.

Teicholz, P., Goodrum, P. M. and Haas, C. T. (2001), "US construction labor productivity trends, 1970-1998", Journal of Construction Engineering and Management, Vol. 127 No. 5, pp. 427-429.

SOU 2002:115. (2002), Skärpning Gubbar! Om Kunkurrensen, Kvaliteten, Kostnaderna och Kompetensen i Byggsektorn, (In Swedish), Stockholm: Byggkommissionen.

SOU 2012:39. (2012), Vägar till Förbättrad Produktivitet och Innovationsgrad i Anläggningsbranschen, (In Swedish), Stockholm: Produktivitetskommittén.

Caerteling, J.S., Di Benedetto, C.A., Dorée, A.G., Halman, J.I. and Song, M. (2011), "RETRACTED: Technology Development Projects in Road Infrastructure: The Relevance of Government Championing Behavior. Technovation", Vol. 31 No. 5-6, pp. 270-283.

Flyvbjerg, B., Skamris Holm, M.K. and Buhl, S.L. (2004), "What Causes Cost Overrun in Transport Infrastructure Projects?", Transport Reviews, Vol. 24 No. 1, pp. 3-18.

Cantarelli, C.C., Molin, E.J., Van Wee, B. and Flyvbjerg, B. (2012), "Characteristics of Cost Overruns for Dutch Transport Infrastructure Projects and the Importance of the Decision to Build and Project Phases", Transport Policy, Vol. 22, pp. 49-56.

Kadefors, A. (1995), "Institutions in building projects: implications for flexibility and change", Scandinavian Journal of Management, Vol. 11 No. 4, pp. 395-408.

Fairclough, J. (2002), Rethinking Construction Innovation and Research: A Review of Government R&D Policies and Practices, Department for Transport and Local Government Regions (DTLR), London.

Winch, G.M. (1998), "Zephyrs of Creative Destruction: Understanding the Management of Innovation in Construction", Building Research & Information, Vol. 26 No. 5, pp. 268-279.

Taylor, J., and Levitt, R. (2004), "Understanding and Managing Systemic Innovation in Project-Based Industries", Innovations: Project Management Research, pp. 83-99.

Colvin, J., Blackmore, C., Chimbuya, S., Collins, K., Dent, M., Goss, J., ... and Seddaiu, G. (2014), "In search of systemic innovation for sustainable development: A design praxis emerging from a decade of social learning inquiry", Research Policy, Vol. 43 No. 4, pp. 760-771.

Segerstedt, A. and Olofsson, T. (2010), "Supply Chains in the Construction Industry", Supply Chain Management: An International Journal, Vol. 15 No. 5, pp. 347-353.

Larsson, J., Eriksson, P.E., Olofsson, T. and Simonsson, P. (2014), "Industrialized Construction in the Swedish Infrastructure Sector: Core Elements and Barriers", Construction Management and Economics, Vol. 32 No. 1-2, pp. 83-96.

Eriksson, P. E., Olander, S., Szentes, H. and Widén, K. (2014), "Managing Short-term Efficiency and Long-term Development through Industrialized Construction", Construction Management and Economics, Vol. 32 No. 1-2, pp. 97-108.

Hale, D., Shrestha, P., Gibson, E. and Migliaccio, G. (2009), "Empirical Comparison of Design/Build and Design/Bid/Build Project Delivery Methods", Journal of Construction Engineering and Management, Vol. 135 No. 7, pp. 579-87.

Song, L., Mohamed, Y. and AbouRizk, S. M. (2009), "Early contractor involvement in design and its impact on construction schedule performance", Journal of Management in Engineering, Vol. 25 No. 1, pp. 12-20.

Shrestha, P., O'Connor, J. and Gibson, E. (2012), "Performance Comparison of Large Design-Build and Design-Bid-Build Highway Projects", Journal of Construction Engineering and Management, Vol. 138 No. 1, pp. 1-13.

Ahola, T., Laitinen, E., Kujala, J. and Wikström, K. (2008), "Purchasing Strategies and Value Creation in Industrial Turnkey Projects", International Journal of Project Management, Vol. 26 No. 1, pp. 87-94.

Eriksson, P. E. (2017), "Procurement strategies for enhancing exploration and exploitation in construction projects", Journal of Financial Management of Property and Construction, Vol. 22 No. 2.

Eriksson, P. E. (2015), "Partnering in Engineering Projects: Four Dimensions of Supply Chain Integration", Journal of Purchasing & Supply Management, Vol. 21 No. 1, pp. 38-50.

Gann, D.M. and Salter, A.J. (2000), "Innovation in Project-Based, Service-Enhanced Firms: The Construction of Complex Products and Systems", Research Policy, Vol. 29 No. 7, pp. 955-972.

Keegan, A. and Turner, J.R. (2002), "The Management of Innovation in Project-Based Firms", Long Range Planning, Vol. 35 No. 4, pp. 367-388.

Blindenbach-Driessen, F. and Van Den Ende, J. (2006) "Innovation in Project-Based Firms: The Context Dependency of Success Factors", Research Policy, Vol. 35 No. 4, pp. 545-561.

Eriksson, P. E. (2013), “Exploration and Exploitation in Project-Based Organizations: Development and Diffusion of Knowledge at Different Organizational Levels in Construction Companies”, International Journal of Project Management, Vol. 31 No. 3, pp. 333-41.

Kähkönen, K. (2015), “Role and Nature of Systemic Innovations in Construction and Real Estate Sector”, Construction Innovation, Vol. 15 No. 2, pp. 130-33.

Crawford, L. and Pollack, J. (2004), “Hard and Soft Projects: A Framework for Analysis”, International Journal of Project Management, Vol. 22 No. 8, pp. 645-53.

Geraldi, J. (2009), “Reconciling Order and Chaos in Multi-Project Firms”, International Journal of Managing Projects in Business, Vol. 2 No. 1, pp. 149-58.

Karrbom Gustavsson, T. and Hallin, A. (2014), “Rethinking Dichotomization: A Critical Perspective on the Use of “Hard” and “Soft” in Project Management”, International Journal of Project Management, Vol. 32 No. 4, pp. 568-77.

Dvir, D. and Lechler, T. (2004), “Plans are Nothing, Changing Plans is Everything: The Impact of Changes on Project Success”, Research Policy, Vol. 33 No. 1, pp. 1-15.

Menches, C., Hanna, A., Nordheim, E. and Russell, J. (2008), “Impact of Pre-Construction Planning and Project Characteristics on Performance in the US Electrical Construction Industry”, Construction Management and Economics, Vol. 26 No. 8, pp. 855-69.

Giezen, M. (2012), “Keeping it Simple? A Case Study Into the Advantages and Disadvantages of Reducing Complexity in Mega Project Planning”, International Journal of Project Management, Vol. 30 No. 7, pp. 781-90.

Widén, K., Olander, S. and Atkin, B. (2013), “Links between Successful Innovation Diffusion and Stakeholder Engagement”, Journal of Management in Engineering, Vol. 30 No. 5.

Tatum, C.B. (1987), “Process of Innovation in Construction Firm”, Journal of Construction Engineering and Management, Vol. 113 No. 4, pp. 648-663.

Yin, R.K. (2013), Case Study Research: Design and Methods, Thousand Oaks: Sage Publications.

Flyvbjerg, B. (2006), “Five misunderstandings about case-study research”, Qualitative inquiry, Vol. 12 No. 2, pp. 219-245.

Patton, M. Q. (2005), Qualitative research, John Wiley & Sons, Ltd.

Miles, M. B. and Huberman, A. M. (1994), Qualitative data analysis: A sourcebook, Beverly Hills: Sage Publications.

Organizational Improvisation in Contracting Firms: A Capability for Overcoming the Project Complexities

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Abstract:

There is a need of competence for open creativity, intuition, sense of urgency, and flexibility for adaptation to changes, and risk perception in order to create a resilient project management approach in complex project environments of construction industry. In this regard, organizational improvisation (OI) merging intuition, creativity, and bricolage help managers to understand and analyze complex and dynamic organizational decisions and actions. The purpose of this research is to introduce a model investigating the influence of OI as an organizational ability through complexity framework. The research involves a questionnaire survey administered to contracting firms on OI constructs in complex project environments. The research provides details on how contracting firms can deploy intuition and improvisation, and examine the role that organizations play in this process. Research findings prove that OI potentially helps contracting firms to adapt unexpected changes and take action in dynamic project environments.

Keywords: *Organizational Improvisation, Project Complexity, Contracting Firms*

1. Introduction

Organizations operate in a flexible, open, problematic, uncertain and complex construction environment, where stakeholders' demands and expectations change (Eisenhardt, 1997). In this kind of environmental setting, organizations need to adapt the circumstances in order to maintain viable improvement. Improvisation is described as complying with the variations that may not be intended, however occur during projects. In project focused operating organizations, improvisation is a competent approach related with change management (Leybourne, 2006). Projects having one of the main characteristics as uncertainty, involve unknowns and are difficult to predict during design phase, implementation phase, etc. Project managers dealing with unknown conditions and incomplete projects will face unexpected events during project life cycle. Under these circumstances if project managers have time, they re-plan the processes, otherwise they improvise (Leybourne, 2006). Chelariu et al. (2002) describe how improvisation occurs in an organization, that managers do not declare doing it, as they are afterwards held responsible for the decision they make. When an unanticipated change arise, the project manager improvises and deals with it. However if this significant information generated from the act of improvisation is not recorded, nothing is learnt and is seen as part of the initial plan. Organizational improvisation (OI) can provide an opportunity for companies to commit

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themselves to an emerging segment of their actions and environmental immunities (Cunha et al. 1999), especially in circumstances described by great promptness, diversity in experience, lots of prospects and high volatility (Bingham and Eisenhardt 2011, 2014). Significant definitions of OI appeared in the literature are shown Table 1.

Table 1. Significant definitions of OI appeared in the literature

Definition	Source
Opinions developing in unintended ways; benefiting from current occasions	Crossan et al. (1996)
Commencement of achievement as it reveals	Cunha et al. (1999)
Intended and practical synthesis of the design and implementation of an innovative production	Miner et al. (2001)
Unintended however focused reaction to an unstable, rapid varying conditions	Chelariu et al. (2002)
Intuition guiding action in a spontaneous way	Crossan and Sorrenti (2002)
The creative and spontaneous process of trying to achieve an objective in a new way	Vera and Crossan (2005)
Commencement of achievement as it reveals, drawing on available resources (bricolage)	Cunha et al. (2003); Cunha et al. (2009)
A merging of intuition, creativity and bricolage determined by schedule stress	Leybourne and Sadler-Smith (2006)
Performing activities in non-routine or unexpected ways	Webb and Chevreau (2006)
The intended spontaneous arrangement and implementation of innovative performance	Hmieleski and Corbett (2008)
A reiterative competence for recurrent and prevalent variation improved with exercise and demonstrated in improvisational competences	Pavlou and El Sawy (2010)
Concurrent commencement and implementation; Obtaining results from existing rather than prime resources (bricolage)	Zheng et al. 2011

This study aims to present a model, investigating how OI as an organizational ability through complexity framework might potentially help contracting firms to adapt unexpected changes and take action in dynamic project environments. The research involves a questionnaire survey administered to contracting firms on OI constructs in complex project environments. The research will provide details on how contracting firms can deploy intuition and improvisation, and examine the role that organizations play in this process.

2. Theoretical Background

This section presents the degree and level of improvisation, and focuses on leveraging OI for overcoming the project complexities.

2.1 Improvisation

Managers repeatedly need to make decisions in slackly structured conditions where there may be a lack of relevant information leading to uncertainty or where time is of the essence and forcing them to perform quickly. In such cases, managers can search for intuitive decision-making and improvisational skills. In a project environment improvisation comprises diverge from a settled plan in order to speed up the carrying out of activities (Cunha et al. 1999; Moorman and Miner, 1998a, Moorman and Miner, 1998b; Leybourne and Sadler-Smith, 2006). Improvisation may be comprehended as concerning to how considerations and action progress over time and in reaction to environmental indications and incentives. Improvisation entails using resources that are obtainable to resolve unpredicted situations: this is the principle of bricolage (Lehner, 2000). Improvisation occurs to diverse degrees, which is a variety of ordinary improvisation within a current process or product (‘minor improvisation’), improvising new processes or products within founded arrangement (‘bounded improvisation’), and improvising new structures (‘structural improvisation’) (Hadida et al., 2015). ‘Minor improvisation’ reveals simple adjustments to pre-existing processes (Moorman and Miner, 1998b) – for example, by applying a current solution in an original method rather than producing a new solution. ‘Bounded improvisation’ comprises improvising innovative processes or products within current structures, which describe apparent limits and deliver an outline within which bounded improvisation occur (Moorman and Miner, 1998b). ‘Structural improvisation’ entails improvising the actual structure itself. Radical improvisation is also hardly recognized like possessing capability to go beyond and re-describe structures (Moorman and Miner 1998b).

2.2 Organizational Improvisation

Cunha et al. (1999) defined OI as the commencement of unrestricted action as it reveals, by an organization or its members, in reaction to an unanticipated disturbance or variation of action. This description abandons further contenders, as its cruelty anyway adapts organizations and organizational actor(s) to perform unrehearsed, impulsely, instinctively and unplanned in an evolving style. OI is mostly expected to occur initially and mainly in organizations that endure setback (Cunha et al. 2009; Sonenshein 2014), possess working conditions that encourage improvised work (Leybourne, 2010), and have insignificant struggle to variation (Leybourne 2006). Improvisation conveys high independence in the setting of well-defined instructions (Cunha et al. 2003). It can assist the organization to learn to improvise better (Chelariu et al., 2002; Crossan et al., 1996), to innovate (Vera and Crossan, 2005), to discover novel solutions or to accomplish particular activities better through practicing successful improvisations (Ferriani et al., 2011; Miner et al. 1997). Minor improvisation may expose the existence of greater restrictions to improvisation in complicated extreme-rapidity conditions and organizations (Cunha et al., 2003; Eisenhardt, 1989). In organizations, bounded improvisation involves progressive innovation. Specifically, proposing new products that have a connection to prevailing products (Kamoche and Cunha, 2001; Miner et al., 1997). Structural improvisation may take place when different parts of an organization gets connected once minimum anticipated, occasionally guiding to the re-description of the goals or working tactics strategy. In minor OI, organizations deviate from routine, top-down methods of administration to describe structures further roughly, promote innovative methods of implementing regular assignments, and generate time for testing. In bounded OI, restricted improvisation described as unrehearsed improvisation is executed with an explicit understanding of, appreciation and commitment to the arrangements and objectives of the organization (Bigley and Roberts, 2001). Restricted improvisation is associated with the organization’s objectives, and characteristically limited. In structural OI, a flat organization keeps a ‘preparedness to sport any structural form is necessary under the conditions’ (Ciborra, 1996).

2.3 Leveraging Organizational Improvisation for Overcoming the Project Complexities

The environmental settings for improvisation — uncertainty, complexity (interdependent environments) and dynamism (short-lived opportunities and big threats) — are becoming the standard (Stacy, 1996). Challenged with these environments, the traditional form of planning and implementation will be less effective (Chelariu et al., 2002). Dealing with the unanticipated may comprise eliminating obstacles to intuitive concepts, or constructing novel concepts out of nothing. The unanticipated may come from either outside or within the organization (Hadida et al., 2015).

Table 2. Studies on improvisation appeared in the literature

Emphasized issues	Authors
New product development team improvisation and speed-to-	Akgun and Lynn (2002)
Learning to improvise, improvising to learn: a procedure of reacting to complicated situations	Chelariu et al. (2002)
Dispersed change agency and the improvisation of strategies during processes of change	Charles and Dawson (2011)
The improvising organization: where projecting fulfils occasion	Crossan et al. (1996)
Making sense of improvisation	Crossan and Sorrent (2002)
Organizational improvisation: what, when, how and why	Cunha et al. (1999)
Organizational improvisation and leadership	Cunha et al. (2003)
Improvisation in service recovery	Cunha et al. (2009)
Organizational Improvisation: A Combining Assessment and Outline	Hadida et al. (2015)
The contrasting interaction effects of improvisational behavior with entrepreneurial self-efficacy on new venture performance and entrepreneur work satisfaction	Hmieleski, and Corbett (2008)
Minimal structures: from jazz improvisation to product innovation	Kamoche and Cunha (2001)
Bricolage during implementation of strategies: effects on flexibility	Lehner (2000)
Managing change by abandoning planning and embracing improvisation	Leybourne (2006)
The role of intuition and improvisation in project management	Leybourne and Smith (2006)
Improvisation as a way of dealing with ambiguity and complexity	Leybourne (2010)
Studying organizationally-situated improvisation in response to extreme events	Mendonca and Wallace (2004)
Organizational improvisation in new product development	Miner et al. (2007)
Organizational improvisation and learning	Miner et al. (2007)
The convergence of planning and execution: improvisation in new product development	Moorman and Miner (1998a)
Organizational improvisation and organizational memory	Moorman and Miner (1998b)
The impact of adding improvisation to sequential NPD processes on cost	Nunez and Lynn (2012)
Improvising organizational transformation over time: a situated change perspective	Orlikowski (1996)
IT-enabled competitive advantage in turbulence through improvisational capabilities	Pavlou and El Sawy (2010)
Improvisation and innovative performance in teams	Vera and Crossan (2005)
Exposing the Unknown of Improvisation in Project Management	Vuckic (2012)
Planning to improvise: the importance of creativity and flexibility in crisis response	Webb and Chevreau (2006)
Improvisation as a mind-set for organizational analysis	Weick (1998)
Collective agility, paradox and organizational improvisation	Zheng et al. (2011)

Improvisation has been accepted both theoretically and empirically, and has an actual contribution to make in resolving the issues of complexity and uncertainty that organizations are facing with in these instable periods. From elsewhere the organization, the external environment may transform as complicated as to deliver projection impracticable (Cunha et al. 1999) or adverse impact. The organization may similarly encounter market and technological instability (Akgun et al., 2007; Nunez and Lynn, 2012; Pavlou and El Sawy, 2010), or an unforeseeable environmental disturbance (Chelariu et al. 2002; Crossan et al. 1996) or crisis (Mendonca and Wallace, 2004; ten Brinke et al., 2010; Webb and Chevreau, 2006). Such disturbances may force the organization to improvise (Crossan and Sorrenti, 2002) and dynamically to exercise itself to improvise emergency processes (Charles and Dawson, 2011). Organizational level improvisation may be an accumulation of individual improvisations or a primarily cooperative and unified process. When the environment is indeterminate, more novel improvisation is most likely to lead to effective consequences (Miner et al., 2001). Environmental factors play a role in determining at what point there is no further effectiveness in producing knowledge. In more complex environments this point may occur later than in less complex environments (Chelariu et al., 2002). It is significant to inform that there are some risks with organizational improvisation, (Cunha et al., 1999). They refer some of these risks being excessive dependence on improvisation, allowing it behave uncontrollably and disruptively and generating evolving condition where there are none. Cunha et al. (1999) also explain how the learning process is related with risk if there are no ensuing influences on the consequences, i.e. the improvised result is not necessarily the rightest one. Leybourne (2002) mentions to the significance of risk perception in improvisation, as he points out the distress faced when workforces exceed a secure margin into the indefinite, e.g. in projects, project managers will continuously watch over the shortcomings and the incidents that may fail, thus originating a border which they will not exceed concerning uncovering the project or receiving punishment (Leybourne, 2002). He refers to the political dimension, i.e. when people improvise there is no one to charge, which is not suitable for the organization as they do not comprehend what occurred and hence do not absorb appropriately. Concurring with Leybourne (2002) organizations that are further compassionate to improvisation could reduce the probabilities of this influence. Sjöberg et al. (2004) define risk perception as the independent evaluation of the likelihood of a definite type of coincidence occurring and how is involvement with the outcomes. The key process encompasses assessing the possibility and significances of negative outcome, and afterwards considering that consequence to be benefited if action is taken related with the risk. Studies on improvisation appeared in the literature are listed in Table 2.

3. Research Method

Building on Cunha et al.'s (1999) and Leybourne and Smith (2006) nature and triggers, elements, organizational conditions, influencing factors and major outcomes of OI, a questionnaire survey was developed to investigate how OI as an organizational ability through complexity framework might potentially help contracting firms to adapt unexpected changes and take action in dynamic project environments.

3.1 Sampling

The research was focused on the contracting firms operating in international construction industry. The 175 contracting firms are the member organizations, which are registered to the Turkish Contractors Association (TCA). The sizes of the firms range from relatively medium to large. Commonwealth of Independent States, Middle Eastern countries, and African countries were the major regions for projects carry out by the Turkish contractors overseas.

3.2 Data Collection

A methodology that involves a questionnaire survey, which was administered to the contracting firms registered to the TCA was adopted. 175 member organizations operating internationally were communicated and informed of the research objectives. Out of 125 respondents, 45 were project managers, representing 36% of the sample; 40 of the respondents were project coordinators, representing 32% of the total sample; and the remaining 40 respondents were chief engineers, representing 32%.

Project information (type and size of the project, parties involved), natures and triggers of OI (external and internal causes), elements of improvisation, organizational conditions for improvisation (tolerate/promote mistakes, promote action, sense of urgency, invisible controls, clear goals, short term milestones, low procedural memory), influencing factors of OI (leadership, skill, creativity, diversity, dealing with affectivity, rich declarative memory, practising improvisation, will to depart memory, disclosure relationships, collateral organization, small groups, general purpose resources), positive outcomes of OI (flexibility, learning, higher motivation to work, higher motivation to improvise, transcendence, team building), and negative outcomes of OI (opportunity traps, amplification of emergent action, addictiveness to improvisation, increased anxiety) were the issues addressed during the interviews.

4. Research Findings and Analysis

This section presents the determination of the level of Relative Importance Indices of the factors in different project phases, discussion of the findings, development and assessment of a conceptual framework of OI.

4.1 Determination of Relative Importance Indices

The participating organizations provided numerical scoring expressing their opinions on the significance of each factor in determining how OI as an organizational ability through complexity framework might potentially help contracting firms to recover from a shock, insult or disturbance in complex environments in different phases of the project. The relative importance index (RII) method is used here to determine from perspective of professionals working in contracting firms, factors affecting performance of consultants on projects developments. RII is computed as (Cheung et al., 2004, Iyer and Jha, 2005):

$$\boldsymbol{RII} = \frac{\sum \boldsymbol{W}}{\boldsymbol{A} \times \boldsymbol{N}} \tag{1}$$

Where:

W is the weight given to each factor by the respondents and ranges from 1 to 5
A = the highest weight = 5
N = the total number of respondents

Table 3. shows a matrix of variations in level of important indices of the factors in terms of OI nature and triggers, elements of improvisation, organizational conditions, influencing factors, positive outcomes, and negative outcomes versus Project Phases. The X-axis of the matrix indicates the Project Phases categorized into four determinants. These phases are believed to have systematic linkage among the OI triggers, organizational conditions, influencing factors, positive outcomes, and negative outcomes. OI factors were listed in Y-axis of the matrix with their index values. Studying the matrix, OI constructs carrying the

highest level of importance are mostly from construction phase. These OI factors are "Uncertainty" from "Nature and Triggers", "Intuition", "Creativity", "Adaption", and "Risk Perception" from "Elements of Improvisation", "Sense of Urgency" from "Organizational Conditions", Skill", and "Practising Improvisation" from "Influencing Factors", and "Flexibility" from "Positive Outcomes".

Table 3. Matrix showing the variations in the level of Relative Importance Indices of the factors

Item	Constructs of Organizational Improvisation	Procurement	Construction	Engineering Commission	Completion and Handover	Rank
		Project Phases				
		RII				
1	Nature and Triggers					
1.1	Uncertainty	0.82	0.85	0.79	0.78	1
1.2	Time Pressure	0.81	0.84	0.79	0.79	2
1.3	Importance Perception	0.81	0.83	0.78	0.79	3
1.4	Organizational Structure and Routines	0.80	0.82	0.78	0.78	4
1.5	Poor Planning	0.81	0.80	0.78	0.77	5
1.6	Communication	0.79	0.80	0.78	0.77	6
1.7	Misfortune or Bad Luck	0.79	0.78	0.77	0.76	7
2	Elements of Improvisation					
2.1	Intuition	0.82	0.85	0.79	0.78	1
2.2	Bricolage	0.81	0.84	0.79	0.79	2
2.3	Creativity	0.82	0.85	0.79	0.78	1
2.4	Innovation	0.81	0.83	0.79	0.78	3
2.5	Adaption	0.82	0.85	0.79	0.78	1
2.6	Learning	0.81	0.83	0.78	0.79	3
2.7	Risk Perception	0.82	0.85	0.79	0.78	1
3	Organizational conditions					
3.1	Tolerate/promote mistakes	0.79	0.80	0.78	0.77	6
3.2	Promote action	0.81	0.83	0.78	0.79	3
3.3	Sense of urgency	0.82	0.85	0.79	0.78	1
3.4	Invisible controls	0.81	0.80	0.78	0.77	5
3.5	Clear goals	0.79	0.80	0.78	0.77	6
3.6	Short term milestones	0.81	0.84	0.79	0.79	2
3.7	Low procedural memory	0.82	0.80	0.78	0.78	4
4	Influencing factors					
4.1	Rotating leadership	0.81	0.83	0.79	0.78	3
4.2	Serving leadership	0.81	0.83	0.78	0.79	3
4.3	Skill	0.82	0.85	0.79	0.78	1
4.5	Diversity	0.80	0.82	0.78	0.78	4
4.6	Dealing with affectivity	0.80	0.79	0.78	0.77	6
4.7	Rich declarative memory	0.84	0.81	0.79	0.79	2
4.8	Practising improvisation	0.82	0.85	0.79	0.78	1
4.9	Will to depart memory	0.81	0.80	0.78	0.77	5
4.10	Disclosure relationships	0.77	0.78	0.76	0.75	8
4.11	Collateral organization	0.81	0.83	0.78	0.79	3
4.12	Small groups	0.78	0.79	0.77	0.76	7
4.13	General purpose resources	0.77	0.78	0.76	0.75	8
5	Positive Outcomes					
5.1	Flexibility	0.82	0.85	0.79	0.78	1
5.2	Higher motivation to work	0.81	0.83	0.79	0.78	3
5.3	Higher motivation to improvise	0.81	0.84	0.79	0.79	2
5.4	Transcendence	0.82	0.80	0.78	0.78	4
5.5	Team building	0.78	0.79	0.77	0.76	7
6	Negative outcomes					
6.1	Opportunity traps	0.82	0.85	0.79	0.78	4
6.2	Amplification of emergent action	0.81	0.84	0.79	0.79	2
6.3	Addictiveness to improvisation	0.80	0.81	0.78	0.77	5
6.4	Increased anxiety	0.80	0.79	0.78	0.77	6
	RANK	2	1	3	4	

4.2 Discussion of Survey

The factors “Uncertainty”, “Intuition”, “Creativity”, “Risk Perception”, “Sense of urgency”, “Skill”, “Practising improvisation”, “Flexibility”, and “Adaption” are ranked #1 and is perceived by respondents to have an influence on OI in construction phase with value of RII 0.85. The interviews and observations highlighted that when uncertainty overall predominates the construction phase for the unanticipated, unintended actions are practically inevitable leading to improvisation (Cunha et al., 1999; Leybourne and Sadler-Smith, 2006). Based on the prior practises and sensitive efforts, managers using their perceptive deductions and instinct, make decisions more promptly (Leybourne and Sadler-Smith, 2006). Managers actuate creativity with intuition, leading to produce added solutions with the available resources to unravel complications not confronted already (Moorman and Miner, 1998a). The higher the level of creativity, the more alterations the improviser can achieve and the more innovative the achievement develops (Cunha et al., 1999; Moorman and Miner, 1998a). Different managers could perceive the similar risk in diverse means (Vuckic, 2012). This is connected with the manager's knowledge and beliefs. It appears that in certain cases the managers were really conscious of the risks they took by performing improvisation. Milestones or action deadlines have been realised to be an efficient instrument for retaining the sense of urgency caused by an unanticipated and spontaneous occurrence. Implementing improvisation regularly, improves an organization's ability to improvise (Crossan et al., 1996). It was revealed that when improvising, teams start with basic deviations gradually followed by a way of growing occasions and claims to improvise. Flexibility sustains a specific level of adequateness with the circumstances by altering the organization to react to variations in it. Flexibility prepares revisions in the organization to react to unanticipated changes in the environment throughout extensive term of time (Cunha et al., 1999). Adaption is the process of responding to the encouraging occasions. Organizations choose to act by improving decided approaches, products and procedures in consensus. (Leybourne and Sadler-Smith, 2006).

The factors “Time pressure”, “Bricolage”, “Short term milestones”, “Rich declarative memory”, “Higher motivation to improvise”, “Amplification of emergent action” are ranked #2 and are comprehended by respondents to have an impact on OI in construction phase with value of RII 084. The interviews and observations highlighted that the incidence of an unanticipated case is not entirely adequate to activate improvisation. The case has to be comprehended as significant and applicable. The higher the time pressure on a specific case in a project, the more crucial it is comprehended and the essential for improvising is higher. In these unanticipated cases, related with both uncertainty and time pressure, a discrepancy occurs between what is intended for and what is essentially comprehended by the surroundings (Cunha, et al., 1999; Miner, et al. 2001). Bricolage is utilising combinations of the available resources to new problems and opportunities (Baker and Nelson, 2005). Organizations use available resources, not planned for that particular problem, but utilise in a manner that they can produce new solutions. In today's varying circumstances organizations discover resources from existing resources to solve unforeseen difficulties achieve competitive advantage (Cunha, 2006). Milestones perform as instants of feedback as uncompleted phases are accomplished and, hence builds the energy and the sense of urgency required for improvisation to be maintained. Milestones, either clearly expressed or indirectly imposed through leadership, are the core drives exceptionally of prompt achievement in many organizations (Brown and Eisenhardt, 1997; Eisenhardt and Tabrizi, 1995). Declarative memory performs a significant role in the level of improvisation. The more actualities an organization knows, the wider and more differentiates its origin for creativity and hence for improvisation (Moorman and Miner 1998b). Improvisaton, with its prominence on milestones and its recurring character (Brown and Eisenhardt, 1997; Eisenhardt and Tabrii, 1995) provides high levels of individual feedback, hence causing to probable rises in individual motivation. Additionally, when the organization appreciates the effects of improvisational action as positive, improvisation is expected to gain a greater validity as an ordinary practice (Miner et al., 1996; Orlikowski, 1996). Thus, the entire organization may get a higher motivation to improvise when meeting unanticipated occasions.

The factors “Importance perception”, “Learning”, “Promote action”, “Rotating leadership”, “Serving leadership”, “Collateral organization”, “Higher motivation to work”, and “Innovation” are ranked #3 and are comprehended by respondents to have an impact on OI in construction phase with value of RII 0.83. The interviews and observations highlighted that improvisation will not occur unless it is comprehended as significant by the managers performing it (Vuckic, 2012). Managers will feel forced to take into account the importance of OI as a crucial capability for operating in unsettled and changing environments (Cunha et al., 1999). Improvisational learning is built on the practice created by the organization in real-time. This practice reports the plan of execution or production as it is accomplished, (Miner et al., 2001). The diversity between improvisational learning and the other categories of learning is that it is not intended. In improvisation compared to the other learning forms, the main purpose is to solve the existing difficulty and learning may occur as a feature of that action (Cunha et al., 1999; Miner et al., 2001; Moorman and Miner, 1998a; Vuckic, 2012). In very competitive environments, the level of learning can be a robust competitive advantage (Crossan and Sorrenti, 1997). Improvisation, with its prominence on investigation, initiates an entire novel learning ground to organizations by presenting that faults and breakdowns are learning opportunities. A trail culture which is the condition for improvisation to happen results from a set of values and beliefs that encourage action (Cunha et al., 1999). To adopt such a culture, the organizations recompense individuals according to the number of skilled mistakes they have done occasioning from innovative ideas and not from defective performance (Picken and Dess, 1997). Leadership is an important factor affecting the degree and effectiveness of OI. The reasoning for the convenience of a rotating leadership is built in contingency leadership theory. In unanticipated and unforeseen situations, a stronger leader shows up, especially when achievement has to be hurried. This is due to developing complexity and interdisciplinary features of the problems organizations experience, which requires for diverse capabilities and knowledge (Stacey, 1996). Therefore every participant is requested to support the current improvisation, and cannot only act as a specialist but alternatively, as a leader, because of the combination of a lack of time and a plenty of complexity for specialised knowledge (Stacey 1996; Weick 1993). The leadership approach of the organization’s official leader is similarly a significant facilitator of improvisation. A servant leader, can have an expressive positive influence on the quality of OI. This kind of leader embraces a dual stewardship for their followers and for the purposes of the organization hence reducing the negative effects of practicing improvisation. In collateral organizations, managers allocate participants to form the required diversity of concepts required for improvisation to happen. These organizations function as an environment where participants can exercise improvisation in a protected setting before executing it in collaboration with the stakeholders (Weick 1993). Improvisation comprises a level of innovation as improvisation encompasses the invention of action beyond procedures and routines, (Moorman and Miner, 1998b). Organizations could revolutionize a new approach of delivering a service by collecting customer data, investigating and arranging a new network (Moorman and Miner, 1998b). However, because of the instable and varying market conditions, improvisation has been applied as an option for innovation (Cunha et al., 1999).

4.3 Conceptual Framework of Organizational Improvisation as a Capability for Overcoming the Project Complexities

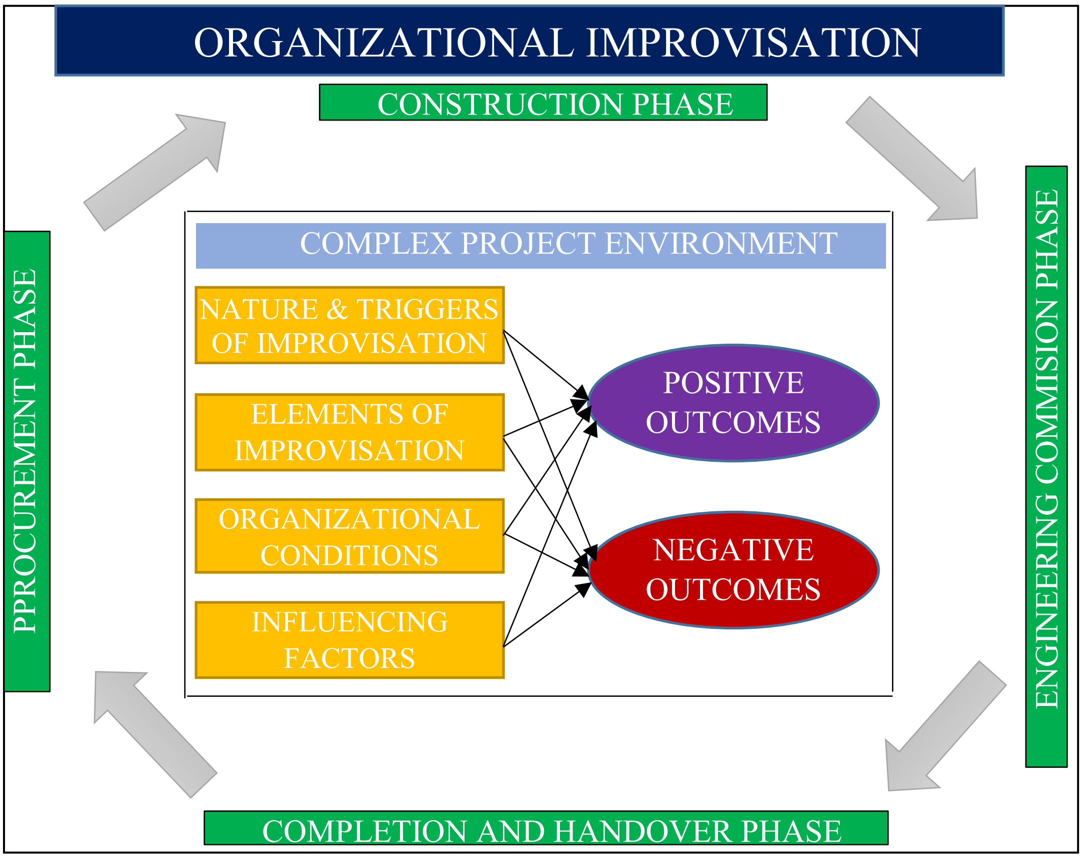

Figure 1. Conceptual Framework of Organizational Improvisation as a Capability for Overcoming the Project Complexities

How OI as an organizational ability through complexity framework might potentially help contracting firms to adapt unexpected changes and take action in dynamic project environments have been investigated in a conceptual framework as shown in Figure 1. The framework presents an integrative approach of measuring the categorized nature and triggers of improvisation, elements of improvisation, distinguished organizational conditions, determined influencing factors and the relationships on the major outcomes of OI during different project phases. Progressively, complex and large civil engineering and construction projects comprise organization of an integrated project environment merging different organizations' skills, designs and constructs. Contracting organizations allow their project managers to create time and opportunity to test with contemporary, novel, and confidently more effective ways of performing work in complex management challenges. The desire to improvise occurs when the action of a new vision involves evolving variations within the organization. OI has been emphasized to have both positive and negative outcomes throughout the different project phases.

The validation of the conceptual framework of OI is specified with an assessment survey as shown by Table 4 displaying the assessment responses. The assessment survey was administered to the same respondents of the previous survey for determination of the RII. Diverse features of the conceptual framework of OI were rated in the questionnaire. It was created on a Likert scale and ranged on five points, which represented from poor to excellent to obtain measureable feedback. The results designate that the mean rate for five questions was equal or higher than 3.75 out of eight questions in the assessment, which signify that the mean rate for 63% of the questions was higher than 3.75 in the questionnaire. The extent of intuition, creativity, bricolage, adaption, innovation, learning, and risk perception as elements to be utilized with the current practices and information to unravel complications not confronted already and achieve OI the highest mean rate as 3.82 in all questions and the extent of amplification of emergent action as negative outcome causing unplanned and unanticipated consequences of implementing OI in complex business environments received the lowest rate as 3.65. Thus, conceptual framework of OI has been approved by the respondents as an effective practice for adapting unexpected changes and take action in dynamic project environments.

Table 4. Evaluation responses to Conceptual Framework of OI

Number	Evaluation questions	Rating (%)					
		1: Poor	2: Fair	3: Satisfactory	4: Good	5: Excellent	Mean Rate
1	How useful do you consider the Conceptual Framework of OI?	-	4	31	53	12	3.73
2	How practical is it to apply the Conceptual Framework of OI?	-	5	33	52	10	3.67
3	To what extent can uncertainty, time pressure, and importance perception as nature and triggers overall predominates the construction phase for the unanticipated actions leading to OI?	-	3	30	56	11	3.75
4	To what extent can intuition, creativity, bricolage, adaption, innovation, learning, and risk perception as elements be utilized with the current practices and information to unravel complications not confronted already and achieve OI?	-	2	25	62	11	3.82
5	To what extent can sense of urgency, short term milestones, promote action as organizational conditions enhance incentive and build energy, and provide perception of formation to OI arising from chaos and disorder?	-	2	30	58	10	3.76
6	To what extent can skill, practicing improvisation, rich declarative memory, rotating leadership, and serving leadership as influencing factors improve participants' capability to deal with duties that entail great expertise, together with the organization's known actualities and perform a significant role in the level and quality of OI?	-	2	27	61	10	3.79
7	To what extent can flexibility, higher motivation to improvise, and higher motivation to work sustain a specific level of adequateness with the circumstances by altering the organization to react to immediate and unanticipated variations and gaining a greater validity of OI?	-	2	32	55	11	3.75
8	To what extent can amplification of emergent action as negative outcome cause unplanned and unanticipated consequences of implementing OI in complex business environments?	-	4	37	49	10	3.65

5. Conclusions

This paper presents a conceptual framework of how OI as an organizational ability through complexity framework might potentially help contracting firms to adapt unexpected changes and take action in dynamic project environments. For developing the conceptual framework, the nature and triggers of OI, elements of OI, organizational conditions, influencing factors, and their impacts as positive and negative outcomes through project phases in complex project environment have been derived. According to the findings of the research, the OI factors “Uncertainty”, “Intuition”, “Creativity”, “Adaption”, “Risk Perception”, “Sense of urgency”, “Skill”, “Practicing improvisation”, and “Flexibility” hold the highest level of RII. Construction is the phase to be highly affected by the OI factors mentioned above. One of the key features of a project is uncertainty that is relating projects with entering to the unknown. This entails the reality that the plans will continuously be roughly incomplete, and managers will find themselves in a situation where they confront the unanticipated. Integrating intuition into decision-making is effective when time is significant, no clear hints and uncertainty exists. Managing the stress between improvisation and control is a task for contemporary organizations. This stress is real, and makes difficult the relationship between prohibited activity and improvised creativity. It is obvious that those organizations that successfully manage the stress between process and improvisation effectively will gain in the unstable organizational environments that form tomorrow's challenging business background. Having risk perception at place could retain improvisation at a more controlled level, since managers are conscious of the concerns, but simultaneously it constrains the spontaneous feature of improvisation. Sense of urgency is a value that an organization must adopt for improvisation to happen. The skill in improvisation is meaningful when to release the framework that encloses prohibited activity in organizations, and when to enforce a greater degree of consistency and arrangement. Practicing improvisation in a modeled environment can help individuals to develop the abilities for effective improvisational activity in actual conditions. This builds a procedural memory for the capability and thus consent them to avoid those mistakes that are typical of first-time accomplishments. There is growing indication of a main concern in flexibility within the project domain. This frequently initiates itself in elements of improvisational activity, and an appreciation of the challenges of dealing with and resolving uncertainty and complexity within the limitations of the project.

References

Akgun, A.E. and Lynn, G.S. (2002), "New product development team improvisation and speed-to-market: an extended model". European Journal of Innovation Management, Vol.5, pp. 117–129.

Akgun, A.E., Byrne, J.C., Lynn, G.S. and Keskin, H. (2007), "New product development in turbulent environments: impact of improvisation and unlearning on new product performance. Journal of Engineering and Technology Management, Vol.24, pp. 203–230.

Baker, T. and Nelson, R.E. (2005), "Creating something from nothing: resource construction through entrepreneurial bricolage", Administrative Science Quarterly, Vol.50, pp. 329–366.

Bigley, G.A. and Roberts, K.H. (2001), "The incident command system: high reliability organizing for complex and volatile task environments", Academy of Management Journal, Vol.44, pp. 1281–1299.

Bingham, C.B. and Eisenhardt, K.M. (2011), "Rational heuristics: the 'simple rules' that strategists learn from process experience", Strategic Management Journal, Vol.32, pp. 1437–1464.

Bingham, C.B. and Eisenhardt, K.M. (2014), "Heuristics in strategy and organizations: response to Vuori and Vuori", Strategic Management Journal, Vol.35, No.11, pp.1698-1702.

ten Brinke, W.B.M., Kolen, B., Dollee, A., van Waveren, H. and Wouters, K. (2010), "Contingency planning for large-scale floods in the Netherlands", Journal of Contingencies and Crisis Management, Vol.18, pp. 55–69.

Brown, S.L. and Eisenhardt, K.M. (1997), "The art of continuous change: linking complexity theory and timepaced evolution in relentlessly shifting organizations". Administrative Science Quarterly, Vol. 42, pp. 1–34.

Charles, K. and Dawson, P. (2011), "Dispersed change agency and the improvisation of strategies during processes of change", Journal of Change Management, Vol.11, pp. 329–351.

Chelariu, C., Johnston, W.J. and Young, L. (2002), “Learning to improvise, improvising to learn: a process of responding to complex environments” Journal of Business Research, Vol.55, pp. 141–147.

Ciborra, C.U. (1996), “The platform organization: recombining strategies, structures, and surprises”, Organization Science, Vol.7, pp. 103–118.

Crossan, M.M., Lane, H., White, R.E. and Klus, L. (1996), “The improvising organization: where planning meets opportunity”, Organizational Dynamics, Vol.24, pp. 20–35.

Crossan, M.M. and Sorrenti, M. (2002), “Making sense of improvisation”. In Kamoche, K., Cunha, M. and Cunha, J.V. (Ed.), Organizational Improvisation, Routledge, London, pp. 27–48.

Cunha MP, da Cunha JV, Kamoche K. (1999), “Organizational improvisation: what, when, how and why?” International Journal of Management Review, Vol.1 No.3, pp. 299–341.

Cunha, M.P., Kamoche, K. and Cunha, R.C. (2003), “Organizational improvisation and leadership: a field study in two computer-mediated settings”, International Studies of Management & Organization, Vol.33, pp. 34–57.

Cunha, M.P., Rego, A. and Kamoche, K. (2009), “Improvisation in service recovery”, Managing Service Quality, Vol.19, pp. 657–669.

Eisenhardt, K.M. (1989), “Making fast strategic decisions in high-velocity environments”, Academy of Management Journal, Vol.32, pp. 543–576.

Eisenhardt, K.M., Kahwajy, J.L. and Bourgeois, L.J. (1997), “Conflict and strategic choice”, California Management Review, Vol.39, pp. 42–62.

Eisenhardt, K.M. and Tabrizi, B.N. (1995), “Accelerating adaptive processes: product innovation in the global computing industry”, Administrative Science Quarterly, Vol.40, pp. 84–110.

Ferriani, S., Garnsey, E. and Lorenzoni, G. (2011), Continuity and change in a spin-off venture: the process of reimprinting. Industrial & Corporate Change, Vol.21, pp. 1011–1048.

Hadida A.L., Tarvainen, W., Rose, J. (2015), “Organizational Improvisation: A Consolidating Review and Framework”, International Journal of Management Reviews, Vol.17, pp. 437–459.

Hmieleski, K.M. and Corbett, A.C. (2008), “The contrasting interaction effects of improvisational behaviour with entrepreneurial self-efficacy on new venture performance and entrepreneur work satisfaction”, Journal of Business Venturing, Vol.23, pp. 482–496.

Kamoche, K. and Cunha, M.P. (2001), “Minimal structures: from jazz improvisation to product innovation”, Organization Studies, Vol.22, pp. 733–764.

Lehner J.M. (2000), “Bricolage during implementation of strategies: effects on flexibility”, American Academy of Management Conference, Toronto, 4–9 August 2000.

Leybourne S.A. (2002), “Project Management and the Implementation of Strategic Change within the U.K. Financial Services Sector” Doctoral Dissertation, Cardiff Business School, UK.

Leybourne, S. (2006), “Managing change by abandoning planning and embracing improvisation”, Journal of General Management, Vol.31, pp. 11–29.

Leybourne S., Sadler-Smith E. (2006), “The role of intuition and improvisation in project management”, International Journal of Project Management, Vol. 24, pp. 483–492

Leybourne, S. (2010), “Improvisation as a way of dealing with ambiguity and complexity”, Graziadio Business Review, 13(3). Available at: http://gbr.pepperdine.edu/2010/08/improvisation-as-a-way-of-dealing-with-ambiguity-and-complexity-3/March 1991

Mendonca, D. and Wallace, W. (2004), “Studying organizationally-situated improvisation in response to extreme events”, International Journal of Mass Emergencies and Disasters, Vol.22, pp. 5–29.

Miner, A., Moorman, C. and Bassoff, P. (1997), "Organizational improvisation in new product development", MSI Report. Marketing Science Institute, Cambridge, MA, pp. 97–110.

Miner, A., Bassoff, P. and Moorman, C. (2001), "Organizational improvisation and learning: a field study", Administrative Science Quarterly, Vol.46, pp. 304–337.

Moorman C, Miner AS. (1998a), "The convergence of planning and execution: improvisation in new product development", Journal of Marketing, Vol. 62 No.3, pp. 1–20.

Moorman C, Miner AS. (1998b), "Organizational improvisation and organizational memory", Academy of Management Review, Vol.23 No.4, pp. 698–723.

Nunez, E. and Lynn, G.S. (2012), "The impact of adding improvisation to sequential NPD processes on cost: the moderating effects of turbulence", Academy of Marketing Studies Journal, Vol.16, pp. 1–18.

Orlikowski, W.J. (1996), "Improvising organizational transformation over time: a situated change perspective", Information Systems Research, Vol.7, pp. 63–92.

Pavlou, P.A. and El Sawy, O.A. (2010), "The 'third hand': IT-enabled competitive advantage in turbulence through improvisational capabilities", Information Systems Research, Vol.21, pp. 443–471.

Picken, J.C. and Dess, G.G. (1997), "Out of (strategic) control", Organizational Dynamics, Vol.25, No.1, pp.35-47.

Sjöberg, L., Moen B. and Rundmo, T. (2004), "Explaining risk perception. An evaluation of the psychometric paradigm in risk perception research". Rotunde publikasjoner. [Online]. Available at: http://www.svt.ntnu.no/psy/torbjorn.rundmo/psychometric_paradigm.pdf (Accessed: 20th Mar 2017).

Sonenshein, S. (2014). How organizations foster the creative use of resources. Academy of Management Journal, 57, pp. 814–848.

Stacey RD. (1996), Complexity, creativity and management. Berrett-Koehler, San Francisco, CA.

Vera, D. and Crossan, M.M. (2005), "Improvisation and innovative performance in teams". Organization Science, Vol.16, pp. 203–224.

Vuckic, A. (2012), Uncovering the Mystery of Improvisation in Project Management: An Exploratory Research Master of Science Thesis in the Master's Programme International Project Management, Chalmers University Of Technology, Northumbria University, Göteborg, Sweden.

Webb, G. and Chevreau, F.R. (2006), "Planning to improvise: the importance of creativity and flexibility in crisis response", International Journal of Emergency Management, Vol.3, pp. 8–9.

Weick, K.E. (1993), "Organizational redesign as improvisation", In Huber, G.P. and Glick,W.H. (eds), Organizational Change and Redesign, Oxford University Press US, NewYork, NY, pp. 346–379.

Weick, K.E. (1998), "Improvisation as a mindset for organizational analysis", Organization Science, Vol.9, pp. 543–555.

Zheng, Y., Venters, W. and Cornford, T. (2011), "Collective agility, paradox and organizational improvisation: the development of a particle physics grid", Information Systems Journal, Vol.21, pp. 303–333.

Re-investigating Approaches on Defining Stakeholder Characteristics

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Abstract:

In last 20 years, stakeholder management attracted the attention of many scholars, which resulted in many research papers dealing with the subject of stakeholder management in general and stakeholder management in the specific field of project management and construction management. One could conclude that vast interest in this field and its maturity resulted in the fact that managing stakeholders in construction projects became very effective and efficient. However, project managers are still struggling with complex stakeholder environment and their ambiguous expectations. In literature, one can find different models, method, and tools of stakeholder analysis aiming to characterize stakeholders ascribing them various terms meant to represent vital stakeholder qualities. Some scholars build their theories on power, legitimacy and urgency while others take power, interest and attitude as their starting point proving that there is still confusion on the specific topic of stakeholder characteristics. In order to solve the problem of a large number of different views on stakeholder characteristics detail desk research is done. Research is based on examination of literature, starting with literature review papers of SM research field and continued with more particular topics of SM in general management, project management and construction management using key words. Research resulted with identification of 14 terms usually used in literature to characterize stakeholders. This terms are considered as stakeholder characteristics, they were analyzed and their definition is provided. Final result is conceptual framework for stakeholder characteristics. This framework consists of detected stakeholder characteristics sorted in four related categories providing new systematization of stakeholder characteristics. Suggestions for future development of this framework are provided.

Keywords: *stakeholder management, stakeholder characteristics, stakeholder analysis, conceptual framework;*

1 Introduction

Stakeholder management (SM) has received great interest as a research topic which can be seen in literature review papers on this subject (Littau et al., 2010, Mok et al., 2015, Yang et al., 2011b) but projects and their managers are still struggling with ambiguous expectations of various stakeholders. Stakeholders are of great importance in projects and therefore it is necessary to effectively manage stakeholders and reach balance between their, sometimes, opposing goals and objectives. They are important because lately in addition to the “hard” project success criteria, time, quality and cost, “soft” dimensions of project success are put in focus (Turner and Zolin, 2012). Soft success criteria are related to perceived success from stakeholders point of view (Burcar Dunovic et all, 2015).

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Origin of different ontology views on who or what is stakeholder and how it should be managed were detected and discussed in (Mitchell et al., 1997) which work brought large contribution to SM field of study. They included arguments and views outlined by leading scholars in this field, and as the result of their study provided classification of stakeholder where classes were determined by possession of one, two or all three stakeholders' attributes. Stakeholder management is usually manifested through stakeholder engagement and communication and to be able to engage key stakeholders properly we need to identify them and determine their characteristics. Review papers of Mok et al. (2015), Yang et al. (2011b) and Littau et al. (2010) tried to synthesize main theoretical concepts portraying this area, but nevertheless there is still confusion in specific topic of stakeholder analysis resulting with different standpoints on stakeholder attributes, interest, attitudes and other terms portraying project stakeholders. In literature, one can find different models, method and tools of stakeholder analysis aiming to characterize stakeholders ascribing them various labels and terms meant to represent vital stakeholder qualities. Some scholars take power, legitimacy and urgency from (Mitchell et al. 1997) salience model, while some scholars build their theories on power-interest-attitude matrix (Murray-Webster and Simon, 2005) presenting this as starting point of SM activities. Although, in literature the term stakeholder characteristic is used, there is not common understanding on its application nor its definition. Scholars often use new terms thereby contributing to the creation of confusion in the field, and there is no synthesis, which would aggregate all these stakeholder characteristics in some meaningful system and thus provide other scholars and project manager clear starting point in stakeholder management.

In order to address this gap it is necessary to answer research questions: *"What distinguishable terms scholars use to characterize project stakeholders and how those stakeholder characteristics can be systemized"?*

To address previously mentioned questions this study aims to provide explanations and structured system of stakeholder characteristics. First part of the paper is literature review aimed at topic of stakeholder analysis, identification and other similar topics from project and construction management point of view. The second part illustrates methodology of this desk research considering all important steps. The third part of this paper provide analysis of stakeholder characteristics starting with discussion of comprehensive literature dealing with topic of stakeholder characteristics and providing overview of all detected stakeholder characteristics. Analysis of stakeholder characteristics is followed by newly developed conceptual framework and as the last step characteristic are sorted in stakeholder categories developed in framework. The paper ends with future research directions and limitations followed by conclusion, which display contribution of this paper in form of advancing stakeholder characteristics body of knowledge and providing scholars and practitioners synthesis of this comprehensive research topic.

2 Literature review

Project stakeholder is defined as "person or a group of persons who are influenced by, or are able to influence the project" (Freeman, 1984). Beside this broad understanding of stakeholders, there is also another, narrower, point of view aiming to provide project managers a way to focus only on the most important stakeholders and therefore save them money and time. Clarkson (1994) states that stakeholders are voluntary or involuntary risk-bearers and that stake can only be considered as something that can be lost.

Stakeholder management is according to (McElroy and Mills, 2007):*"continuing development of relationships with stakeholders for the purpose of achieving a successful project outcome"* (p. 760). Although many scholars developed numerous concepts of SM process, most of those models comes down to two constituents of SM and that is stakeholder analysis and stakeholder engagement. Karlsen (2002) proposes 7 processes of stakeholder management starting with identification and finishing with developing strategies and following up, and (Walker et al., 2007) work consists of 5 process; identification, prioritization, visualization and engagement of stakeholders, and monitor effectiveness and communication. Yang et al., (2011a) identifies various approaches to stakeholder analysis and engagement describing them as two vital parts of SM and defining their processes.

In this paper, focus is set on portraying theoretical status of stakeholder characteristics and resolving dissimilarities regarding this specific topic, which is vital part of stakeholder analysis. Stakeholder analysis according to many scholars consists of stakeholder identification and characterization as their main parts, which can be complemented with classification, prioritization and other constructs and outcomes of these two main activities.

2.1 Stakeholder analysis and engagement

According to Mok et al. (2015)

> *"...traditional stakeholder analysis methods categorize stakeholders and analyse their impact based on individual attributes, attitudes, roles and predictability."* (p. 452).

while Jepsen & Eskerod (2009) states that

> *"...stakeholder analysis increases the project manager's ability to anticipate opportunities and problems for the project at a time when the project team still has time and opportunity for manoeuvring."* (p. 335).

Aaltonen (2011) finds that by conducting stakeholder analysis project manager is building "correct" picture about project environment and Newcombe (2003) stated that it is technique to determine how stakeholder interact with organization. Considering all these definitions it could be said that stakeholder analysis is focused on learning about stakeholders and stakeholder environment by detecting their various characteristics with intention to provide input for stakeholder engagement and other SM activities.

Stakeholder management beside role of analysing and identifying stakeholder play more active role in project and construction management and this role is reflected in timely engaging all project stakeholders. Yang et al. (2014) states that stakeholder engagement includes communication, involvement and developing relationships with stakeholders. Mok et al. (2015) paraphrases Deegan and Parkin (2011) and Webler and Tuler (2000) which stated that stakeholder engagement in mega construction projects MCP aims at involving all project stakeholders in the planning, decision making and implementation of the project, so as to reduce conflicts and establish clear project priorities. As it can be seen, the stakeholder engagement emphasise involving project participants and reducing possible conflicts, and this can be done by delivering proper information to all stakeholder involved and involving them in right time can contribute to project success. Stakeholder engagement cannot be conducted properly without having quality information that can only be gathered and systemized in stakeholder analysis and that information are mainly various characteristics of project stakeholders.

2.2 Stakeholder identification and classification

Identification of stakeholders is mentioned as issue by (Achterkamp and Vos, 2008) because in their literature examination targeted at stakeholder identification they concluded that 25 out of 42 papers didn't provide any definition of stakeholder identification. Part of the problem probably lies in fact that results of this same examination was even worse when they observe stakeholder definitions. Only 7 out of 42 articles clearly stated definition on stakeholder, which is only way to provide authors concept and understanding of project stakeholders. Stoney and Winstanley (2001) also argue that first step is to clarify our stands with regard to our beliefs and position on who can be viewed as valid stakeholders so that our ontological position is familiar to other scholars dealing with this area. Project manages interviewed by Jepsen & Eskerod (2009) stated that it is not worth to list every possible stakeholder, rather is important to find out who are the most important stakeholders. Many scholars agrees on that thought and to be able to do that they produced various classifications, allowing project manager and scholars to put stakeholders in classes and thus shorten the process of stakeholder identification. Mitchell et al. (1997) work resulted in 7 classes of stakeholders which is probably the most known classification, although Achterkamp and Vos (2008) stated that their classification for innovation projects might be more useful in providing structured stakeholder identification and they presented role-based identification method. Nguyen et al. (2009) listed numerous types of stakeholder identifications developed over years from Freemans (1984) internal and external to 2 level classification developed by Winch (2002), one level is sorting stakeholder as internal or external and second is assigning them one or more roles because in some projects it is normal for stakeholder to have more than one role. Yang and Shen (2015) interviewed project managers commended role classification but warned on the possibility that one stakeholder can play more than one role. Bourne & Walker (2005) sorted stakeholders in four groups: Upstream, downstream, external, and project stakeholder group all comprising some more detailed stakeholder groups or roles and this 2 types of stakeholder groupings are the most elaborated classification found in literature. Usually classification and identification of stakeholders are followed by assessment of their characteristics.

2.3 What are stakeholder characteristics?

Usual terms to describe stakeholders used in various research papers ranges from stakeholder attributes, interests and attitudes to stakeholder knowledge and many more. Common understanding of analysis and assessment is much needed and this leads us to the term "characteristic". According to Cambridge dictionary characteristic is: "a typical or noticeable quality of someone or something" or used as adjective "typical of a person or thing" so when we characterize someone we ascribe him particular quality, or to say systematically describe him. In this paper, we refer to project and construction management research area and community and our goal is to provide insight and develop systematic way to observe stakeholder characteristics. This paper will bring comments and insights from reviewing literature concerning stakeholder characteristics ending with analysis and synthesis of stakeholder characteristics.

3 Research goals and methodology

In order to answer research questions a desk research was done in four steps. The first step is literature review based on papers retrieved by searching ISI Web of Science and Google

Scholar database. We were searching for SM literature review or SM theory overview of general management, project management and construction field excluding other research area like medicine and education, which are not relevant for this paper. With this first step, we confirmed research gap since there was no literature review papers dealing with stakeholder characteristics as we proposed. In the second stage we were searching ISI Web of Science and Google Scholar database to find papers dealing with stakeholder characteristics using key words stakeholder identification, stakeholder analysis, stakeholder characteristic and stakeholder attribute, stakeholder interest and stakeholder impact. Paper examination resulted with different concepts for stakeholder analysis and research that use 14 different terms for stakeholder characteristics. Each term is analyzed using scholar papers containing explanations to characterize stakeholders combining with Cambridge dictionary definitions. The analysis resulted with conceptual framework for stakeholder characteristics. Explanations of main constructs of this framework are provided. Framework consists of 13 detected stakeholder characteristics (one is discarded) sorted in four related categories. Framework as final result provides new systematization of stakeholder characteristics by providing list of all detected stakeholder characteristics, which are now properly defined and sorted in categories and thus easier to observe and comprehend.

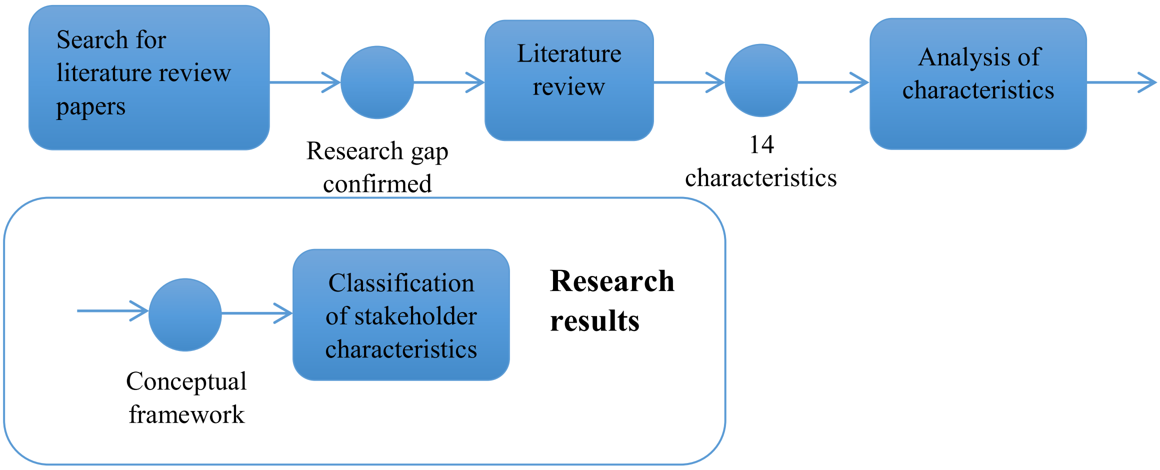

Figure 1 Research methodology

4 Analysis of stakeholder characteristics

4.1 Overview and insight in stakeholder characteristics

In the literature research, we found that scholars do not widely use stakeholder characteristic as a term, but we also found that it is necessary to define what scholars use to describe and define stakeholders. In this paper term stakeholder characteristic comprises every term and expression that can be ascribed to stakeholder and was formerly used to assess and analyze stakeholders. It can be very hard to understand exact meaning of characteristics used by scholars in their papers because they simply do not state any explicit definition of terms they use. Achterkamp and Vos (2008) revealed that 25 of 42 papers dealing with stakeholder identification do not provide any definition of what stakeholder identification is. The same problem occurs with stakeholder characteristics which are often mentioned through various terms (Bourne and Walker, 2005; Olander, 2006; Yang and Shen, 2015). When scholar use a term as ordinary stakeholder characteristic or as variable trying to grade this characteristic, they tend to give them different meaning and value i.e attitude as opinion ranging from totally negative to totally positive (Burcar Dunovic et al., 2015) or attitude as way of behaving ranging from active opposition to active support(McElroy and Mills, 2007). Next paragraphs will provide insight in stakeholder characteristics through explanations of detected 14 terms emphasizing similarities and differences in manner that these terms were used.

4.1.1 Insight in stakeholders attributes

Most of papers acknowledged term *attribute* which (Mitchell et al., 1997) first used to describe constructs of his salience model. Power, legitimacy and urgency become 3 stakeholder attributes and later (Bourne, 2005) presented stakeholder proximity as fourth. Definition of attribute is very similar to definition of characteristic but characteristic as term exceeds scope of attribute and covers wider field of different terms. It is probably the reason why scholars never added more stakeholder attributes rather they listed additional terms to portray project stakeholder and his characteristics. In this paper attribute as term will not be considered as stakeholder characteristics because it has similar meaning as characteristic, thus it is sufficient. Power, legitimacy, urgency and proximity on the other hand will be taken into account as stakeholder characteristics.

Power is the oldest and the most used attribute since it is characteristic that has very long interdisciplinary usage history. Power is ability to make other social actor to do something he wouldn't otherwise do (Mitchell et al., 1997). He explains coercive (force), utilitarian (material, incentive) and normative power while Yuki (2006) states and defines three source groups (types) of power: positional, personal and political and Green and Elfrers (1999) outline 7 forms of power based on these sources i.e connection power (personal with political). Burcar Dunović et al., (2014) states and rates 4 types of power and they are: legal, business, political and social. Many other scholars used power as variable in their models and tools such as power-interest matrix (Olander and Landin, 2005), stakeholder circle (Bourne, 2005) and many others.

Table 1 Various types of power stated in few research papers

Mitchell et al 1997.	*Yukl 1998.*	*Green and Efrers 1999.*	*Burcar et al. 2014.*
Coercive, Utilitarian, Normative	Positional, Personal, Political	Connection (personal and political), Legitimate (position and political), Information (position, personal and political)	Legal, Political, Business, Social

Legitimacy is defined by (Suchman, 1995) as

> *"... a generalized perception or assumption that the actions of an entity are desirable, proper or appropriate within some socially constructed system of norms, values, beliefs and definitions."* (p. 574)

Bourne and Walker (2005) in their work represented tool Stakeholder circle and they didn't include legitimacy as attribute and Yang et al. (2014) included it initially but discarded it as a result of research based on interviews with practitioners. They stated that stakeholder wouldn't be taken into account if they don't possess legitimacy. Nguyen et al. (2009) takes legitimacy into account and his explanation of is:

"...legitimacy reflects the contractual relations, legal and moral rights in relationships between stakeholders and a project." (p. 1133).

Urgency is according to Mitchell et al., (1997) also independent attribute and it is defined as

"...the degree to which stakeholder claims call for immediate attention." (p. 867).

Urgency is based on time sensitivity and criticality, accepted by other scholars, and not questioned to this time.

Proximity is according to Bourne (2005) self-explanatory and ranges from: 4 which is "directly working in a project" to 1 which is "relatively remote from the project". Yang et al. (2014) presented definition of proximity as: " the physical or social distance of a stakeholder to the project, which can be interpreted from four aspects: (1) physical sharing; (2) interest similarity and connection (e.g., suppliers on the value chain); (3) ubiquity (e.g., the public and communities in a highway project); and (4) affinity (e.g., members in the same association)." This paper does not follow proximity definition provided by Yang et al. (2014) because authors consider that is sufficiently narrow characteristic to be divided into smaller constructs.

4.1.2 Stakeholder interests and vested interests

Interest is mentioned a lot but very few definitions are stated and in some papers where interest is discussed it is hardly to fully understand implicitly stated definition of what is interest. Burcar Dunović et al. (2014) and Murray-Webster and Simon (2005) defines it as willingness to engage in project. This is complementary with dictionary definition explaining interest as involvement. Often interest is used as part of power-interest matrix (Newcombe 2003, Oleander and Landin 2005) where interest variable is clearly stating stakeholder involvement in project.

The problem is another term *vested interest* used not to describe stakeholder level of interest rather they provide explanation of their possible gains from project and this is complementary with dictionary definition explaining interest as advantage. Nguyen et al. (2009) stated that stakeholder could be interested from many reason such as legal right, political support, health and safety, which is closer to observing interest as advantage. Mok et al. (2015) state list of 17 interests in mega construction project such as improving international reputation or enhancing infrastructural facilities. His discussion is pointing out on all possible goals and objectives of wider stakeholder environment confirming that some scholars takes vested interest advantage point of view instead of involvement point of view. It can be understood that stakeholder vested interest or to say stakeholder goals and objectives in particular project can be drivers for their level of interest. This paper considers interest and vested interest as two different stakeholder characteristics.

4.1.3 Stakeholder synonyms of attitude, support and position and stakeholder behaviour

Most commonly used concept of stakeholder *attitude* is from stakeholder commitment matrix (McElroy and Mills, 2007) where attitude goes in 5 grades form active opposition to active support. This concept of attitude was used by Nguyen et al. (2009) and Olander (2006) who used term *position*. Comparing this explanation of attitude with one provided by dictionary and used in this paper as referent, it can be seen that this definition implies more than mere attitude because also display level of involvement which is commonly used to describe interest. When scholars uses attitude described by McElroy and Mills (2007) they actually refer to two stakeholder characteristics: interest (active or passive) and attitude (support or opposition). In their paper Bourne and Walker (2005) in engagement step of their stakeholder management processes displayed support-receptiveness matrix where term *support* is used to refer on McElroy and Mills (2007) attitude proving that there are papers using different terms to describe same characteristic.

Scholars who uses the Murray-Webster and Simon's (2005) "Stakeholder cube" which contain 3 characteristic stakeholder power, interest and attitude, describe attitude similar as dictionary definition consider attitude as opinion. The grade of stakeholder attitude goes from totally negative to totally positive clearly stating opinion and nothing more while interest play role in defining whether stakeholder is active or passive. Yang and Shen (2015) on the other hand, considered stakeholder behavior in their paper rather than attitude, and they stated four types of behavior: cooperative potential, competitive threat and opposite position, and neutral attitude. Difference between behavior and attitude originates in dynamicity aspect because attitude from the most common point of view represent static characteristics in terms of action (not in terms of possible change) and behavior implies action and thus it is dynamic characteristics. Behavior as stakeholder characteristic have same the goal as attitude and it is to define stakeholder opinion and possible direction of stakeholder future actions. It could be said that behavior in most occasion depends on stakeholder attitude.

4.1.4 Stakeholder impact and influence

As we mentioned earlier, narrower point of view on stakeholder seeks to define only those stakeholders that are most important to our project and some scholars (Nguyen 2009, Oleander 2006) prioritize stakeholder by determining their overall *impact and influence*. Discussion of impact and influence is here directed to examine if it is necessary to characterize stakeholder with these two similar characteristics or they are too similar and only one of them is sufficient. If we follow definition it can be said that impact implies direct pressure that stakeholder has on project and influence implies overall direct and indirect power that project stakeholder have over project. Oleander's (2006) Sii (Stakeholder impact index) is based on three attributes: first one is attribute taken from (Mitchell et al, 1997), vested interest-impact index taken from (Bourne, 2005) and position (attitude) taken from (McElroy and Mills, 2007). Nguyen et al. (2009) criticized Oleander's (2006) model and tried to improve it by adding stakeholder *knowledge* as characteristic and he provide new formula to calculate impact because he argued that it is wrong to include impact and power as characteristics of equal importance so he placed power as driver of impact. Both impact and influence are observed in this paper as stakeholder characteristic

4.1.5 Seldom or potential stakeholder characteristic

Stakeholder salience model (Mitchell et al, 1997) is a classification model in which salience was based on possession of one, two or all three stakeholder attributes that was offered in their model (power, legitimacy and urgency). Attributes presented in this paper became for many other scholars center point of stakeholder analysis and characterization but they were used as variables and not as mean to classify stakeholder, while salience as characteristic was not taken into account. Salience was mentioned later by Aaltonen et al. (2008) in context of stakeholder strategies to gain more salience in project. Salience can be ascribed to stakeholder and its meaning is clear but the problem is that it is perhaps too connected with project manager perception of stakeholder. Nevertheless, at this point it is included as characteristic.

Stakeholder *knowledge* is brought by McElroy and Mills (2007) which graded it from full awareness to total ignorance and Nguyen et al. (2009) used it as variable to calculate stakeholder influence. This characteristic is definitely different from most of other characteristics mentioned and in this paper it will be considered as one because main goal is to portray all characteristics and it has its place as one based on fact that it is different from others. It could be used to help project manager to be more objective and to give salience to those who are really the most important.

Stakeholder *commitment* which is characteristic taken from psychology research area is presented by (Leung et al., 2004)and it can be considered as stakeholder characteristic which can help to determine future stakeholder behavior.

4.2 Defining stakeholder characteristic

Important step of analysis is defining the basic constructs of analysis or in this case stakeholder characteristics. In previous paragraph, we provided insight in most common practice of using 14 detected stakeholder characteristics. It can be seen that even though scholars followed same basic theoretical concepts they gave those terms different meaning or they used them in different manner. As dictionary provides several meaning for each term, we represented in Table 2 those definitions that were seen as the most precise and accurate taking it as formal explanation and starting point of future considerations

Table 2 Selected Cambridge dictionary definition of stated terms representing stakeholder characteristics

Attribute	Interest	Vested interest	Attitude	Behavior	Impact	Influence
a quality or characteristic that someone or something has	(Involvement) - the feeling of wanting to give your attention to something or of wanting to be involved with and to discover more about something	a strong personal interest in something because you could get an advantage from it	(Opinion) **-** a feeling or opinion about something or someone	a particular way of acting	a powerful effect that something, especially something new, has on a situation or person	the power to have an effect on people or things, or a person or thing that is able to do this
Salience	**Knowledge**	**Power**	**Proximity**	**Urgency**	**Legitimacy**	**Commitment**
the fact of being importa nt to or connected with what is happening or being discussed	the state of knowing about or being familiar with something	(Control) - ability to control people and events, strength	the state of being near in space or time	needing immediate attention	the quality of being legal or the quality of being reasonable and acceptable	a willingness to give your time and energy to something that you believe in, or a promise or firm decision to do something

Attribute is excluded as stakeholder characteristics because it is very similar to stakeholder characteristic and it is sufficient.

5 Conceptual framework for stakeholder characteristic

As it is already mentioned all of these analyzed terms and expressions, which have been used to describe stakeholder, are in this paper observed as stakeholder characteristics. Most of scholars divides stakeholder analysis into few steps and stakeholder identification and assessment are most common steps in which stakeholder are characterized. These characteristics need to be systemized in order to move toward making stakeholder analysis in construction project clearer and more operational. In this paragraph conceptual framework for stakeholder characteristics will be provided in order to synthesize numerous stakeholder characteristics that were unconsolidated.

As a result of this desk research four categories are provided as main constructs of conceptual framework for stakeholder characteristics. These categories have broad but still distinguishable features. Also as this research is based on previous work of scholars dealing with stakeholder analysis explanation in Table 3 also offers common way that characteristics were used and this provides additional explanation of why this categories should be observed separately from one another.

Table 3 Explanation of main constructs of conceptual framework for stakeholder characteristic

	Categories of stakeholder characteristics			
	Basic characteristic	**Operational characteristic**	**Complex characteristic**	**Perceptual characteristic**
Main features of categories of stakeholder characteristics	• is not based on other characteristics	• based on basic characteristics • conceived to be used as variable • having clear distinction from one another	• based on basic or operational characteristics • conceived to be calculated as sum of operational characteristics	• depends on subject perception • can be connected to one or more basic, operational or complex characteristics
Indicators derived from former concepts stated in literature	• usually part of stakeholder identification or stakeholder assessment	• usually part of stakeholder assessment	• usually part of more complex stakeholder analysis	• mentioned but rarely part of any classification

These categories have features that make them distinctive from one another, but they only have two or three features because they portray certain concepts that are connected to already established stakeholder characteristics. This conceptual framework is result of synthesizing and systematizing many different concepts used to portray stakeholders and this categories are tailored to these detected stakeholder characteristics. Intention of this framework is to provide easier and comprehensible way to characterize stakeholders. It could be said that goal is same as any other classification model or framework and this is to synthesize different views and understandings and provide way to sort observed subjects in brackets.

Features of basic characteristics are stated in Table 3 and it could be said that they provide basic information on stakeholders. That information can be collected using methods for gathering information about project and his stakeholders. Operational characteristics are those usually assessed through stakeholder analysis model i.e power-interest-attitude matrix. They represent characteristics that are most commonly used as variables having its value range. In addition, important feature, which separate them from basic characteristics is that they are distinctive from one another allowing them to be operational because they can be observed as independent variables. Complex characteristic are those aiming to provide us some information that are very comprehensive and hard to assess without some form of calculation using operational characteristics as main variables. They can give us some crucial information on stakeholder future actions that could affect project on large scales. Perceptual characteristic are those, which are not usually observed as characteristics but are mentioned in papers as way to describe stakeholders. Probably this is due to fact that they are even less objective then other characteristics and harder to assess it or grade it in any way. Perceptual characteristics does not have direct link to characteristics from other categories but one can assess them based on some basic, operational or complex characteristics or it can be assessed based on characteristics from all 3 categories.

Taking into account abovementioned characteristics detected in numerous papers, this paper provides conceptual framework Figure 2 to sort these particular characteristics in explained categories.

In **basic characteristic** category there are 5 characteristics:

- proximity
- urgency
- legitimacy
- knowledge
- vested interest,

Operational characteristics that are suitable to be used as variables in stakeholder analysis and should be based on basic characteristics are:

- interest
- attitude
- power

Complex characteristics meant to give overall sum of operational and basic characteristics are:

- impact
- influence

Perceptual characteristics that can give useful information but depends on other characteristics and perception of project manager are:

- salience
- commitment
- behavior

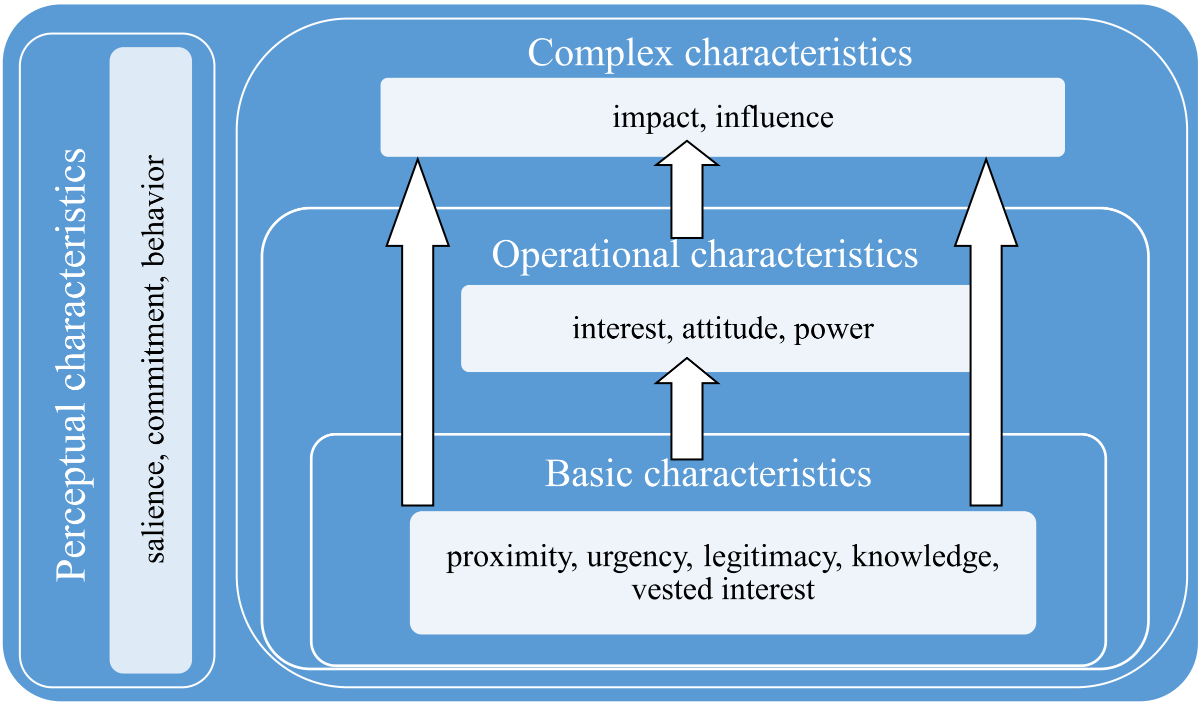

Figure 2 A conceptual framework for stakeholder characteristics

Very important information that can't be observed as stakeholder characteristics but must be included in stakeholder analysis are *project role* and *position* which must be stated for internal stakeholders. For external stakeholder is it good to determine some new roles and positions in order to better understand their actions in project.

6 Future development of research and limitations

This framework need to be further developed to become more useful to scholars and practitioners. Development could go in two different streams. First is to further develop every category by providing more features and more detail descriptions giving project manager more sense of stakeholder analysis based on these categories. Second and more important is to find links between those categories and provide direct descriptions of how to assess, calculate and determine operational and complex characteristics and how to identify basic and perceptual characteristics.

- For operational characteristics, it is necessary to link particular basic characteristics to operational by determining drivers for power, interest and attitude and to provide range of values for each characteristic.
- For complex characteristics it should be determined on what basis do we calculate stakeholder impact and influence and is it necessary to have both of those characteristics.
- For perceptual characteristics, it should be determined whether to develop them as variables or as directions and indicators for other characteristics.

Beside further development of this particular conceptual framework, some other gaps and needs for further research are detected. One gap that needs to be addressed is importance of particular characteristic for particular project phase. This could be very useful to make stakeholder management more efficient. Second gap is linked to project life cycle model of stakeholder characteristics aiming on need to emphasize and examine dynamic aspects of characteristics that are changing through project phases and thus overcome problem of ascribing characteristics that are unnecessary for particular project phase.

Limitation of this conceptual framework lies mostly in its scope and level of elaboration due to paper limitations. This framework could be also empirically examined and verified including some project managers and other experts in process in order to refine it and add more practical dimension to it. This paper did not take into account stakeholder interrelationships, which some scholars include in process of stakeholder assessment. Although stakeholder interrelationships are not in accordance with this particular topic of stakeholder characteristics some scholars may think otherwise. Almost all stakeholder characteristics was derived from papers falling under project and construction management research area thus it is limited to this particular areas. Taking into account general management, business and other areas where stakeholder characteristics are also being examined and taking into account psychology research area that observes attitude, interest and knowledge of stakeholders it is possible that it could bring some improvement to this topic and conceptual framework designed in this paper.

7 Conclusion

Analysing stakeholder identification and analysis concepts in literature we found that project stakeholders are described in very different ways and that characteristics are not used consistently. For that reason, we analysed concepts existing in the literature in order to analyse the meaning of terms used for describing stakeholders and provided overview of all detected stakeholder characteristics. As result, we proposed the conceptual framework of stakeholder characteristics, which classifies them into four categories: basic, operational, complex and perceptual. Interesting finding is that concepts found in literature use different classes of characteristics and the most interesting is that we found that power is not basic attribute as it was considered. Also, different authors use the same term for different characteristics without clear explanation of its meaning which is confusing for readers and can lead to taking into account the same characteristics twice in the same analysis. This framework contributes to clarification of variety stakeholder characteristics used for stakeholder research and analysis and provides framework for future research of stakeholder characteristics. There is need to further develop this conceptual framework and this paper provides suggestions on how to direct this development.

Literature

Aaltonen, K., 2011. Project stakeholder analysis as an environmental interpretation process. Int. J. Proj. Manag. 29, 165–183. doi:10.1016/j.ijproman.2010.02.001

Aaltonen, K., Jaakko, K., Tuomas, O., 2008. Stakeholder salience in global projects. Int. J. Proj. Manag. 26, 509–516. doi:10.1016/j.ijproman.2008.05.004

Achterkamp, M.C., Vos, J.F.J., 2008. Investigating the use of the stakeholder notion in project management literature, a meta-analysis. Int. J. Proj. Manag. doi:10.1016/j.ijproman.2007.10.001

Bourne, L., 2005. Project Relationship Management and the Stakeholder Cyrcle. Dr. Proj. Manag.

Bourne, L., Walker, D.H.T., 2005. Visualising and mapping stakeholder influence. Manag. Decis. 43, 649–660. doi:10.1108/00251740510597680

Burcar Dunovic, I., Colombo, R., Mancini, M., Littau, P., 2015. A case study approach to megaprojet stakeholder analysis through sustainability issues, in: Proceedings of IRNOP 2015.

Burcar Dunović, I., Łukasiewicz, A., Brookes, N.J., 2014. In pursuit of a framework to explore stakeholder influence in megaproject. People, Build. Environ. 2014, an Int. Sci. Conf.

Clarkson, M.B.E., 1994. A risk based model of stakeholder theory, in: Proceedings of the Second Toronto Conference on Stakeholder Theory.

Freeman, R.E., 1984. Strategic management: A stakeholder approach, Freeman Edward. doi:10.2139/ssrn.263511

Jepsen, A.L., Eskerod, P., 2009. Stakeholder analysis in projects: Challenges in using current guidelines in the real world. Int. J. Proj. Manag. 27, 335–343. doi:10.1016/j.ijproman.2008.04.002

Karlsen, J.T., 2002. Project stakeholder management. Eng. Manag. J. 14, 19–24. doi:doi:10.1201/b15011-20

Leung, M.-Y., Chong, A., Ng, S.T., Cheung, M.C.K., 2004. Demystifying stakeholders' commitment and its impacts on construction projects. Constr. Manag. Econ. 22, 701–715. doi:10.1080/0144619042000300736

Littau, P., Jujagirl, N.J., Adlbrecht, G., 2010. 25 Years of Stakeholder Theory in Project Management Literature (1984-2009). Proj. Manag. J. 41, 17–29.

McElroy, B., Mills, C., 2007. Managing stakeholders, in: Turner, R.J., Sinister, S.J. (Eds.), Gower Handbook of Project Management. Gower Publishing Limited, p. 757–75.

Mitchell, R.K., Agle, B.R., Wood, D.J., 1997. Toward a theory of stakeholder identification and salience: Defining the principle of who and what really counts. Acad. Manag. Rev. 22, 853–886. doi:10.5465/AMR.1997.9711022105

Mok, K.Y., Shen, G.Q., Yang, J., 2015. Stakeholder management studies in mega construction projects: A review and future directions. Int. J. Proj. Manag. 33, 446–457. doi:10.1016/j.ijproman.2014.08.007

Murray-Webster, R., Simon, P., 2005. Make sense of stakeholder management with sensible stakeholder mapping.

Newcombe, R., 2003. From client to project stakeholders: a stakeholder mapping approach. Constr. Manag. Econ. 21, 841–848. doi:10.1080/0144619032000072137

Nguyen, N.H., Skitmore, M., Wong, J.K.W., 2009. Stakeholder impact analysis of infrastructure project management in developing countries: a study of perception of project managers in state-owned engineering firms in Vietnam. Constr. Manag. Econ. 27, 1129–1140. doi:10.1080/01446190903280468

Olander, S., 2006. External stakeholder analysis in construction project management. Lund University.

Olander, S., Landin, A., 2005. Evaluation of stakeholder influence in the implementation of construction projects. Int. J. Proj. Manag. 23, 321–328. doi:10.1016/j.ijproman.2005.02.002

Parkin, B.D.J., 2011. Planning networks for cycling: relevant human factors and design processes 164, 85–93.

Stoney, C., Winstanley, D., 2001. Stakeholding: confusion or utopia? Mapping the conceptual terrain. J. Manag. Stud. 38, 603–626. doi:10.1111/1467-6486.00251

Suchman, M.C., 1995. Managing Legitimacy: Strategic and Institutional Approaches. Acad. Manag. Rev. 20, 571–610. doi:10.5465/AMR.1995.9508080331

Turner, J.R., Zolin, R., 2012. Forecasting Success on Large Projects: Developing Reliable Scales to Predict Multiple Perspectives by Multiple Stakeholders Over Multiple Time Frames. Proj. Manag. J. 43, 87–99. doi:10.1002/pmj

Walker, D.H.T., Bourne, L.M., Shelley, A., 2007. Influence, stakeholder mapping and visualization. Constr. Manag. Econ. 26, 645–658. doi:10.1080/01446190701882390

Webler, T., Tuler, S., 2000. Fairness and competence in citizen participation: Theoretical reflections from a case study. Adm. Soc. 32, 566–595. doi:10.1177/00953990022019588

Yang, J., Shen, G.Q., Bourne, L., Ho, C.M., Xue, X., 2011a. A typology of operational approaches for stakeholder analysis and engagement. Constr. Manag. Econ. doi:10.1080/01446193.2010.521759

Yang, J., Shen, G.Q., Ho, M., Drew, D.S., Xue, X., 2011b. Stakeholder management in construction: An empirical study to address research gaps in previous studies. Int. J. Proj. Manag. 29, 900–910. doi:10.1016/j.ijproman.2010.07.013

Yang, R.J., 2014. Stakeholders' Attributes, Behaviors, and Decision-Making Strategies in Construction Projects: Importance and Correlations in Practice. Proj. Manag. J. 45, 74–90. doi:10.1002/pmj

Yang, R.J., Shen, G.Q.P., 2015. Framework for Stakeholder Management in Construction Projects. J. Manag. Eng. 31, 1–14. doi:10.1061/(ASCE)ME.1943-5479.0000285.

Yuki, 2006. Leadership in Organizations. J. Chem. Inf. Model. 53, 1689–1699. doi:10.1017/CBO9781107415324.004

A Comparison between Early Contractor Involvement (ECI) and Project Alliancing Delivery Systems

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Abstract:

The advantages of integrating construction knowledge into design development have long been recognised by the construction industry. Early Contractor Involvement and Project Alliancing are two recent relational contracting labels that have been largely utilised in the Australian construction industry for the public and private infrastructure projects over the last few years. Both models introduce the project delivery contractor's expertise and advice much earlier in the project lifecycle than has traditionally been the case. Although both models are classified as collaborative form of procurement, there are some substantial different requirements in project management behaviours and working relationships between these models. This paper contributes to this area by comparing these two models through in depth semi-structured interviews with experts at the senior management level who have been involved in ECI and Alliances projects and played significant roles in the project process. The findings suggest that the change in relationship resulted by transitioning from collaborative approach at the early stage into a traditional type of working environment; gaining greater control through trust, price certainty and contract formality together in different stages of the project; lesser extent and length of senior level managers involvement in the project; and reluctance of contractor to contribute in innovation before the construction stage, are the key project management behaviours and working relationship differences when ECI is adopted for a project in comparison with Project Alliancing.

Keywords: *Australia, Early Contractor Involvement, ECI, Project Alliancing, Relationship Based Procurement.*

1. Introduction

Complex projects require a high degree of integration between design, construction, and operations groups. The relationship based contracting strategy has been found to be more successful than the conventional approach in effecting integration between the diverse groups involved in delivering projects due to the fundamental principles of collaboration and cooperation (Love *et al.*, 2010). It is generally agreed that relationship based procurement (RBP) approaches tend to generate collaborative relationships between the parties involved to ensure that the purpose of the project fits strategically with the owner’s organisation. However, despite the wealth of studies explaining the differences between RBP approaches contractually, majority of the literature classifies these approaches under collaborative category as opposed to the traditional segregated delivery systems (Walker *et al.*, 2000, Masterman, 2002, Walker and

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Hampson 2003). The reason for this classification is perhaps the similarity of the project management behaviours, working relationship and the ambience required by collaborative form of procurements (Walker and Lloyd-Walker, 2014). Nonetheless, beside the contractual mechanism, there are some substantial different requirements in project management behaviours and working relationships between RBP models, which distinguish them from one another. Lack of knowledge about these differences may cause a great deal of confusion when clients consider using one of the RBP methods. Knowing the differences can help offset this confusion and understand what is expected of teams and reasons why one procurement form may be suitably deployed over another (Walker and Lloyd-Walker, 2012). It is also important to maintain the behaviour required for that type of delivery method throughout the project as different delivery approaches require different set of individual and organisational behaviours. Therefore, understanding the differences between various types RBP methods can be useful for the project participants to help them to evaluate their individual and organisational behaviours to ascertain that they are adequately capable to adopt alternative types of collaborative-based approaches. This paper aims to contribute in this area to highlight the different project management behaviours and working relationship between two particular relational contracts namely Project Alliances and Early Contractor Involvement (ECI) that are widely adopted in Australia. Influenced by the aim of this study, the principal research question is *“what characteristics of an Early Contractor Involvement (ECI) differ from Project Alliancing?”*

This paper is structured in four sections. In the next section, the background of the study is outlined to explain the ECI and Project Alliancing *status quo*. This is followed by a brief discussion about the adopted research methodology for conducting this research. The main findings of the study are presented and finally the concluding remarks are providedEffective communication

2. Background

The type of project should determine at what stage of the project lifecycle the contractor should get involved. For simple projects where the owner has very specific ideas about the project scope, early involvement of contractor may lead to additional costs as the contractor inputs do not conform to the client’s specific outlines. On the other hand, if the clients do not have a good understanding of their needs, the contractor’s efforts will not help the client as the developed ideas will not be aligned with the client’s expectations (Walker *et al.*, 2000). In addition, despite the numerous benefits that involvement of contractor at the early stage of project can offer to the project and participants, if the contractor gets engaged too early, there would be a risk that they do not provide their best resources including human and knowledge assets. Late involvement of contractor, when the contractor input is essential, would also inhibit opportunities for innovative solutions, constructability, and health and safety planning into design (Edwards, 2009, Mosey, 2009). It is, therefore, essential to engage the contractor at the right stage of the project in order to enhance the benefits of their involvement.

2.1. Project Alliancing and ECI

Project Alliancing and ECI are two recent relational contracting labels that have been largely utilised in the Australian construction industry for the public and private infrastructure projects over the last few years (Whitehead, 2009, MacDonald *et al.,* Walker and Lloyd-Walker, 2012) Both contractual arrangements introduce the project delivery contractor's expertise and advice much earlier in the project lifecycle than has traditionally been the case in an effort to generate value by ensuring that the project is effectively defined and designed when the available information is limited (Walker and Lloyd-Walker, 2012). Originated in the UK in 1998 and introduced later to Australia in 2005, ECI is a two-stage contractual model in which the client appoints construction professionals early in the project development process through a non-price based selection. Before appointing the contractor the employer appoints a Probity Advisor (PA) and Independent Estimator (IE) on the basis of project value or risk to act as a consultant to help client identify the need and objectives for a project, rates, overheads, margins; prepare procurement documents; and assist clients with the process of selecting a contractor for a contract. The PA and IE will be retained by the employer, throughout the contract, to act as client advisor and supervisor (Agency, 2004, Roads, 2009). The contractor is then appointed on the basis of their track record and availability, understanding of the project and quality of new ideas (Laursen and Myers, 2009). The contractor is selected before the statutory procedures have been implemented and when the proposed project may be little more than a line on a plan. The first stage of the process is “Design Development” in which the design progresses from a concept to a preliminary design covering around 70% complete design to a point where a price for the final design and construction can be agreed between parties. The second stage is “Design and Construction” which is completion of detailed design and construction. Once the contractor has been selected, a separate contract for each phase of the process is signed.

Since the contractor’s responsibilities are limited to only preliminary design completion during stage 1, the majority of risks are assumed by the client, while stage 2 is a typical risk transfer contract from the client side to the constructor. For stage 1, the contractor is reimbursed for the time of its personnel and designers at the rates contained in the tender on an "open book" basis. Once the client obtains all approvals and acquisition of necessary land, the contractor is requested to submit a stage 2 offer including Risk Adjusted Price (RAP) to complete the works. The methods of payment for the RAP can be a lump sum, a schedule of rates with provisional sums, or a combination of both. If the stage 2 offer conforms to the client’s requirements and budget, the offer is accepted and General Conditions of Contract and Brief are amended as necessary. The contractor then becomes responsible for the completion of the design, documentation and construction of the project. In the event of the offer being rejected, the contract may be terminated and the detailed design is completed by either the current or another designer and the construction is undertaken by another contractor through an open market tender process under a construct-only contract (Roads, 2009).

Project Alliancing agreement normally starts with appointing an Alliance Facilitator when the owner made the decision to adopt an alliance. The Alliance Facilitator consists of skilled alliance experts who provide high level external facilitation and coaching services and facilitate the establishment and implementation of successful alliance culture management program (Ross, 2003). The owner alongside with the Alliance Facilitator selects the Non-Owner Participants (NOPs). The process of scope development and target price formulation is prepared by the collaboration of the owner and the NOPs in an integrated team. Upon the approval of the owner, commercial incentives including gain/pain mechanisms are established and the project proceeds to the delivery phase where the owner and the NOPs work together in an integrated team to deliver the project. Project alliance operates as virtual organisation performing all of the functions required to deliver a project including procuring all goods and services required to deliver the project. Under a project alliance, risks and responsibilities are shared and managed collectively with equitable sharing of the pain or gain as opposed to a traditional form of contract in which risks are generally allocated to the party considered best able to manage them (The Secretary Department of Treasury and Finance, 2006).

2.2. Comparison between ECI and Project Alliancing contractual process

Generally, both Alliancing and ECI contracting strategies use a relational approach during the front end phase where the scope of project and preliminary planning is developed. However, the use of a relational approach during the front end does not necessarily lead to the use of such an approach during detailed design and execution phases (Hobbs and Andersen, 2001). With alliancing, the contract is structured around a coalition of firms that form separate virtual organisation responsible for delivery of the project from front end phase throughout the detailed design and delivery phase. Under an ECI, despite the fact that participants work together collaboratively during the front end phase, they keep their own identity.

In terms of contractual arrangement, only one agreement governs the entire project from the project definition to the delivery phase with a Project Alliancing whereas the contractual arrangement with an ECI consists of two separate phases; the first phase is a relational oriented type of contract similar to a Design Alliances (DA) for the pre-construction phase and a strictly traditional hard dollar lump sum type of contact for the detailed design completion and construction phase. Alliancing agreement focuses on problem-solving within a no blame setting. In other words, the issue of "no disputes" is an inherent feature of an alliance contract making all project participants responsible for resolving any disputes that arise during the project and only in the ,event of "wilful default" a participant has an express legal cause of action against another participant under the terms of the agreement (Abrahams and Cullen, 1998). The nature of the conditional preconstruction phase agreement in the context of contract theory embedded in the ECI model is the key difference to the alliancing approach. Some authors see this as the weakness of ECI framework as it breaks the continuity of the contractual system and requires two separate deals to be concluded (Walker *et al.*, 2000, Mosey, 2009). On the other hand, some others argue that all governments' authorities have not embraced that alliancing for various reasons the chief among which are concerns over demonstrating value for money and having Target Outturn Cost instead of a lump sum contact price. Hence the use of ECI model is preferred since it follows a collaborative approach without moving radically from the traditional form of contracts (Swainston, 2006, Edwards, 2009)

Mosey (2009) in his book "Early Contractor Involvement in Building Procurement" suggests that standardised form of building contract for the all phases of the projects with high degree of uncertainty appears to fail to do the whole job that a contract can and should do. Formulating the contract is based upon the assumption that complete project information is available at the point when the formal contract is created which is not the case when the uncertainty in the construction phase presents. This shortage can be seen as the reason for a need for a new type of contract compromising two-stage procurement governing the pre-contraction and construction phases. Finally, the gain/pain share mechanism is a key element associated with the alliancing contact that draws a distinctive line between this contractual arrangement and ECI.

3. Research Methodology

To answer the research question, the research employs a qualitative approach as advocated for the study of the complex nature of the phenomenon when the objective of the research is to develop new techniques and processes (Creswell, 2008) based on understanding and describing the phenomena from the participants' position (Flick, 2009).

The choice of techniques for collecting data is highly influenced by the strategy adopted for conducting the research. The data was collected through in-depth semi-structured interviews with fourteen key managers and experts at the senior management level who have been involved in ECI and Alliances projects and played significant roles in the project process and thus have the potential to provide high quality data with deep insights from different angles into the research problem being explored. The strategy for recruitment of participants for this study was driven by the principles of 'purposive sampling' advocated by Corbin and Strauss (1998). The purposive sampling strategy seeks involvement of participants who could contribute to generating the concepts being explored. Targeted participants were involved in the construction industry within Australia and those who were involved in an ECI and Alliancing schemes. The participants were in the infrastructure departments of public sector client organisations including state government departments and one leading professional consultant organisation specialising in the establishment and delivery of collaborative contracts for complex projects and programs. According to Gibb and Isack (2001) the regulated infrastructure clients are more knowledgeable about the construction process and standard components than other private or public clients. Since all of the participants in the client organisation had experience with ECI and Alliances, the answers could have been biased from a wish to either promote or discourage the delivery strategies. In order to mitigate this issue and reduce the possibility of responses that skew the results, two participants from a private professional consultant company that provided strategic commercial advice, education and facilitation in all aspects of Alliancing and collaborative contracting, were also selected to ensure the reliability of the responses from the client organisations. Table 1 provides details of the interviewees. Interviews helped to document individual attitudes, feelings, beliefs, experiences and reactions. With semi-structured interviews, the researcher was able to probe or ask detailed questions about the respondents' situations, and not adhere only to the interview guide. In addition, the researcher could explain or rephrase the questions if respondents were unclear about the questions.

Table 1: Details of interviewees

Ref	Department	Role	Notes and Comments
P1	State Program Office-Program Delivery And Operations	Director of Programs and Specialist Delivery	Involved in delivery of projects, mainly transport industry, for about 30 years
P2	State Program Office-Program Delivery And Operations	Director of Program Services	Working for over 25 years including delivering marine projects and major road projects
P3	State Program Office-Program Delivery And Operations	Assistant Director in Infrastructure Management and Delivery	Worked in construction for over 30 years mainly for major infrastructure projects
P4	State Program Office-Program Delivery And Operations	Construction Team Leader	Worked for the department for more than 20 years and performed mostly consulting role with designers and contract administrators.
P5	North District Office in Program Delivery and Operations Branch of the Department	Principal Engineer (Civil)	Working over 40 years mainly in road construction looking after contracts and building major infrastructure

P6	State Program Office-Program Delivery And Operations	General Manager	Working for more than 20 years in traffic and transportation
P7	Contracting Services	General Manager	Working in the department for 33 years and has worked for various Design & Construct sections
P8	Rail at Public Transport Services	Senior Contract Manager	Working for 16 years in civil engineering and performed as a contract manager within the department
P9	Rail Revitalisation Program	Project Director	Worked in the major capital projects delivery area for 16 years including revitalization of the metro and suburban rail net way
P10	Network Safeguard and Development	General Manager	Working for more than 20 years for the department in the contract management and project management
P11	Infrastructure Delivery Directorate	Project Director	Worked for the department for about 20 years and been involved in a number of major road works contracts including Alliance-type contracts and an ECI contract
P12	Department of major projects	Project Manager	Working for more than 20 years for the department including large contracts projects
P13	Specialist consultant	Founder of the organisation	Over 30 year experience in RBP methods
P14	Specialist consultant	Senior Consultant and Partner	Working in management consulting for 30 years

There are six states in Australia including Victoria (VIC), New South Wales (NSW), Queensland (QLD), South Australia (SA), West Australia (WA) and Tasmania with their own state constitution dividing the state's government into the same divisions of legislature, executive, and judiciary as the federal government. The organisational chart of infrastructure department of each state was obtained and approval to conduct the interview within the department was sought from senior executives through emails. Four out of six participation requests were approved including states of VIC, SA, QLD and WA; and one professional consultant organisation in VIC also confirmed its interest to be participating in the research. Once the approval has attained, a list of candidates and their contact details who were interested in precipitating in the research study was obtained. Invitational emails were sent directly to the participants or to their secretary in order to confirm their availability and consent. Each interview took approximately 45 minutes. It was recorded and then transcribed. This produced approximately 150 transcription pages in the text format. All interview texts were uploaded to the latest version of qualitative data analysis toolkits, QSR, NVivo 10 to organise and assist with the analysis of contents from interviews.

4. Research Findings

Findings from the analysis indicate that both ECI and Project Alliancing own the essence of partnering and thus they are very similar in terms of the type of soft skills, personality and attitude that the project participants including the client (or the project owner) and contractor (or NOP) should possess. ECI follows the Project Alliancing principles where both methods create a working ambiance characterised by the cooperation and collaboration between project parties. The only different is seen at the hard aspects including risks arrangements, contractor selection process, contractual obligation and compensation mechanism. However, the contractual transition from the pre-construction stage to the construction stage impacts the working relationship and the quality of collaboration that has been built at the early stage of project. The findings of this study suggest a number of distinctive characteristics of ECI, which are substantially different from Project Alliancing. The following sections provide the result of the findings accordingly:

4.1. Change in working relationship

One of the fundamental characteristics of Alliancing is sharing of information, knowledge and skill in a trust-based environment where a non-adversarial culture dominates (Ross, 2003). In such environment, contractors are willing to share their knowledge and experience in an effort to deliver the project with reduced project cost or reduced overruns of time and cost which will be eventually of their own benefits. Such performances are attributed to alleviating scope definition and planning problems leading to better understanding of project objectives. However, the change in relationship protocol is one of the ECI characteristics resulted by transitioning from collaborative and open-book approach at the early stage into a more traditional type of working environment. Team's understanding of the behavioural and contractual requirements in both phases is the key to an effective ECI.

Therefore, despite the fact that managing risks are undertaken collectively in an ECI arrangement, understanding that which party is contractually obliged to deal with the risks, if eventuated, is essential. Since there is no pain/gain share mechanism in an ECI method, all team members should be aware of the risks and recognise their team's responsibility for the risks that they are contractually obliged to deal with.

4.2. Gaining different forms of control

Gaining control on the entire project process is found as a distinctive characteristic of the ECI procurement approach differentiating it from project Alliances in which a collaborative approach is utilised throughout the project.

The decision to adopt an ECI is made in a condition when the project encounters rather high complexity with prediction of noticeable alterations. In the beginning of the project, clients are not able to fully measure goal attainment and they do not know the appropriate actions to achieve the goal. In such circumstances, the early collaboration of contractor in the design development is advocated (Abrahams and Cullen, 1998, Walker and Hampson 2003, Walker and Rowlinson, 2008, Ng *et al.*, 2012) to obtain the advantages and synergies of cooperative relationships through the early establishment of trust (Aulakh *et al.*, 1996). However, when the project complexity is not realised too high and the uncertainty associated with the project can be managed and unfolded, clients are more likely to choose a procurement method enabling them to gain greater control over the target price and the entire contractual process in an attempt to absorb uncertainty and avert dependency risks (Van der Meer-Kooistra and Vosselman, 2000, Dekker, 2004, Emsley and Kidon, 2007).

This is evident that the use of ECI enables the client to gain all forms of control through trust, price certainty and contract formality together in different stages of the project. At the front-end of project when defining the project scope is difficult due to the uncertainty associated with the project and the lack of necessary knowledge and skills to utilise appropriate actions to achieve the goal, facilitating trust and commitment is the most efficient instrument (Das, 2001) within establishing a collaborative relationship between client and contractor. During the detailed design and delivery stage, the client is then able to employ appropriate methods to achieve the goal. However, the client has limited knowledge to monitor the transformation process, measuring and monitoring the results or outcomes produced by the contractor. The use of a formal contract with more comprehensive contractual specifications and managerial arrangements, is favourable since it can offer the client greater control over the final price and the process (Das, 2001). More specific clauses in a formal contract make it more legally binding with higher enforcement power (Woolthuis *et al.*, 2005). Higher control over price and process are obtained when the transaction is governed by authority. Therefore, clients are more likely to gain control over price and process when the contractual process and the target price are governed by a standardised or formal contract; i.e. D&C or C only (Eriksson and Laan, 2007).

4.3. Resource engagement

The need for engagement and strongly commitment of senior level managers excessively during the course of project is one of the challenges that clients face when using Alliancing form of contract (Cowan and Davis, 2005). Alliancing requires the contractor to be involved throughout the whole project from the definition phase to the execution phase. This arrangement needs a commitment of all parties to common objectives and outcomes. ECI contract seems to be less resource hungry due to the transitioning phase from an alliance-oriented approach to a conventional risk transfer form of contract. Although availability of senior staff for critical decision making is vital due to the novelty of many aspects of the approach in an ECI project (Scheepbouwer and Humphries, 2011), the extent and length of such involvement in comparison with the Alliancing framework is notably less.

4.4. Contribution of contractor in innovation before the construction stage

Facilitating innovation by project participants is one of the common characteristics between Alliancing and ECI. Projects that require high innovation to be completed successfully, suit Project Alliancing or ECI (Chen *et al.*, 2012, Rahmani *et al.*, 2016, Young *et al.*, 2016). However, contribution of contactor in innovation before the construction stage in ECI contracts is challenging.

One of these reasons for the reluctance of the contractors to introduce innovation before the construction stage is the concern about adequate regulations to prevent other competitors to run off with their ideas and the intellectual property issues of their contributions to the design. As a result, their contributions to the design, the degree of commitment, integration, motivation, skill, teamwork and trust that the contractor is supposed to bring to the project is undermined. Choosing a suitable project, client and contractor for an ECI, and ambiguity in defining the role of consultants and their relationship between client and contractor throughout an ECI contract also can be seen as the challenges in using an ECI from the consultant's point of view (Bundgaard *et al.*, 2011).

5. Concluding Remarks

The both Project Alliancing and ECI contractual models are considered as relationship-based procurement method, which is not only about systems and methods but also essentially about people, enabling them to operate more efficiently, effectively and economically.

However, the key elements of ECI and Project Alliancing distinguish these models from other relational delivery process. Whilst the fundamental components of all of them lie in the formalised mutual objectives; agreed problem resolution methods; and an active search for continuous measurable improvements, in reality they have little similarities with the key principles of ECI and Project Alliancing. Since the ECI framework possess both relational and transactional attributes, it shares many characteristics with Project Alliancing, especially during the pre-construction phase where the arrangement is similar. Nevertheless, the transitional issue from a pure relational environment during the preconstruction phase into a formal traditional environment in the construction phase creates different sort of ambiance. Despite the general agreement on the improvement of quality and innovation when an ECI is adopted, the necessary collaborative culture is not present in the construction stage. This finding is in line with Swainston (2006) who has questioned the ECI as whether having a first phase based on alliance principles, followed by a traditional contract (i.e. D&C) for the second phase, would give the benefits of each strategy or the process would be compromised to the point where it was the worst of both strategies. However, Even though the most challenging stage in implementing an ECI is the move from a relational approach in the pre-construction phase to a traditional risk allocation approach in construction phase, the teamwork and collaboration have been developed during the first phase, has generally continued into the construction phase. The factors such as contractor's sense of belonging and commitment to the project success coupled with the improved communication and discussion mechanism without contractual status are resulted by implementing a collaborative contract in the first phase. Finally, even though Project Alliancing and ECI offer significant benefits to all project participants, lack of transparency and inability to demonstrate the full value for money in Alliancing; and lack of a robust mechanism to prevent the contribution of contractor in design being exploited by other competitors in ECI make these models remain unproved for a number of advisors in government departments.

6. References

Abrahams, A. & Cullen, A., 1998. Project alliances in the construction industry. *Australian Construction Law Newsletter,* 62**,** 31-36.

Agency, B.H., 2004. Early Contractor Involvement Contract Guidance Manual. London, England: British Highways Agency.

Aulakh, P.S., Kotabe, M. & Sahay, A., 1996. Trust and performance in cross-border marketing partnerships: A behavioral approach. *Journal of international business studies,* 27**,** 1005-1032.

Bundgaard, K., Klazinga, D. & Visser, M., 2011. Traditional procurement methods are broken: can early contractor involvement be the cure? *Terra et Aqua*.

Chen, G., Zhang, G., Xie, Y.-M. & Jin, X.-H., 2012. Overview of alliancing research and practice in the construction industry. *Architectural Engineering and Design Management,* 8**,** 103-119.

Corbin, J & Strauss, A 1998, *Basics of qualitative research: Techniques and procedures for developing grounded theory, 2nd ed.*, 2nd edn, Sage publications.

Cowan, B. & Davis, J., 2005. Development of the'Competitive TOC'Alliance-A Client Initiative. *Retrieved May,* 1**,** 2009.

Creswell, J.W., 2008. *Research design: Qualitative, quantitative, and mixed methods approaches*: Sage Publications, Incorporated.

Das, T.K., 2001. Trust, Control, and Risk in Strategic Alliances: An Integrated Framework. *Organization studies,* 22**,** 251-283.

Dekker, H.C., 2004. Control of inter-organizational relationships: evidence on appropriation concerns and coordination requirements. *Accounting, Organizations and Society,* 29**,** 27-49.

Edwards, R., 2009. Early Contractor Involvement (ECI) Contracts in the South Australian Transport Infrastructure Construction Industry. South Australian Department of Transport, Energy and Infrastructure, Adelaide.

Emsley, D. & Kidon, F., 2007. The relationship between trust and control in international joint ventures: Evidence from the airline industry. *Contemporary Accounting Research,* 24**,** 829-858.

Eriksson, E. & Laan, A., 2007. Procurement effects on trust and control in client-contractor relationships. *Engineering, Construction and Architectural Management,* 14**,** 387-399.

Flick, U., 2009. *An introduction to qualitative research*: Sage.

Hobbs, B. & Andersen, B., 2001. Different alliance relationships for project design and execution. *International Journal of Project Management,* 19**,** 465-469.

Laursen, T. & Myers, B., 2009. *Public investment management in the new EU member states: strengthening planning and implementation of transport infrastructure investments*: World Bank Publications.

Love, P.E., Mistry, D. & Davis, P.R., 2010. Price competitive alliance projects: identification of success factors for public clients. *Journal of Construction Engineering and Management,* 136**,** 947-956.

Macdonald, C., Walker, D.H.T. & Moussa, N., 2012. Value for money in project alliances. *International Journal of Managing Projects in Business,* 5**,** 311-324.

Masterman, J., 2002. *Introduction to building procurement systems*: Taylor & Francis.

Mosey, D., 2009. *Early contractor involvement in building procurement: contracts, partnering and project management*: Wiley-Blackwell.

Ng, T., Luu, D. & Chen, S., 2012. Decision criteria and their subjectivity in construction procurement selection. *Construction Economics and Building,* 2**,** 70-80.

Rahmani, F., Khalfan, M.M. & Maqsood, T., 2016. Analysing the drivers for Early Contractor Involvement (ECI) adoption by construction clients. *International Journal of Procurement Management,* 9**,** 373-397.

Roads, D.O.M., 2009. Standard Contract Provisions- Early Contractor Involvement (ECI) Contract. *In* D.O.M. Roads (ed.) Queens land.

Ross, J., 2003. Introduction to project alliancing. *Project Control International Pty Limited*.

Scheepbouwer, E. & Humphries, A.B., 2011. Transition in Adopting Project Delivery Method with Early Contractor Involvement. *Transportation Research Record: Journal of the Transportation Research Board,* 2228**,** 44-50.

Swainston, M., 2006. Early Contractor Involvement. *Queensland Roads Technical Journal,* Edition 2.

The Secretary Department of Treasury and Finance, J.R., 2006. Project Alliancing: Practitioners' guide. The Department of Treasury and Finance.

Van Der Meer-Kooistra, J. & Vosselman, E.G., 2000. Management control of interfirm transactional relationships: the case of industrial renovation and maintenance. *Accounting, organizations and society,* 25**,** 51-77.

Walker , D. & Hampson , K., 2003. *Procurement strategies: a relationship-based approach*: Wiley-Blackwell.

Walker, D.H., Hampson, K.D. & Peters, R., 2000. *Relationship based procurement strategies for the 21st Century*: AusInfo.

Walker, D.H. & Lloyd-Walker, B., Year. Understanding Early contractor involvement (ECI) Procurement Formsed.^eds. *Twenty-Eighth ARCOM Annual Conference, Edinburgh*, 5-7.

Walker, D.H. & Rowlinson, S., 2008. Project types and their procurement needs. *Procurement Systems: A Cross-Industry Project Management Perspective***,** 32-69.

Walker, D.H.T. & Lloyd-Walker, B.M., 2014. The ambience of a project alliance in Australia. *Engineering Project Organization Journal,* 4**,** 2-16.

Whitehead, J., 2009. Early Contractor Involvement-The Australian Experience. *Const. L. Int'l,* 4**,** 20.

Woolthuis, R.K., Hillebrand, B. & Nooteboom, B., 2005. Trust, contract and relationship development. *Organization studies,* 26**,** 813-840.

Young, B., Hosseini, A. & Lædre, O., 2016. The Characteristics of Australian Infrastructure Alliance Projects. *Energy Procedia,* 96**,** 833-844.

Impact of the Project Management Process on the Quality of the Final Product in the Definition and Planning Phase

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Abstract:

Although the quality of the process affects the quality of the end product, there is currently an insignificant amount of knowledge about the quality of project management (PM) processes that directly affect the quality of deliver product (constructed building). This paper will show a proposal of modeling the impact of the quality of the project management process on the quality of the constructed building. The quality of the project management process is presented through the key quality factors and product quality indicators over the quality of the product. It will show the results of the interviews that were conducted in Bosnia and Herzegovina with a variety of project participants (different managerial perspective) on indicators of quality of deliver product. All participants, regardless of managerial perspective believe that the most important indicator of the quality of products for each phase of the project "customer satisfaction in the end phase" whose measurement is different for each project phase that will presented. The results of the factor analysis of definition and planning phase show that variables - the quality factors of the PM process, 11 variables can be grouped into 3 new factors, which is described as 66,61% of the basic set of variables.

Keywords: ***građevinski*** *construction project, key quality factor, product quality indicators, modeling results;*

1. Introduction

Construction companies live from the production and sale of construction products or from the provision of construction services and in order to achieve success and competitiveness in the market they must strive for ongoing optimization of relations: quality - costs - price - technical/technological progress.

The purpose of project management in construction projects is undoubtedly the delivery of successful projects in terms of the agreed objectives of the project, which contributes to its value. Generally, project management in literature suggests that the project management process is directed towards delivering successful projects. (Zulu, 2007)

Quality is considered important for modern organizations because it increases competitiveness and production, reduces costs and ensures long-term relationships with clients. (Raković, 2007)

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According to the report of the Standish Group, 29,6% of the projects covered by the study have a cost overrun of 51-100%, 35,5% of projects have exceeded the timeline for 101-200%, changes are occurring in 39,1% of the projects for 75 -99% in compared to the initial plan. The average increase from the original estimated cost for all companies is 189%, and 222% of the original time estimates. More than a quarter of the projects are finished with only 25% to 49% of originally specified features and functions. (Standish Group, 2015)

Participants in construction (Investor, Contractor/Subcontractor, Designer, Project Manager, Consultant), as well as the end users of the project will directly benefit from the research on the mutual influence of the quality of the project management process on the quality of the end product, i.e. the constructed structure.

The research methodology was the following: analysis and synthesis of the literature overview, making and sending of the questionnaire, analysis of the results of the completed survey, discussion and conclusion creation, which was the first step of the research, followed by a factor analysis in order to group the factors of quality of the project management process that is used as an input during the modeling process. The next step was analysis of the results obtained from the interviews related to the " quality" of products for each phase of the project, which were also used as input data for the process of modeling. Afterwards, all the measuring variables were defined in order to be "recorded" through interviews during real projects and a hypothetical - zero model was created after that.

The research was conducted in Bosnia and Herzegovina (BH) in the construction sector, which presents the basis for further research that go in the direction of forming a model that will be easily applied in practice, and will show the impact of project management on the quality.

This research will provide an overview of the literature about the project, project phases and project management, and also about quality and quality management. Afterwards, the research questions will be presented which will have a response by the end of the research. The research conducted in the construction companies in BH will then be interpreted and in the end the results and the following steps in the further continuation of research will be presented.

This paper will show the results of the interview and survey conducted in BH and further steps in the research.

2. Literature overview

In literature different, but very similar definitions of the term project are present, because a project in itself is a venture which is a set of interrelated activities with the included resources (available and limited), all in order to meet the set goal. The project is a unique, temporary, multidisciplinary operation that attempts to meet the agreed defined delivery. (ICB, 2015) A significant number of companies adopt the techniques of project management (Berssanetti *et al.,* 2015), invest funds and efforts in the implementation of project management.

Since the purpose of this research was to look at a project through different phases, different methodologies and authors give different phase divisions. Some of them are: initiation, planning, execution, control, closing (ISO, 2013), or start/concept, planning/defining, performance/execution, monitoring and control, closing (PMI, 2013), or conceptualizing, defining, implementing, closing/guaranteed deadline. (Ljevo *et al.,* 2013)

The quality is viewed through the quality of process and product quality, but for many years the quality has been primarily seen as quality product and its definition was aimed at meeting the technical functioning, and when viewed as a cost factor, an emphasized control of production and other activities of the company resulted in a reduction of costs. The growing complexity and multiplicity of product variants, in the '60s and '70s of the last century, hindered the achievement of level of quality that meets customer's requirements at an acceptable cost. Improvement of the quality was mirrored in the complex specifications and tests, which caused additional costs. Today, the concept of quality has a wider coverage. The turning point in determining the notion of quality in business practice was supported by the results of a study conducted by Stern in 1995. (Stern, 1995) According to this study, only 18,2% of the companies view quality as simply compliance with the technical and functional specifications (which represent product quality), 15,9% of the companies attribute characteristics of sustainability, reliability and security to quality, and 2,3% of the companies see quality as minimizing the loss for the society. If the right things are done in the right way 25% of the companies considered this quality (effectiveness and efficiency), while 38,6% of the surveyed companies consider that the term implies the ability to satisfy quality requirements of customers (which is one of the conditions of TQM).

Each system wants to survive, grow and continue to grow. Therefore development of market relations and compliance with the growing consumer's demand for better, more functional, complementary products and information, are the goals and policies of the company. They are also a prerequisite for the timely development of enterprises and meeting the social needs. Hence the need for any manufacturing or service process to comply with quality requirements. (Kwak *et. al.,* 2009)

The quality of a product or service is determined by the relation between desires and needs of the users and their implementation by the manufacturer. The definition that states: "Quality is a set of properties that determine the matter or occurrence in comparison to the requirements", is not ideal but it allows us to temporarily resolve the problem of the exact definition and to move on. Perfectionists would disagree here, but most of us know that the absence of a generally accepted definition is not an obstacle for a multitude of activities related to quality. (Raković, 2007)

Different authors give different definitions of what is quality, and below is table 1, which shows some of them. (Wysocki *et al.,* 2006) (QP Staf, 2010) (Oakland, 2014). American Society of Quality states that the definition of quality of a subjective concept which can be defined differently by each person or sector. The quality of the project consists of two dimensions: product quality and process quality. (Turner, 2002)

Table 1. The review of definition

Autor	The quality definition is...
E. Deming (QP Staf, 2010)	solution to the problem
J. Juran (QP Staf, 2010)	suitability for use
P. Crosby (QP Staf, 2010)	free, but not a gift
T. Wayne (Summers, 2009)	customer satisfaction
M. Tacher (Summers, 2009)	when a buyer returns, not a product
Oakland (Oakland, 2014.)	meeting customer requirements

ISO (ISO, 2013)	compliance with the required requirements

Table 2 shows the steps for quality management (PMI, 2013) and it is intended to be compatible with that of the Internacional Organization for Standrardaziation (ISO 9001:2015), in quality planning we have to be based on the following criteria: setting quality objectives, identifying the customer, the customer's needs assessment, the development of product features, the development of process features, setting process control, transfer to the operations. In the next step of assuring quality the focus is on selecting the object of control, choice of units of measurement, goal setting, creation of a sensor, measurement of actual effectiveness, interpretation of diversity, impact on diversity. At the phases of quality improvement proved the needs, identify the project, organize the project teams, diagnose causes, prescribe corrective action, and deal with resistance to change and overall control the process in order to have an advantage. Research in China has shown that the availability of resources is extremely important because of the quality of construction in developing economies, and greater labor productivity is directly related to better quality of construction. Construction quality has improved over the years, due to the mandatory implementation of the supervisory system. (Yung *et al.,* 2010.).

Table 2. Steps to Quality Management (PMI, ISO 9001:2015, 2013., 2015.)

QUALITY PLANNING

- Identify the standards and levels relevant to the project;
- Determining activities to meet the requirements of this standard.

QUALITY INSURANCE

- Planned and continuous activity in order to meet quality standards;
- Provides the required quality of products or services;
- The achievement of the quality plan and its promotion;
- Continuous quality assessment.

IMPROVING QUALITY

- Measuring and comparing basic project results with quality requirements and relevant standards throughout the project;
- Analyze and report on achieved requirements and standards in performance;
- Provision of the necessary corrective actions;

TQM, EFQM model, Kaisen, reengineering , SixSigma ...

- Customer orientation;
- Planning process;
- Management process;
- Improvement process;
- Complete involvement;

The literature found and analyzed factors that affect the quality management in consultation and with university professors they were separated as factors which directly affect the quality of the processes of project management (Project Management process). The factors identified in literature are: expertise, knowledge and training, incorrect/incomplete invoice, commitment to management, coordination among project participants, changes/variations during the realization of the project, improper planning, inadequate project schedule, project supervision, employee involvement, expertise, and the training systems involved in the project, incomplete or incorrect cost estimates, focus on the customer/client, organizational skills, communication, continuous improvement, the interpretation of the expectations of the buyer/customer, quality policy, changes during the realization of the project, availability of resources, project environment, the implementation of the relationship between time and cost, the uniqueness of the project, organizational skills. (Ogwueleka, 2013) (Husin *et al.,* 2008) (Joaquin *et al.,* 2008) Eleven of them were implemente (X_1 - planning and control, X_2 - involvement, teamwork ..., X_3 - expertise, knowledge ..., X_4 - a focus on the customer ... customer satisfaction, X_5 - top management support/commitment, X_6 - communication, X_7 - continuous improvement, X_8 - coordination between project participants, X_9 - quality policy, X_{10} - availability of resources, X_{11} - supplier's quality management) which are further analyzed in the survey conducted in BiH and which are used as inputs for further actions in the research. (Ljevo *et al., 2015*)

When we talk about the quality of the products of each phase of the project, or the project as a whole, it refers to the delivered object. For manufacturers, quality means that the product or service is made in accordance with design specifications. After the product is produced, it undergoes a check whether it is in accordance with the established specifications. (Taylor *et al.,* 2006) This is called quality conformity or the capacity of the production process to meet the set specifications. In order to observe product quality in construction projects, the statutory obligations such as complete and revised technical documentation, obtaining a zoning permit, obtaining a building permit, conducted technical inspection and obtaining the use permit are taken into account. All factors and measures that were analyzed through interviews and surveys are supplemented with a model that shows the success of the project through five dimensions with 27 indicators, but only indicators relating to product quality through customer satisfaction in project phases are observed as part of the overall success of the project. (Shenhar i Dvira, 2007) For example, for the performance/execution phase, the following factors were ranked best by the participants in the project: customer satisfaction at the end phase, the viability of the project, the efficiency (compliance with the scope and arrangement), contribution for future projects; technical inspection completed and a use permit obtained; transfer without errors and shortcomings; the difference between the planned and the final cost of construction.

3. Methodology of the research and the results

After reviewing the literature and defining the basic critical factors of quality management process for projects, the survey in Bosnia and Herzegovina was conducted, followed by the analysis of results. The surveys took into account the phases of conceptualizing, defining and planning, execution, monitoring and control. The factors that are analyzed have a primary impact in the listed phases, so they are not analyzed for the closing phase of the project. For the purposes of further research, the focus is on the phases of conceptualizing, defining and planning, performation and execution.

The research was conducted through surveys (surveys and interviews) regarding the factors of quality of the project management process, product quality, and the participants were investors in construction projects, civil engineers and architects (101 – project management process; 91 – product). Data show (figure 1) that 6% of the subjects have a working experience under 5 years, from 5 to 10 years (25% and 23%), from 11 to 15 years (30%, or 33%), between 16 and 20 years (15% and 16%) and over 21 years (24% and 22%). This reveals that a large part of the respondents have more than 10 years of experience in the construction industry and their experiences are of great value in this study. Results (surveys and interviews) shows that 64% (60%) of respondents are experienced also building construction projects and engineering.

The importance of factor-variable quality of project management process and product was evaluated according to the Likert scale of assessment (1 - not at all important; … 6 - most important), this scale 1- 6 was used to avoid having a neutral answer.

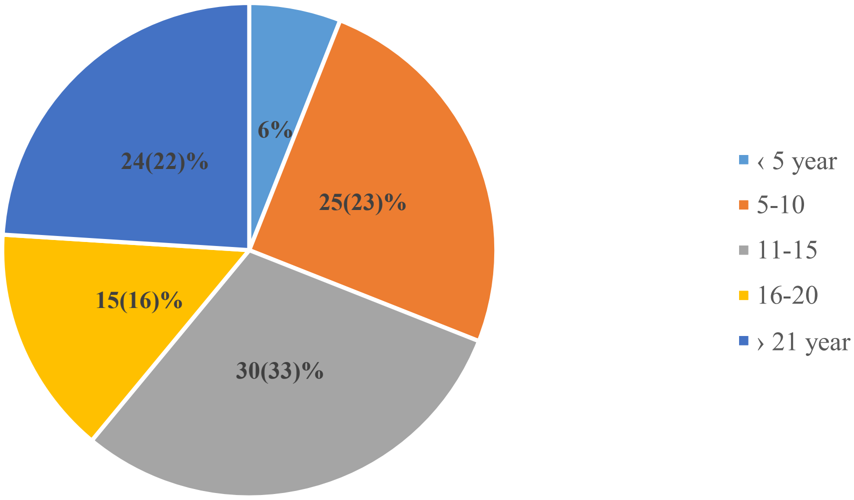

Figure 1. Working experience participants in the research quality factor of the product and project management process

The next step was to assess the suitability of the data (through the correlation matrix) for the application of factor analysis where the key factors-variables of the quality of processes would be grouped into new factors. Using factor analysis, the grouping of 11 variables-quality factors of the project management process, and 4 variables-quality factors of the product into new factors was conducted, as shown below. The condition that the sample size of the minimum number of respondents of the studied variables is 5:1 was satisfied. (Hair *et al.,* 2016)

Examination of the correlation matrix confirmed the appropriateness of data for performing the methods of factor analysis. Kaiser-Meyer-Olkin measure was the following criteria by which the suitability of the data for the application of factor analysis can be examined. The value of Kaiser-Meyer-Olkin measurement in this case is 0,827, made in SPSS 20.0, and the Bartlett's test of sphericity was conducted also (tests the null hypothesis that the variables are not correlated, P <0,001, and there is a reasoning behind the factor analysis). Value of the Hi square for the observed collection is 481,195 which indicates that the observed collection does not represents a unit matrix.

MSA (Measure of Sampling Adequacy) is another method to quantitate the degree of correlation between the variables and the justification of the factor analysis. The index ranges from 0 to 1. The closer MSA is to the unit, it is easier to predict the specified variable with the help of other variables. MSA is observed according to the following scale: over 0,80 - very strong correlation, between 0,70 and 0,80 - strong, between 0,60 and 0,70 - medium, between 0,50 and 0,60 - weak and below 0,50 - unacceptable. The value of MSA is from 0,718 to 0,887, which presents the strong correlation, and the collection is suitable for the application of the factor analysis.

The factor model with three factors is used to describe 66,61% of the elementary set of variables (the table 3), and the Kaiser method was used, which as a measure of choosing the number of factors uses the value of the Eigenvalue (representing the variance of all the variables included by the factor) larger than 1.

The factor loading for three factors and eleven variables after the Varimax rotation (maximizing the sum of variances of the square of factor loading), are shown in the table 4.

Factor R1 consists of the following variables: planning and control; involvement, teamwork ...; expertise, knowledge ...; communication; coordination between project participants. Factor R2 consists of the following variables: continuous improvement; quality policy; the availability of resources; supplier's quality management, and the factor R3 consists of the following: focus on the customer; top management support/commitment (figure 2).

Analysis of survey results and interviews related to the quality of the products in phases is given below.

For the conceptualization phase, 62,6% of respondents stated that customer satisfaction in the end of the conceptualization phase (compliance with the project task - scope, concept, project structure, with the business plan – estimation of resources and expected revenues, in order to know the profitability i.e. to anticipate profit) is the key factor of the quality of products. Regarding secured financing, 59,3% of the respondents consider this to be a factor of product quality, because if the planned finances are not secured, it may come to adjustments and changes in vision, ideas, and at the end changes in the original objectives, and in most cases all that is carried out through the incorporation of materials of lower quality than originally intended, but allowed.

Table 3. Total Variance Explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	4,931	44,828	44,828	4,931	44,828	44,828	3,015	27,413	27,413
2	1,209	10,995	55,824	1,209	10,995	55,824	2,225	20,226	47,639
3	1,186	10,781	66,605	1,186	10,781	66,605	2,086	18,966	**66,605**
4	,797	7,248	73,853						
5	,653	5,935	79,788						
6	,601	5,460	85,249						
7	,432	3,930	89,178						
8	,406	3,688	92,867						
9	,305	2,773	95,639						
10	,292	2,655	98,294						
11	,188	1,706	100,000						

For the phase of defining and planning, 57,1% respondents consider that the key factor of quality is the customer satisfaction at the end of the phase (use of new processes, methods or technologies), and 42,9% state that the key factor is the complete technical documentation (main project, a study of occupational safety… and other legally required documentation) and obtained urban planning and construction approval.

For the performance/execution phase, 52,7% of respondents considered a key factor in quality is the customer satisfaction at the end of the phase (the client was delivered what he/she expected according to the business plan or to their expectations), and 42,6% stated that the key factor was that the technical inspection was carried out and that the usability permits were obtained, while 29,7% respondents stated that the key factor was that everything is delivered without errors and shortcomings.

Table 4. Factor structure matrix after Varimax rotation

	Rotated Component Matrixa			Communalities
	1	2	3	
X_1	**0,804**	-0,085	0,090	0,662
X_2	**0,771**	0,175	0,226	0,676
X_3	**0,743**	0,323	0,067	0,661
X_4	0,109	-0,088	**0,853**	0,747
X_5	0,144	0,228	**0,668**	0,520
X_6	**0,581**	0,236	0,551	0,697
X_7	0,190	**0,628**	0,433	0,618
X_8	**0,720**	0,422	0,201	0,737
X_9	0,489	**0,605**	0,242	0,663
X_{10}	0,073	**0,846**	-0,104	0,732
X_{11}	0,232	**0,559**	0,498	0,614

The factor model with one factors of variables-quality factors of product and the Kaiser method was used, which as a measure of choosing the number of factors uses the value of the Eigenvalue larger than 1, but the communalities are less the 0,5. The number of respondents increased by ten and received acceptable results for factor analysis.

R1 - planing and control

- planning and control
- involvement, teamwork ...
- expertise, knowledge ...
- communication
- coordination between project participants.

R2 - resource

- continuous improvement
- quality policy
- the availability of resources
- supplier's quality management

R3 - coustomer

- focus on the customer
- top management support/commitment

Q1 - quality of product

- complete technical documentation
- acquired urban and building permits
- predicted and planned budget, sustainable budget of the build
- customer’s satisfaction at the end of the phase

Figure 2. Quality factor of the project management process and quality factor of product - definition and planning phase

The factor loading for one factors and four variables after the Varimax rotation (maximizing the sum of variances of the square of factor loading) showed: Y_1 – 0,788, Y_2 – 0,735, Y_3 – 0,746. Y_4 – 0,788.

4. Findings and conclusion

Examination of the correlation matrix confirmed the appropriateness of data for performing the methods of factor analysis (for project management process). The value of Kaiser-Meyer-Olkin’s measure is 0,827, which is > 0,5, and also the Bartlett's test of sphericity was made (which tests the null hypothesis that the variables are not correlated, P <0,001, which justifies the performance of factor analysis). Value of the Hi square for the observed collection is 481,195 which indicates that the observed collection is not a unit matrix, hypothesis can be dismissed with probability greater than 99%. (Field, 2005)

Factor analysis of variables showed that factor 1 has a high positive loading for variable X_1 (planning and control), where the load is 0,804 and X_2 (involvement, teamwork ...) – 0, where the load is 0,771, and it also consists of variables X_3 (expertise, knowledge ...) 0,743, X_6 (communication) – 0,581 and X_8 coordination among participants – 0,720.

Variable X_4 has 74,7% of the total variable variation covered with three common factors, and the remaining 23,3% of the variable variations are related to the specificity of the variable plus a certain amount of error in the measurement.

After analyzing the data collected through interviews and surveys, which have been included in further research for the phase of definition and planning, the quality factors of product are: Y_1 - complete technical documentation, Y_2 - acquired urban and building permits, Y_3 - predicted and planned budget, sustainable budget of the build, Y_4 - customer’s satisfaction at the end of the phase (use of new processes, methods or technologies).

Factor analysis of variables showed that factor 1- Q1 has a high positive loading for variable : Y_1 - complete technical documentation – 0,788, , Y_2 - acquired urban and building permits – 0,735, Y_3 - predicted and planned budget, sustainable budget of the build - 0,746, Y_4 - customer’s satisfaction at the end of the phase – 0,788.

The quality of project management processes are three latent (three new factors) values obtained after factor analysis. The first latent value includes measuring variables: X_1 - planning and control, X_2 - involvement, teamwork ..., X_3 - expertise, knowledge ..., X_6 - communication, X_8 - coordination between project participants, which constitute a new factor R1. The second latent value includes measuring variables: X_4 - the focus on the customer, customer satisfaction ..., X_5 - top management support/commitment, which makes up a new factor R2. The third latent value includes measuring variables: X_7 - continuous improvement, X_9 - quality policy, X_{10} - availability of resources, X_{11} - supplier's quality management, which make up a new factor R3.

On the other side of the model is one latent variable (new factor) which includes four variable manifests for this phase: Y_1 - complete technical documentation, Y_2 - acquired urban and building permits, Y_3 - Predicted and planned budget, sustainable budget of the build, Y_4 - customer's satisfaction at the end of the phase (the number of new processes, methods or technologies that are envisaged at this phase), which constitute a new factor Q1.

After this step, defined measures which will be used to carry out evaluations (scores) of each individual variable manifest, and then ″recorded″ (through structured interviews) data on specific projects is carried out (for the phases of the project) in Bosnia and Herzegovina in order to detect differences in factor analysis of results obtained through interviews and case studies in the field.

The projects which are recorded are selected randomly with the condition that they were not completed a long time ago (in order for the recorded data to be as credible as possible), so that the phase of execution has not been still completed or is still in progress. Both projects of building/ industrial and bridge/ road are recorded, without including the ratio of their participation in the research. After factor analysis of the data, it is suggested by the hypothetical-zero model of the impact of the quality process (project management) on product quality. Then, that results will be analyzed by SEM (Structural Equation Modeling) methodology and a hypothetical-zero model is optionally modeled.

In order to even talk about the quality of project management and the quality of products, finished projects should be thoroughly and carefully reviewed and the lessons learned should be documented and included in the next project to avoid repetition of errors. (Dogbegah *et al.,* 2011)

The methods, techniques and tools for project management are available to participants of construction projects in BiH, but the legislation absolutely does not cover this area, so it is left to the companies and direct participants in the projects to decide whether they will use and apply them or not.

References

Berssaneti, F.T. and Carvalho, M.M. (2015), "Identification of variables that impact project success in Brazilian companies", International Journal of Project Management, 638–649.

Dogbegah, R. et al. (2011), "A principal component analysis of project management competencies for the Ghanaian construction industry", Australasian Journal of Construction Economics and Building, pp. 26-40

Field, A. (2005), "Factor Analysis Using SPSS: Theory and Application", http://www.sussex.ac.uk/users/andyf/factor.pdf

Hair, F.J., Anderson, E.R., Tatham, L.R., Black, C.W. (2016). "Multivariate Data Analysis", 7th Edition, Prentice- Hall International, Inc,

Husin, N.H., Adnan, H. and Jusoff, K. (2008), "Management of Safety for Quality Construction", Journal of Sustainable Development, pp. 41- 47.

ISO Standard ISO 9001:2015, Geneva: International Organization for Standardization, 2015.

Kwak Y.H., Anbari F.T. (2009), "Analyzing project management research: Perspectives from top management journals", International Journal of Project Management, pp. 435–446.

Ljevo, Ž., Vukomanović, M. (2013). "Characteristic project management model found in construction companies of Bosnia and Herzegovina", Technical Gazette, pp. 689-696.

Ljevo, Ž., Vukomanović, M. and Rustempašić, N. (2015), "Assessing the influence of project management on quality in the construction industries of Bosnia and Herzegovina and Croatia", 12th International Conference Organization, Technology and Management in construction conference proceedings, Croatia, 2015., Primošten, pp. 524-534.

Oakland, J.S. (2015), "Total Quality Management and Operational Excellence", Routledge, Taylor & Francis Group

Ogwueleka, A. C. (2013), "A Review of Safety and Quality Issues in the Construction Industry", Journal of Construction Engineering and Project Management, pp. 42-48.

Project Menagment Institute (2013), "A Guide to the Project Management Body of Knowledge (PMBOK® Guide)—Fifth Edition", Pennsylvania, USA

Raković, R. (2007), Kvalitet u upravljanju projektima, Građevinska knjiga, Beograd

Shenhar, A.J., Dvir, D. (2007). Reinventing Project Management: The Diamond Approach to Successful Growth and Innovation, Harvard Business Scholl Press

Standish Group (2015), Chaos Report, available at: http://www.infoq.com/articles/standish-chaos-2015, (accessed 20 Decembar 2016)

Stern, C. J. (1995), "Total Quality Management und Unternehmensstrategie, Chapter Total Quality Management als Erfolgsstrategie", Volume 2 of the series Herausforderungen an das Management, Springer Verlag, pp 99-114.

Taylor, B.W., Russell, R.S. (2006), Operations management: Quality and Competitiveness in a Global environment, 5th Edition, Hoboken, NJ Wiley

Turner, J.R. (2002), "Managing Quality. Chapter 16"Gower Handbook of Project management, Gower Publishing

Yung, P. and Yip, B. (2010), "Construction quality in China during transition: A review of literature and empirical examination", International Journal of Project Management 28, pp. 79–91.

Summers, D. (2009), Quality Management: Creatingand Sustaining Organizational Effectiveness, Pearson International Edition

Zulu, S. (2007), "Impact of project management on project performance: a structural equation modelling approach", 23rd Annual ARCOM Conference, 3-5 September 2007, Association of Researchers in Construction Management, UK, 2007., Belfast, pp. 651-660.

QP Staff, Guru Guide (2010), "Six thought leaders who changed the quality world forever", Qality Progress, available at: https://www.scribd.com/document/62280996/Guru-Guide-Six-thought-leaders-who-changed-the-quality-world-forever (accessed 22 Mart 2017)

Risks of Highway Construction in the Republic of Croatia in Regards to the Research of Cost Overruns

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Abstract:

Studies of cost overruns show that the frequency of exceeding the planned construction costs is in the range from 80 to 90%, and the span is from 20% to 164% planned cost. Results obtained by research depend on methodology of the survey, data processing, sample size and definition of estimated cost. However, the large span of cost overruns across different countries also points out to the impact of countries specificities as the environment in which the project was conducted. Development of the system for reduction overruns efficiency in identifying and risk management and quality of project definition varies among the states.

The paper will present the results of the survey of construction experts that will help in defining the environment of road infrastructure projects in the Republic of Croatia. The survey was conducted in relation to the risks that followed the construction of the motorway network in the Republic of Croatia.

The survey point out to the specificities of the Republic of Croatia as a project environment in terms of its historical economic heritage, the lack of systematic cost estimation and the governance of projects from the Government point of view. Furthermore, the result of the study are the most significant risks in the opinion of practitioners regarding the construction of individual motorway projects. In addition, with risk ranking, have been made preparations to assess the impact of risk on cost overrun and further research of cost overruns in the Republic of Croatia.

Keywords: *Republic of Croatia, Highway, Cost overruns; Risks;*

1. Introduction

The connection between civil engineering and the economic growth (Wells, 1984), infrastructural development and state competitiveness and the influence of the economic growth on the development of the infrastructure (Dzeng, Wang; 2008) positions and characterizes the meaning of infrastructural projects. This reflects on the fact that in order to mitigate the effects of the financial economic crisis from 2005 to 2008, in the USA, Europe and China there were projects started in the value a trillion dollars. However, big projects are often connected to sizable cost overruns. The cost overrun for the tunnel la Manche was 80 percent, for the Denver International Airport 200 percent, for the Sydney Opera 1400 (Flyvbjerg, 2014). The impressive

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World Trade Center Transportation Hub in New York was opened in February 2016 with double the time of the deadline and double of the cost overrun (New York Times, Feb 24 2016). The airport in Berlin was not opened even after 10 years after the foreseen deadline and the cost overrun of 1.5 billion euros. In 9 out of 10 traffic infrastructure projects the costs are underestimated and for randomly picked projects the probability that the real costs will be higher than the projected ones amounts to 86%. (Flyvbjerg 2002). Research on 620 Norwegian road projects has confirmed the frequency of cost overruns of estimated costs (Odeck 2014). The consequences, which are caused by the variation between the real value and the projected one, are manifesting as wrong planning, not only of the elements which are connected to the project but also of the wider financial and organisational framework in which the organisation which handles the project is operating. Underestimated budgets of individual projects are creating a false potential for the possibility of investing into other projects. Insincere and false budgets are causing a false ranking of the projects so that there is a danger that the possibly worse projects are being implemented, that the resources, which could have been fairly allocated, are depleted, and that these projects are not capable of returning the invested resources (Cantarelli 2010).

Study	Geographical area	Frequency cost overrun (%)	Magnitude of cost overrun							
			Road		*Rail*		*Fixed Links*		*Other*	
			%	N	%	N	%	N	%	N
Merewitz (1973)	US	79	26	49	54	17				
Morris (1990)	India				164	23			4	10
Pickrell (1990, 1992)[b]	US	88			61	8				
Auditor General (1994)[c]	Sweden		86	8	17	7				
Nijkamp and Ubbels (1999)	Netherlands, Finland	75							0-20	8
Bordat et al. (2004)	US	55	5	2668[d]						
Odeck (2004)	Norway	52	8	620						
Dantata et al. (2006)	US	81			30	16				
Ellis et al. (2007)	US		9	3130						
Lee (2008)[e]	South Korea	95	11	138	48	16				
Flyvbjerg et al. (2003a)	World	86	20	167	41	58	34	33		

a In which: %: the percentage cost overrun and N: the number of projects with cost overruns b In van Wee (2007) c In Odeck (2004)

d Projects include: Road and bridge construction and rehabilitation projects; maintenance projects, with road maintenance and resurfacing contracts; Traffic and traffic maintenance contracts e In Siemiatycki (2009)

Table 1: Studies of frequency and the magnitude of the overruns

Source: Cantarelli, CC, Molin EJE, van Wee, B, Flayvbjerg, B, 2012, Characteristics of cost overruns for Dutch transport infrastructure projects and the importance of the decision to build and project phases, Transport Policy, 22, p. 51

Table 1 is showing the studies, which investigated the frequency and the scope of the overruns and are pertaining to cost overruns of individual countries. Analyzing the reasons for the disparity between the figures of the overruns, the authors have stated that, for example, the conclusions relating to Europe do not necessarily have to relate to each European state (Cantarelli et al., 2012). They have uttered the need for further studies of the costs of individual countries in relations to the projects of traffic infrastructure. More precise, the research goal was to determine the characteristics of too high costs in the big traffic infrastructure projects in the Netherlands.

Study no.	Publication year	Author(s)	Country of study	Continent	No. of projects (road)	Average % overrunn[a]
1	2009	RGL Foresenics, Frontier Economics, Faber Maunsell and Aecom (2009)	Some EU countries	Europe	21	9.4
2	2011	Lundberg et al. (2011)	Sweden	Europe	102	11.1
3	1997	Skamris and Flyvbjerg (1997)	Denmark	Europe	7	14
4	2004	Odeck (2004)	Norway	Europe	620	8
5	2006	Qing WU (2006)	Canada	North America	50	82
6	1973	Merewitz (1973)	US	North America	49	26
7	2004	Bordat et al. (2004)	US	N. America	2668	5
8	2007	Ellis et al. (2007)	US	N. America	3130	9
9	2008	Lee (2008)	South Korea	Asia	138	11
10	2003	Flyvbjerg et al., 2003	World	World	167	20
11	2012	Cantarelli et al. (2012a)	Netherlands	Europe	37	18.6
12	2009	Kaliba et al. (2009)	Zambia	Africa	8	69
13	2010	Singh (2010)	India	Asia	157	15.84
14	1994	Riksrevisionsverket (1994)	Sweden	Europe	8	86
15	USA	INDOT (2004)	USA	N. America	2668	4.5
16	1995	Odeck and Skjeseth (1995)	Norway	Europe	12	5
17	2007	UK National Audit Office (2007) National roads	England	Europe	36	6
18	2007	UK National Audit Office (2007) Local authorities	England	Europe	20	18
19	2007	Flyvbjerg (2008)		World	44	44.9
20	2008	Nicanor and Chalermpong (2008)	Philippines	Asia	85	5.4
21	2011	Makovšek et al. (2011)	Slovenia	Europe	36	19

Table 2: Studies of the frequency and the scope of the overruns

Source: Odeck, J., 2014, Do reforms reduce the magnitudes of cost overruns in road projects? Statistical evidence from Norway, Transportation Research Part A 65 (2014)

Table 2 is showing the studies about the cost overruns, which includes all of the world's continents. It is an obvious fact that the cost overruns are quite common in road projects (Odeck, 2014). However, there are huge variations in the scope of the overruns and the methodology so the author has given his attention to the research of Norwegian road projects. Basic conclusions are not necessarily applicable to certain cases so it is desirable the state of the certain country is to be included in the research. This points to the specificity of the cost projections of future projects in certain countries. The cost projection is necessary for the implementation of the evaluation methods of public projects, amongst of which the Cost Benefit Analysis (CBA-) (Salling & Lelur, 2015, Beria et al. 2011, Nicolaisen et al. 2012, Odgaard et al. 2005, Nickel et al. 2009) is predominantly used in the world. CBA is also present in the institutions of the European Union which are deciding about the funnelling of resources into certain projects (Hertogh et al. 2008) and is included in secondary legislation and binding for all users. (Guide to Cost-Benefit Analysis of Investment Projects Economic appraisal tool for Cohesion Policy 2014-2020, 2014). The range and the reasons of overruns, characteristics of the projects, developmental phases, and the organizational and operational framework in which the overruns occur are becoming the subject of interest for the researchers. The importance of institutionalised managing of the procedure of project evaluation and approval (Magnusses&Samset, 2005), and the connection between the characteristics of the project and the management regime (Miller& Hobbs 2005) is being pointed out. HM Treasury demands that all ministries develop and implement procedures for megaprojects which will counteract the so-called "optimism bias" (Flyvbjerg, 2006). The parliament Council for the infrastructural projects in the Netherlands has conducted a comprehensive public consultation to determine the measures, which will limit the misinformation about the big infrastructure projects presented to the parliament, the public and the media. (Dutch Commission on Infrastructure Projects, 2004). Magnussen and Olsson (2006) have shown that the magnitude of the cost overrun has diminished after the implementation of the mandatory process of quality assurance. The reform of the Norwegian Public Roads Administration (NPRA) has led to a vast improvement in cost and time projection, that is, to their decrease (Odeck 2014). Attention is focused on the governance of public projects, that is the relations between the project owner and the organisation, which is implementing it, and it includes a complex process of management of multiple agencies and companies (Klakegg et all. 2015).

The obvious question, which arose to the researchers, were the reasons, which cause the cost overrun. The most accepted approach was proposed by Flyvbjerg (2009) who classifies the reasons of the cost overruns by technical, psychological and political explanations. Technical explanations are traditionally thought of as the main reason for the overrun and are widely mentioned in the references (Morris and Hough,1987; Nichols, 2007; Van Wee and Tavasszy 2008; Lee 2008; Park and Papadopoulou, (2012; Vanston and Vanston, 2004; Wachs,1990). They include questions like the ones about imperfect projection techniques and inadequate data, changes in the scope, changes in the regulatory directives, lack of skills and planning competency, inflation and so on. Technical reasons were recognised by some guides to cost projections in their suggestions. DG REGIO guide (1998) emphasises the unexpected soil conditions, changes in the project documentation, weak project management, costs of land acquisition, inflation and the price changes, force majeur, lack of materials and equipment, currency change, inadequate contracts and the problem of the foundation. The study concluded by ECORYS Transport (2005) on 60 projects co-financed out of the Cohesion Fund in the period 1993-2000, is stating that the dominant causes of the cost overruns are the change in the project documentation, inflation influence because of the time delay, and the construction site questions of the contractor and all of which is pointing to the inadequate project preparation. Flyvbjerg claimed that it is improbable that only the technical questions can explain the magnitude of the cost overrun. He states, that it would be logical to expect better projections with the passage of time if only the technical questions could explain the magnitude of the cost overruns, and that is not happening. The cost overrun remains a problem on all the continents in all of the sectors. That is why he puts the psychological and political explanation of inaccuracy over the technical explanations. He introduces the psychological explanation for the inaccurate projections through optimism bias, as a cognitive predisposition of most people to judge future events in a more positive light despite being warned otherwise by real experience. He associates the political explanation of inaccuracy with the term strategic misrepresentation. That means that when the forecaster and the project planners are projecting the results of the project, that they are knowingly and strategically overestimating the advantages and are underestimating the cost as to increase the probability that their project, and not the projects of the competition, get the approval and financing. Osland and Strand (2010) have found a few flaws with the theory of the strategic misrepresentation in the theoretical as in the methodological conditions. Even if there are examples of strategic misrepresentation and even if the participants involved in the project have admitted to the false presentation,that does not mean that the strategic misrepresentation is the only explanation as to why the projections are inaccurate. The proposers of the political explanations were claiming that the observed projection bias must be due to intentional human error. However, Flyvbjerg did not provide any arguments, which would support this claim (Eliassona & Fosgeraua, 2013). Eliasson and Fosterage have shown that the bias can occur because of the selection process, even when there was no bias in the projection ex-ante. All that it takes for bias to take place is that the choice of projects is relating to the ex-ante predictions, that is, the decision if the project should or should not be implemented.

In practice, the question of cost overruns is viewed through risks and with analysing the risks to foresee additional costs. The link between cost overruns and the risks was also established in a study of the revision of the outcome of big public procurement projects in Great Britain (Mott MacDonald, 2002). The study has indicated that the optimism bias, which is the deviation from the estimated value is a result of the nonexistence of the effective identification and management of the risks and the badly defined scope of the project. The fields of risks, which are adding to the overruns with the highest probability, according to the study, have been analyzed, and the result of the study was the proposal to calculate the estimated costs.

Knowing the risks can help in improving the cost estimations in the early phase of the project, which are in practice mostly unavoidable during the formation of a four-year plan. Cost assessment produced in different phases of the of the same project carry different levels of insecurity/risks and thereby different levels of assessment accuracy.In general, more unpredicted risks are being implemented in the early phases than in the later ones. Studies have shown that the common accuracy of the assessment lies between 30-50% in the conceptual phase (Ashworth i Skitmore, 1982.), around 20% in the design phase (Morrison, 1984.), around 10% in the tender process phase (Flanagan i Norman, 1983), and 5% in the preparation phase (Ferry and Brandon, 1991). Odeck (2014) distinguishes three different types of cost assessment for Norway: (1) Assessment of the feasibility study with the confidence interval of ± 40%, (2) Assessment plan with the confidence interval of ± 25%, and (3) Detailed assessment plan (that is, in the phase in which the project documentation, the specifications and the final assessment are developed) with the confidence interval of ± 5% during. The link between the costs and the risks is provided by Liu et al. (2010). Typical project assessment is shown as the sum of the "base assessment" and the Risk Contingency. The base assessment calculates the material and the amount of work by multiplying the prices and the components of the project. The potential unpredicted risk is the "amount that is expected to be (or is) spent and which is added as to include all of the items, conditions and cases for which the state, occurrence or the effect is unknown, but the experience shows that it will probably result in a pile up of additional costs "(Anonymous, 2007 taken from Liu et. all., 2010). Risk and uncertainty in the cost assessment are trying to be incorporated into the Decision Support System (DSS) in a direct and understandable. It is the intent that in addition to existing deterministic procedure the stochastic approach be implemented which would conduct the QRA (Quantitative Risk Assessment), allowing the analyst or the fitter to improve the deterministic results in the probabilistic outcomes, that is, to exchange the dashed ones with the intervals (Salling 2008, Salling and Leleur 2012).

The Republic of Croatia does not have a developed systematical cost assessment of future projects. There are also no recorded works which would observe the cost assessment on the basis of an "outside aspect" with the detachment from the base cost assessment on the principle of resource consumption. In that regard, it is inevitable to start a process of observing the elements, which exert and influence on the cost assessment in a specific project in the environment of the Republic of Croatia. The Recent implementation of the highway network construction in the Republic of Croatia is a good opportunity for that. This paper will show the link between the risks and the cost overruns in 2 chapters. This link provides the basis from which the identification of the risks, which came along with the implementation of the Program, would contribute to the assessment of the costs of future construction projects. These risks are partially a consequence of historic and economic circumstances because the implementation of the Program took place in a transitional period of a newly created state. The methodology of data collection and processing will be shown. Information from the conducted surveys will be shown in the third chapter, on which basis the conclusions of the conducted surveys will be shown.

2. Methodology of conducting risk identification survey

Identification of risks of implemented projects is to contribute to the beginning of the cost overrun research in road infrastructure projects in the Republic of Croatia. The link between the risks and the optimism in the assessment as a measure of cost overruns was noted in the study of the revision of the outcome of big public procurement projects in Great Britain (Mott MacDonald, 2002). The final cost of the project is a random variable whose value is uncertain and it represents a random occurrence. It is the function of a basic variable, which are costs and other influences and even risks in reality. Generally speaking, one can say that the observing of the behavior of random variables is generally conducted by using the terms distribution function and density function of random variables. The principles of the probability theory are used in Referent Class Forecasting method based on the outside view (Flyvbjerg and COWI, 2004). Statistical monitoring of cost overruns as random variables had made the approach, which is based on information from the category of similar and comparable projects possible. The projection on a reference category is proven more precise than the conventional projection (Flyvbjerg, 2007). Therefore, no matter if the problem of cost assessment is addressed with the study of the cost overrun of implemented projects or with the study of basic variables and forming the summary of random construction cost variables, the identification of significant risks is welcome in the understanding of cost structuring.

The perception, planning, preparation and selection, and with that risks, which came along with the construction of the highway network in the Republic of Croatia, have been undoubtedly influenced by the historical, political and economic setting. Croatia was, as part of former Yugoslavia, susceptible to communistic planned economy and the strong influence of the state. These circumstances have formed a specific starting point and to a certain extent determined the quality of the activity and accuracy of the assessment, which followed, as well as the risks, which came up. One could say that the construction of the highway networks in the Republic of Croatia was under the immense pressure of the politics, and with the public. If we fit into that the context of the cost overruns, it is to be assumed that the political and economic reasons have immensely influenced the assessed cost overruns. By comparing the cost overruns in the Republic of Croatia with the European experiences, one can conclude that the evident overruns are well within the expected framework. (IBR Consulting, 2008). Furthermore, the implementation of the highway network construction program did not avoid yet another effect, which comes up with every major infrastructure project, and that is the negative perception. It is not doubtful that the constructed highways have contributed to the state development, especially in tourism and the transport of passengers and goods, and with regard to technical matters, there were no evident problems besides the usual ones connected to the construction and later usage of the highways. Although in comparison with other European countries the construction cost is one of the lower ones, a completely different picture was created in the Croatian public. The negative perception, the public pressure regarding the justification and implementation of big projects are commonly found with big infrastructure projects. These are complex undertakings which mobilize big financial resources, require a long preparation, a complex construction process, including a big number of stakeholders, influence million of people and usually are implemented by the usage of public funds. A big range of conveniences which are expected by some members of the community from public projects, and the fact that the profit is not the main goal in the end and that the taxpayers mostly bear the costs does explain such public pressure (Flyvbjerg2008, 2014, Odeck 2014).

Qualitative assessment can point out some key risks and their sources, which is a quality information for understanding the technical reasons of assessed cost overruns. Which represents a useful information for practitioners and researchers in the field of accuracy approved of cost assessment.

In that regard, it was the intent to gather information from people which were directly included in the implementation of the highway network project. To diminish the bias, which is possible from the aspect of the grouping of project participants, experts from all three groupings were surveyed. During the year 2009., the questionnaires were delivered to 50 experts. From the group of investors (responsible for managing certain sections or contracts) 20 experts were surveyed, from the contractors 20 (leading management and experts charged with managing individual projects) and the supervision 10 (people which supervise the dynamic and the quality of the work) The target grouped of fifty experts from ten different business entities should provide diversified, but representative pictures of the problems which occur on the highway construction site.

The questionnaires were handed out personally or over the e-mail and were containing a short explanation of the evaluation method as to give an impression about the goal of the survey to the surveyed experts. Risks presented in tabular form were selected by consulting the referenced books, from personal experience and from a conversation with the experts. Additionally, at the end of the questionnaire, there was an opportunity given to the surveyed experts to add a risk, which was not mentioned but they find that risk important. In that way, there was an attempt to make sure that some risk, which is recognized by the experts and which was not found during the preparation of the questionnaire, has not been left out.

To avoid different interpretation of individual effects of the risks, individual risks were explained to the respondents, some expected examples mentioned and the possibility of comments about listed risks given. The questionnaire also contained columns for a subjective evaluation of the risk impact (deadline, price) of the experts and the subjective assessment of the risk occurrence probability. The survey offered in total forty-two risks with the description of the evaluation according to the descriptions taken from the TenStep methodology (Ten Step, Basic Methodology, Primakon: Croatian translation 2005).

IMPACT	EVALUATION
Low	no impact regarding the price and the deadline
Potential impact 2-4%	2-4% regarding the price and the deadline
Potential impact 5-7%	5-7% regarding the price and the deadline
Potential impact 8-10%	8-10% regarding the price and the deadline
High impact	over 10% regarding the price and the deadline

Table 3. Simple instructions for respondents regarding the evaluation of the impact and the effects of the risks

Table 3 shows the instructions, which were given for the gradation of the impact of the listed risk. The respondents have used the instructions in the way that they wrote down the percentage or the qualitative description of the risk impact. On the other hand, regarding the probability of the occurrence, they were free to write the percentage of the probability of their own choice.

Assessment according to the listed risks (part of the table)					
No.	RISK		IMPACT in the case of RISK occurrence	PROBABILITY of RISK occurrence	DESCRIBE WHAT YOU UNDERSTAND UNDER THE RISK (risk for the owner/investor)
1	Payment delays by the owner	Deadline	*Low*	*2%*	*Bigger construction firms work for serious investors, which have an elaborate financial structure*
		Price	*Low*		

2	Imposing of unreal schedules by the owner	Deadline	*High*	*20%*	*The inclusion of politics with state projects. With private projects, there are no higher risks, because they know in general what they want and how they want it done.*
		Price	*High*		
3	Inadequate intervention by the owner	Deadline	*imp. perc. 2-4%*	*20%*	*Bureaucratic structure of decision-making. Insufficient knowledge and experience.*
		Price	*imp. perc. 5-7%*		
4	Blueprint changes requested by the owner	Deadline	*imp. perc. 2-4%*	*1%*	*It is highly unlikely that the owner will request the blueprint changes, but when it does happen, it certainly almost leads to the increase of the price and/or the deadline delay*
		Price	*imp. perc. 8-10%*		
5	The owner does not give the definition of the scope of the work	Deadline	*High*	*40%*	*This is a very common case and it has an especially high impact on "turnkey" contracts*
		Price	*High*		
6	Delay of the access to the construction site and the right of way	Deadline	*High*	*40%*	*Unadjusted documentation – the access roads, landfills, needed material sources are not being taken care of. All of this should be resolved with a construction permit, that is the Main project.*
		Price	High		

Suggestions of risks which were not listed in the initial table (part of the table)					
No.	RISK		IMPACT	PROBABILITY	DESCRIBE WHAT YOU UNDERSTAND UNDER THIS RISK
1	Bad preparation of the Tender documentation.	Deadline	High	60%	*Insufficiently clear scope of the works, insufficient amount of detail was taken care of in the phase of tender documentation, which leaves a too big of a space for disputes*
		Price	High	60%	
2	Insufficiently good Main project	Deadline	High	60%	*The function of the Main project is not doing its job. The projects are not adjusted. Insufficiently defined technical*
		Price	High	60%	

					specifications, which are norms. All was left for the oversight engineers.

Table 4. Excerpt from the questionnaire

Table 4 shows an excerpt from the collected and filled out questionnaires. Since there the surveyed experts were persons with whom there was an intensive business relation, forty-five of the fifty survey requests were answered. After the collected responses, an evaluation of each risk by each respondent was done.

IMPACT	**SCALE**
Low	1
Potential impact 2-4%	2
Potential impact 5-7%	3
Potential impact 8-10%	4
High impact	5
PROBABILITY	**SCALE**
Low probability (≤10%)	1
Not probable (≤35%)	2
Could happen, but it doesn't have to (35%-60%)	3
Probable (>60%)	4
Very probable (>90%)	5

Table 5. Simple instruction for the respondents regarding the evaluation of the risk impact and probability

Table 5 shows the grades which were given according to the individual risks by every respondent. In this way, the percentage and the qualitative evaluation were exchanged by numbers from 1 – 5. In the first step, a selection took place and the risks with no significance in the project were eliminated for a better transparency. This way risks like e.g. usage of drugs and alcohol, conflict because of cultural differences, criminal acts, bribery and corruption in the field… were eliminated.

For the calculation of the final grade of the risk impact multiplying of numerical values was done, which were then assigned to risks, namely: impact on the deadline*probability and impact on the price*probability.

					MARJANOVIĆ		KOVAČEVIĆ
LEGAL RISK SOURCES	Law and regulation changes						
	impact on		deadline		1	1	2
			price		1	1	1
			probability		1		1
					1%		10%
	Delay of dispute settlements						
	Impact on		deadline		1	1	1
			price		1	1	1
			probability		1		1
					1%		10%

Table 6. Evaluation of the impact and the probability of risk occurrence

Table 6 shows an example of one risk evaluation by two respondents. From the questionnaire for the answers of the first respondents regarding the deadline and the price a grade 1, and the probability of occurrence 1% and that equals the grade 1. The column next to it represents the product of the probability multiplied with each of the grades and for the first respondent we get the grade 1 for the deadline and grade 1 for the price. According to that, the respondent believes that the listed risks has a small impact on the deadline and the price. The shown procedure was done for all the respondents and all the risks. Responses of all the respondents, transformed into numerical values were added for each of the risks separately in regards to the deadline and the price and were prepared for the analysis.

3. The analysis of obtained survey results – qualitative evaluation of the risks as a basis for the probabilistic definition

Based on the obtained numerical values, the average values were calculated and were sorted into a decreasing value list. With that, up to ten most significant risks were selected according to the values given by the practitioners, and they will be further analyzed. Given the above mentioned target structure of the respondents (from all the groups participating in the project implementation), and a large percentage of respondent questionnaires (90%), we consider that the resulting list of risks is representative.

Ten of the biggest risks with the impact on the deadline	
Delay of the access to the construction site and the right of way	11,07
Substandard blueprint	7,93
Deficiency in the blueprints and the specifications	7,57
Payment delays by the owner	7,43
Blueprints and the documents are late	6,93
Inadequate intervention by the owner	6,69
Imposing of unreal schedules by the owner	6,43
Unexpectedly bad weather conditions	6,36
Blueprint changes requested by the owner	6,29
Incompetence of the contractor	6,07
Ten of the biggest risks with the impact on the price	
Substandard blueprint	10,21
Deficiency in the blueprints and the specifications	9,86
The owner does not give the definition of the scope of the work	9,79
Delay of the access to the construction site and the right of way	9,5
Inflation and the sudden price change	8,93
Frequent blueprint changes by the designers	7,79
Blueprints and the documents are late	7,36
Imposing of unreal schedules by the owner	7,21
Inadequate intervention by the owner	6,38
Currency change	5,93
Ten of the biggest risks with the impact on the deadline + price	
Delay of the access to the construction site and the right of way	**20,57**
Substandard blueprint	**18,14**
Deficiency in the blueprints and the specifications	**17,43**
The owner does not give the definition of the scope of the work	**15,58**
Blueprints and the documents are late	**14,29**

Frequent blueprint changes by the designers	**13,79**
Imposing of unreal schedules by the owner	**13,64**
Inflation and the sudden price change	**13,14**
Payment delays by the owner	**13.07**
Inadequate intervention by the owner	**13,07**

Table 6 display of the choice of the most influential risks according to the selection of the practitioners, which participated in the project implementation

Five of the main sources of the risks, according to the results of the response analysis, are located within the legal and economic, which is management, technical documentation and the contract. In the risk analysis by the sources, which are shown in Table 6, it is apparent that the respondents – practitioners, which are extremely oriented on the completion, have identified the inner sources which are resolved by the participants in the projects. Problems related to the technical documentation, management function and the decision of the client also the contract terms are especially standing out. Out of the outer sources, the most prominent are legal problems regarding the property relations and actions with which the economic inputs, according to which the business operations of the executor were planned, are being altered.

By analyzing the ten biggest risks for the deadline and the price, one can notice that the practitioners mostly associate them with the technical documentation, construction site access conditions and the financing. In this way, they are confirming the world studies to date about the causes of the cost overruns, where in the technical reasons the weaknesses, which result from financing, the request of accelerated construction and the solving of property right relations, are being mentioned. The post-project analysis on the completed parts is indicating that the management of the program and of the associated projects have substantially mitigated the possible maximum negative impacts of the risks. The high position of the impact of the price changes and the inflation and the payment delay are a consequence of the time when the study was made. It was the time of the global crisis, which did not pass by the highway construction, so, for example, the increase in material prices (oil; steel, …) and the disrupted payment dynamic have had an effect on the business operations of the contractor. The biggest indicated risk, which had the biggest impact on the deadline, a high place in the impact on the price and in general recognized as the biggest risks was the delay of the access to the construction site. With the beginning of the construction works deadlocks occur because the purchase of the private property was not secured and because of the unregulated property and legal relations even on the land which is the property of the state, and because of the archeological studies. Unregulated land registry is the result of unregulated property relations from the socialist period. The problem of the quality of the technical documentation was not directly linked to competence and solidness of the production, but primarily a consequence of an accelerated construction, which was planned by the state and the detailed construction preparations were not done. Low quality or lacking blueprint is a risk which has a significant price change as a consequence, a consequence of a bad assessment but also of additional involvement to hold up the deadline. Short deadlines of document drafting with insufficient research works and the imprecise surface result in changes, that is in delays, expansions of existing tasks and unpredicted and subsequent works.

However, the completion of a project within the set and short deadlines is a result of joint operations and concern about the interest of all the participants in the implementation as one of the strategic guidelines of the state. The concern about the business operations of the contractors, designers and the oversight has been paid back through greater efficiency, rationality and the discipline of the participants.

The risks, which were singled out in accordance with their significance by the practitioners occur mainly in the beginning phases of the project implementation. The singled out risks are such, that the mitigation or avoidance of their negative effects requires truly a joint action of all the contract parties. As an example: Delay of the access to the construction site because of unsorted property relations or the lack of an agreement with the landowner is a source of additional costs for the contractor. As it is mostly the obligation of the investor, there is a justification of expense reimbursements caused by the delay. On the other hand, the investor has initiated a line of activities on other projects. Some construction sites and locations are located very close and some of the construction sites have the same investor. By cooperation and coordination of planning additional costs were avoided in a way, in which the activities of the contractor would be diverted onto other projects until the delay has been cleared. Such an approach has a significantly higher efficiency than the rigid pursuit of short-term interests and it has influenced the efficacy of the project regarding the deadline and the price. Incomplete or unclear blueprints, and the alteration of the documentation in accordance with the needs that arise on the field and the technology are also coordinated by a mutual appreciation of the contract parties. Adaptation of project solutions to the technology of the contractor was regarded as a contribution to the quality, speed and cost-effectiveness and the project managers were participating in finding a solution as the representatives of the investor. Such practice has proven to be successful and welcome in the project implementation.

Besides knowing the risk itself, in the preparation of the probabilistic approach, it is important to know the driving force of the risk. That fact can largely indicate a potential bias, but also the competence at the project assessment. The driving force is a participant or an incident, which moves the risk from a passive state to an active one. A part of the driving force has its origin in specific regions and the other part in the quality of planning. States in this region have largely originated form communist systems, which have disturbed the question of ownership. That is the reason why the true owner of the land is unknown, or the state has entered itself into the register of the land, which is being used for decades by a private person and similar. Inadequate and insufficient blueprints are most commonly the consequence of forcing the documentation procurement and the beginning of the constructions. That means that the period untill the signing of the agreement is not sufficient for the creation of quality blueprints. The driving force of these risks is formally the designer. However, he is not the real source of the risk, which is truly hiding in a political and economic demands, which are forcing an accelerated delivery of the blueprints. As a successful response of the practitioners to these circumstances is the cooperation of all the contract parties, which includes the necessary understanding. And by that, the strong support of the state in securing the financial means is meant so that the project can be continued with the requested dynamic.

Risk	**Scenario**	**Driving force**
Delay of the access to the construction site	Unsorted property relations or the lack of an agreement with the landowner, which is preventing the beginning of the construction	The state as the successor of the unsorted property relations from the past

Substandard blueprint	Incomplete or superficial blueprint	An investor, trying to gain implementation speed under the influence of politics
Insufficient blueprint	Complete, but inaccurate blueprint	Designer
Undefined scope of the works	Widening of the scope of the project because of the subsequent interventions.	Local authorities, political influence
Inflation and the price change	Cost increase, contractor profit decrease	global crisis
Blueprint changes	Alteration of technical solutions due to specific technology	Contractor
Payment delay	Disruption in the payments between the contractor – manufacturer	Contractor due to impeded business operations, global crisis

Table 7: Overview of the scenarios which initiate the most influential risks on the deadline + price

4. Conclusion

In this study, we have found that in the Republic of Croatia exist influence of the historical-economic heritage on conduction of the construction road projects. In addition, we have found the main risks, which follow constructions highway project in the Republic of Croatia, and we ranked them according their influence. From the conducted study, risks can be observed which were a part of the implementation of the highway project in Croatia, but are in some way representative for the whole region. That is especially true for the access to the construction site due to unsorted property relations as historical heritage. During the period in which the study was conducted, influences of the global crisis are noticeable through the high positioning of the risks of payment delays and the influence of the inflation, as a reaction, which is specific in relations to the reactions of other regions, of the market. However, at the end can be stated that the project, although complex in all of the aspects, was implemented very successfully. According to the analysis of IBR Consulting, s.r.o. (MOTORWAYS CONSTRUCTION COST COMPARISON IN THE CZECH REPUBLIC WITH OTHER EU STATES) the costs of the highway construction in Croatia are amongst the lowest in Europe. Highways from the technical aspect are of good quality, which was confirmed by some international rewards (reward for the best tunnel and the service station). The effectiveness was enviable, and for which the risk management was crucial. It can be concluded that the risk management system can be institutionalised better, but the deviation from the planned values in a financial sense is in the framework of the EU average. During the implementation interventions, which have resulted in a better outcome than the initial ones, were quite common. Interventions are the consequence of a fast-paced construction dynamic and a good project monitoring and management in the implementation phase. The teams, formed by the Investor for individual road section, which was given them to manage, with separate contracts, were able to react swiftly to a problem in the field and induce changes in the project documentation. However, the key to success is the communication between all the contract parties.

The risk projection is extremely important for the activity planning, and therefore quite logically, for the construction cost assessment. Recognizing the risks from an aspect of an investor is the basis for risk management, according to which he can plan for the time and resources more accurately, which are the basis for the calculations of the coast assessment. On the other hand, for the contractor, the identification of the risks means a preparation of a reliable offer, which ensures the quality work. The success of a project relies on the satisfaction of all parties involved in the implementation, so the sincere approach to the cost assessment, which provides knowledge about risks, is the basis for a successful project.

These experiences can be efficiently used in the preparation of new projects in the Republic of Croatia, but also in the surrounding countries in project management and the road infrastructure construction cost assessment.

References

Ambrasaite, I., Nicolaisen, M.S., Leleur, S., Salling, K.B., 2012. UPD – the UNITE Project Database: Collection of reference class information. Database concerning cost and demand inaccuracies, database developed as part of the UNITE (Uncertainties in Transport Project Evaluation), funded by the Danish Council for Strategic Research (2009–2013).

Ambrasaite,I., Barfod,M.B., Salling K.B., 2011, MCDA and Risk Analysis in Transport Infrastructure Appraisals: the Rail Baltica Case, Procedia Social and Behavioral Sciences 20 (2011) 944–953

Beria, P, Maltese, I, Mariotti, I 2011, Comparing cost benefit and multi-criteria analysis: the evaluation of neighbourhoods sustainable mobility; Società Italiana degli Economisti dei Trasporti-XIII Riunione Scientifica, Messina

Board, A., Greenberg, D, Vining, A & Weimer, D 2014, Cost benefit analysis concept and practice, Pearson Education Limited, Harlow

Burcar D., I, Radujković, M., Vukomanović, M., 2013, Razvoj i implementacija registra rizika kod građevinskih projekata (Development and implementation of risk register for construction projects), GRAĐEVINAR. 65 (2013), 9; 23-35

Cantarelli, C. C., Flyvbjerg, B., Molin, E.J.E., and van Wee, B. 2010. "Cost Overruns in Large-Scale Transportation Infrastructure Projects: Explanations and Their Theoretical Embeddedness," European Journal of Transport and Infrastructure Research, 10 (1): pp. 5-18.

Cantarelli, CC, Molin EJE, van Wee, B, Flayvbjerg, B, 2012, Characteristics of cost overruns for Dutch transport infrastructure projects and the importance of the decision to build and project phases, Transport Policy, 22, pp. 49-56

Cerić, A., Marić, T., 2011, Određivanje prvenstva pri upravljanju rizicima građevinskih projekata, GRAĐEVINAR. 63 (2011), 3; 265-271

Crnjak M., Puž G.; Pregled razvitka mreže autocesta u Republici Hrvatskoj, HRVATSKE AUTOCESTE d.o.o., Sektor za razvoj, tehničku regulativu i tehnologiju

Dzeng, RJ, Wang, SS 2008, An analysis of infrastructure development based on national competitiveness perspectives, Construction Management and Economics 26, pp. 47-61 EIB (2005), RAILPAG-Railways Project Appraisal Guidelines, European Commission and European Investment Bank, avilable at: www.railpag.com

Eliasson, J., Fosgerau, M., 2013. Cost overruns and demand shortfalls-Deception or selection? Transp. Res. Part B: Methodology. 57 (2013), 105–113.

European Commission, eurostat; http://epp.eurostat.ec.europa.eu/

Flyvbjerg, B, Holm, MS & Buhl, SL 2002, Underestimating Cost in Public Works Projects: Error or Lie, Journal of the American Planning Association, vol. 68, no.3, pp.279-295

Flyvbjerg, B., Skarmis Holm, M.K. and Buhl, SL (2003): How Common and How Large are Cost Overruns in Transport Infrastructure Projects? Transport Reviews, volume 23, No. 1, January-March 2003,pp. 71-88

Flyvbjerg, B, Skamris Holm, M.K., Buhl, S.L. (2005), How (in)accurate are demand forecast in public works projects? The case of transportation, Journal pf the American Planning Association, 71 (2), Spring, pp.131-146

Flyvbjerg, Bent in association with COWI (2004), 'Procedures for Dealing with Optimism Bias in Transport Planning: Guidance Document', for the British Department for Transport, London.

Flyvbjerg, B (2006), From Nobel Prize to Project Management: Getting Risks Right, Project Management Journal, vol. 37, no. 3, August 2006, pp. 5-15

Flyvbjerg, B., Skarmis Holm, M.K. and Buhl, SL (2004): What Causes Cost Overrun in Transport Infrastructure Projects? Transport Reviews, Volume 24, No. 1, January 2004, pp. 3-18

Flyvbjerg, B.,2014, "What You Should Know about Megaprojects and Why: An Overview," Project Management Journal, vol. 45, no. 2, April-May, pp. 6-19, DOI: 10.1002/pmj.21409

Fuguitt, D & Wilcox, SJ 2013, Cost-Benefit Analysis for Public Sector Decision Maker, Quorum Books, Westport

HM Treasury (2003a) The Green Book: Appraisal and Evaluation in Central Government, Treasury Guidance (London: TSO).

HM Treasury (2003b) Supplementary Green Book Guidance: Optimism Bias (London: HM Treasury).

HM Treasury Green Book, Appraisal and Evaluation in Central Government, Treasury Guidance (London: TSO),

Hrvatske autoceste d.o.o. (2003) Izvješća o poslovanju Hrvatskih autocesta d.o.o. u razdoblju 2005,2006, 2007, 2008 godine. Zagreb,

IBR Consulting, s.r.o., Motorways construction cost comparison in the Czech republic with other EU states, godina 2008

Jonas Eliassona, J, Fosgeraua, M, 2013, Optimism bias in project appraisal: deception or selection?, Centre for Transport Studies, KTH Royal Institute of Technology, Stockholm, DTU Transport, Copenhagen

Lee, L. (2008). "Cost Overrun and Cause in Korean Social Overhead Capital Projects: Roads, Rails, Airports, and Ports." Journal of Urban Planning and Development 134(2): 59-62

Leleur, S., Petersen, N.B., & Barfod M.B. (2007). The COSIMA Approach to Transport Decision Making - Combining Cost-Benefit and Multi-Criteria Analysis for Comprehensive Project Appraisal. In K.S. Kim (Eds.), Improving Public Investment Management for Large-ScaleGovernment Projects: Focusing on the Feasibility Studies - Lessons and Challenges (pp. 100-122). KDI.

Love P.E.D., 2011, Plugging the Gaps' Between Optimum Bias and Strategic Misrepresentation and Infrastructure Cost Overruns, Procedia Engineering 14, p.p. 1197–1204

Mackie, P., Preston, J., 1998. Twenty-one sources of error and bias in transport project appraisal. Transport Policy 5 (1), 1–7.

Magnussen, OM, Samset, K. (2005); Successful megaprojects: Ensuring quality at entry, Munich: Proceedings of EURAM 2005

Merrow, E., Industrial Megaprojects, Concepts, Strategies, and practices for Success, J. Wiley & Sons, New Jersey, 2011.

Miller, R., Hobbs, B., (2005) Governance regimes for large complex projects, Project Management Journal, Vol.36, pp. 42-50

Mott MacDonald (2002) Review of Large Public Procurement in the UK, Study for HM Treasury (London: HMTreasury).

Narodne novine br. 147, Program for construction and maintenance of public roads for the period from 2009 to 2012, 10.12.2009.

Næss, P., Nicolaisen, M.S., Strand, A., 2012. Traffic Forecasts ignoring induced demand: a shakyr fundament for cost-benefit analyses. Eur. J. Transp. Infrastruct. Res. 12 (3), 291–309.

NETLIPSE , Managing Large Infrastructure Projects, AT Osborne BV, the Nederlands, 2008.

Nicolaisen, M.S., Ambrasaite, I., Salling, K.B., 2012,Forecasts: uncertain, inaccurate and biased? Artikler fra Trafikdage pa Aalborg Universitet

Nickel, J, Ross, AM & Rhodes, DH 2009, Comparison of Project Evaluation Using Cost-Benefit Analysis and Multi-Attribute Trade space Exploration in the Transportation Domain; Second International Symposium on Engineering System, MIT, Cambridge, Massachusetts, June 15-17, 2009

Odeck, J., 2014, Do reforms reduce the magnitudes of cost overruns in road projects? Statistical evidence from Norway, Transportation Research Part A 65 (2014) 68–7

Odgaard, T., Kelly, C., Laird, J., 2005, Current practice in project appraisal in Europe, Deliverable 1, European Commission EC-DG TREN HEATCO Work Package 3

Priemus, H, Flyvbjerg, B, van Wee, B, (2008); Decision-Making on Mega-Projects Cost–Benefit Analysis, Planning and Innovation, Edward Elgar Publishing Limited, Glensanda House Montpellier Parade, Cheltenham, UK, Edward Elgar Publishing, Inc., William Pratt House, Northampton, Massachusetts, USA

Radujković M. - “Risk Sources and Drivers in Construction Projects”, International Symposium PRM’97 Helsinki, International Project Management Association IPMA, E&FN SPON, London 1997, pp. 275 - 284.

Radujković, M. - Upravljanje rizikom i promjenama u projektno usmjerenom građevinskom poduzeću» , istraživački projekat broj 082......, Ministarstvo znanosti , obrazovanja i športa RH, 2007-2011. g.

Salling, K.B., Leleur, S., 2015, Accounting for the inaccuracies in demand forecasts and constructio cost estimations in transport project evaluation, Transport Policy 38 (2015), p.p. 8-18

Transport development strategy of the Republic of Croatia. Ministry of Maritime Affairs, Transport and Infrastructure of the Republic of Croatia, Zagreb 1999.

Ten Step, Basic methodology translation to Croatian, PrimaKon, 2005

Effects of Collusion on Performance of Construction Projects

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Abstract:

Collusion is an immoral and dishonorable alliance among competitors that is geared towards circumventing the laid down principles and right process of achieving an objective in a sector or organization. In this study, effect of these unethical practices in the construction industry were examined with a view to improving the performance of construction projects. Relying on the expert opinions of learned and experienced stakeholders in the construction industry, questionnaire was adopted as the research instruments, which were distributed to professionals in the construction industry. Cronbach's alpha value of 0.827 computed for this study indicate an acceptable level of consistency among the identified variables. There is a need to check the activities relating to collusion in the industry because of the potential of causing unfair competition among competitors bidding for professional or construction services among other effects. This eventually result to increase in tender amount and also limit the growth and development potential of emerging contractors and professionals in the industry. Agencies, bodies as well as professional institutions and bodies shouldered with the responsibilities of regulating and monitoring activities of people involved in construction process will find the information provided by the study useful in their quest to curb unethical practices, especially collusion in the industry. People in construction especially clients, professionals and contractors that are directly involved with construction activities will also find the outcome of this study useful in their pursuit of service excellence.

Keywords: *Construction industry; Corruption; Project performance; Project stakeholder, Unethical practice.*

1. Introduction

The construction industry plays a significant role in the economic growth and social development. In addition, it provides the physical infrastructure that is the backbone of economic activity. It is also a large-scale provider of employment opportunities. One of the missions of the government of South Africa is to uplift historically disadvantaged persons, develop small medium contractors and ensure fair competition. This study highlighted the effects of collusion in the construction industry which holds back the development of new contractors and reduce overall performance of construction projects. Hekima advisory (2014) explained that, cartels in 2010 stadia upgrades in the country enjoyed a quiet and huge amount of profits. This clearly shows that collusion is caused by contractor greed, insufficient monitoring and regulatory policies as well as lack willingness to do things in the right way (Doree, 2004). Collusion has negative effects not only on the performance of the construction industry but on

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the economy as a whole (Organization of Economic Co-operation and Development, 2012).

Allix (2014) stated that the reason competition and corruption laws are introduced is because cartels impose serious damage on the productivity, economic growth and trade expansion. In addition, Constantinou, et al. (2014) noted that effective cartels also increase the tender amount that will be paid by clients, at the same time decreasing the quality supplied to the market. Collusive tendering and corruption in both public and private procurement have been existing for a while, as a result, the effectiveness of public procurement is affected on the basis of the money is wasted, ultimately results in fewer public funds (Organization of Economic Co-operation and Development, 2010). The effects of collusion in the public procurement is more alarming than in the private sector and this is due to the fact that the public funds are lost, which affects the performance of the infrastructure and public services. Moreover, it has the huge impact particularly on societies that are historically disadvantaged, which mostly depend on public funds. The major effect of collusion is that it restricts developing companies from gaining experience and opportunities to tender for large projects. In view of this, this study evaluates the influence of collusion practices among construction stakeholders with a view to create necessary awareness among construction individuals and improve the overall performance of construction projects.

2. Review of the Effects of Collusion

Collusion in the construction industry or any other industry is prohibited by the competition law. However, collusion in the construction industry is increasing drastically. Collusion has a negative effects on the economy and the construction industry, and several investigations by the Construction Industry Development Board (CIDB) found that larger companies are more involved in collusion than smaller companies. What large companies do is that, they develop a strong relationship with large clients in the market which makes it more difficult for emerging contractors to gain experience, and to build a good reputation of satisfying client. As a result, emerging companies may even not be allowed to tender for large projects (Organization of Economic Co-operation and Development, 2008). Moreover, collusion may decrease the number of companies who wish to tender, an increase in the average tender price and a decrease in the tender variance disregarding of the collusive tendering arrangement (Zarkada and Skitmore, 2000).

2.1 Bid rigging

The main objective of bid rigging schemes is to take prices high for the winning bid, ultimately takes the amount high that the winning bidders will gain. The mechanisms to allocate and share additional profits that were obtained from raising the final contracted amounts amongst the conspirators is often included in bid rigging schemes. However, agreements of bid rigging that exist for a while tend to employ much more detailed methods of designating contracts to winners, allocating and monitoring bids gains over a period of time. Bid rigging also involves fiscal payment by the chosen winner to those who were involved in the conspiracy.

Chwedhury (2008) argued that bid rigging aims to take the cost of clients high, as they’re the ones who will be paying for products or services. Moreover it has been judged tentatively that bid rigging practices, can raise prices of products or services up to more than 10% of the total contract amount. Based on the experience of Japan Fair Trade (JFT) state project, Shoga

(2006) noted that bid rigging can push contract prices up by 20% to 30%. In view of this, Chwedhury (2008) concluded that higher prices as a results of bid rigging leads to clients having few available resources that can be dedicated to other needs. Furthermore, there are certain types of bid rigging that entails designated winning bidder to compensate the losers as to recoup their loss either by sub-contracting some part of the works or paying off in cash. The World Bank (2004) also put forward the idea that the winning bidder tends to inflate prices of the bill particularly material, labor or under-deliver on quality, and quantity in comparison to the specifications of the contract.

Chwedhury (2008) concluded that the main objective of bid rigging is to remove domestic competitors not only within the purchasing country but also among international competitors, and as a result, it has an effect on the economic development as a whole. Furthermore, the Organization of Economic Co-operation and Development (OECD, 2010) observed that bid rigging eliminates competition and as a result, discourages qualified competitors to bid and compete which also leads to low quality standards. According to Ratshisusu (2014), bid rigging is one of the practices that are anti-competitive at which international cartels perpetuated actively. In areas of the world where local markets are dominated by few companies, bid rigging and cartels are common practices, and they tend to inflate prices.

2.2 Monopolistic context

Monopoly is a market situation in which there is a single seller of commodity of lasting distinction without close substitutes (Licetti, 2013). A monopoly company enjoys the power of producing and selling commodity, however this does not mean that the company is absolutely free from competition. Another means of viewing monopolistic concept is through formation of cartel. According to Organization of Economic Co-operation and Development (2010), a cartel is an agreement of cooperation formed between competitors in a specific industry. It is a group of companies in the same industry or market colluding together as to act as one firm. The main objective of monopoly scheme is to restrict output and thus by increasing prices, cartels also tend perform exactly the same way as monopoly by colluding.

According to Licetti (2013), the inefficiencies that tend to arise when markets are being centralized and the fact that why hard-core cartel are agreed to be illegal. If a conspiracy is successful, it enforces more or less the same inefficiencies on consumers and on the economic growth as monopoly. Consumers that still buy the good and services are basically paying a higher price than they would have been paying under competitive conditions, even if the nature of that competitive alternative would be oligopolistic (Khan, 1996). As a result, it was further pointed out that the consumers that would have been prepared to consume at the oligopolistic competitive price are denied that chance. This implies that the market is priced out as a result of conspiracy.

2.3 Development projects

According to Messick (2011), bid rigging has a huge impact on the projects that are in development stage or those construed for developmental purpose. Bid rigging has an impact on these projects as prices are pushed up, which can lead to inefficient allocations of resources. As a result, the flow of other projects are interrupted. It is also worthy of note that projects that are under-delivered are often as a result of bid rigging which impacts the public at large (Sohail and Cavill, 2008). Moreover, it has a negative effect on the poor in particular because most of the projects are conceptualized for their own exclusive benefit.

Bid rigging in development projects affects the credibility of borrowing money from institutions, such as the World Bank, which lends money to countries for public projects (World Bank, 2004). Sohail and Cavill (2008) also put forward the idea that the spreading of corruption i.e. bribery, defalcation, fraud and kickbacks in the sector of construction is a major cause of poor or non-delivery of infrastructure projects.

2.4 Developing countries

Investing in infrastructure projects is very vital for the development of the construction industry and the overall growth of the economy. However, there is a widespread of dissatisfaction with the outcome of construction investment in developing countries, which has affected their growth and overall development (Ayodele, 2011). Challenges that are faced by most of developing countries include poor quality standards, cost overruns, schedule overruns excessive high prices, inadequate maintenance and low returns (Organization of Economic Co-operation and Development, 2014). As a result these challenges impacts the development negatively and poverty alleviation. Ayodele (2011) noted that construction outcome which tends to be poor in developing countries are always related to collusive tendering and inefficient management. It was further stated that the construction sector of the economy is one of the corrupt sectors worldwide.

Khan (1996) classified effects of collusion on developing countries into primary and secondary. The primary effect of collusion is allocation of resources for instance if the resources are used by someone who already benefited not the one who doesn't have access to those resources. A secondary effect is on the economy as a whole, that resources are being lost due to collusion which results in a decay of social output. Thus collusion in developing countries has a negative effect. According to the Organization of Economic Co-operation and Development (OECD, 2014), competition in any market has a positive effect on productivity and overall growth of the market.

According to Ravindran (2004), practices such as bid rigging in developing countries mostly affects the tax payers of those countries, this is because as they are the ones paying back the lost money that are sometimes borrowed from development banks. This implies that the impoverished are not only cheated out of the development benefits, they are left to repay the resulting debts to banks. Bid rigging in developing countries is particularly vulnerable due to adoption of inappropriate procurement method especially for public projects, inadequate legal and framework of regulation for antitrust enforcement, and the absence of awareness (Organization of Economic Co-operation and Development (OECD, 2009). The World Bank (2004) also noted that developing countries are more prone to collusive tendering at an international level, the reason being that they lack the capacity to execute large infrastructure projects on their own, and as a result, foreign firms are invited to tender for such projects.

Constantinou, et al. (2014) stated that effective cartels also increase the tender amount that will be paid by clients, at the same time decreasing the quality supplied to the market. More so, Levenstein, et al. (2003) stated that effects of cartel formation may not be just on the financial gain of the final consumer who should pay high prices, it can also undermine the profitability or competitiveness of developing country manufactures who rely on centralized goods for inputs to production, which adversely affect the development process of the country.

3. Research Methodology

To evaluate the effect of collusion on construction project performance, survey design was adopted for the purpose of obtaining information from individuals and experts in the area. Using quantitative approach, questionnaires were administered on construction professionals practicing within construction, consulting and government establishments within Gauteng region of South Africa. These includes quantity surveyors, architects, construction managers, project managers and engineers. 50 questionnaires were distributed among these professionals using purposive sampling method and 45 were retrieved. A minimum of 5 years working experience was adopted as the basis for the choice of respondents.

The questionnaire was prepared to evaluate the perception of professionals regarding the effects of collusion as well as giving respondents a chance to rank the identified causes. The questionnaire is divided into two sections in which the first section is concerned with general and background information of respondents while the second section focuses essentially on the effects of collusion on project performance in the construction industry. A cover page was also provided which is basically a cover letter highlighting a description of the researcher and their firms. The cover letter seeks permission of respondents to participate in the survey and also highlighted the main purpose of the study.

To evaluate the identified effects of collusion on project performance, a rating scale with five (5) points was adopted. The adopted 5-point scale was as follows: 1=Strongly Disagree (SD); 2=Disagree (D); 3=Neutral (N); 4=Agree (A); and 5=Strongly Agree. The 5-point scale were transformed to mean item score for each aspect to rank the factors. The ranking helped to identify the relative importance of each variable as recognized by the respondents. The mean item score (MIS) and standard deviation (SD) were determined from the total of all weighted respondents and then relating it to the total response on a particular aspect. This was based on the principle that respondents' scores on all the selected criteria, considered together, are the indices of importance of the factors. After analytical calculation and the computation of standard deviation (SD), the variables were raked in descending order of their mean item score from highest to lowest. Cronbach's alpha value of 0.827 computed for this study indicate an acceptable level of consistency and agreement among respondents for the study.

4. Findings and Discussions

Table 1 reveals the effects of collusion on the construction industry and the overall effect on the development of the country and the most significant effect is unfair competition with MIS of 4.15 and SD of 0.760. Other significant effects include limitation of the growth potential of emerging contractors (MIS of 4.12 and SD of 1.029); high increase in tender amounts (MIS of 4.02 and SD of 0.961); discourages qualified bidders to compete (MIS of 3.98 and SD of 0.88); impose damage on the economic (MIS of 3.93 and SD of 0.932); results in dwindle of public funds (MIS of 3.9 and SD of 0.889); poor standards or non-delivery of infrastructure projects (MIS of 3.90 and SD of 0.800); impose damage on trade expansion (MIS of 3.83 and SD of 0.919).

Other effects of collusion in the construction industry include schedule overrun with MIS of 3.83 and standard deviation 0.946; increases tax as public funds are lost (MIS of 3.71 and SD of 0.955); increases poverty (MIS of 3.71 and SD of 1.078); negatively affects the performance of infrastructure (MIS of 3.68 and SD of 1.192); affects the credibility of lending funds from institutions such as world bank (MIS of 3.61 and SD of 1.022); and increase in maintenance cost (MIS of 3.51 and SD of 1.028). The least effects of collusion were found to be its potential to reduce productivity project performance with MIS of 3.49 and SD of 1.121; as well as elimination of foreign investments with MIS of 3.46 and SD of 1.075.

Table 1: The effects of collusion in the construction industry

Effects of collusion	MIS	SD	R
Unfair competition	4.15	0.760	1
Limit the potential of emerging contractors to grow	4.12	1.029	2
High increase in tender amounts	4.02	0.961	3
Discourages qualified bidders to compete	3.98	0.880	4
Impose damage on the economic growth	3.93	0.932	5
Results in dwindle of public funds	3.90	0.889	6
Poor standards or non-delivery of infrastructure projects	3.90	0.800	7
Impose damage on trade expansion	3.83	0.919	8
Schedule overrun	3.83	0.946	9
Increases tax as the public funds are lost	3.71	0.955	10
Increases poverty	3.71	1.078	11
Negatively affects the performance of the infrastructure	3.68	1.192	12
Affects the credibility of lending funds from institutions such as World Bank	3.61	1.022	13
Increase maintenance cost	3.51	1.028	14
Impose damage on the project productivity	3.49	1.121	15
Eliminates foreign investments	3.46	1.075	16

MIS-Mean Item Score; SD- Standard Deviation; R-Rank

A study by OECD (2010) and OECD (2008) concluded that collusion in the construction industry limit the potential of emerging contractors to grow as they only rely mainly on subcontractor, which is in agreement with the findings of this study. Collusion leads to unfair competition among the known and established contractors, and it is detrimental to the performance of construction projects and the industry at large. Furthermore, it has been observed that collusion increases the amount of contracts, and as a result, clients end up paying high prices (Chowdhury, 2008). Due to the importance of the construction sector as a major contributor to the economy development of a country, there is a need to monitor the various acts of cartel and collusion. This is in agreement with the observations of Khumalo et al. (2010) and Allix (2014) that collusion affects the productivity and performance of construction projects, which eventually affect the construction industry at large.

5. Conclusion and Recommendations

This research evaluated the effects of collusion in the construction industry. The reviewed literature materials revealed that there are a variety of effects of collusion in the construction industry and they include such things as limits the potential of emerging contractors to grow, imposes damage on the project productivity, imposes damage on the economic growth, imposes damage on trade expansion, results in dwindle of public funds, increases tax as the public funds are lost, negatively affects the performance of the infrastructure, affects the credibility of lending funds from institutions such as world bank, high increase in tender amounts, discourages qualified bidders to compete, poor standards or non-delivery of infrastructure projects, eliminates foreign investments, increases poverty, unfair competition, increase maintenance cost and schedule overrun were some of the effects identified.

Findings obtained through questionnaires administered on relevant and experienced construction professionals reveals that collusion has the likelihood of limiting the potential of emerging contractors to grow, result in unfair competition, leads to high increase in tender amounts, results in poor standards or non-delivery of infrastructure projects, imposes damage on the economic growth, discourages qualified bidders to compete, results in dwindle of public funds, as well as imposes damage on trade expansion, schedule overrun, which negatively affects the performance of construction projects in general.

Most of the projects that experience collusion or corruption results in either poor standards or non-delivery of infrastructure projects to time, cost and satisfaction of clients and other stakeholders. Emerging contractors will always struggle to grow as long as the issues of collusion and corruption persist, and this also leads to other effects such as poverty and lack of employment. This implies that the need to monitor collusive activities in the construction industry and enforcement of appropriate sanctions on individuals caught in the act cannot be overemphasized. Agencies such as construction industry development board (cidb) should therefore be empowered not only to regulate and monitor construction business and activities in South Africa, but should be able to sanction and melt out appropriate penalties to culpable individuals and companies.

References

Allix, M. (2014, March). Construction collusion “was almost entrenched”, Available at: http://www.bdlive.co.za/business/industrials/2014/03/11/construction-collusion-was-almost-entrenched (Accessed 12 May 2015)

Ayodele, E.O. (2011). "Corruption in the construction industry of Nigeria: Causes and solutions" Journal of Emerging Trends in Economics and Management Sciences, Vol. 2 No. 3, pp.156-159.

Chwedhury, J. (2008). The basics of bid rigging. Unpublished thesis. India: CUTS center for competition Investment & Economic Regulation.

Constantinou, A., Sylvester, A. & Mahlaba, S. (2014, February). Cartels have an insidious effect, Available at: http://www.bdlive.co.za/opinion/2014/02/21/cartels-have-an-insidious-effect (Accessed 16 August 2015)

Dorée, A.G. (2004). Collusion in the Dutch construction industry: An industrial organization perspective’. Building and research information, Vol. 32 No. 2, pp.146-156.

Hekima Advisory (2014). "The role of CIDB in limiting construction industry cartels". University of Johannesburg, Johannesburg.

Khan, M. H. (1996). A typology of corrupt transactions in developing countries. Ids Bulletin, Vol. 27 No. 2, pp. 12-21.

Khumalo, J., Pamela, N. & Njisane, Y. (2010). Cover pricing in the construction industry: Understanding the practice within a competition context, Available from http://www.compcom.co.za/wp-content/uploads/2014/09/Cover-pricing-in-the-construction-industry-Final.pdf. (Accessed 16 August 2016)

Levenstein, M.Suslow, V. & Oswald, L. (2003). International price-fixing cartels and developing countries: A discussion of effects and policy remedies. Michigan: William Davidson Institute.

Licetti, M.M. (2013). Combating cartels in developing countries: Implementing challenges on the ground, Competition Policy International, Inc., UK.

Messick, R. (2011). Curbing fraud, corruption, and collusion in the roads sector. The World Bank, Washington, DC:

Organization of Economic Co-operation and Development (2008). OECD annual report, Organization of Economic Co-operation and Development, available at: https://www.oecd.org/newsroom/40556222.pdf (Accessed 12 May 2015)

Organization of Economic Co-operation and Development (2009). OECD annual report, Organization of Economic Co-operation and Development, available at: https://www.oecd.org/newsroom/43125523.pdf (Accessed 12 May 2015)

Organization of Economic Co-operation and Development (2010). OECD annual report, Organization of Economic Co-operation and Development, available at: https://www.oecd.org/dac/44449684.pdf (Accessed 12 May 2015)

Organization of Economic Co-operation and Development (2012). OECD annual report, Organization of Economic Co-operation and Development, available at: https://www.oecd.org/newsroom/45121132.pdf (Accessed 12 May 2015)

Organization of Economic Co-operation and Development (2014). OECD annual report, Organization of Economic Co-operation and Development, available at: https://www.oecd.org/newsroom/46233432.pdf (Accessed 12 May 2015)

Ratshisusu, H. (2014). "Limiting collusion in the construction industry: A review of the bid-rigging settlement in South Africa". Journal of economics and financial sciences, Vol. 7 No. 7, pp.857-606.

Ravindran, P. (2004). The Hindu Business Line. Available from: http://www.blonnet.com. (Accessed 22 January 2016).

Shoga, I. (2006). Japan fair trade commission barks. Available from: http://www.jftc.go.jp/e-page/policyupdates/speeches.html. (Accessed 12 May, 2016)

Sohail, M. & Cavill, S. (2008). "Accountability to prevent corruption in construction projects", Journal of Construction Engineering and Management, Vol. 9 No. 134, pp. 729-738.

The World Bank Group (2004). Annual report on investigations and sanctions of staff misconduct and fraud and corruption in bank-financed projects. World Bank.

Zarkada-Fraser, A. & Skitmore, R.M. (2000). "Decisions with moral content: Collusion", Construction Management and Economics, Vol. 1 No. 18, pp. 101-111.

Review of Adoption of Sustainable Procurement in Construction Organizations

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Abstract:

Adopting sustainable procurement in construction organizations significantly improve competitive advantage, reputation, compliance with policies/regulations and efficient and effective use of natural resources. Sustainable procurement is now considered as a way for the industry to address this imbalance and contribute to this larger effort of achieving sustainable development. , However, the construction industry has to contend with its traditional objectives of cost; time and quality alongside the new challenge of sustainability.

This paper presents a critical review of literature of sustainable procurement adoption in the construction industry from a variety of perspectives and identifies needed future research.

On the basis of the analysis the following gaps were identified in terms of the practice and research: slow adoption of sustainable procurement by contracting construction organizations; construction organizations lag behind the adoption of sustainability; limited studies and understanding of adoption and diffusion of sustainability; limited research agenda on sustainable procurement in the industry; and limited use of theories in sustainable procurement studies.

The implication of the findings, therefore, calls for organizational integrative model grounded in the innovation adoption approach to examine how construction organization adopts sustainable procurement.

Hence, the motivation for the forgoing studies is to build a model for adoption of sustainable procurement in construction organizations.

Keywords: Sustainability; sustainable procurement, Adoption, construction organizations;

1 Introduction

The construction industry acknowledges the vital contribution towards the attainment of sustainable development (Jacqueline et al., 2012). Sustainable development is about achieving economic and social objectives while minimizing adverse environmental impacts (Bill and Roger, 2001). The construction sector is seen has a considerable contributor to global resource depletion (Bo et al., 2015; Qinghua et al., 2012). The Construction industry accounts for one-tenth of the global economy (Bo et al., 2015). The building sector consumes 30-40% of global energy requirements (UNEP, 2007).

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Sustainable procurement is an approach for the industry to address this imbalance and contribute to this larger effort of achieving sustainable development (Joanne and David, 2015). Sustainable procurement has received a considerable amount of attention in academic research and practice in recent times (Joanne and David, 2015; Veronika et al., 2014; Helen et al., 2012). Suzanne and Suzanne, (2014) point out the multiple increasing adoptions of sustainability in the supply chain of organizations generating interest in academic research. Despite the increase in academic research and practice, still much needs to be done. For instance, sustainability continues to be more of rhetoric than reality in the construction industry (Joanne and David, 2015; Will and Samuel, 2013). Will and Samuel (2013) pointed out that "future directions needed to translate sustainable procurement from rhetoric to reality including the development of suitable incentives and appropriate organizational structures". Quite recently Joanne and David (2015) drew attention to the continuous rhetoric of sustainability policies and the extent to which they are implemented in constructions organizations. Surprisingly public sector empirical research is limited (Alexander, 2017). In addition, theoretical understanding of what drives organizations to implement sustainable procurement is rare (Suzanne and Suzanne, 2014Alexsander (2017) posited that theory testing and development is in its infancy. The gap must be bridged by the adoption of organizational theories in sustainable procurement empirical research.

More interestingly the emergence of sustainability means they industry has to contend with the traditional objectives of cost, time and quality alongside the new challenge of sustainability (Sachie, 2013; Francis and Andrew, 2009). Notwithstanding this, the benefits of sustainable procurement in construction are not in doubt. It significantly ensures competitive advantage, reputation, compliance with policies/regulations and efficient and effective use of natural resources (Alex and Chris, 2014; Stefan and Adam 2012; Jacqueline et al., 2012; Matthew, 2012). Matthew, (2012) examined the potential benefits of adoption of sustainable procurement practices. Some of the benefits identified were long-term efficiency savings; more efficient and effective use of natural resources; reducing the harmful impact of pollution and waste, and reducing the impact of hazardous substances on human health and the environment. Alex and Chris (2014) highlighted the huge social, economic and environmental benefits in the adoption of sustainable practices. ,However, the construction industry has not yet fully adopted sustainable procurement and lags behind many other industries (Mazharul et al., 2016**;** Michelle and Alison 2014; Israel et al 2008). Sustained attention and pressure from stakeholders, policies, laws, and regulations are though pushing the industry to move towards sustainable procurement (Joanne and David, 2015; Umberto, 2012). Michelle and Alison,(2014) pointed out that notwithstanding the sustained interest, motivations and reforms undertaken by governments, the construction industry continuously lags behind other industries in sustainability adoption and implementation.

The purpose of this study is to review literature on sustainable procurement adoption in the construction industry from a variety of perspectives and identifies needed future research directions. The outline of the paper starts with current sustainable procurement and sustainable construction procurement trends, adoption processes of sustainable procurement, followed by enabling sustainable procurement in construction organizations and available tools, models and guidelines. The penultimate section dwells on theoretical perspectives underpinning sustainable procurement. The conclusion draws on the need for the development of an integrated framework underpin by grounded theories.

2 Sustainable procurement

In the last two decades, a substantial amount of literature on Sustainable procurement has been generated (Alexander, 2017; Suzanne and Suzanne, 2014; Helen et al 2012). Suzanne and Suzanne (2014) point out the increasing adoption of sustainability in the supply chain of organizations generating interest in academic research. Helen et al. (2012) analyzed 35 journals in the field of sustainable procurement from 1998 to 2010; the findings show a steady increase in the number of papers dealing with sustainable procurement. From 2009 to 2010, the number of sustainable procurement papers had increased from 40 to 100. The situation is not different in the construction industry, in particular, sustainability research continues to surge (Bo et al., 2015). Bo et al. (2015) reviewed the number and trends of sustainability related papers in 12 internationally recognized construction journals from 2000 to 2012. The results show an increasing trend in the number of sustainable construction-related papers from 30 papers in 2000 to 127 papers in 2012. Several terms are used to describe sustainable procurement practices, however practically having the same meaning (Samuel et al., 2013). Sustainable procurement is defined by the United Kingdom Government Commissioned Sustainable Procurement Taskforce as ‘‘a process whereby organizations meet their needs for goods, works and utilities in a way that achieves value for money on a whole life basis in terms of generating benefits not only to the organization, but also to society and the economy, whilst minimizing damage to the environment", (Procuring the Future, Sustainable Procurement Task Force, 2006). In other related terms green procurement is defined as the approach by which an organization integrate environmental criteria into all stages of the procurement process" (Maarten et al., 2005). In the context of construction, sustainable procurement is a process whereby the client and participating organizations meet design and development requirements in a way that achieves value for money on a whole life basis so as to generate benefits not only for project stakeholders but also to society and the economy, while minimizing any environmental damage (Zaid and Jupp, 2012).

Sustainable procurement research continues to be centered on the environmental aspect particularly energy and eco-efficiencies (Alexander, 2017; Helen et al 2012). Helen et al (2012) reviewed literature from 2000 to 2010 found environmental aspects of sustainable procurement outnumber those concerning the social aspects by more than two-to-one. There is no doubt that substantial progress has been made regarding the environmental aspect of sustainability, however, the integration of the three dimensions of sustainability: environmental, economic and social continues to be neglected (Israel et al, 2011). More research is called for to empirically study the tradeoff between the three dimensions of sustainability (Walker et al., 2012).

According to Vidal and Kozak (2008), diffusion and adoption of sustainability are poorly understood. So et al. (2012) developed a conceptual framework using Everett' (2003) Innovation Diffusion Theory; with emphasis on the rate of adoption and implementation of sustainability within a manufacturing supply chain context. The conceptual framework essentially outlines the decision process at various stage of sustainability adoption in supply chain enterprises. They concluded that diffusion of sustainability within the supply chain is not well understood. The few studies that have examined diffusion of sustainability practices focus more on environmental practices (Qinghua et al 2012, Kark and Peter, 2011; Vidal and Kozak, 2009). Samuel et al., (2013) called for more research in the diffusion and implementation of Sustainable procurement throughout the construction supply chains.

In addition, the concepts of sustainable procurement have mainly progressed in the developed countries (Helen et al 2012; Vidal and Kozak 2008). This concern must be addressed because “the path and approach to achieved sustainable procurement differ from country to country” (Robert, 95). Helen et al (2013) and Vidal and Kozak (2008) called for bringing the developing countries perspective into the international sustainability agenda as a way of having more equitable sustainability practices that reflect different contexts.

Public clients are under intense pressure from national and international organization to adopt and implement sustainable construction in their procurement strategies (Mazharul et al. 2016; Johnny et al., 2016). Mazharul et al. (2016) affirmed the growing domestic, international legal and regulatory pressure on construction organizations to adopt and implement sustainable procurement practices to reduce their blueprint on the environment. The linkage could be attributed to the significant influence clients have on the adoption of sustainable procurement due to their critical involvement in selecting the other stakeholders including consultants, contractors and determining construction products (Sara et al., 2015; Jacqueline et al., 2011). Halen et al. (2009) are of the view that if public sector were to demand sustainability in the procurement of goods, services, and works, a considerable amount of progress could be made towards sustainable development. For instance, the insistence of clients demanding incorporation of sustainability in construction projects resulted in 5,500 private companies signing up to the Global Reporting Initiative on Sustainability (Sara et al., 2015), public sector sustainable procurement research is often neglected. (Alexander, 2017; Halen et al.,2009). Comparable to the private sector, is under study (Sara et al., 2015, Stephen and Helen, 2012).To achieves the benefits of sustainable procurement, the public sector needs much attention in both practices and in the field of academic research (Stephen and Helen, 2012).

3 Adoption of sustainable procurement in construction

Traditionally procurement in the construction industry largely focused on price, quality and time (Sachie, 2013; Israel et al 2008). The construction industry mostly explores sustainability within the economic dimension and predictably projects are awarded to the contractor with the lowest evaluated tender price (Francis and Andrew, 2009). For example contracts in Ghana are awarded based on the lowest evaluated bidder at the cost of social and environmental considerations such as health and safety, recycling and re-use of waste, and energy consumption (Harold et al., 2016). Sachie, (2013) stressed that notwithstanding this, construction procurement has undergone significant transformations in recent years with focus shifting to ‘best value’ from traditional ‘least value’ concepts. Samuel et al. (2013) further observed that sustainable construction procurement has become of great significance within both the public and the private sector in recent years particularly since 1996 when research publications started to emerge on the subject. The increasing attention and pressure from stakeholders, policies, and regulations are fuelling the industry to move towards sustainable procurement (Joanne and David, 2015; Sara et al., 2015). For example, the increasing demands from clients for incorporation of sustainability in construction projects has compelled about 5,500 private companies to sign up to the Global Reporting Initiative on sustainability (Sara et al., 2015). Currently, more organizations are accepting the need to move beyond traditional concerns of immediate profit to a long term of objective of sustainability (James et al., 2016; Kent et. al, 2011). Notwithstanding this, most construction organizations are yet to fully adopt sustainable procurement and the industry lags behind many other industries (Mazharul et al., 2016; Michelle and Alison 2014). Mazharul et al. (2016) assert that construction organizations in the public and the private sector have not fully fused sustainability practices in the bulk of procurement decisions in most developing countries. Michelle and Alison pointed out that notwithstanding the sustained interest, motivations and reforms undertaken by the UK government, the construction industry continuously lags behind other industries with respect to sustainability adoption and implementation. This is further highlighted by Joanne and David (2015) that despite the high positive commitments to sustainable procurement at organizational and construction sector levels, it has not resulted in an equal measure of adoption and implementation in the United Kingdom's social housing sector. Rajeev and Kasun, (2015) also observed that Sustainable procurement in the Canadian construction industry is still in its infancy not widely adopted and implemented. Moreover Samuel et al., (2013); and Jacqueline et al., 2012); suggest that currently there is limited practice and research agenda in the area of sustainable procurement in the industry.

Academic research and practice efforts have also been criticized for narrowly focusing on environmental sustainability more than the whole sustainability concept (Rajeev and Kasun, 2015; Qinghua et al., 2012; Joanne and David, 2011). Johnny et al. (2016) for example in their study focused on the environmental aspect of sustainable procurement. Peter and Olusanjo, (2013) also analyzed the determinants of environmentally sustainable practices in the UK construction industry. Qinghua et al. (2012) further pointed out that the social aspect of sustainability has not received its fair share of both existing industry practice and academic research compare to environmental. These studies confirm the growing focus of environmental aspect of sustainability practice and research in the industry and suggest a failure to integrate economic, social and environmental concerns in procurement (Joanne and David 2011). . . Quite recently, Rajeev and Kasun, (2015) articulated similar view and confirmed the neglect of the triple bottom line (TBL) of sustainability in construction procurement. Rajeev and Kasun, (2015) noted that the attainment of the triple bottom line of sustainability (society, environment, and economy) is important to deliver a holistic sustainability in construction successfully and suggested that the concept should move more beyond the sole promotion of environmental and green ideas.

The current state of sustainable procurement adoption in the construction industry is attributed to the inadequate funding, insufficient/confusing guidance and tools, insufficient/inconsistent policies, regulations, organizational culture and lack of leadership and commitment of stakeholders of the industry to adopt and implement sustainable procurement practices (Rajeev and Kasun, 2015; Sara et al., 2015). For instance in the study of Alex and Vian (2014), lack of clients requirements; lack of understanding sustainability; perceived higher cost of sustainability; inadequate knowledge and skills of employees were pointed as some of the challenges. Also in the study of Sara et al., (2015) hindrance based on lack of knowledge, resource constraints and weak frameworks were identified. According to Mazharul et al (2016), varying barriers affect the adoption and implementation of sustainable procurement practices across countries, organizations, and sectors. For example in the USA, most important barrier is perceived cost (Mazharul et al., 2016; Stephen and Halen, 2011), lack of awareness - Malaysia (Mazharul et al. 2016), lack of policies and strategies-UN (Mazharul., 2016); attitude of top management and the cultural aspects-Saudi Arabia (Mazharul et al., 2016). For instance, in Ghana, the adoption and implementation of sustainability in construction are hindered by limited demand for sustainable buildings, the absence of policy to stimulate adoption, perceived initial higher cost, limited public awareness and lack of government support (Djokoto et al. 2014). These findings suggest the need to identify industry specific challenges. A mix of solutions will be needed to address the issues in the sector. For example, James et al. (2016) and Tarja and Kaisa, (2011) suggest the hindrances can be reduced by learning what kind of decision-making phases, new tasks, actors, roles and ways of networking which are needed. Moreover, Sara et al. (2015) and Alex and Vian, (2014) posit that the industry is client driven and therefore clients can be pushed and motivated to play a major role by demanding sustainable construction services and products. Mohsen et al. (2014) argued that vigorous adoption and implementation of sustainable procurement could occur if organizations position itself at the macro and micro level as the forefront of sustainability coupled with the needed support and incentives by political leadership. Combined with the fact that there is slow adoption in the industry and it is noted for its slow adoption of innovation enforces the development of an organizational decision model to guide the adoption and diffusion of sustainable procurement by construction organizations grounded on organizational theories.

4 Adoption processes of sustainable procurement

The adoption of sustainability is a difficult concept (Joanne and David, 2011). The adoption involves a high degree of complexity and can affect the operations and the decision making process of organizations (Joanne and David 2011). Studying the decision-making phases of sustainability in construction could lead to successful adoption (Tarja and Kaisa, 2011)). Despite the fact that sustainable procurement has seen increasing attention in academic circles and industry practice, the question of how it is adopted and implemented in a multi-stage process in construction organizations is yet to be fully answered. Moreover little is known about how sustainable procurement practices are adopted within the public procurement systems (Alexander, 2017; Halen and Stephen, 2012). Everett, (2003) defines "adoption decision process as the process through which an individual (or another decision-making unit) passes from first knowledge of an innovation to forming an attitude toward the innovation, to a decision to adopt or reject, to implementation of the new idea, and to confirmation of this decision". Different kinds of adoption decision processes have presented in literature. Everett, (2003) presents two stage models for the innovation adoption process; an individual and organizational contexts. Everett (2003) conceptualizes five main steps in the individual process: knowledge, persuasion, decision, implementation, and confirmation. He categorizes the innovation process in an organization into initiation, adoption-decision, and implementation.

So et al. (2012) and Qinghua et al. (2011) of the view that sustainable procurement can be viewed as a multiple stage process of initiation, persuasion, planning, adoption, and confirmation and called for studying of its diffusion in different stages of adoption. However current researchers focus on single stage adoption, such as one-shot adoption decision, or a combination of adoption and implementation as one stage process (e.g. Mazharul et al., 2016; Joanne and David, 2015; Swan et al., 2013; Joanne and David, 2011). Moreover little is known on how sustainable procurement practices are adopted within public procurement in a multi-stage adoption process (Helen and Stephen, 2009). For example, Helen and Stephen, (2009) combined adoption and implementation in the examination of sustainable procurement practices in public sector organizations. They did not differentiate adoption from implementation. William et al. (2013) also studied sustainable retrofit adoption in social housing in a single stage process approach. Joanne and David, (2015) in a similar fashion examined the adoption of sustainable procurement in the social housing sector in a single stage approach. Francesco et al. (2016) in their study did operationalize the adoption of green procurement in a single stage approach. Mazharul et al. (2016) adopted a single stage approach to measure the level of implementation of sustainable procurement practices in organizations.

Louis and Katherine (1982) emphasized; innovation research adoption needs to focus on multi-stage assimilation processes. Andreas et al. (2008) are of the view that understanding organizations innovation adoption behavior is thus crucial for the successful diffusion of new ideas like sustainable procurement. They further stated that much is not known of innovation adoption behavior of construction clients. Not much emphasis has been placed on empirically modeling the adoption decision behavior of sustainable procurement by construction organizations in a multi-stage assimilation. There is the need to study how construction organizations adopt sustainability into their procurement strategies (Joanne and David, 2011). Johnny et al. (2016) also called for the development of models to guide the adoption decision of construction organizations. Any future integrated theoretical model developed, should permit the evaluation of how the contextual factors may have differential effects at each stage of the adoption process. Robert, (2000) argued that the same factors may have “differently directional effects,” depending on the state of the adoption process, therefore it is important to study the different stages of the adoption process of sustainable procurement.

5 Enabling sustainable procurement in construction organizations

Strategic approaches in the adoption of sustainable procurement in construction are informed by political, economic, social, technological, environmental and legal pressures (Joanne and David2011). Many drivers to general sustainability and sustainable procurement have been identified in published literature (e.g Johnny et al., 2016; Rajeev and Kasun, 2015; Sara et al., 2015). Sachie, (2013) identified internal and external factors as the sets of factors influencing the adoption of sustainability in construction. Some of the salient internal drivers of sustainability are top management support (Sachie, 2013; Helen et al., 2009, Suzanne and John, 2008); organizational values (Sachie, 2013; Stefan and Adam, 2012); reputation (Sachie, 2013; Stefan and Adam, 2012; Jacqueline, 2011) and resources and capabilities (Sachie, 2013; Stefan and Adam, 2012).

External drivers of sustainability adoption published in literature include government policy and regulations (Johnny et al., 2016; Stefan and Adam, 2012; Sachie, 2013); Stakeholder pressure (Belfitt et al., 2011; Suzanne and John, 2008); Competitive Environment (Stefan and Adam, 2012; Jacqueline et al., 2012 et al., 2011; Israel et al., 2008). In the study of Johnny et al. (2016), facilitating effective green procurement in Hong Kong's construction industry, determined three most significant enablers including mandatory environmental regulations by government and client requirements in tendering (government and non-governmental organization). Hong Kong's government, for instance, has promoted sustainable procurement through the promotion of competitions/awards, incentive schemes, and shown government commitments and requirements in the procurement process (Johnny et al., 2016). Amr, (2011) noted categories of factors that are important for the UK public sector clients to better address sustainable construction when developing procurement strategies. These include; knowledge and perception, organizational and management support, political and regulative factors, contractual and financial factors. Kent et al. (2011) also developed an integrative model of the influences on the organizational implementation of sustainability.

The integrative model validates the effects of external influences, foundational organization enablers, decision drivers, and inhibitors had on both sustainability implementation and organizational performance. Sachie, (2013) contextualized five internal factors influencing the process of implementing sustainable construction at project level into; cultural, organizational/ managerial, organizational policies, client demand and leadership, suppliers and sub-contractors commitment to sustainability and resource factors. Sachie, (2013) study also identifies external factors influencing the process of implementing sustainable construction including legislation and regulatory environment, availability of expertise opportunities and perception and importance attributed to sustainability issues by public institutions. The identification of the drivers to sustainable procurement in construction is vital to gaining an understanding of how the benefits of sustainable procurement can be used to increase its diffusion, adoption and to develop a model to embed sustainable procurement practices in organisations (Samuel et al., 2013). Joanne and David, (2011) argued that despite the existence of these drivers to sustainable procurement adoption in construction, there is a huge failure to translate these drivers into sustainable procurement practices in construction. They attributed this situation to the lack of triggers to drive sustainable procurement and inertia of construction organizations to adopt sustainable construction. Suzanne and Suzanne, (2014) also pointed out that even though there are multiple increasing adoptions of sustainability in the supply chain of organizations, thereby generating interest in academic research; however tin practice there is little theoretical understanding of what drives organizations to implement sustainable procurement.

Moreover, prior studies fail to draw a conclusion on how different factors affects and relate to influence the sustainable procurement in multi-stage adoption process. Francesco et al., (2016) note the emerging strong need to analyze which factors drive the inclusion of environmental criteria in public tenders.

6 Available tools, models and guidelines

Researchers have attempted to provide guidance and tools on how the process of sustainability takes place and implemented in an organization (Okasana and Charlotte, 2009). IIDS (2007) identified over 300 tools, including guidelines, handbooks, databases, and software. IIDS (2007) attributed this numerous tools to each national and local institutions appear to have developed their unique set of tailor-made tools to suit their context. IIDS (2007) categorized these materials into: awareness-raising and training tools; tools to provide information on the environment and social characteristics of products and services (catalogues, software, databases, help lines etc.); Labels and standards that certify the environmental and social attributes of products and services; and life-cycle assessment tools that provide for full-life costing and the inclusion of externalities. Stefan (2013) also identified three major techniques in modeling in sustainable procurement namely life cycle assessments (LCA), use of equilibrium models and multi-criteria decision-making. Attempts have been made to model sustainability in construction. Luqman et al (2015) borrowed balanced scorecard (BSC) and business excellence model (BEM) to explore the development of an integrated model to measure sustainability performance of construction organizations. Niamh, et al., (2016) explored the theory of self-determination to model the relationship between motivations of architectural designers and environmentally sustainable construction design. James et al. (2016) utilized organizational learning and absorptive capacity (ACAP) perspective to model the role of learning in sustainability standards implementation. Bal et al. (2013) employ stakeholder engagement in achieving sustainability in the construction sector. Yeong and Federik, (2015) proposed a capacity development model builds on the theory of change management. These numerous tools and models provided for adopting sustainability into construction; provide little detail of how the triple bottom line of sustainability can be adopted into organization's policy, strategy, general decision making and specific to procurement decision-making (Joanne and David, 2011). Joanne and David, (2011) argued that the tools also create anxiety and confusion at the operational level of sustainable procurement resulting in inertia among organizations. Halen et al. (2012) further argued that the tools do not describe the adoption behavior of organization's and factors influencing adoption of sustainable procurement. Amr, (2011) also described this guidance as insufficient and confusing and provide limited insight into the methodologies and factors that influence Organization's decisions in integrating environmental and social criteria in the procurement process. Further assessment and evaluation of these tools and models indicate a focus on environmental performance of buildings and infrastructures, materials and service parts, related design and construction activities and post occupancy situations (Bo et al., 2015; Israel et al., (2008). The lack of an efficient framework to evaluate and model the decision behaviour of construction organizations can limit the rate of adoption of sustainable procurement in the industry. While efforts have been made in the development of sustainability assessment tools and models in the supply chain, there is still more gap in the current literature in terms of studying the adoption behavior of construction organizations in the area of integrated sustainable procurement.

7 Theoretical perspective of sustainable procurement studies

Adopting or developing theories of sustainable procurement is relatively rare across literature (Alexander, 2017; Johnny et al., 2016; Suzanne and Suzanne, 2014). Most research fails to show any grounding in theory building and testing (Thomas et al., 2014). In a literature review by Stefan and Adam (2012) of sustainable procurement papers from 2000 to 2010, reveal that only 3.7 % had the theoretical background. Notwithstanding this, there is an upsurge of the number of scholars who have adopted established theories from Economics and Sociology to explore sustainability practices research in recent times (Suzanne and Suzanne, 2014). Craig and Dale (2008) combined Resource Dependency Theory (2008). Florence and Emmanuelle (2012) used legitimacy theory to illustrate how the firm conquers its legitimacy in sustainable procurement through the evolution of its supply network. Halen and Norah, (2012) drew on contingency theory to study sustainable supply chain management across the United Kingdom private sector in an attempt to develop a typology of approaches to sustainable supply chain management. Craig and Dale, (2008) presented a framework for sustainable supply chain management and develop relationships among environmental, social, and economic criteria that allow an organization to achieve long-term economic performance based on resource dependence theory, transaction cost economics, population ecology, and the resource-based view of the firm. Suzanne and Suzanne, (2014) also conceptualized the adoption of sustainable procurement using institutional theory perspective and concluded by presenting three theoretical propositions to explain sustainable procurement adoption. More recently Alexander, (2017) borrowed institutional and stakeholder theories to institutionalize sustainable procurement practices within structures and behaviors of organizations. Thomas, et al. (2016), also reviewed theories that underpin sustainable supply chain papers, found out that significant proportion of sustainable purchasing and supply management papers adopt stakeholder theory, institutional theory, and resource-based perspectives, however, relatively few papers rely on diffusion of innovation approach. There is a need for more focused theory building and testing, and the development of further models and conceptual frameworks that draw closely on sustainable procurement practice (Johnsen, et al., 2016; Suzanne and Suzanne, 2014; Stefan and Adam, 2012). Paolo et al. (2013) note that researchers have highlighted the need to develop integrated tools, frameworks and models for organizations in the adoption of sustainability based on building and/or testing theory. These integrated tools, frameworks and models should be tailored to industry specific and the triple bottom line of sustainability.

Per, (2015) and Brain et al. (2011) highlighted the need to combine multiple theoretical perspectives to uncover rich and complex ways of explaining firm behavior on sustainable business practices. However, Brain et al. (2011) also cautioned the contradictory views that arise as researchers examine sustainability through multiple theoretical lenses. Per, (2015) "posits that poor theoretical underpinnings make it difficult to understand and explain how and why implementation succeeds or fails, thus restraining opportunities to identify factors that predict the likelihood of implementation success and to develop better strategies to achieve more successful implementation". The above-mentioned studies provide the importance of this field, highlighting the limited theoretical foundation of this field and strongly call for further research to develop it. However, none of the above-mentioned studies or other studies to the authors' knowledge presents a model for the adoption, diffusion of sustainable procurement in construction organization's in a multi assimilation state. This clearly shows a research gap in this field that needs to be addressed

8 Discussion and future research

From the review of existing sustainable procurement studies given above, several comments can be made. Despite widely acknowledgement that there are significant benefits its offers in terms of improve competitive advantage, reputation and pride, compliance with policies/regulations and efficient and effective use of natural resources, adopting sustainability in construction organizations are described as a complex concept (Joanne and David, 2011). This author posits that it involves a high degree of complexity in decision making and can affect the operations and the decision-making process of organizations'. Not surprising construction organizations are yet to fully adopt sustainable procurement and lag behind many other industries (Mazharul et al., 2016**;** Michelle and Alison, 2014; Alkillani and Jupp 212).Will and Samuel, (2013) argued strongly that the "future directions needed to translate sustainable procurement from rhetoric to reality including the development of suitable incentives and appropriate organizational structures". Notwithstanding the call, Joanne and David, (2015) noted that sustainability continues to be rhetoric to the extent to which they are implemented in constructions organizations. The industry must move to deal with the numerous hindrances its faced including inadequate funding, insufficient/confusing guidance and tools, insufficient/inconsistent policies and regulations, lack of organizational culture and lack of leadership and commitment of stakeholders in the attempt to adopt and implement sustainable procurement practices (Johnny et al. 2016; Sara et al., 2015; Alex and Vian 2014; Amr, 2011). It is argued that the lack of organizational models and the complexity of existing models are hindering the adoption of sustainable procurement (Halen et al., 2012; Joanne and David**,** 2011; Amr, 2011). The few available tools have been described as insufficient, confusing and provide limited insight into the methodologies and factors that influence organization's decisions in the integration of environmental and social criteria in the procurement process. Moreover, these available tools and models focus mainly on environmental performance at the project not at national and organizational viewpoint (Bo, et al., 2015; Stefan et al., 2013; Huang and Hsu, 2011). Mohsen et al., (2014) pointed out that the available performance assessment models also do not address the three aspects of sustainability. These shortcomings in the adoption and implementation decision behaviors of sustainable procurement by organizations must be addressed by the academic researcher (Bo, et al., 2015; Halen et al., 2012; Amr, 2011; Israel et al., 2008).

It has also evidently been established that there is a dearth of application of organizational theories in great magnitude within the literature of sustainable procurement in construction. Notwithstanding the current application of organizational theories in sustainable procurement research, few have adopted it in sustainability studies (e.g. Suzanne and Suzanne, 2014, 2014; Halen and Norah, 2008). Johnsen et al. (2016) pointed out that the commonly used theories in sustainable procurement related researches were; stakeholder theory, institutional theory, and resource-based perspectives. Mohsen et al. (2014) acknowledged the availability of several management and organizational theories which could provide potential applications in sustainability research. Qinghua et al. (2011) presented comprehensive organizational theories towards the building of theory, which can easily be adapted for use by researchers exploring theoretical issues in sustainability in construction. These included Complexity; Ecological Modernization; Information; Institutional; Resource-Based View; Resource Dependence; Social Network; Stakeholder; Diffusion of Innovation; Path Dependency; Social Embeddedness; Structuration and Transaction Cost Economics theories.,

These findings support the call for more use of robust organizational theories like Diffusion of Innovation Theory (DIT) and Technology-Organization-Environment Framework in the development of organizational tools, frameworks and models to guide construction organizations' in the adoption of sustainability (Johnsen, et al., 2016; Suzanne and Suzanne, 2014). These integrated tools, frameworks and models could be tailored to the construction industry specific triple bottom line of sustainability. However, relatively few papers have relied on the diffusion of innovation theory approach. Diffusion of Innovation Theory (DIT) by Everett, (2003) and Technology-Organization-Environment Framework (TOE) by Louis and Mitchell, (1990) provides a robust theoretical foundation and empirical support for studying various innovations (Jeff, 2012; Mumtaz et al. 2012). Qinghua et al. (2011), suggest that DIT provides a very valuable source of theoretical underpinnings for investigating and furthering research in sustainable procurement. it has also been demonstrated that the DIT and TOE model has broad applicability and possesses explanatory power across in many types of research across a number of technological, industrial, and national/ cultural contexts (Jeff, 2012; Mumtaz et al., 2012). DIT and TOE framework allows organizational studies to examine adoption processes within a distinctive set of factors from each context depending on the specific innovation and provides flexibility in the study of innovations no matter the type of innovation and context (Mumtaz et al., 2012). It is suggested that DIT and TOE could be used to further study the adoption decision processes of sustainable procurement in constructions and relates it to the contextual factors that influence its adoption.

9 Conclusions

Undoubtedly sustainable procurement has received considerable attention in academic research and within the industry in the past two decades. A review of literature suggests that the industry is gradually shifting towards sustainable procurement, however its lags behind other industries. The paper presents a critical review of literature of sustainable procurement adoption in the construction industry from a variety of perspectives and identifies needed future research. The inadequacies of the prevailing sustainable procurement literature can be summarized in the following issues:

i. The limited studies of adoption and diffusion of sustainability studies;
ii. Limited research agenda on sustainable procurement in the construction industry
iii. sustainable procurement research adopts more of the single stage adoption decision process approach more than multi-stage adoption;
iv. Sustainable studies are more focused on environmental sustainability;
v. Sustainability studies focus mainly on developed countries;
vi. Dearth of organizational theories underpinning sustainable procurement research;
vii. Diffusion and adoption of sustainability is poorly understood; and
viii. Most construction organizations lag behind the adoption of sustainable procurement comparable to other industries

In view of the above the above gaps in literature, a number of most essential directions for future research in sustainable procurement areas is presented in this paper as follows:

i) developing an integrated/holistic organizational model underpin by multiple organizational theory; ii) future models should also include the holistic view of the bottom three line of sustainability; iii) studying the adoption decision behaviors of construction organizations in a multi-stage assimilation; v) more research focuses on public sector adoption of sustainable procurement and vi) more focus research on the perspective of emerging/developing countries view of sustainable construction practices.

References

Addis, B. and Talbot, R., (2001), "Sustainable construction procurement: a guide to delivering environmentally responsible projects" (Vol. 571). London: Ciria

Adetunji, I., Price, A.D.F. and Fleming, P. (2008), "Achieving sustainability in the

Construction supply chain, Proceedings of the ICE - Engineering Sustainability", 161 (3)

161-172.

Adjarko, H., Agyekum, K. and Offei, I., (2016),"Incorporating Environmental Sustainability into Construction Procurement at the District Assembly Level in Ghana", International Journal of Construction Engineering and Management, *5*(2), pp.31-41.

Baker, J. (2012), "The technology–organization–environment framework", In Information systems theory (pp. 231-245), Springer New York

Belfit, R.J., Sexton, M., Schweber, L. and Handcock, B., (2011), "Sustainable

Procurement: Challenges for Construction Practice", In TSBE EngD Conference (pp. 1-9).

Berardi, U. (2012), "Sustainability assessment in the construction sector: rating systems

and rated buildings, Sustainable Development", 20 (6) 411-424.

Bouwer, M., Jonk, M., Berman, T., Bersani, R., Lusser, H., Nappa, V., and Viganò, C. (2006), "Green public procurement in Europe 2006–Conclusions and recommendations", Haarlem: Virage Milieu and Management (http://ec. europa. eu/environment/gpp/pdf/take_5. pdf, accessed July 4, 2017).

Brammer, S. and Walker, H. (2011), "sustainable procurement studies on the public sector: an international comparative study", International Journal of Operations and Production Management, Emerald, 31(1) 452–476.

Brennan, C. M. and Cotgrave, J. A., (2014), "Sustainable development: A qualitative

Inquiry into the current state of the UK construction industry", Structural Survey, *32*(4), 315-330.

Carter, C.R. and Rogers, D.S. (2008), "A framework of sustainable supply chain management: moving toward new theory", International Journal of Physical Distribution and Logistics Management, **38**(5) 360 – 387.

Connelly, B., Ketchen, D. and Slater, S. (2010), "Toward a "theoretical toolbox", for

sustainability research in marketing", Journal of the Academy of Marketing science, 39, 86

100.

Djokoto, S.D., Dadzie, J. and Ohemeng-Ababio, E., (2014), "Barriers to sustainable

construction in the Ghanaian construction industry: consultant's perspectives", Journal of Sustainable Development, *7*(1), 134.

Edum-Fotwe, F.T. and Price, A.D., (2009), "A social ontology for appraising sustainability of construction projects and developments", International Journal of Project Management, *27*(4), 313-322.

Essa, R. and Fortune, C., (2008), "Pre-construction evaluation practices of sustainable housing projects in the UK", Engineering, Construction and Architectural Management, 15(6), 514-526.

Fairfield, K. D., Harmon, J. and Behson, S. J. (2011), "Influences on the organisational

implementation of sustainability: an integrative model", Organisation Management Journal,

8(1) 4-20.

Goodland, R., (1995), "The concept of environmental sustainability" Annual review of ecology and systematics, *26*(1), pp.1-24.

Fichman, R.G., (2000), "the diffusion and assimilation of information technology innovations, Framing the domains of IT management: Projecting the future through the past*", 105127.*

Grob, S. and Benn, S. (2014), "Conceptualising the adoption of sustainable

Procurement: an institutional theory perspective, Australasian Journal of Environmental

Management", 21 (1) 11-21.

Grob, S. and Crawford J. (2008), Diffusing sustainability: towards a framework for

Adopting sustainable procurement, Australian and New Zealand Academy of Management

(ANZAM) Conference Auckland, New Zealand.

Gunatilake S. (2013), The uptake and implementation of sustainable construction: transforming policy into Practice, a thesis submitted in partial fulfillment for the requirements for the degree of Doctor of Philosophy at the University of Central Lancashire.

Glass, J., (2012), The state of sustainability reporting in the construction sector, *Smart and Sustainable Built Environment, 1*(1), pp.87-104.

Häkkinen, T. and Belloni, K., (2011), "Barriers and drivers for sustainable building" Building Research & Information, 39(3), pp.239-255.

Hartmann, A., Reymen, I.M. and Van Oosterom, G., (2008), "Factors constituting the innovation adoption environment of public clients" Building Research & Information, 36(5), pp.436-449.

Hoejmose, S.U. and Adrien-Kirby, A.J., (2012), "Socially and environmentally responsible procurement: A literature review and future research agenda of a managerial issue in the 21st century", Journal of Purchasing and Supply Management, *18*(4), pp.232-242.

Huang, R.Y. and Hsu, W.T., (2011), "Framework development for state-level appraisal indicators of sustainable construction", Civil Engineering and Environmental Systems, *28*(2), pp.143-164.

Islam, M.M., Murad, M.W., McMurray, A.J. and Abalala, T.S., (2016), Aspects of sustainable procurement practices by public and private organisations in Saudi Arabia: an empirical study, International Journal of Sustainable Development & World Ecology, pp.1-15.

Johnsen, T., Howard, M. and Miemczyk, J., (2014), "Purchasing and supply chain management: a sustainability perspective*",* Routledge.

Kalubanga, M., (2012) International Journal of Economics and Management Sciences, Management, *1*(7), pp.01-07.

Meehan, J. and Bryde, D.J., (2015), A field-level examination of the adoption of sustainable procurement in the social housing sector, International Journal of Operations & Production Management, *35*(7), pp.982-1004.

Meehan, J. and Bryde, D., (2011), Sustainable procurement practice, Business Strategy and the Environment, *20*(2), pp.94-106

Murtagh, N., Roberts, A. and Hind, R., (2016), The relationship between motivations of architectural designers and environmentally sustainable construction design, Construction Management and Economics, 34(1)

Nilsen, P., (2015), Making sense of implementation theories, models and frameworks, Implementation Science, 10(1), p.53

Ugwu, O.O. and Haupt, T.C., (2007), Key performance indicators and assessment methods for infrastructure sustainability—a South African construction industry perspective, Building and Environment, *42*(2), pp.665-680

Opoku, A., Ahmed, V. and Cruickshank, H., (2015), Leadership style of sustainability professionals in the UK construction industry, Built Environment Project and Asset Management, *5*(2), pp.184-201.

Oyewobi, L.O., Windapo, A.O. and Rotimi, J.O.B., (2015), Measuring strategic performance in construction companies: a proposed integrated model, Journal of Facilities Management, *13*(2), pp.109-132.

Rogers, E. M. (2003), *Diffusion of Innovations,* 5th ed., Free Press, New York.

Roman, A.V., (2017), "Institutionalizing sustainability: A structural equation model of

sustainable procurement in US public agencies", Journal of Cleaner Production, *143*, pp.1048

1059.

Ruparathna, R. and Hewage, K., (2015), Sustainable procurement in the Canadian construction industry: current practices, drivers and opportunities, Journal of Cleaner Production, *109*, pp.305-314.

Sarkis, J., Zhu, Q., Lai K. H. (2011), An organisational theoretic review of green supply

Chain management literature, International Journal of Production Economics, Elsevier, 130 (1) 1-15.

Seuring, S., (2013), A review of modeling approaches for sustainable supply chain management. Decision support systems, *54*(4), pp.1513-1520

Sim, Y.L. and Putuhena, F.J., (2015), Green building technology initiatives to achieve construction quality and environmental sustainability in the construction industry in Malaysia**,** Management of Environmental Quality: An International Journal, *26*(2), pp.233-249**.**

Smerecnik, K.R. and Andersen, P.A., (2011), The diffusion of environmental sustainability innovations in North American hotels and ski resorts, Journal of Sustainable Tourism, *19*(2), pp.171-196.

Sourani, A., (2011), Barriers to addressing sustainable construction in public procurement strategies.

Swan, W., Ruddock, L., Smith, L. and Fitton, R., (2013), Adoption of sustainable retrofit in UK social housing, Structural Survey, *31*(3), pp.181-193.

Taticchi, P., Tonelli, F. and Pasqualino, R., (2013), Performance measurement of sustainable supply chains: a literature review and a research agenda, International Journal of Productivity and Performance Management, *62*(8), pp.782-804

Testa, F., Annunziata, E., Iraldo, F. and Frey, M., (2016), Drawbacks and opportunities of green public procurement: an effective tool for sustainable production, Journal of Cleaner Production, *112*, pp.1893-1900.

Tornatzky, L.G., and Fleischer, M. (1990), "The Processes of Technological Innovation",

Lexington Books, Lexington, Massachusetts.

United Nations Environment Programme (2007), "Assessment of policy instruments for reducing greenhouse gas emission from buildings", United Nations Environment Programme, sustainable buildings and construction initiatives and the Central European University, Budapest.

Upstill-Goddard, J., Glass, J., Dainty, A. and Nicholson, I., (2016) Implementing sustainability in small and medium-sized construction firms: the role of absorptive capacity, Engineering, Construction and Architectural Management, *23*(4), pp.407-427.

Varsei, M., Soosay, C., Fahimnia, B. and Sarkis, J., (2014), Framing sustainability performance of supply chains with multidimensional indicators. *Supply Chain Management: An International Journal*, *19*(3), pp.242-257.

Vidal, N.G and Kozak. R.A. (2008), Corporate responsibility practices in the forestry

sector, Journal of Corporate Citizenship, **31** (1) 59-75.

Walker, H., Miemczyk, J., Johnsen, T. and Spencer, R. (2012*), Sustainable procurement: Past, present and future*, Journal of Purchasing and Supply Management, Pergamon, **18** (4) 201-206.

Walker, H., Miemczyk, J., Johnsen, T. and Spencer, R., (2012), Sustainable procurement: Past, present and future. *Journal of Purchasing and Supply Management*, *18*(4), pp.201-206.

Wilkinson, S.J., Sayce, S.L. and Christensen, P.H., (2015) Developing property sustainably, Routledge

Wong, J.K.W., San Chan, J.K. and Wadu, M.J., (2016), Facilitating effective green procurement in construction projects: An empirical study of the enablers, Journal of Cleaner Production, *135*, pp.859-871

Xia, B., Zuo, J., Wu, P. and Ke, Y., (2015), Sustainable construction trends in journal papers*, In Proceedings of the 19th International Symposium on Advancement of Construction Management and Real Estate* (pp. 169-179). Springer Berlin Heidelberg.

Zaid Alkilani, S. and Jupp, J.R., (2012), paving the road for sustainable construction in developing countries: a study of the Jordanian construction industry, In 37th Annual International Conference, The University of New South Wales.

Zhu, Q., Joseph, S., and Lai, K. (2012*),* Green supply chain management innovation

diffusion and its relationships to organizational improvement: An ecological modernization

perspective*,* Journal of Engineering and Technological Management, Elsevier, **29**, (1) 168- 185.

Overview of Performance of Project Management Tasks and Activities in Building

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Abstract:

The Croatian Parliament passed at its session held on 3 July 2015 the Act on Physical Planning and Building Tasks and Activities published in the Official Gazette No. 78. On the date of its entry into force the Act on Architectural and Engineering Activities in Physical Planning and Building (Official Gazette No. 152/08, 124/09, 49/11, 25/13) ceased to be in effect. The paper will provide an overview of relevant provisions of the Act on Physical Planning and Building Tasks and Activities which concern the performance of the building project management tasks and activities. Authors will, where necessary, compare the provisions of this act with the provisions of the Act on Architectural and Engineering Activities in Physical Planning and Building in the parts concerning the performance of the building project management tasks and activities. Authors will give an overview of passed bylaws which concern the issues of project management, namely the Ordinance on required expertise in the field of project management (Official Gazette No. 45/09), the Ordinance on required expertise in the field of project management (Official Gazette No. 85/15).

Keywords: *building project management, building project management activities, difference between present and past legislation, acts and ordinances of the Republic of Croatia*

1. Introduction

The activity of project management in building was introduced into the building system of the Republic of Croatia approximately 10 years ago by the Act on Architectural and Engineering Activities in Physical Planning and Building (hereinafter: Former regulations). The reason for introducing project management in building was the increasing performance of tasks which were needed, on the one hand, to ensure that the building is constructed in compliance with the relevant project documentation and to obtain the use permit, and, on the other hand, to complete the legal preconditions (registration in the cadastre and land registry) as well as to achieve economic effectiveness. These tasks, which we could call complex interdisciplinary tasks, were not regulated by legislation until 2008. Former regulations were amended several times.

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Five years after the adoption of Former regulations the Building Act was adopted, which called for passing of a new regulation, that would, in accordance with the Building Act, regulate the issue concerning the activity of project management in building.

However, besides these formal and legal arguments, practical reasons were present, which occurred during the implementation of Former regulations as well as new political and economic guidelines. Therefore we proceed to point out, from the Proposal of the Act on Physical Planning and Building Tasks and Activities along with the Final proposal, the arguments for repealing the Former regulations and the need for adopting a new regulation.

„Provisions of the Act Proposal needed to be entirely conformed in terms of content and technical and legal issues with the new Act on Physical Planning and Building Act. The current Act complies with the Directive 2006/123/EC on services in the internal market and the Directive 2005/36/EC on the recognition of professional qualifications, however, due to amendment of this Directive, it is necessary to make certain adjustments in the part concerning the recognition of foreign professional qualifications and conditions under which the foreigners may perform the abovementioned tasks in the Republic of Croatia.

Moreover, since the adoption of the Act on Architectural and Engineering Activities in Physical Planning and Building some significant changes occurred in the market, especially concerning the building activities which were affected the most by the consequences of the economic depression, as well as by the effects of accession of the Republic of Croatia to the European Union and opening of the market.

Therefore, it was necessary to review the provisions containing the administrative barriers to free performance of physical planning and building tasks and activities, conform them with normative solutions and practice of the EU member states and thereby eliminate the negative impact on business entities.

Condition of non-discrimination will also be fulfilled, since the provisions of the existing Act impose very strict conditions concerning the number of employees on domestic entities. This condition could not be imposed on foreign service providers in the Republic of Croatia because they comply to the provisions regulated by the country of their establishment.

At the same time, elimination of administrative procedures enables moving to solutions based on greater control of performance of professional tasks concerning physical planning and building, which is exercised by the ministry and chambers.

This Act regulates further harmonization with relevant Directives concerning the conditions under which the foreigners may perform the abovementioned tasks in the Republic of Croatia, which will lead to acceleration of these procedures, as well as procedures of issuing EU certificates for our service providers in the member states of the EU economic area.

Numerous persons (both natural and legal) took part in the conducted consultation concerning the draft of the Act on Physical Planning and Building Tasks and Activities which was held by the proponent, among them being representatives of the Croatian Chamber of Architects, Croatian Chamber of Civil Engineers, Croatian Chamber of Mechanical Engineers, Croatian Chamber of Electrical Engineers, Croatian Chamber of Economy, Croatian Chamber of Trades and Crafts, Croatian Employers' Association, Croatian Chamber of Transport Engineers, higher education institutions, professional organizations and other business entities. They all contributed to improvement of the draft Act as well as to the Act itself.

Out of many complaints and suggestions which arose during the consultation, we emphasize the proposal to determine the value of the lowest and highest fee for project management tasks and activities as well as the proposal to assign project management tasks to rebuilding and not only to building.

The abovementioned proposals were not accepted.

2. Performance of the building project management tasks and activities in Croatian legislation

Act on Physical Planning and Building Tasks and Activities, which was passed by the Croatian Parliament at its session held on 3 July 2015, published in the Official Gazette No. 78/15 (hereinafter: Act).

Provisions concerning the project management in building are found in title V of the Act, articles 33-39, but alternatively in some other articles (e.g. in penal provisions).

The building project management activities include the following tasks:

- providing financial, legal and technical consulting pertaining to the design, building, use and removal of building works;
- financial, legal and technical preparations and the planning of tasks pertaining to building and the monitoring of the implementation of this plan;
- consulting, selecting and contracting tasks for designers, design auditors, supervising engineers, contractors, certified geodetic engineers and other persons performing tasks pertaining to the building of building works and consulting in contracting tasks with these persons;
- linking and coordinating the work of designers, design auditors, supervising engineers, contractors, certified geodetic engineers and other persons participating in building and the supervision of their work for the purpose of protecting the rights and interests of the investor;
- obtaining acts, analyses, studies, expert reports and other documents necessary for the development of conceptual, main and detailed designs and a design for the removal of a building work;
- obtaining all documents and the conclusion of all legal transactions required for the issuance of administrative acts related to the implementation of physical planning and building documents and the use and/or removal of building works and the obtaining of these administrative acts;
- obtaining all documents and the conclusion of all legal transactions required for the building of a building work and the performance of actions that the investor is required to perform during the building of a building work.

Accordingly, tasks performed through building project management activities are indisputably complex (in their scope, and even more in their quality). For instance, we mention tasks concerning financial, legal and technical consulting which require competent knowledge and coordination of several complex tasks from multiple different professions (good understanding of finances, good understanding of civil obligations and good command of engineering tasks). Therefore, the Act's provision is clear, stipulating that the abovementioned tasks may be performed only by a legal person or a natural person – craftsman that is registered for carrying out the building project management activities and employs a project manager. Pursuant to provisions of the Labour Act, employees may enter into a full-time employment contract (usually no longer than forty hours per week) and part-time employment contract (working hours which are less than full-time).

2.1 Requirements for the performance of building project management activities

As we've already described the complexity of tasks which constitute the activity of project management, it is required that the legal or natural person - craftsman who performs building project management activities ensures that each project management task in building is performed by a person who has at least eight years of relevant work experience, completed education in the fields of architecture, civil engineering, electrical engineering or mechanical engineering, completed undergraduate and graduate university studies or integrated undergraduate and graduate university studies which lead to the title of master, master of engineering or who has successfully completed specialist professional university studies in the abovementioned fields which lead to the title of professional specialist engineer if the person obtained at least 300 ECTS credits, i.e. who has achieved, in another manner provided for in a special regulation, the appropriate level of education and possesses the necessary knowledge in the field of project management.

Pursuant to the Act, minister of building and physical planning passed the Ordinance on required expertise in the field of project management (Official Gazette No. 85/15) which more closely specifies internationally recognized certificates of competency in project management as well as educational programmes which provide the required expertise in the field of project management.

The internationally recognized systems for project management certification are the following:

- system of certification by the International Project Management Association (IPMA), with its headquarters in Switzerland, and
- system of certification by the Project Management Institute (PMI) with its headquarters in the United States of America.
- The following documents are considered as proofs of the required expertise in the field of project management:
- certificate of competency issued by the national member of the International Project Management Association, regardless of the level of competency for which it is issued, i.e.
- certificate of competency issued by the Project Management Institute, regardless of the level of competency for which it is issued.

Educational programmes which provide the required knowledge of project management in the fields of architecture, civil engineering, electrical engineering or mechanical engineering are those which involve the courses in:

- project planning and control
- management of construction projects (building projects)
- contract law in construction
- construction regulations
- management of human resources
- organization of business systems in construction
- building organization.

Certified copy of diploma supplement or grade transcript is regarded as proof of required expertise.

Total sum of courses' ECTS credits has to amount to at least 30 credits, and for study programmes which didn't use ECTS credits, the total sum of courses' hours has to amount to at least 360. This provision was necessary since graduate study programmes organized and implemented by the higher education institutions in the Republic of Croatia before the so-called Bologna studies typically didn't use ECTS credits.

Since the Ordinance concerned entered into force, the Ordinance on required expertise in the field of project management (Official Gazette No. 45/09), which equally regulated the matter concerned, ceased to be valid.

The Act significantly lowered the requirements for performing building project management tasks with regards to the Former regulations, which stipulated that legal person registered for performance of those tasks has at least one of the following employees in full-time permanent employment:

- project manager,
- certified architect with at least 5 years of professional work experience,
- certified civil engineer, mechanical engineer and electrical engineer with at least 5 years of professional work experience,
- master of law with at least 5 years of professional work experience and
- master of economics with at least 5 years of professional work experience.

Required work experience according to the Former regulations was at least 10 years, as opposed to 8 years according to the Act. We also wish to emphasize the difference regarding work hours, since pursuant to the Former regulations it was necessary that the employee has a full-time employment contract, and pursuant to the Act, as we've already mentioned, employment contract can also be part-time.

According to the Former regulations, Ministry kept records of legal persons performing the activity of project management in building. Those business entities needed to notify the Ministry at least 14 days prior to commencement of that activity, as well as provide the proofs for the fulfillment of requirements for performance of that activity, and notify the Ministry of any change which could have effect on fulfillment of requirements for performance of that activity.

Comparison of mentioned qualitative and quantitative differences between the Act and Former regulations, in our opinion, doesn't call for a special commentary.

Because of the complexity of tasks (particularly tasks regarding work execution, design, supervision), but also, alternatively, the application of the Building Act, the Act stipulates that legal or natural person – craftsman performing the building project management activity of a certain construction can't perform the tasks of design and professional supervision of building of that construction, and that employee can't be a designer as well as a supervising engineer of that construction.

Additional limitation is that a legal or natural person – craftsman performing the activity of building project management of a certain construction can't carry out the execution of that construction.

2.2 Obligation to appoint a project manager

The legislator demonstrated the significance and role of the project manager (optimizing the expenditure of funds and time and for the lawful and quality execution of a construction work) with the provision regarding investors who, pursuant to the legislation governing the public procurement (the Public Procurement Act) are deemed to be public clients, and shall be required to appoint a project manager when:

1. investing funds in the construction of infrastructural and other construction works of a total investment value in excess of HRK 10,000,000.00 before VAT;

2. investing funds in the construction of buildings of a total investment value in excess of HRK 50,000,000.00 before VAT.

This provision, which explicitly concerns the public clients, doesn't prohibit private investors from appointing project managers for at least equal, as well as lesser investment values.

2.3 Foreign persons performing tasks of project manager

Provisions regarding project management tasks are found in the Act's title concerning foreign persons performing tasks and activities of physical planning and building.

Foreign certified person who performs project management tasks in the Republic of Croatia is held responsible for serious and minor infringement before the disciplinary authorities of a relevant chamber, and is obligated to apply legislation of the Republic of Croatia and use Croatian language.

In that way, a natural person, who has the right to perform project management tasks in a foreign country, shall have the right, under the assumption of reciprocity, to perform these tasks in the Republic of Croatia, on a permanent basis, in the capacity of a certified person, under the same conditions as apply to a project manager if the person possesses professional qualifications required for the performance of those tasks in accordance with a special law governing the recognition of foreign professional qualifications and other special regulations. The assumption of reciprocity does not apply to nationals of the states that are contracting states of the European Economic Area (hereinafter: EEA) and of the member states of the World Trade Organization.

A certified natural person from another EEA contracting state shall be entitled to permanently perform project management tasks in the Republic of Croatia if the person is entered in the register of certified construction managers in accordance with a special law governing association in chamber.

Person shall be entitled to temporarily or occasionally perform project management tasks in the Republic of Croatia in the capacity of a responsible person under the professional title the persons certified to perform these tasks have in the Republic of Croatia, if prior to the commencement of the first activity they inform the relevant chamber by submitting a statement in writing or electronic form (submitted yearly), and if it is determined, according to provided proofs, that the needed requirements are fulfilled.

If, in the country from which a certified person comes, no specific certification is required for performing project management tasks, the applicant shall submit proof that he has performed project management tasks in the capacity of a responsible person as a full-time or part-time job equivalent to the total duration of at least one year in the past ten years in the Member State in which that profession is not regulated.

The applicant is required to deliver evidence of professional liability insurance, which is appropriate to the nature and the extent of the risk, covering for damage that he may incur to the investor or other persons while performing project management tasks. If there are significant changes in the circumstances established by previously submitted documents, the documents decisive for the assessment of such significant changes shall also be submitted.

The chamber shall verify, in accordance with the provisions of a special law governing the recognition of foreign professional qualifications and other special regulations, whether the applicant meets the prescribed conditions for the temporary or occasional performance of project management tasks in the capacity of a responsible person, and shall issue a certificate thereof.

The document on the issuance of the certificate, or the document rejecting an application of a foreign certified person authorized for the temporary or occasional performance of project management tasks in the capacity of a responsible person shall be entered into the records of the appropriate chamber that is kept in accordance with a special regulation governing association in a chamber. Appeals against these documents are permitted and shall be submitted to the Ministry.

A foreign legal person that is established in an another EEA State and performs building project management activities, may perform in the Republic of Croatia on a temporary and occasional basis those activities for which it is authorized by the legislation of the state of its establishment, after the person has notified the Ministry and delivered the required evidence thereof.

The procedure for the recognition of foreign professional qualifications for performing project management tasks shall be conducted and a decision thereon shall be made by the relevant chamber in the manner prescribed by a special law governing the recognition of foreign professional qualifications and by other special regulations.

2.4 Supervision

The Ministry supervises the application of the Act, therefore, natural or legal persons performing the tasks or activities of building project management are required to submit to the Ministry, for the purpose of conducting supervision, all of the requested data, documents and reports within the required time period. A decision ordering the elimination of the illegalities found during supervision may not be appealed against, but an administrative dispute may be initiated.

2.5 Penal provisions

Provisions concerning project management are also found in the Act’s title concerning penal provisions.

Fines are specified for several misdemeanours which can be made during project management. A legal person shall be guilty of a misdemeanour and shall be fined a sum between HRK 100.000,00 and HRK 150.000,00 for failing to carry out building project management activities in accordance with the provisions of the relevant legislation.

The responsible person of the legal person shall be fined from HRK 10.000,00 to HRK 20.000,00 for committing the same misdemeanour.

A legal person carrying out building project management activities shall be guilty of a misdemeanour and shall be fined a sum between HRK 25.000,00 and HRK 50.000,00 if:

- it carries out building project management activities without having employed a project manager
- it carries out building project management activities while an employee who performs those activities is a designer and supervising engineer of the construction
- with respect to individual building project management tasks, it fails to appoint a project manager who has the appropriate professional qualifications (e.g. required professional work experience)

The responsible person of the legal person shall be fined from HRK 10.000,00 to HRK 15.000,00 for committing the same misdemeanours.

A natural person shall be guilty of a misdemeanour and shall be fined a sum between HRK 25.000,00 and HRK 50.000,00 for carrying out the project management tasks without having the required professional qualifications (required professional work experience)

A legal person who is a public client shall be guilty of a misdemeanour and shall be fined a sum between HRK 35.000,00 and HRK 70.000,00 for failing to appoint a project manager if it is so required.

The responsible person of the legal person shall be fined from HRK 10.000,00 to HRK 15.000,00 for committing the same misdemeanour.

In addition to abovementioned penal provisions which explicitly concern legal persons performing project management activities and responsible persons of the legal persons, a foreign certified person shall be guilty of a misdemeanour and shall be fined a sum between HRK 35.000,00 and HRK 50.000,00 for performing project management tasks in the capacity of a responsible person without being verified by the relevant chamber

A supervised legal person shall be guilty of a misdemeanour and shall be fined a sum between HRK 50.000,00 and HRK 150.000,00 for failing to submit to the Ministry, for the purpose of conducting supervision, the requested data, document or report within the required time period

The responsible person shall be fined from HRK 5.000,00 to HRK 10.000,00 for committing the same misdemeanour.

3. Conclusions

The project management activity is present in Croatian construction, especially in building, for approximately 10 years. In the article, the authors stated the reasons for introducing that institution in the Croatian legislation, presented an overview of the most relevant Act's provisions as well as byelaw which regulates that activity, and compared these provisions with the appropriate provisions of the former legislation.

We believe that the number of investments which require persons performing project management tasks will increase in the following years in the Republic of Croatia. By observing their activity as well as potential implementation of Directives it will be possible to conclude whether and in what manner it will be necessary to change the legislation regulating the project management activities.

References

Act on Architectural and Engineering Activities in Physical Planning and Building (Official Gazette No. 152/08, 124/09, 49/11 and 25/13)

Act on Physical Planning and Building (Official Gazette No.76/07, 38/09, 55/11, 90/11, 50/12 and 55/12)

Act on Physical Planning and Building Tasks and Activities (Official Gazette No. 78/15)

Act on Recognition of Foreign Educational Qualifications (Official Gazette No. 158/03, 198/03, 138/06, and 45/11)

Building Act (Official Gazette No. 153/13)

Labour Act (Official Gazette No. 93/14)

Ordinance on required expertise in the field of project management (Official Gazette No. 45/09)

Ordinance on required expertise in the field of project management (Official Gazette No. 85/15)

Public Procurement Act (Official Gazette No. 120/16)

Protective Instruments for Public Works Contracts for the School Buildings

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Abstract:

The hedging of public construction contracts against potential business risk is an important thing in the public procurement process. The appropriate selection of protective instruments and adjustment of their parameters can help the contracting authority to protect the potential business risks within the public works contract. This paper analyses the contracts for work in the field of revitalization of school buildings. The aim is to determine which are the most frequently used protective instruments applied to solve the potential business risks, how efficient they are and whether the frequency of the applied instruments contrasts with other types of construction contracts. The aim of this case study was to extend the scope of previous research in one field of construction work to other relevant field and to discuss and consider the relationship between them.

A qualitative analysis of the currently used protective instruments in the contracts for work is performed. The frequency of their usage regarding the efficiency for public investor is determined to observe the conditions of contracts for work in public construction projects. One of outputs of this research is comparison between the contract price and the estimated value within award procedures in tenders during the period under review and analysis of the data. The research data and the selection of protective instruments in the branch of school building were compared with the recommended instruments in the branch of the sewage facilities and equipment.

The data are analysed and discussed in order to propose effective protective instruments for public works contracts aiming to protect both investors and suppliers during the contract period and ensure quality of public construction works contract within the project triangle: budget, schedule and scope from the investor's point of view.

Keywords: *Business risk, protective instrument, bank guarantee, retention, public works contract, contractual business conditions, revitalization of school buildings*

1. Introduction

According to many cases, the construction industry is susceptible to more risks and uncertainties than any other industry. Risk management aims to avoiding, reducing, absorbing or transferring risk and exploiting potential opportunities. Project risks are considered to be dynamic and therefore risk assessment should be a continuous process spanning all phases (Smith et al., 2014). In order to take advantage of economic opportunity and to achieve their objectives people must find ways to align their interests or minimise conflicts of interest by avoiding potential business and financial risks in public works contracts. Ross and Williams

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(2013) observe the contractors and subcontractors spend money on materials, labour, plant and overheads in the expectation of getting paid for their work on a regular basis. If actual revenue is less than anticipated this can cause cash flow problems. Work in progress becomes a problem when the contractor has not been recompensed through the contract. The construction projects are dominated by objectives based on time, cost and quality, particularly with respect to economy, efficiency and effectiveness.

During the launching of the procurement procedure or the award of a public contract of public works contract, it is obligatory to obey the Act on Public Procurement which specifies the method to be used for selecting the most suitable supplier of the construction works. Act on Public Procurement in the Czech Republic contains a detailed guide for contracting authorities on how to proceed when awarding public contracts to ensure they meet all legal requirements, both when actually awarding public contracts, in proceedings before awarding public contracts (e.g. when determining the value of the public contract, evaluation criteria, etc.) and following the award of public contracts.

In the Czech Republic, the Act on Public Procurement 134/2016 Coll. provides (in accordance with the EU directives) for nine different types of procedures and differentiates between above-threshold public contract, below-threshold public contract and small-scale public contracts, depending on the expected monetary obligation of the contracting authority. In an open procedure, the suppliers are invited to demonstrate their qualifications and submit their offers in one stage. A restricted procedure consist of two stages, the suppliers prove their qualifications and those which fulfil the qualification requirements are invited to tender.

The authors of this paper worked with the public construction contracts in the field of revitalization of school buildings published by a territorial self-government unit or its partially budget-funded organisation in regime under below-threshold public contract or small-scale public contracts. In the Czech Republic, the contracting authority shall act in a **transparent and proportionate manner**, shall treat suppliers **equally and without discrimination**.

Public procurement regime shall be determined on the basis of its estimated value. Small-scale public contract means that a public contract has an estimated value equal to, or lower than CZK 6,000,000 excl. VAT (EUR 222,000) in the case of a public works contract. If the character of the subject of the contract allows, the contracting authority (public contractor - school as organization financed by local government) prepares and executes market research in the following way:

- at least three suppliers shall send the invitation to submit tenders; the call may be sent by post, as well as electronically;
- in the case of public procurement contracts whose estimated value is at least CZK 500,000 (EUR 18,500), the contracting authority shall publish, on the **contracting authority profile**, the public contract including all supplements and amendments thereto within 15 days from their conclusion or from the end of each quarter with regard to public contracts awarded on the basis of a framework agreement or under a dynamic purchasing system;
- the contracting authority shall publish, on the contracting authority profile, not later than within three months from the completion of the contract, the actually paid price for the performance of the contract (Czech Republic, 2016).

Tenderers should understand the importance that the contracting authority will ascribe to each aspect in order to be able to prepare their tender. Language used in the call to tender must be precise, and importantly, must be formulated so as to ‘allow reasonably well-informed tenderers of normal diligence to interpret them in the same way’ (ClientEarth, 2011). Ross and

Williams (2013) underline the careful attention to detail at the tender stage will help to identify risk, flag up potential cash flow issues and avoid surprises during contract when it will be too late to do anything about it. Risk can be allowed for in the tender. A judgement can be made to mitigate the effect of onerous contract conditions, allowances for possible liquidated and ascertained damages (LADs) can be included in the tender.

According to the Act on Public Procurement (2016), the contracting authority specifies the set of **economic qualification criterion and technical qualification criteria** in order to establish human resources, technical resources or the expertise and experience necessary to perform the contract in quality. Knebl and Nemec (2010) state that only tenderer's bids which fulfil the qualification criteria prescribed by the contracting authority or in the tender documentation in accordance with the Act on Public Procurement are taken into account. The qualification criteria must be described transparently and non-discriminatorily in the contract notice or tender documentation.

The construction sector has a wide range of standard forms of contract which are intended to balance the risk of the parties but more importantly, through extensive and repeated use, give rise to a certainty of meaning. Well known standard form contracts include the Joint Contracts Tribunal (JCT), the New Engineering Contract (NEC) and for international projects Fédération Internationale des Ingénieurs-Conseil (FIDIC) (Designing Buildings Limited, 2017). In the Czech Republic, standard contracts issued by the FIDIC or adjusted FIDIC-based contracts are usually used for large construction projects.

For building construction project, meeting all qualification requirements does not yet represent protection of the contracting authority to the potential business risks connected with the construction contract. At this moment, protective instruments must be used. The aim of this research paper was to find out what protective instruments are currently employed, at what values and whether the instruments fulfil the functions required. The research question is how efficient these instruments are and whether the frequency of the applied instruments contrasts with other types of construction contracts. The outcomes of this case study are compared with previous research of author in the field of sewage facilities and equipment.

2. Methodology

The database was created by choosing the public works contracts which were realized between October 2011 and September 2016. Creating the database consisted of listing the public works contracts awarded in the contracting authority profile. The database of the chosen public works contracts was extended subsequently, by looking up the contracts for work (written agreement typically used between the Contracting Parties in the CR) which the contracting authority should publish on the contracting authority profile after tender's final decision. Analysis was carried out on a sample of 35 final contracts for work in the field of construction revitalization of school buildings designed to decrease energy consumption. The public works contracts from this branch were chosen from the large amount of data for the following reasons:

- Public works contracts were important from the public interest point of view and from the importance of hedging a partially state budget-funded organisation against the financial risks.
- Significant contracts in municipalities/regions were of a higher price. It was important to ensure these public works contracts against business risks in compliance with the quality of the work with regard to sustainability.
- Contracts were important from the perspective of ensuring against additional construction works that can threaten compliance with budget approved by municipality/region.

- Public works contracts were related with respect to one specific branch – renovation of school buildings.

The analyses contained the contracts awarded as open tenders or small-scale public contracts in the years 2011-2016 and included 35 individual procedures: 24 below-threshold procedures and 11 small-scaled procedures. For each procedure there were 6 offers on average. Total value of the contracts awarded reached CZK 277 million without VAT (EUR 10,260,000).[2] The average value of the contracts was CZK 7.5 million (EUR 277,000). The lowest contract value was CZK 0.7 million (EUR 26,000). The highest contract value was CZK 26.4 million (EUR 977,000). The lowest contract value was 0.7 million (EUR 26,000).

3. Results and discussion

This research analysis employed the data during the period 2011-2016, i. e. at the time when the Czech Public Contracts Act was amended. In 2012, the amendment left out from the Act the investors' requirement to request the contractor to prove his financial and economic qualifications prerequisites. The requirement to arrange the insurance was included in qualifications prerequisites within the tender. The tenderer who passed the qualifications procedure had concluded the required insurance and it was not necessary to include this in the contract.

The total sample of 35 contracts (with the exception of one contract in 2011) required the five-year warranty period. The research data provided interesting characteristic of public works contracts. Construction works usually have a 60 month-warranty, which is the requirement of grant within the project supported by the EU.

Prior to the launching of the procurement procedure or the award of a public contract, the contracting authority shall determine the estimated value of procurement. The comparison between the tender price and the estimated value is shown in Figure 1. The data provided the fact of the construction works in the Czech Republic during period 2011-2016. The line was a raising tendency. The analysis of contracts has brought an interesting turn in the tendency of the difference between the estimated value and the contract price. In Figure 1 we can see 81% (13 out of 16) of contracts were below 80% limit of the change between the estimated value and the contract price in years 2011-2013 while from the year 2014 it was only 21% (4 out of 19) of contracts which were under 80% limit. Thus from 2014 most of the contracts (79%) approached the limit of the estimated value and only one contract exceeded the estimated value. The constant decrease of construction works forced the suppliers to obviously undervalue the tender's offers in period 2011-2013 (tenders No. 1-16) as shown in Figure 1. The comparison was changed in period 2014-2016 (tenders No. 17-35) and it showed the tendency not to undervalue the tender's offers. The raising tendency comparing the research data copied the line tendency of the GDP in construction industry (data from Czech Statistical

[2] Average rate of exchange in the years 2013-2016 was 27 CZK/EUR.

Office), where the amount of construction works was decreased before 2012 and was raised since 2013.

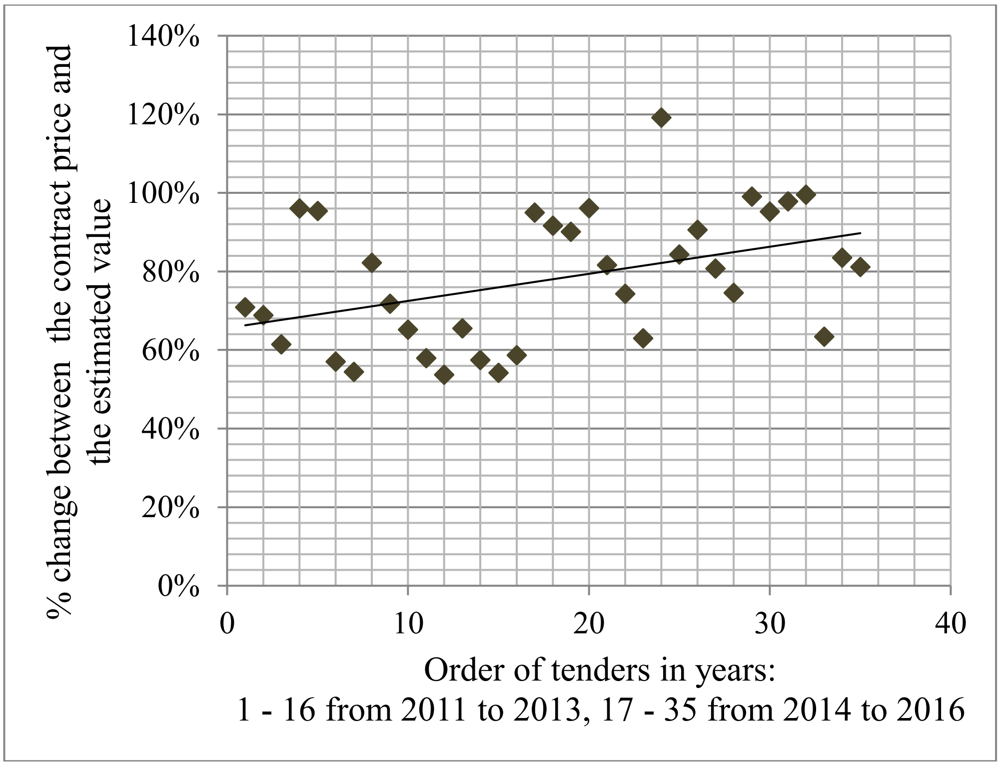

Figure 1: Comparison between the Contract Price and the Estimated Value according to order of tenders in years

The most frequently used risk protective instruments for public construction works contracts in a branch of revitalization of school buildings in the Czech Republic included particularly:

- property insurance and insurance of liability for damages,
- contractual penalty and
- bank guarantee (see Table 1).

In comparison with a branch of sewage facilities and equipment, **retention** belonged to traditional forms of business risk hedging in contracts for work until year 2013 in the Czech Republic (Korytárová et al., 2015). The research data have provided the fact that occurrence of retention was changed. This case study in the field of school buildings confirmed the results of Korytárová et al. (2015) in the field of sewage facilities and equipment. As in Korytárová et al. (2015) this analysis indicated that the use of retention (generally 10% in the field of school buildings) in contracts for work ceased to be used from the beginning of 2014 and was substituted by bank guarantee. For example, in Germany, provisions concerning retention of title are rather unusual in construction contracts. If the parties have agreed upon the application of the German Standard Building Contract Terms (VOB/B), the client has the right, following termination of the construction contract, to take advantage of the equipment, scaffolding, other installations, delivered materials and building components present on the site for the continuation of the work in exchange for reasonable compensation (Global Legal Group, 2017).

The financial sources obviously have caused greater importance of bank guarantees for the contracting authorities and have lowered effect the use of retention in public works contracts. In the Czech Republic, public contracts are mostly financed by the EU funds. Public subsidies are not allowed to keep the part of investments grant in current assets after the completion of the construction works in general. Public subsidies have to be paid in the full amount of the cost eligibility, which probably caused the transition of retention occurrence into using bank guarantees.

The **property insurance and insurance of liability for damages** was found in 77% of the examined samples and it was minimally equal to contract price. The **Performance Guarantee** occurred in the contracts for work before 31 December 2013 in only 31% (5 out of 16 contracts), the **Warranty Guarantee** even only in 6% (1 out of 16 contracts) of contracts. Since 1 January 2014 the occurrence has changed significantly. The **Performance Guarantee** was recorded in 47% of contracts (9 out of 19 contracts) and the **Warranty Guarantee** in 21% (4 out of 19 contracts) of contracts. It is worth mentioning that almost a fifth of contracts (17%) was not protected by insurance nor by warranty guarantee.

The examples of **contractual penalties** which occurred most frequently are shown in Table 1. Some other examples of contractual penalties occurred:

- Delay for the breach of a list of subcontractors change without notice
- Violation of fundamental duties of a contractor in the course of work on site arising from the Labour Code and other legal regulations
- Absence of the supervisor on the construction site
- Failure to comply with the project documentation: 10% of price of work

The comparison between the branches of sewage facilities and equipment and revitalization of school buildings is also shown in Table 1.

Risk protective instruments		Recommended parameters for sewage facilities and equipment (Korytárová et al., 2015)		Existing parameters for school buildings
Insurance	Liability for damage and property	80 – 100%	Of price of work	100 – 200%, in minimum the price of work
Contractual Penalty	Contractors delay in the construction completion day	0.10%	Of price of work	0.05 – 0.3% Median 0.12%
	Exceeding deadline for elimination of defects and arrears of work	CZK 5,000 (EUR 185)	Per damage and every commenced day	CZK 1,000 – 10,000 Median CZK 5,000
	Investor's delay in payment invoices	0.10%	Of outstanding amount	0.01 – 0.10% Median 0.05%
	Failure in keeping the term of clearing the construction site	CZK 5,000 (EUR 185)	Per every commenced day	CZK 1,000 – 10,000 Median CZK 3,000
	Others	To select others useful penalty		Examples are above this table
Retention		Not to apply		10% until 2013, not applied from 2014
Bank Guarantee	Performance guarantee	Not to apply		5 – 10% Median 10%
	Warranty guarantee	10%	Of price of work	2.5 – 5.5% Median 3.7%
	Retention guarantee	5%	Of price of work	Not applied

Table 1: Protective instruments for standard work contract in the Czech Republic – comparison of recommendation for contracts in a branch of sewage facilities and equipment (Korytárová et al., 2015) and in a branch of revitalization of school buildings

The comparison of two branches confirmed firstly, the liability for damage and property was raised from 80-100% to 100-200% (see Table 1). The authors supposed that obligatory conditions of hedging the public works contract are established by EU funds. Secondly, the comparison has shown that construction works contract with higher contract price such as sewage facilities and equipment in price limit CZK 24 mil. – 30 mil. (EUR 0.9 – 1.12 mil) contained higher parameters of the protective instruments than the branch of school buildings in average price limit CZK 7.5 million (EUR 0.3 mil.) (see Table 1 for example of the contractual penalty for investor's delay in payment invoices, failure in keeping the term of clearing the site and warranty guarantee). Thirdly, the occurrence and the parameters of contractual penalties of this study were not changed significantly in the course of time. The selection of protective instruments and their parameters were proposed effectively to protect both investors and suppliers during the contract period. Fourthly, retention and retention guarantee were not applied from 2014. Finally, performance and warranty guarantee substituted the occurrence of retention. Bank guarantees provide the investor a similar security as retention while offering the contractor many advantages.

4. Conclusion

This paper focuses on the qualitative analysis of use of risk protective instruments employed in public construction contracts and on the assessment of a reasonable extent of their use in contracts for work. Main focus was to determine how the protective instruments are used and how they are set up especially in the branch of revitalization of school buildings. The research data was compared with the data acquired from previous study in the branch of the sewage facilities and equipment.

Based on the analysis of the sample examined, these protective instruments are most frequently used in the Czech Republic: property and damage liability insurance, contractual penalties and bank guarantees. The research has confirmed that retention is not used. Since 2014, the performance and warranty guarantee has been used more often which substitutes the retention or even provides a greater extent of protecting the potential business risk.

Recommending an appropriate set of protective instruments and their parameters for the contractual business conditions within the public sector in the Czech Republic can help hedging of public finances and public works contracts with the criteria of economy, efficiency and effectiveness. Secondly, it helps the Contracting Parties to achieve the objectives aiming to ensure the delivery of contract on time, cost and quality.

The Brazilian Civil Code establishes that private contracts are governed by the principle of good faith and *pacta sunt servanda*, which means that contracts are laws with binding force between parties, who require that every contracting party must keep its promise and fulfil its obligation. Therefore, the amount of retention and the conditions for its release shall be agreed upon by the parties to the contract. In Germany, it is obvious the compensation is only due upon acceptance of the work, i.e. when the work is substantially complete. The contractor is obliged to carry out work in advance. As he carries the full risk, the contractor can demand progress payments corresponding to the works completed thus far. Corresponding contractual provisions are frequently agreed. The client can deny the progress payments if the services are not rendered in accordance with the contract (Global Legal Group, 2017).

References

ClientEarth (2011), Identifying Opportunities for Sustainable Public Procurement Briefing Series, Briefing No. 3: The guiding principles of public procurement transparency, equal treatment and proportionality, available at: https://www.clientearth.org/reports/procurement-briefing-no-3-guiding-principles-equal-treatment-transparency-proportionality.pdf (accessed 10 March 2017).

Czech Republic (2016), Act No. 134/2016 Coll., on Public Procurement, In: Public Procurement and Concessions Portal, Ministry for Regional Development, available at: https://www.portal-vz.cz/getmedia/ac061a0a-d8c1-4ff1-b8d2-691aa89269b1/Zakon-c-134_2016-Sb-o-zadavani-verejnych-zakazek.pdf (accessed 10 April 2017).

Designing Buildings Limited (2017), Designing Buildings Wiki, available at: https://www.designingbuildings.co.uk/wiki/Construction_contract_conditions (accessed 10 April 2017).

Global Legal Group (2017), International Comparative Legal Guides, Comparison Tool, available at: https://iclg.com/compare/construction-and-engineering-law (accessed 12 April 2017).

Knebl, O. and Nemec, J. (2010), The International Comparative Legal Guide to: Public Procurement 2010, chapter 11: Czech Republic, p. 66-72, BBH, Attorneys at Law, v.o.s. available at: http://www.bbh.cz/cs/publikace-1/ (accessed 8 April 2017).

Korytárová, J. et al. (2015), “Financial Risk Hedging Instruments for Public Work Contracts”, Organization, Technology & Management in Construction: An International Journal, The University of Zagreb, Faculty of Civil Engineering, Zagreb, Croatia.

Ross, A. and Williams, P. (2013), Financial Management in Construction Contracting, John Wiley & Sons, p. 456.

Smith, Nigel J., Tony Merna and Paul Jobling (2014), Managing risk in construction projects, 3rd ed., Chichester: Wiley-Blackwell.

Maintenance Management Strategy of the Airport's Traffic Area

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Abstract:

This paper deals with the maintenance management strategy of the airport's traffic area. An open interview method with professionals at Zagreb International Airport is used in order to identify important indicators of the successful maintenance management strategy according to Airport Cooperative Research Program (ACRP). In addition, a guideline for the maintenance management improvement of the airport's traffic areas in the Republic of Croatia is given. This guideline can be used for other airports and enable implementation of the highest European and World standards regarding maintenance management strategy.

Keywords: *maintenance management strategy, airport's traffic areas, open interview method, Airport Cooperative Research Program (ACRP)*

1. Introduction

Facility's period of usage today is often neglected and insufficiently included during conception and project phase despite the fact that the exploitation phase is indeed the longest, functionally the most significant and at the same time pretty financially important for entire building's life expectancy .

Maintenance is set of activities that provide usage of facility in its full purpose within the project's intended period of time that also meets all necessary criteria for usage of facility considering prescribed quality requirements. Maintenance and proper usage of airport's facilities and its traffic areas is of significant importance and it's necessary for regular, unimpeded, rapid and above all safe traveling.

This research paper deals with relevant literal topics and gives concise definitions of basic terms related to maintenance, usage and strategic management of airport's traffic areas. In order to define which are successful strategy's key indicators of maintenance airport's traffic areas, apart from relevant literature's available facts, open interview method was used which included a number of experts who directly participated in creating and conducting maintenance strategy of ZIA traffic areas according to Airport Cooperative Research Program. As a result of all received data, based on conducted interviews and available literature, a guideline for maintenance of ZIA 's traffic areas management improvement was given , also applicable to other Croatian airports. Also guidelines were given for further research and progress in the field of airport's traffic areas maintenance management.

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2. Facility maintenance strategy

Maintenance of facility is a term that implies much wider range of activities than the ones that are only in domain of construction. Maintenance is defined as set of all activities that provide usage of facility, where owner of the building shall maintain the building so that in certain time of its duration essential building requirements should be preserved and these are: mechanical resistance and stability, fire protection, health and hygiene postulate, environmental protection, usage safety, noise protection, energy savings, heat protection (Simovic, 2002)

The above-mentioned definition points out the significance of maintenance during facility's life expectancy as a comprehensive project that inquires investment funds during the entire period of usage, that provides for entire facility and all its parts a level of service in specific acceptable limits (Cerić and Katavić, 2000). Unquestionably, building maintenance is multidisciplinary and multidimensional task, quite complex and requires high level of multidisciplinary approach and thinking as well as the ability of good management or skilled balancing within almost always strictly limited financial means. (Kušar et al.2013)

With the emergence of bigger and more complicated facilities whose maintenance requires large financial expenses in comparison to construction price, a need for facility management appears.

Also great emphasis, in entire process of facility management today, is put on environmental protection or so called green construction and sustainable development. Tendency and ability of facility manager and others participants of facility management process is emphasizing the importance of environmental protection and its crucial significance in achieving high level of sustainability in construction and development business. (Khalil, 2011).

Clearly financial aspect dictates expenses formation on one side and benefits creation as their result on the other. Finding an optimal ratio is task of every manager in charge of facility maintenance management according to defined strategy. Here we're introduced to the term "facility management strategy" which is a part of enterprise strategy or state authorities that possess the facility (Vanags and Butane, 2013). Need for more effective , planed in advance and predictable maintenance management building process has led to emergence and development of concept that is elaborated in contemporary literature under the abbreviation of CREM (Corporate Real Estate Management) and includes three the most important principals of facility management- strategy, logistics and tactics.

3. Maintenance management strategy of the airport's traffic area

Facility management is very complex and demanding process depending on the type of facility. Every facility has its own management and maintenance distinctiveness and one of very specific and relatively rare, comparing to the number and share in other types of facilities are airport's traffic areas. In order to be able to understand complexity and extent of maintenance of airport's traffic areas we should define it first. Airport's traffic areas are divided into airside and landside zone. Airside traffic areas imply all areas of planes, helicopters, other flying objects and all accompanied technical vehicles range that are included in direct process of monitoring planes before/ after rising or landing, plane supply vehicles and vehicles of service for emergency situations. Furthermore, there is a division to waiting areas for planes, taxiways, plane runway, and ancillary rutes for communication and Air-side roadways maintenance (Book of regulations for airports, 2014). Traffic areas of airside zone are places where movement of people is for authorized personnel only and that implies strict people movement regime and strict rules of conduct. Traffic areas of landside zones imply parking lots and roadways that are used for arrival and departure of passengers by cars, taxis, buses and they don't undergo the security level and airside zone rules, although these are also places with higher degree of security and checkouts than the other public places. The above mentioned classifications and demanded security levels as well as the specific rules of conduct derive from international standards and regulations for airport areas (International standards and recommended practices, Aerodromes, Annex 14/I)

Some significant characteristics of airports and their traffic areas:

- Large areas within entire airport's space
- Continual circulation of planes and other flying objects in specific time intervals
- Specific rules and regulations that exceed the state laws
- Large degree of traffic security imposed by international rules
- World unification of quality and provided service demand
- Large impact of local atmosphere factors on functioning and maintenance
- Relevance of their functioning for international traffic or possibility of rapid and secure interconnection between city/state and the rest of the world
- Political, military strategic and economic impact taking in consider size and traffic possibilities of airport's areas
- Important strategic elements of every state's property

All above mentioned characteristics are rendering creating and conducting maintenance management strategy of airport's traffic areas rather complex. Therefore, a question remains how and which factors we should perceive and consolidate in order to successfully form maintenance strategy, to apply it and track results, so that in the end we could have quality response to it.

"Measurement is first step that leads to control and possible improvement. If you can't measure a thing, you can't understand it, If you can't understand it, you can't control it. And if you can't control a thing, you can't improve it either."(Harrington et al.1997)

In order to successfully manage a facility or achieve aims intended in management strategy of facilities, it's necessary to measure and monitor specific parameters based on which is possible to evaluate implementation success or management as a process in general. Primarily it is necessary to determine and choose parameters, based on some criteria how to place them in groups and subgroups and the most importantly how they would be monitored and measured. Key Performance Indicators (KPI) represent a set of measures and parameters focused on representation and measuring those particular parts of organization the most critical for success and quality for present and future success of entire organization (Parmenter, 2007) KPI are measures ,quantitative and qualitative, may have different structure and different units. Sometimes, these measures do not say anything by themselves, but may be compared to historical data or to equivalent measures for other airports and this comparison may show rise or declination of measuring indicators (Humphreys, 2002)

There are many different opinions of significant number of authors and their research papers on how to divide KPI into groups and subgroups .Oum et al. emphasize the importance of measuring the total airport system, and not just the parts of the airport. They state that focusing on specific parts of areas, might lead to sub optimization and failure to reveal bottlenecks or incorrect data. In addition, according to them it is important to consider other external parameters which are not directly connected to airport issues, but in the end affect its business success. Granberg et al .for assessment and monitoring success in maintenance of airports use DEA (Data Envelopment Analysis) to compare business and management results of different airports with intention to create new assessment and success measures of different groups of airports. The focus of airlines, from elite flights reserved for rich clientele, has changed to flights at lower costs available for majority of people around the world. According to that certain parameters, criteria of measurement and monitoring airport's management, along with that relatively large number of new KPI s emerged like Assets revenue per passenger number, concession revenue per number of foreign passenger's departure , etc. (Curran et al, 2012)

Table 1. KPI's division to functional zones groups according to ACRP

Key Performance Indicators with functional zones and types	
Functional zone	KPI
Airport operations	Total traffic in terms of aircraft movements
	Real time capacity of runway
Airport service	Total amount of transported cargo in tons
	Number of commercial flights
Cargo	Total amount of cargo when lending (t)
	Share of cargo in total financial transactions
Concessions	Concession revenue per number of flights
	Concession revenue per airport's square meters
Environment	CO2 emission
	Consumption of defreeze liquid (t)
Co-financing/ incentives	Financing from State Agency for Aviation
	Total financing from incentives and co-financing
Human resources	Salaries and other expenses of employees
	Number of arrivals/departures per employee number
Maintenance	Average age of all vehicles
	Airside traffic areas maintenance expenses
Planning/Construction	Current expenses in comparison to those budgeted

	Total expenses of construction /calculated (%)
Real estate / contracts	Tax rate for possessions
	Tax rate for possessions
Quality of services	Contentment of airport's passengers and customers
	Airport's accessibility as well as the surrounding roads

Browsing through indicators in tables you may notice the emphasis on amount and location of different expenses. The interesting facts in the field of airport's traffic areas are maintenance expenses that can be divided to regular, periodic and emergency maintenance.

Elements of maintenance expenses are:

- Operating expenses
- Replacement of used materials and facility's elements expenses
- Reactive maintenance expenses
- Periodic repair expenses
- Expenses for examinations required by law

4. Case study

Zagreb International Airport, which is the largest airport in the Republic of Croatia, is chosen for the case study. Method used for this study was open interview method along with relevant literature. A number of relevant professionals working in ZIA's management and maintenance were interviewed and all required data was obtained.

While interviewing maintenance sector director we found out that maintenance sector is divided into 6 subsectors each one led by its manager. Maintenance sector's primarily assignments are: maintenance of electro and engineering installations, small interventions and construction repairs; traffic roadways, green areas and environment maintenance; servicing and maintenance of some device for air traffic, in airport's domain. Other complex service and servicing, larger renewals or construction work are held if needed in arrangement with external companies. Jobs are assigned to those companies by Public purchase usually for a period of one year or once per completion of some renewal and sl. Need for external companies , apart from emergency and sudden interventions and breakdowns, is determined in advance by annual plan of maintenance .

Maintaining processes are divided into three subcategories:

- Remedial and emergency repairs
- Regular maintenance
- Necessary repairs

Into remedial and emergency repairs subcategory we can put all urgent operations and they are essential for normal functioning of airport that are performed by sector maintenance services or permanent subcontractors nominated at annual tender who deal with more complex situations. Breakdowns and failures in this category are fixed during 24h time. Regular maintenance subcategory implies all work that have to be regularly done so that all airport's traffic areas may function normally or at least have its esthetic function. These are: green areas maintenance and mowing the lawn, entire light system maintenance of runway, aprons and car tracks, light system for car's parking lots and for external part of airport's building, parking lots and video surveillance system maintenance, maintenance of all significant roads crucial for civil and official transport and also winter service with snowplows in charge of snow removal and maintaining the surfaces ice-free especially runways. They are conducted in three possible forms:

- Self-maintenance
- Occasional outsourcing maintenance service
- Outsourcing of entire maintenance package

In necessary repairs subcategory we have electro, mechanical and construction works whose completion is not urgent so it doesn't affect essential features of functionality and safety of airport's traffic flow. In addition we have enlargement and modernization of parking lots and intern airport's roads or even new system of light signalization and lamps installation. Zagreb International Airport had significantly procreative system that was always in touch with new technologies and maintenance standards, especially with arrival of the new concessionaire who emphasized above mentioned feature and brought in modernization to all systems, from those energy effective ones to environment friendly mode and maximum environmental protection. Some examples of these are: airport's terminal and accompanied facilities reconstruction of heating system or apron reconstruction.

While interviewing number of employees of ZIA' s maintenance sector as well as the employees in leading positions we gathered their operating and business data and nominated them according to ACRP's Key Performance Indicators in the table below:

Table 2. Operating and business data according to ACRP's Key Performance Indicators

KEY PERFORMANCE INDICATORS OF ENFORCEMENT ZIA MAINTENANCE STRATEGY	
Annual number of maneuver activities of planes	**38.348**
Real capacity of runway per hour	**18 planes/h**
Time needed for (snow) removal	**20min in one way**
Total amount of transported cargo in tons	**9500 t**
Airside's electric energy consumption	**1.200.000 kWh**
Number of official and operative vehicles which use renewable energy sources	**11 vehicles**
Time of every individual system's failure repair	**up to 2h, essential systems**
Number of employees	**58**
Salaries and other expenses of employees	**11.732.000 kn**
Percentage of employee expenses in total expense number	**63%**
Number of training hours per employee	**20 h/year**
Average age of all vehicles	**17 years**
Expenses for service companies per square meter	**48,11 kn/m2**
Airside traffic area's maintenance expenses	**5.700.000 kn**
Parking lot income per passenger	**3,70 kn**
Efficient utilization of parking lots (%)	**76%**
Accessibility of airport and surrounding roads	**4,3/ 5**
Number of take-offs per runway size	**0,11 per m2**

5. Results

Based on obtained Key Performance Indicators data we can say that ZIA maintenance system is well organized, up to date, considering emergency interventions, and with intention to follow latest technology and trends taking in consider its finances. It's positive the airport management's tendency to introduce as many, renewable energy sources and "green" vehicles in everyday business, as possible. For example parking ticket vending machine use solar cells for power supply, transport vehicles for luggage now are powered by electricity. Maintenance system of airport's or its traffic areas stand out for its complete informatization and computer surveillance. In other words, entire lighting and navigation system, as well as the surveillance system and weather monitoring system are completely digitalized and monitored out of one center place within the airport. Thus allowing 24h surveillance of entire system by few employees of maintenance service monitoring center and quick response to a system failure. Furthermore, the remaining part of airport's system elements, that can't be monitored digitally so they are not in possession of adequate equipment , is under everyday surveillance and control by coordinators who are circling around all parts in vehicles or by foot and they inform technical maintenance service about its accuracy. Significant advantage of current maintenance system is above mentioned IT system usage in business thus achieving improved control over resources and costs and at the same time enabling agility, simplicity and transparency in a maintenance process. For that purpose all the employees completed IT course. Using this system following activities are performed:

- Monitoring the condition of electro and other equipment in charge of ZIA
- Evidence of current equipment ,machines , vehicles and other work required resources
- Orders for materials and other resources and its approval
- Addressing failure to right person/firm for repair
- Reporting and archiving on maintenance situation
- Monitoring and surveillance of vehicles and employees working in airside zone
- Special management of winter service etc.

Furthermore, we can recognize current system's flaws in two parts of maintenance sector and these are winter service and environment and green areas maintenance service. Especially that's the case with outdated equipment used in this operations, machines and vehicles whose average age is 17 years. This way work is significantly harder and slower, but it would be easier with new equipment and machines . The problem has been recognized by the ZIA administration, but high costs of new machines, vehicles and their equipment is the reason why process of solving this problem lasts up to several years. Certainly, annual maintenance budget does not allow purchase of all above mentioned machines and vehicles in one year period, but gradually the ones in the most critical condition are replaced with new ones. This problem is temporary solved with outsourcing when winter service during the winter season and lawn maintenance service during the summer are severely occupied. In this period also administration of technical service maintenance monitors the effect of work and associated costs in order to make right decision about the rentability of purchasing certain machine or vehicle or possible permanent outsourcing of machines and vehicles.

6. Conclusion

Maintenance of airport's traffic areas is very important segment of airport's maintenance in general, so business quality, work rentability and functioning of airports in general depend on particular airport's quality, rentability and its own functioning.

We reached a number of conclusions from conducted research based on open interview method and detection of successful airport's maintenance key indicators according to ACRP:

- ZIA has excellent system maintenance with tendency for constant improvement and development of technics and equipment
- Employees who work in maintenance accept principles of economy, environmental sustainability, and have awareness of need for constant improvement
- Current maintenance system responds well to specific failure situations and extreme weather conditions
- System is pretty advanced in technology with quality IT support
- Obvious system flaw is relatively high average age of vehicles, but the administration tends to renew it focusing on "green" vehicles
- Current system reorganization with other improvement parameters tends to higher financial efficacy in order to invest saved funds in the further development of the system
- Planned Outsourcing is used for not so common maintenance elements or the ones demanding narrow specialization for their performance
- ZIA has the most efficient maintenance system above all others airports in the Republic of Croatia considering number of employees in maintenance sector per total airport's and its active zone's area.
- Considering all parameters ZIA maintenance system may be fairly evaluated and compared to European ones

The largest and leading generator of every maintenance system's flaws still remains insufficient commitment to maintenance system during the projecting and construction phase of each facility as well as the airports. For not taking in consider specific maintenance conditions and requirements, when projecting, we get facilities demanding greater employee, machine and equipment engagement for the same level of maintenance service that eventually leads to unnecessary expenses and less resources for other aspects of maintenance.

Obtained informations and guidances may be used as a guidline for maintenance system of airport's traffic areas improvement for similar airports in Croatia and other countries in her region. Further research should certainly include all the others Croatian airports of all purposes-military, sports and civil in order to gain the big picture of actual situation in airports and their traffic areas maintenance and to enable the implementation of highest European and World standards regarding maintenance in order to create unique and comprehensive strategic program of maintenance on a state level.

As well, other research may focus on expanding researching to as many different business types of airports around the world possible, in order to unify better the obtained maintenance guidelines and to achieve wider use of new guidelines in all types of airports no matter where they are.

References

Cerić, A., Katavić, M. (2000), Upravljanje održavanjem zgrada, Građevinar, Vol. 53, No. 2, pp. 83-89.

Curran, R., Calck, E. (2012), Simulation of Taxiwy System Mainteance to Optimize

Granberg,T., Munoz, a. (2013), Developing key performance indivators for airports, ENRI Int. Workshop on ATM7CNS, Tokyo, Japan

Harrington, H.J., K.C. Esseling, Van Nimwegen, Business Process Improvement Workbook: Documentation, Analysis, Design, and Management of Business Process Improvement, McGraw-Hill Education, 1997

Humphreys, F.G., Jackie, J.,The benchmarking of airport performance, Journal of Air Transport Management, 8, 239-247

Khalil, N., Husin, H.N., Mahat, N., Nasir, N. (2011), Sustainable Environment: Issues and Solutions from the Perspective of Facility Managers, Procedia Engineering.

Kušar, M., Šubic-Kovač, M., Šelih, J. (2013), Selection of Efficient Retrofit Scenarios for Public Buildings, Procedia Engineering, Vol. 57, pp. 651-656

Parmenter, D., Key performance indicators: developing, implementing and using winning KPI's, New Jersey: John Wiley& Sons, Inc., 2007

Pravilnik o aerodromima, Narodne novine 127/13, section 1,article 1

Simović, V. (2002), Leksikon građevinarstva, Masmedia, Zagreb

Airport Operationla Value, Delf University of technology.

Vanags, J., Butane, I. (2013), Major Aspects of Development of Sustainable Investment Environment in Real Estate Industry, Procedia Engineering, Vol. 57, pp.1223-1229.

General Management and Economics in Construction

World Quality Management Trends Implemented into Construction Company

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Abstract:

It is often said that quality is one of the most important factors of market competition. However, quality does not include only product or service features but also quality of business systems, quality of management, quality of relationships with partners, quality of effective production methods, quality of sales and related services, quality of distribution and quality of company culture. If an organization wants to achieve sustained success, it must not neglect any of these areas and must prove excellent quality in at least one of them. In our contribution will be described changes brought by new version of ISO 9001:2015 and specific features for higher levels of Quality Management, like Total Quality Management, KAIZEN method, Reengineering and EFQM Excellence Model, which can be effectively implemented into construction companies with aim of continuing improvement of their Quality Management. Achievement of exceptional quality is now considered a necessity if an organization wants to succeed in a market in a hard competitive fight. Quality management forms mentioned in the contribution represent a significant help for construction organizations in this effort.

Keywords: *quality; management; construction company; world trends;*

1. Introduction

In the course of history, quality and quality management has undergone a long development process. From self-control of own products (manufacturers of tools, craftsmen) through specialized controllers (manufactories and factories of the Industrial Age) to statistical quality control methods (influential pioneers: Shewhart, Ishikawa); from product quality to quality of all business processes; from development of revolutionary philosophies, principles and methods (works of prominent quality experts: Deming, Juran, Crosby, Feigenbaum) to their worldwide acceptance in the form of stable, respected systems and defined standards (Total Quality Management - TQM, Quality management systems according to ISO 9001, Kaizen, Six Sigma, EFQM Exellence Model).

Quality Management is part of management of the organization. The role of quality management is to draw up and implement policies, principles and requirements for quality in the organization. It has four main components: quality planning, quality assurance, quality control and quality improvement.

Ouality Management activities include for example data analysis, monitoring of performance and reliability of processes, recording achievement of goals, customer satisfaction

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analysis, etc. Quality management pertains not only to products and services but also to company management and strategy.

Essential aspects of contemporary quality management include:

- strong management with a clear vision and policy of quality in the organization,
- effort to implement processes and their products correctly at first attempt,
- active involvement of all organization members in the quality improvement process and process effectivity growth,
- customer focus (product or service user),
- implementation of a team-work system and self-control system,
- implementation of a system of incentives and bonuses for achieved results,
- continual process of employee trainings in the organization.

In our contribution will be described changes brought by new version of ISO 9001:2015 and specific features for higher levels of Quality Management, like Total Quality Management, KAIZEN method, reengineering philosophy and EFQM excellence model, which can be effectively implemented into construction companies with aim of continuing improvement of their Quality Management.

2. Changes brought by new version of ISO 9001:2015

This chapter compares the current version of ISO 9001:2015 with the previous version - ISO 9001:2008. It covers the main differences between these versions and deals with issues concerning validity of certificates obtained pursuant to the previous version of the ISO 9001 standard.

List of the most significant differences between the current and the previous version of ISO 9001:

- ISO 9001:2015 does not contain the term preventive actions. Organizations are required to implement risk and opportunity management instead, which is covered in Chapter 6 Planning, subchapter 6.1 Activities to Handle Risks and Opportunities.
- A management review is no longer performed once a year but it has become a permanent component of the life of a corporation. In ISO 9001:2015, the management review is covered in Chapter 9 Performance Evaluation. New terms are considered: performance, trend, alignment with the strategic direction of the organization, risks, influences and improvement opportunities.
- ISO 9001:2015 no longer includes a definition of the position of a Quality Management Representative (QMR). The responsibilities and tasks of the QMR are taken over by the management of the organization led by the director. However, in practice it will be possible to assign tasks related to the process of the Quality Management System implementation and maintenance to an employee and create a specialized position called e.g. quality coordinator of Quality management System (QMS).
- ISO 9001:2015 does not oblige organizations to have a Quality Manual.
- ISO 9001:2015 does not recognize the terms document and record. It uses the term documented information instead. It is information that is required to be controlled and maintained by the organization and the medium on which it is contained.

Structuring of clauses of the current and the previous version of the standard is compared in Table 1. Differences in terminology in the current and the previous version of the standard are shown in Table 2.

There is no obligation to replace the terms used by the organization with the terms used in ISO 9001. The organization can choose to use the terms which are suitable for its operations (e.g. “records“, “documentation“, „protocols“ rather than “documented information“ or “supplier“, “partner“, “vendor“ rather than “external provider“).

The International Accreditation Forum endorsed a three-year transition period from publication of the standard. The transition period is a period of time during which new or amended requirements under ISO 9001:2015 shall be implemented into exisiting management systems. The transition period ends on 15 September 2018. Certificates obtained under ISO 9001:2008 remain valid until this date and it is still possible to obtain a certificate under ISO 9001:2008 (ISO 9001:2008), which, however, will cease to be valid on 15 September 2018 (Figure 1).

Table 1. Structuring of clauses of the current and the previous version of the standard ISO 9001:2015

Clause	ISO 9001:2015	ISO 9001:2008
0	Introduction	Introduction
1	Scope	Scope
2	Normative references	Normative reference
3	Terms and definitions	Terms and definitions
4	Context of the organization	Quality management system
5	Leadership	Management responsibility
6	Planning	Resource management
7	Support	Product realization
8	Operation	Measurement, analysis and improvement
9	Performance evaluation	
10	Improvement	

Table 2 Differences in terminology in the current and the previous version of the standard ISO 9001

ISO 9001:2008	ISO 9001:2015
Products	Products and services
Exclusions	Not used (Instead, the organization examines the applicability of existing requirements to the size and complexity of the organization, management model, which uses with regard to the scope of activities of the organization and nature of the risks and opportunities)
Management representative	Not used (Similar responsibilities and authorities are assigned but no requirement for a single management representative)
Documentation, quality manual, documented procedures, records	Documented information
Work environment	Environment for the operation of processes
Monitoring and measuring equipment	Monitoring and measuring resources
Purchased product	Externally provided products and services
Supplier	External provider

Figure 1. Transition period, validity of ISO 9001:2008 certificate

As compared to the previous version, the ISO 9001:2015 standard contains more requirements. On the other hand, it provides more flexibility in meeting these requirements. The wording of the standard can be seen as a step forward - it is transparent, it reflects the current situation in the business environment and its structure is more compatible with other management systems. In addition to obtaining a certificate, the standard can significantly contribute to achievement of higher efficiency and better business results of the organization.

2.1 Characteristics of ISO 9001:2015

International Organization for Standardization (ISO) issued ISO 9001:2015 in September 2015, thus completing more than a three-year long review process in which 81 countries and experts from business, government and academic sectors were involved. Review of the ISO 9001 standard reflects the current situation in business and social environment. It also reflects contemporary phenomena such as globalization, the complexity of business environment, the existence of complex networks of supply chains as well as the growing importance of services. The objective in developing the new standard was to ensure a closer link between quality management and overall corporate strategy, attempt to meet the needs of all stakeholders, take into account the context of the organization and provide a framework for integration of ISO 9001 with other standards for management systems (e.g. the Environmental Management System).

The most significant features of the current version of ISO 9001:2015 include:

- Application of PDCA (Deming‘s) cycle (PDCA = Plan, Do, Check, Act) in the Quality Management System) – see Figure 2 .
- Better compatibility of ISO 9001 with other management system standards.
- Closer link to the general management system of the organization and to its strategic direction. The standard requires greater involvement of top management in development of policies and goals.
- The current wording of the standard enables easier application also in organizations providing services.
- The requirements of the standard are less specific than expected when it comes to defining responsibilities and obligations.
- The standard requires a closer alignment of the Quality Management System with real operation of the organization in order to prevent bureaucratic approach to implementation of the Quality Management System and perception of the System only as a tool to obtain the certificate.

- Implementation of a risk management system which will help the organization to identify risks and opportunities and define key priorities for operation of the organization.

ISO 9001:2015 is based on a process approach which includes the PDCA cycle (Plan – Do – Check – Act) with risk-based thinking. The process approach enables organizations to plan their processes and their interactions. The PDCA cycle enables organizations to ensure that their processes are managed properly, have sufficient resources and define and implement improvement opportunities. Risk-based thinking enables organizations to identify factors which might cause that their processes and the Quality Management System will divert from the planned results and to take preventive management actions in order to minimize negative impact and maximize use of opportunities if they arise. The process approach requires systematic definition and management of processes and their interactions so that the intended results can be achieved in line with quality management and strategic direction of the organization. Figure 2 shows the QMS structure according to ISO 9001:2015.

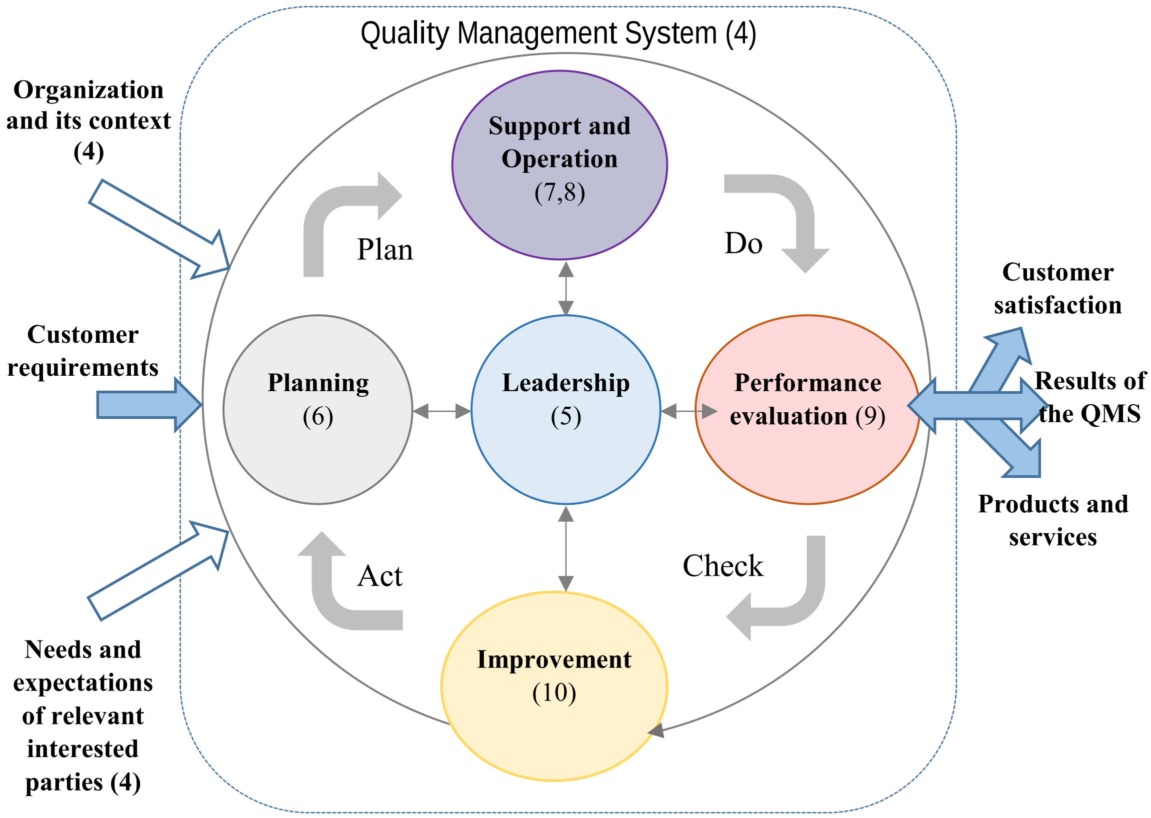


Figure 2. Structure of QMS according to ISO 9001:2015 in PDCA cycle

Application of the process approach in the Quality Management System enables:

- understanding and consistency in meeting requirements,
- consideration of the added value of processes,
- achievement of efficient performance of processes,
- improvement of processes based on data and information evaluation.

3. Higher forms of Quality Management

Implementation of the Quality Management System (QMS) in the organization is a milestone which clearly confirms achievement of a certain quality standard. However, the process of quality improvement does not end with achievement of this standard; on the contrary, it is the first step on the path to excellence. Higher quality management forms are a superstructure built on a firm base formed by the QMS.

The following picture (Figure 3) shows methods of increasing the level of quality management in relation to time (reengineering means a radical change of corporate processes whereas Kaizen, for instance, means gradual improvement step by step).

3.1 Total Quality Management

TQM is an attitude, philosophy but also a process which emphasizes personal responsibility of all employees striving for continual improvement. The process as such has no end. TQM is also a system composed of organizational, administrative and technical procedures, techniques and tools. The basic TQM concept focuses on customers, employees

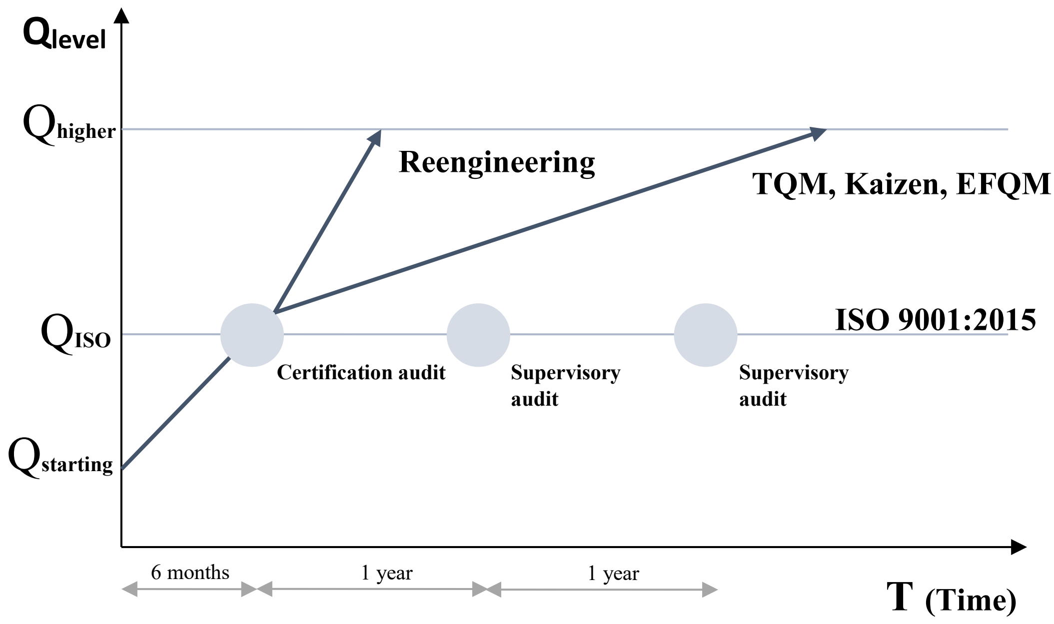


Figure 3. Quality improvement in the organization (Gašparík,J.& Gašparík,M., 2016)

of the organization, processes, working environment, goals and results, and forms a basis of ISO 9000 standard series and of the EFQM model.

Total Quality Management can be defined as follows:

- TQM is a quality-focused approach of the organization’s management based on involvement of all its members and aimed at sustained success achieved through satisfied customers, prosperity of the entire organization and profit for all members of the organization.
- TQM is mobilization of the entire organization to achieve quality in a sustained and economical way.

- TQM is an approach to improvement of competitiveness, effectiveness and flexibility of the entire organization through planning, organizing and understanding of every activity. It is dependent on every individual at every level.
- TQM means that corporate culture is defined as constant exploration of customer satisfaction through an integrated system of tools, techniques and trainings. This involves continual improvement of organizational processes resulting in high-quality products.
- TQM is a management philosophy forming a customer-driven and learning organization so that it could achieve full customer satisfaction through continual improvement of the effectivity of processes taking place in the organization.

Basic TQM principles:

- Customer focus: The customer is a key arbiter in terms of quality of products and services. The organization should understand their present and future needs, meet their requirements and exceed their expectations.
- Development of partnerships :Partnerships with suppliers are based on mutual trust and appropriate integration, which generates an added value for both customers and suppliers.
- Employee development and involvement : Total employee potential is achieved through shared values, fostering mutual trust and facilitating initiative. Involving employees and communicating with them allows the organization to benefit from their skills and abilities.
- Fact-based process management : Activities are systematically managed in terms of processes. Processes have owners, are understood and prevention-based improvement activities are carried out in the daily work of each employee. Management is based on facts, measurements and information.
- Continual learning, innovations and improvement: There is a culture of continual improvement. The process is based on sustained improvement of the level of knowledge. Original ideas and innovations are supported. Benchmarking (comparison with market leaders) is used to foster innovations and improvement.
- Leadership and Stability of Intentions: Leaders develop corporate culture and steer resources and goals of the organization towards excellence. Policies, strategies and goals are disseminated in a structured and systematic way throughout the organization and all activities are mutually compatible. Employee behaviour is also in accordance with policies and strategies of the organization.
- Public responsibility :The organization and its employees adopt an ethical approach and seek to meet regulatory and statutory requirements beyond standard levels.
- Result orientation: Sustained success depends on balancing and satisfying the interests of all stakeholders: customers, suppliers, employees and those having a financial stake in the organization. Excellence means achievement of results that satisfy all stakeholders.

TQM requires a change in attitudes and behaviour of employees of the organization in relation to internal and external customers and controlled and coordinated fulfilment of obligations. TQM effects can be divided as follows:

- direct: minimizing poor-quality production, minimizing costs of repairs, reconstructions, etc.,
- indirect: increase of customer confidence in the organization, revealing hidden potential of individuals, improvement of corporate culture.

3.2 Kaizen

Kaizen is a philosophy of continual improvement, which originated in Japan and has been widely used in Japanese companies since the 1950s. The word Kaizen means improvement in Japanese (KAI – improvement, ZEN – continuing). Improvement is achieved through gradual and constant steps involving all employees from managers through operation supervisors to workers. It does not matter where and when improvement is achieved in the organization; in the end, it always leads to improved production quality. In Japan, change is a way of life. Whether it is work, social or personal life, everyone needs to improve constantly. Quality campaigns are frequent and very common in corporations, media and at schools. According to the Japanese, good management makes changes. If it does not make them, it needs to be replaced. In contrast to Western managers who prefer sudden major changes which are usually very costly and involve technological innovations, the Japanese approach to management prefers gradual but constant changes – improvement is achieved through small but constant steps. Under the Kaizen philosophy, thinking of managers is oriented on processes and procedures, which makes it different from the Western management style oriented mainly on results (particularly in the USA). According to Kaizen, behind all results there are always processes and people. Orientation on the human factor, which is the main component of the production process, is very strong whereas in the Western approach, improvement refers mainly to technical equipment. In the West, quality means chiefly product quality; in Japan, employee quality, which guarantees product quality, is placed first.

Although Kaizen is based on features typical for the Japanese mentality, it is used increasingly often all around the world. Kaizen is an important tool which can help construction companies to solve problems such as low productivity, non-system management or low work efficiency.

Basic Kaizen principles include: customer orientation, application of TQM philosophy, massive employee initiative, employee orientation and employee performance increase, employees own and co-create corporate values, process automation and robotics, quality circles aimed at continual improvement of quality of products and processes, discipline at workplace, full equipment maintenance, improvement of all processes in the value chain of corporate activities, minimizing stock and effective cooperation and system of incentives.

The Kaizen method rests on the following principles: attention is paid to every improvement, all employees participate in improvement of products and processes, every improvement is analysed, positive and negative impact is reviewed, task of managements: development, maintenance and improvement of standards, frequent meetings in order to solve problems, strong top-down support, active bottom-up work, motivation in improvement efforts and rewarding employee creativity.

3.3 Reengineering

Reengineering is a fundamental rethinking of existing processes in the organization and focuses on innovation of processes and achievement of extraordinary effects. Business Process Reengineering is a radical change enabling rapid progress in quality assurance. Reengineering was first introduced in the 1990s by Michael Hammer and James Champy at the Massachusetts Institute of Technology. Hammer and Champy defined Reengineering as follows: *Reengineering is the fundamental rethinking and radical reconstruction of business processes to achieve dramatic improvements in critical measures of performance such as cost, quality and speed.*

Another definition comes from Robson and Ullah: *Business process reengineering means creation of completely new and more effective business processes regardless of what has been before.*

For two centuries, companies were founded and developed following the principle that production processes should be split into the simplest and most basic partial tasks. At present, companies are founded and developed with regard to the fact that these partial tasks need to be merged into complex business processes. The technique that can be used to achieve this is called business reengineering. Business processes after reengineering are very different from traditional processes. The industry model used so far is based on the principle that the work or partial tasks assigned to employees are very simple. However, simple tasks require complex processes so that they could be integrated into a single unit. Despite their various forms, reengineering processes share several typical features. In order to meet the current requirements for quality, low cost, flexibility and level of services, it is necessary to keep processes simple. This need of simplicity has immense impact on projecting processes and on the form of organizations.

Reengineering requires radical reconstruction of business processes of the construction organization. Even though reengineering begins with new process projecting, it certainly does not end with that. Fundamental changes in business processes affect all other parts and aspects of the organization. Job functions are transformed from a narrow and task-oriented concept to a versatile concept. People who used to work according to instructions have now a right to choose and make their own decisions. Assembly line work disappears. Existence of functional units is no longer necessary. Managers become coaches. Employees focus on customer needs rather than on the needs of their bosses. Virtually every aspect of the organization is transformed.

The concept of fundamental changes in activities and approaches in all selected areas can be characterized as follows:

- tailored customer satisfaction,
- multi-unit cooperation (within the organization) and cooperation between external partners,
- care for individual employee development (special care for top employees),
- disruption of management hierarchy (cooperation and participation of all employees, remuneration according to assets generated for the company, elimination of differences between employers and employees),
- innovation of each area by each employee through initiative (permanent application of qualified methods and techniques),
- application of progressive procedures and technology,
- disappearance of formal quality management systems,
- results of the organization's activities beneficial for the whole society,
- full acceptance of the environmental aspects of business.

Reengineering as a management method can be characterized as follows:

- business processes are the object of changes; they are considered outside the current organizational structure and in terms of customer added value,
- changes are fundamental and radical,
- changes lead to a new arrangement of the logistic chain,
- top management of the organization is the owner of changes because subordinate departments are not able to handle this task in a satisfactory way.

Reengineering brings major changes also to corporate culture. It requires that employees firmly believe that they work for their customers, not for their bosses. They will believe it only to the extent to which this conviction will be supported by corporate remuneration schemes. If these values do not change, new processes will not work. Changing values is just as important as changing processes.

3.4 EFQM Excellence model

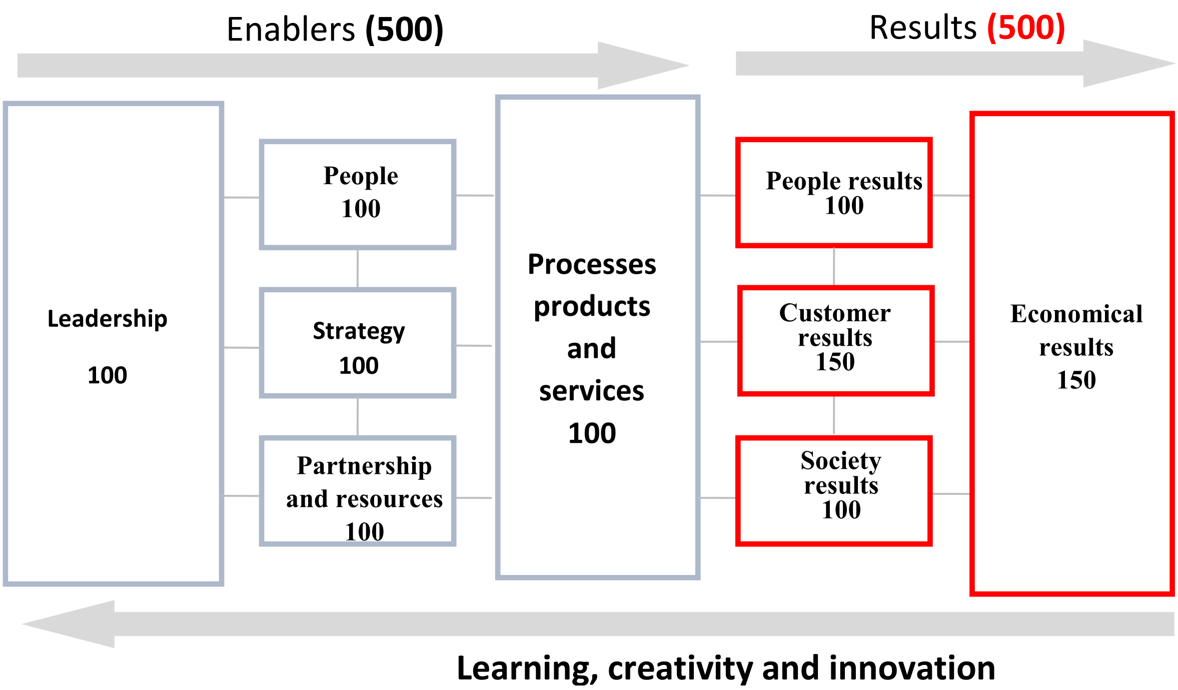
The EFQM excellence model was developed by the European Foundation for Quality Management with the aim to provide a single structured framework for self-evaluation of performance of the organization and to introduce a versatile quality management tool for seeking possibilities of continual improvement of the construction organization on its road to excellence. Nationwide recognition of quality in the USA (Malcolm Baldrige National Quality Award) and in Japan (Deming Prize) revealed the fact that application of TQM models brings measurable business results to organizations. The EFQM Model is one of TQM models.

The EFQM Model constitutes a basis for assessment and evaluation of businesses aspiring to the European Quality Award (EQA) and to the National Quality Award. The EQA requires application of the model for at least three years and ability to demonstrate corresponding results.

The EFQM Model can be applied in any organization in the business sector as well as in public administration (however, the Common Assessment Framework (CAF) is intended primarily for public administration). Nowadays, many companies use this model as their internal methodology to measure their own performance.

The EFQM was first introduced in 1991 as the European Model for Business Excellence. In 1999, it was innovated and became more versatile and applicable in more organizations. The Common Assessment Framework (CAF) was developed for the public administration sector. It was introduced in 2000 and reviewed in 2002.

In recent years, minor revisions are made regularly in the EFQM Model, concerning in particular names and definitions of the criteria and the points that can be obtained for each criterion. The EFQM Model is based on nine criteria. The first five criteria are Enablers (what the organization has), the other four are Results (what the organization achieves). Each criterion is further divided into sub-criteria – altogether there are 32 sub-criteria. The scheme of the EFQM Model and the points that can be obtained for each criterion can be seen in Figure 4. The direction of the arrows shows the dynamic nature of the model. Learning, creativity and innovation help to improve Enablers which then lead to improvement of Results. This process is constant.



Figur 4. EFQM model scheme with the score for the criteria

Achievement of a higher quality level and economic prosperity of the construction organization are not the only benefits of the EFQM Model. It encourages application of approaches in line with moral and ethical values and principles of responsibility. It also encourages organizations to come up with a vision including these values and leads to responsibility towards the society as a whole – environment, region, etc., emphasizing positive public image of the organization.

Based on the knowledge in the field of quality management gained from literature and from practical experience, the following main benefits of the EFQM Model and its application in the organization can be formulated: complexity, versatility, excellence as a goal, possibility of self-evaluation, compatibility with ISO 9000 standards, European and global dimension, flexibility in application, integration of improvement methods and systems, links to quality awards.

The Deming PDCA cycle and comparison with industry leaders are useful tools in application of the EFQM Model methodology and self-evaluation. Although the European excellence model is not new, our survey clearly shows that its application in practice is still not common, mainly because of low awareness of the benefits of application of this model in practice and concerns of corporate managements about time and resource requirements for implementation of the model. In the past, organizations implemented the model chiefly with the aim to win a quality award but our findings show that the EFQM Model can be used also as an important internal tool for evaluation and complex continual improvement of quality of the organization at all levels.

Conclusion

This contribution analyses the most significant forms of quality management that can be applied in construction organizations. The Quality Management System according to ISO 9001:2015 is an internationally recognized standard which increases credibility in the eyes of customers and other business entities and boosts chances of being successful in tenders. The organization itself benefits from it in the form of higher effectiveness, savings and process optimization. The QMS constitutes a system which should ensure and standardize quality procedures in the organization. Some of them are obligatory and required by regulations, others can be defined by the organization itself and the QMS can be used to document, monitor and control them and assess their success rate. Organizations aiming to grow and progress in the field of quality can benefit from the QMS as well. The QMS is a strong pillar for application of higher quality management forms such as TQM, Kaizen, Reengineering and EFQM Model.

Total Quality Management (TQM) and Kaizen focus on gradual and sustained improvement of quality of products and processes and they represent a superstructure of the implemented Quality Management System and are highly compatible with its principles. Reengineering is a fundamental rethinking of existing processes in the organization and focuses on innovation of processes and achievement of extraordinary effects.

The EFQM Model was being implemented by the organization in previous years mainly to obtain awards for quality (e.g. European Quality Award), but as our findings indicate, this model is universally usable also as an great internal tool for company's self-evaluation and for comprehensive, continuous improvement of organization on all levels.

Achievement of exceptional quality is now considered a necessity if an construction organization wants to succeed in a market in a hard competitive fight. Quality management forms mentioned in the chapters of this book represent a significant help for organizations in this effort. It is a long-term process, which begins with great strategic decision and continues as persistent, purposeful attitude of management and all the people participating on construction company's life. This paper was prepared during research work at international project ERASMUS+ PROGRAMME , Project Number: TAP- 573738-EPP-1-2016-1-PS-EPPKA2-CBHE-SP

References

ISO 9001:2015 : Quality management systems - Requirements.

ISO 9000:2015 : Quality management systems – Fundamentals and vocabulary.

OAKLAND, J. S. (2003), Total Quality Management, Elsevier Ltd, , Oxford

Gašparík, J. & Gašparík, M. (2016), Quality Management in Organizations, TRIBUN EU, Brno

HAMMER, M. & CHAMPY, J. (1993), Reengineering – A manifesto for Business Revolution, Harper Collins Publisher Inc., New York:

EFQM. 2003. Introducing Excellence. Brussels: EFQM, 2003. 16 p. ISBN 90-5236-072-3

EFQM. 2003. The Fundamental Concepts of Excellece. Brussels: EFQM, 2003. 12 p. ISBN 90-5236-077-4

JURAN, J. M. 2003. Juran on Leadership For Quality. New York: Simon & Schuster, 2003. 384 p. ISBN 0-7432-5577-1.

DEMING, W. E. 2000. The new economics: for industry, government, education. Cambridge, Massachusetts: MIT Press, 2000. 247 p. ISBN 0-262-54116-5.

FEIGENBAUM, A. V. 1991. Total Quality Control. New York: McGraw-Hill, 1991. 863 p. ISBN 0070203547.

HAKES, C. 2007. The EFQM Excellence Model to Assess Organizational Performance: A Management Guide. Zaltbommel: Van Haren Publishing, 2007. 116 p. ISBN 9087530277

ISHIKAWA, K. 1990. Introduction to Quality Control. New York: Productivity Press, 1990. 435 p. ISBN 978-4906224616

Value Engineering in Construction Projects – a Challenge to Contractor

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Abstract:

There are many definitions of value engineering. Essentially, it is a combination of technical and economic methods. Value engineering has been developed as a methodology focusing on continuously increasing the value provided by a project and is widely believed to be an important tool in management of construction projects. In short, value engineering methodology can be defined as a systematic and investigative process that strive for accomplishment of value for money by providing all required functions at the lowest cost consistent with essential levels of quality and performance in a project. This objective cannot be achieved unless there is a clear representation of actual situation of the projects in terms of cost, time and quality which are also causes of concern in value engineering method. This paper examines the application of value engineering methodology to construction projects in various stages of the project life cycle and specifically in the execution stage. There have been numerous researches done regarding the application of value engineering by project managers; however, not much studies have been done exploring the role which contractors can play in this process. Little attention has been given to the basic question which is how to motivate a contractor to put efforts in terms of time and money in order to provide benefits to the project stakeholders. Having examined a number of references, it was found that FIDIC General Conditions of Contract for Construction and World Bank Request for Bids - Plant provide good examples of incentives for contractors to use value engineering for increasing revenue.

Keywords: *Value Engineering; Life Cycle Cost; Job Plan; FIDIC*

1. Introduction

While there are many definitions of value engineering the concept itself is sometimes misunderstood. It is too often used just as a buzzword, rather than a process to be applied for the benefit of the project.

In most cases value engineering methods are not applied until it becomes apparent that the project will not meet its goals. By the time such a problem becomes evident, the project is in

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the late stages. Performing such delayed value engineering is unproductive. True value engineering should be initiated early in the project and implemented continuously.

In the construction industry a common goal is to get over-budget construction projects back within the budget through a cost-cutting exercise. Such a simple approach may not be considered as value engineering. Even the American Society of Civil Engineers [ASCE, 2012] incorrectly states: "*Value engineering of a design focuses on potential cost saving…*". This statement does not reflect the true meaning of value engineering. Simply reducing cost is not value engineering, but merely cost-cutting.

As considered by many experts in this field, Larry Miles is the father of value engineering [Sky Mark, 2017]. He introduced this process when developing the analytical field of value analysis for General Electric Company after the Second World War. Because of the war, there were lacks of materials and some finished products. Manufacturing was organized at maximum capacity, and ideas were required to expand production. Miles was responsible for procuring raw materials for the company and recognised that if he was not able to obtain one specific material, then it was necessary to find a replacement material which could perform the same function. Because the General Electric Company was manufacturer, the term „engineering" was understood as more appropriate than „management". Along the process, Miles identified function and cost as two elements of the so called "value equation" and balanced them against one another.

Later, value engineering started to spread across the world, but because of differences between the conduct of American companies compared to European companies, value engineering, as developed in the USA needed to undergo some adjustment also in terminology. The European Community's Strategic Programme for Innovation and Technology [SPRINT 1993] adopted "value management" as the official term. However, due to predominance of US based research and dedicated literature the term "value engineering" is today prevailing in practice.

A very good and comprehensive explanation of value engineering is given by the Society of American Value Engineers International which defines value engineering as an approach called Value Methodology [SAVE, 2017]:

„The Value Methodology (VM) is a systematic and structured approach for improving projects, products, and processes. VM, which is also known as value engineering, is used to analyse and improve manufacturing products and processes, design and construction projects, and business and administrative processes. It helps achieve an optimum balance between function, performance, quality, safety, and cost. The proper balance results in the maximum value for the project, whereby the value is the reliable performance of functions to meet customer needs at the lowest overall cost."

Value engineering has been recognized as a method that focuses on continuously increasing the value provided to the client and is generally accepted as a significant tool in management of construction projects. It does not influence just project costs and quality, but it has also been shown to have positive effects on the environment and the movement of green construction.

It has been proven that value engineering can result in significant savings and benefits to a project. An example of such results is shown in the table no. 1

Table 1. Federal-aid Value Engineering Summary Report 2015 [FHWA, 2017]

Summary of Past Value Engineering Savings in Federal-Aid and Federal Lands Highway Programs					
	FY 2014	FY 2013	FY 2012	FY 2011	FY 2010
Number of Value Engineering Studies	215	281	352	378	402
Cost to Conduct Value Engineering Studies	\$8.7 M	\$9.8 M	\$12.0 M	\$12.5 M	\$13.6 M
Estimated Construction Cost of Projects Studied	\$20.9 B	\$23.0 B	\$30.3 B	\$32.3 B	\$34.2 B
Total Number of Proposed Recommendations	1,664	2,381	2,905	2,950	3,049
Total Value of Proposed Recommendations	\$3.0 B	\$2.91 B	\$3.78 B	\$2.94 B	\$4.35 B
Number of Approved Recommendations	697	1,011	1,191	1,224	1,315
Value of Approved Recommendations	\$1.73 B	\$1.15 B	\$1.15 B	\$1.01 B	\$1.98 B
Percent of Project Cost Saved	8.32%	5.01%	3.78%	3.12%	5.79%

While the concept and purpose of value engineering is today widely recognized and accepted, the question remains how to effectively apply it in practice.

2. The Value Engineering

As defined by Miles the objective of value engineering analysis is to identify all elements of function and cost, and to express their mutual interdependency, so that a decision could be made between the two. His equation was *Value = Function/Cost.* In this equation *the function* is the specific work that a design/item must perform, *the cost* is the life-cycle cost of the product and *the value* is the most cost-effective way to reliably achieve a function that will meet the user's needs, desires, and expectations [Sky Mark, 2017].

In other words, as stated by Miles, an item that maximizes function with a minimal cost is of greater value than an item of lesser function with the same cost. Equally, an item that serves little or no function, but has a high cost is considered to be of little or no value. Following Miles' approach to value engineering many methods of analysis have been developed.

The US Federal Highway Administration (FHWA) defines value engineering analysis as [Federal Register, 2014]: "A systematic process of review and analysis of a project, during the concept and design phases, that is conducted to provide recommendations for:

- providing the needed functions safely, reliably, efficiently, and at the lowest overall cost;
- improving the value and quality of the project; and
- reducing the time to complete the project."

A very important first activity before the start of value engineering analysis is the selection of appropriate projects. It would be a waste of time and money if analysis done for a selected project costs more than expected benefits. Therefore FHWA has established criteria for selection of projects which are suitable for value engineering analysis. The criteria include *inter alia* [FHWA 2015]:

- high-cost and/or high-priority projects;
- complex or challenging projects with multiple stages;
- projects with extensive or costly environmental or geotechnical requirements;
- projects that substantially exceed their initial cost estimates;
- projects that have encountered "scope creep";
- projects involving multiple stakeholders;
- projects that involve the use of other quality and cost review techniques.

Once the suitable project is selected, a team of experts may start the value engineering analysis. It normally has two components performed concurrently:

- An engineering and economic assessment; and
- An analysis of life-cycle costs.

When applied to construction projects, the engineering assessment must follow the standards and criteria determined by the owner. Through a systematic study the value can be improved by one or several of the following actions:

- Eliminating, reducing or modifying elements that are not essential to required functions.
- Adding elements that achieve required functions that has not been realized yet.
- Changing elements to improve quality or performance to meet more preferred levels established by the owner.

The life-cycle costs are related to procuring, operating, maintaining, and disposing of a building and usually consists of the following cost categories [Fuller, 2016]:

- Initial costs: purchase, acquisition and construction costs
- Operation, maintenance, and repair costs
- Building replacement costs
- Residual value or disposal costs
- Finance charges
- Non-monetary benefits or costs

Only those costs that are appropriate to the analysis and substantial in amount are considered in making a valid decision. All costs are counted as base-year amounts in today's value. All amounts are to be escalated to their future year of occurrence and discounted back to the base date converted into present values.

3. Job Plan

Value engineering is often prepared by analytically following a multi-stage job plan. Larry Miles' original system was a six-step procedure which he called the "value analysis job plan." Others varies the job plan to fit their purposes and constraints. FHWA defines job plan as [FHWA, 2015]:

"The Job Plan is a systematic and organized plan of action for conducting a value engineering analysis and assuring the implementation of the recommendations. The methodology utilized for any value engineering analysis shall follow widely recognized systematic problem-solving procedures that are used throughout private industry and governmental agencies." Each analysis should address each phase in the job plan. However, the level of analysis for each phase can be scaled to meet the requirements of each single project."

The job plan as determined by FHWA should include and document seven phases regardless of the project type:

1. Information Phase: Gather project information including project commitments and constraints.
2. Function Analysis Phase: Analyse the project to understand the required functions.
3. Creative Phase: Generate ideas on ways to accomplish the required functions which improve the project's performance, enhance its quality, and lower project costs.
4. Evaluation Phase: Evaluate and select feasible ideas for development.
5. Development Phase: Develop the selected alternatives into fully supported recommendations.
6. Presentation Phase: Present the value engineering recommendation to the project stakeholders.
7. Resolution Phase: Evaluate, resolve, document and implement all approved recommendations

Almost identical to FHWA job plan, is the standard job plan recommended by SAVE International, which consists of six phases [SAVE, 2017]:

1. Information: Gather information to better understand the project.
2. Function Analysis: Analyse the project to understand and clarify the required functions.
3. Creative: Generate ideas on all the possible ways to accomplish the required functions.
4. Evaluation: Synthesize ideas and concepts and select those that are feasible for development into specific value improvements.
5. Development: Select and prepare the "best" alternative(s) for improving value.
6. Presentation: Present the value recommendation to the project stakeholders.

The Information Phase should identify the three fundamental concepts of value engineering that are function, cost, and value which are specific to the problem. This concept makes the value engineering process different from other management as well as cost control methods. During this phase several basic questions have to be asked and answered such as [FHWA 2015]:

- What is it?
- What does it do? (what is the function?)
- What must it do? (is this function basic?)
- What is its value?
- What does it cost?

The basic information needed in this phase such as the length of the project and its cost estimate, as well as other major elements can be easily identified from the plans and other documentation. The Pareto's "Law of Distribution" can be helpful in identifying potential savings as it states that 80% of project's cost will be in 20% of the work.

Functional Analysis is the next step in the process. In this context the function means the specific achievement to be realized by a project element or combination of elements. A function should be described by the use of two words [FHWA, 2015] - an action verb and a measurable noun (that is acted upon); for example the function of a bridge is to "cross obstacle." In other words the basic function of a bridge is to provide a means to cross an obstacle. The description of functions should be as non-specific as possible in order to leave as many options open as possible to resolve the problem or achieve the function that the project presents.

The goals to be achieved at the end of functional analysis are to:

- Identify the project's high-cost elements
- Conduct a functional analysis of the high-cost elements
- Assess their cost/value relationships

During the Creative Phase, brainstorming techniques are usually used to develop viable alternatives to the design of the project. Brainstorming through synergism boosts people to be creative. Creativity is applied to the functional statements chosen from the earlier performed cost/value estimates to produce a list of potential solutions to the problem.

Throughout the last steps in the process, the Evaluation and Development Phases, the advantages and disadvantages of each selected alternative are determined. Advantages and disadvantages are described in general terms. A weighted matrix analysis is performed to decide which alternative is best, using the relative importance of each of the selected criteria. If found that the disadvantages offset the advantages of any alternative, the alternative is not any longer considered at this point. As the result of these phases, the best alternative for improving value is selected and elaborated for presentation to and decision by the project stakeholders. The best alternative is expected to achieve the best blend of performance, cost, and schedule.

While the methods and procedures for value engineering analysis to be used by project managers have been well and comprehensively developed, the question remains how to stimulate contractors to put their efforts in terms of time and money in order to eliminate unnecessary cost and provide benefits to the project stakeholders as well as to increase their profit. So far, not many studies, if any, have been performed in this regard.

4. Review of standard work contracts

The authors have reviewed the most known worldwide used work contracts in order to determine which of them contain provisions that stimulate and motivate contractors to perform value engineering process. The following groups of work contracts issued by prominent institutions were examined.

Institution of Civil Engineers (ICE) is an independent engineering institution and represents approximately 80,000 civil engineers worldwide. The ICE documents are traditionally for engineering contractors. Pre 1987 versions of FIDIC were very much based on ICE forms, but there is far less similarity now. The most used standard forms of contract are [ICE, 2017]:

- ICE Conditions of Contract Measurement Version 7th Edition July 2004
- ICE Conditions of Contract Design and Construct 2nd Edition July 2004
- ICE Conditions of Contract Minor Works 3rd Edition July 2004

- ICE Conditions of Contract Term Version July 2004

Since 1931 the Joint Contracts Tribunal (JCT) based in London, England, has been producing standard forms of contract, guidance notes and other standard documents used in the construction industry. The JCT range of contracts are fundamentally building rather than civil engineering contracts, but are also used for projects where both building and civil engineering works are involved. They cover traditional contracting and design and build and management contracts [JBT, 2017]:

- Major Project Form
- PCC 2005 Standard Form of Prime Cost Contract
- WCD 2005 Standard Form of Building Contract With Contractor's Design
- 2005 Standard Form of Building Contract
- IC 2005 Intermediate Form of Building Contract
- MTC 2005 Standard Form of Measured Term Contract

FIDIC, the International Federation of Consulting Engineers produces standard forms of contract for civil engineering construction which are used throughout the world. FIDIC contracts are often referred to as the international standard. The present suite of FIDIC contracts, often known as “Rainbow Suite” because of their colours, replace the set issued originally in and before 1987 [FIDIC, 1999]. The suite consists of eight models of general conditions of contracts; however only five of them, as listed below, are relevant regarding the subject of this review:

- Conditions of Contract for Construction For Building and Engineering works designed by the Employer First Edition 1999 (known as Red Book)
- Conditions of Contract for Construction For Building and Engineering works designed by the Employer MDB Edition 2005 (known as Pink Book)
- Conditions of Contract for Plant and Design-Build For electrical and mechanical plant, and for building works, designed by the Contractor First Edition 1999 (known as Yellow Book)
- Conditions of Contract for EPC/Turnkey Projects First Edition 1999 (known as Silver Book)
- Conditions of Contract for Design, Build and Operate Projects First Edition 2008 (known as Gold Book)

The World Bank, which is a major financing institution of projects worldwide, produces a number of standard procurement documents, out of which the following ones are relevant for the purpose [WB, 2017]:

- Request for Bids - Works (after prequalification) [January 2017]
- Request for Bids - Works (without prequalification) [January 2017]
  Request for Bids - Works – Roads (Output and Performance Based Road Contracts) [January 2017]
- Request for Bids - Plant (after prequalification) [January 2017]
- Request for Bids - Plant (without prequalification) [January 2017]

5. Value Engineering by Contractors

Having examined the above listed contracts in respect of provisions aming at motivating contractors to perform value engineering analysis, the authors found the following:

Only one of the analysed ICE contracts, namely the Major Project Form, contains a clause dealing with cost savings and value improvements. However, the provisions are not very specific in terms of procedures and incentives for contractors.

On the contrary, except for the Silver Book, all of the analysed FIDIC general conditions of contract contain clauses related to value engineering and incentives for contractors. The most elaborated and specific provisions are included in the Red Book, clause 13.2. Value Engineering [FIDIC, 2017]:

"The Contractor may, at any time, submit to the Engineer a written proposal which (in the Contractor's opinion) will, if adopted, (i) accelerate completion, (ii) reduce the cost to the Employer of executing, maintaining or operating the Works, (iii) improve the efficiency or value to the Employer of the completed Works, or (iv) otherwise be of benefit to the Employer.

The proposal shall be prepared at the cost of the Contractor and shall include the items listed in Sub-Clause 13.3 [*Variation Procedure*]. If a proposal, which is approved by the Engineer, includes a change in the design of part of the Permanent Works, then unless otherwise agreed by both Parties:

(a) the Contractor shall design this part,
(b) sub-paragraphs (a) to (d) of Sub-Clause 4.1 [*Contractor's General Obligations*] shall apply, and
(c) if this change results in a reduction in the contract value of this part, the Engineer shall proceed in accordance with Sub-Clause 3.5 [*Determinations*] to agree or determine a fee, which shall be included in the Contract Price. This fee shall be half (50%) of the difference between the following amounts:
    (i) such reduction in contract value, resulting from the change, excluding adjustments under Sub-Clause 13.7 [*Adjustments for Changes in Legislation*] and Sub-Clause 13.8 [*Adjustments for Changes in Cost*],and
    (ii) the reduction (if any) in the value to the Employer of the varied works, taking account of any reductions in quality, anticipated life or operational efficiencies.

However, if amount (i) is less than amount (ii), there shall not be a fee."

Regarding the procurement documents used in the projects financed by the World Bank, it should be noted that the general conditions of contract contained in the Request for Bids - Works are identical to the contract conditions in the FIDIC Red Book. Very good and detailed provisions are included in the Request for Bids – Plant, clause 39.1.2. Value Engineering [WB 2017]:

"The Contractor may prepare, at its own cost, a value engineering proposal at any time during the performance of the contract. The value engineering proposal shall, at a minimum, include the following;

(a) the proposed change(s), and a description of the difference to the existing contract requirements;

(b) a full cost/benefit analysis of the proposed change(s) including a description and estimate of costs (including life cycle costs) the Employer may incur in implementing the value engineering proposal; and
(c) a description of any effect(s) of the change on performance/functionality.

The Employer may accept the value engineering proposal if the proposal demonstrates benefits that:

(a) accelerates the delivery period; or
(b) reduces the Contract Price or the life cycle costs to the Employer; or
(c) improves the quality, efficiency, safety or sustainability of the Facilities; or
(d) yields any other benefits to the Employer, without compromising the necessary functions of the Facilities.

If the value engineering proposal is approved by the Employer and results in:

(a) a reduction of the Contract Price; the amount to be paid to the Contractor shall be the percentage specified in the PCC of the reduction in the Contract Price; or
(b) an increase in the Contract Price; but results in a reduction in life cycle costs due to any benefit described in (a) to (d) above, the amount to be paid to the Contractor shall be the full increase in the Contract Price."

6. Conclusions

There are numerous standard procedures established by relevant institutions as well as studies done by researches regarding the value engineering analyses performed by project managers; however, so far very few studies, if any at all, have been conducted to find how contractors are treated in this respect and what incentives are included in work contract to motivate contractors to undertake value engineering analysis in the projects they execute. The review of standard general contract conditions used worldwide has shown that in several of the reviewed general conditions there are relevant provisions in this regard.

Best elaborated clauses regarding the value engineering among all documents reviewed are those included in the FIDIC Red Book and WB Request for Bids – Plant. Both contracts describe well the procedure to be followed by the contractor in preparing value engineering proposal for consideration by the employer.

Both clauses determine also incentives for the contractor and remuneration to be paid to the contractor if the proposal is worth acceptance. The FIDIC Red Book determines the remuneration as 50% of total savings while the WB Request for Bids – Plant distinguishes two types of remuneration. If the proposal results in a reduction of the contract price, the remuneration shall be the percentage of the reduction in the contract price specified in the particular contract conditions. If the proposal results in a reduction in life cycle costs due to any action that increases the contract price, the remuneration shall be the full increase in the contract price.

Further studies and analyses are desirable to find out how the described value engineering contract clauses have been implemented in practice.

References

ASCE (2012), “Quality in the construction projects a guide for owners, designers, and constructors”, third edition 2012, ASCE Manuals and Reports on Engineering Practice, no. 73, ASCE, 1801 Alexander Bell Drive, Reston, Virginia

Sky Mark (2017), “Larry Miles and value engineering”, available at: http://www.skymark.com/resources/leaders (assessed on 8 March 2017)

SPRINT (1993) “European Community Strategic programme for innovation and technology transfer”, available at http://bookshop.europa.eu/en/european-community-strategic-programme-for-innovation-and-technology-transfer-sprint--pbCDNA14643 (assessed on 13 March 2017)

SAVE (2017), “About Value Engineering”, available at: http://www.value-eng.org/page (assessed 8 March 2017)

FHWA (2017), “Federal-aid Value Engineering Summary Report 2015”, available at: https://www.fhwa.dot.gov /ve/vereport.cfm (assessed 13 March 2017)

Federal Register (2014), “Rules and Regulations”, 5 February 2014, Vol.79, No. 172, Part 627 – Value Engineering

FHWA (2015), “The Value Engineering (VE) Process and Job Plan”, available at: https://www.fhwa.dot.gov/ ve/veproc.cfm (assessed on 13 March 2017)

Fuller, S. (2016), „Life-cycle cost analysis“, available at: http://www.wbdg.org/resources/ assessed 13 March 2017).

FHWA (2015), “The Value Engineering (VE) Process and Job Plan”, available at: https://www.fhwa.dot.gov/ ve/veproc.cfm (assessed on 13 March 2017)

ICE (2017) Bookshop, available at: http://www.icebookshop.com/Law_and_Contracts.asp (assessed on 17 March 2017)

JCT (2017) Bookshop, available at: http://www.jctltd.co.uk/ (assessed on 17 March 2017)

FIDIC (1999) Bookshop, available at: http://www1.fidic.org/bookshop/offline_page.asp (assessed on 17 March 2017)

WB (2017) Procurement, available at: http://www.worldbank.org/en/projects-operations/products-and-services/brief/procurement-new-framework#SPD (assessed on 17 March 2017)

Effect of MMC Selection on Construction Costs

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Abstract:

Modern methods of construction (MMC) are mostly defined as the methods providing effective processes of construction designing and realizing, resulting in greater volume of production with higher quality and shorter time of their purchase. The modern methods of construction have a great potential to improve the efficiency of construction production, quality, customer satisfaction, environmental impact, sustainability and predictability of construction projects delivery in relevant terms. However, the MMC have some limits. The methods require a time-consuming and more precise design, approval procedures as well as quite often off-site production. Several sources have declared lower construction cost of buildings realized through the MMC. Even though, the results of the research study, presented in this paper, demonstrate often higher or comparable construction cost of the MMC when comparing to conventional methods of construction. The cost analysis of MMC selected from segment of family houses in Slovakia, is presented and discussed in the paper.

Keywords: *Modern Methods of Construction, technologies, costs, on-site construction, off-site construction, construction systems;*

1. Introduction

In Slovakia, the concept of Modern Methods of Construction (MMC) is practically still unknown, it is difficult to promote modern technological solutions in addition to conventional systems, which are time-tested. Simply put, retail investors (builders of houses) accept some partial modern structures - “tweaks”, that can be easy removed in case of failure and can be forgotten in a short time. But acceptance of MMC in case of structural skeletons and complete construction systems is not so easy and clear. It is not possible to “change” the complete skeleton of a house for another one if the declared characteristics of MMC are not provided. Higher construction cost can be considered as one from other reasons of low acceptance of MMC in practice. Even though, the MMC are often promoted as construction solutions reducing construction cost. However, one from certain benefits of MMC consists in reduction of user cost. Without authentic experience of such building solutions dwelling, the level of user cost reducing can be only estimated. Moreover, if the boundary conditions of a building using are not respected, the level of user cost reducing is difficult to achieve. In such atmosphere of the building market, it is easier to choose some conventional construction system which is time-tested. Demand for MMC among investors of family houses could increase, if the construction cost of such construction solutions were for example at least by one-third lower compared to conventional construction systems. The formation of a national program of development

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support of MMC technologies application presents one from tools to provide for higher acceptance of such construction systems. It refers to use of state bonuses for family houses applying MMC, as it is current in case of alternative sources of heating and water heating. Abroad, promotion of MMC in family houses based on legislation support is common. The support covers major builders – developers, who are by grants motivated to apply MMC solutions. In Slovakia, such assistance of state does not exist in any segment of buildings. Nowadays, there is not unmanageable growth of population in Slovakia, as it is in United Kingdom, especially in London. London is challenging to onslaught of immigrants needing some rental accommodation. Based on the life philosophy of Slovak population, people prefer having their own flat or house rather than live in some house for rent. They prefer a mortgage instead of a rent. However, in rich European countries as Swiss and Austria, residents prefer living in rented houses. In the United Kingdom, the existence of so called "housing cooperatives" is motivated to use MMC for fast and decent quality supply of low-cost flat houses because of lack of housing units. Young families would welcome an intensive construction of rental houses conducted and supported by state. Then the use of MMC could come into higher dimension and the cost of MMC could be reduced in such case.

The concept of MMC is mostly seen as an innovative solution for prefab and off-site construction (Kozlovská et al. 2014; Bašková et al., 2014). But a period of extensive prefabrication (prefab construction of flat houses with bathroom core in various construction systems) was finished in 90`s of the last century. The settlements built in this period are still strongly inhabited. However, the flat houses are not very appetizing from architecture point of view. This past period was characterized by a lack of flats for young families, it was necessary to supply many flat houses in a short time. All this construction was planned and applied for rental flats. It was not possible to be the owner of a flat, as it is today. People preferred living in rental flats. This philosophy changed through an option to buy a rental flat and to become the private owner. Based on several surveys, young families still prefer rental housing. But state construction of rental flats and acquisition of a rent with better conditions practically does not exist. There is no possibility to apply for allocation of a flat from the state which should ensure construction of rental housing. In United Kingdom, the MMC have been developed in such atmosphere. The state must provide housing for a big rush of immigrants applying for housing issues solution from the state side. The state cooperates with developers who provide construction. The state law obliges developers to use MMC. Moreover, it is stated what percentage of MMC solutions is compulsory in the new projects in order to reduce construction time, construction cost, construction waste and to use all other benefits of MMC, that are described below.

Many of the benefits of using MMC for housing are still unproven or contentious. On the other hand, the advantages and disadvantages are closely related to the drivers and barriers of prefabrication use (Lovell and Smith, 2010). Several studies have alleged various advantages and disadvantages of the MMC (BURA Steering and Development Forum, 2005; AMA Research Ltd. et al, 2007; Kyjaková and Bašková, 2010). Mostly presented and discussed advantages of MMC involve: smaller demands on facilities and equipment construction site; safer working environment at the off-site production of building components and faster construction over labour costs; the possibility of using state budget funds, special purpose funds, or foundations; fewer design errors and better quality in the manufacturing of components; easier quality control at the factory; less waste on the construction site and less environmental pollution during construction; easier quality control at the factory; less waste on construction site and less environmental pollution during construction. Disadvantages of MMC largely include: requirements for size and site equipment for handling MMC components; security risks when mounting MMC components at the site; higher costs of prefab construction products and higher costs of subcontracting; initial costs of setting up a production line for manufacturing components; time consuming proposals; compliance and quality control in the contact joints; multiple transport materials into factory and from factory to construction site.

According to the National Association of Realtors in Slovakia (NARS), Slovakia is for a long time suffering from a lack of rental housing. In the total number of flats, less than 3% of flats are rental, what ranks Slovakia to last places in the European Union. In Slovakia, there is still deep-rooted idea, that privately-owned flats present the feature of a rich society. In fact, the opposite is true. For example, in Germany almost a half of residents (47,5%) live in rental housing, in Austria it is more than 44% and in France it is 35%. Moreover, in such rich state as the Swiss is, more than 55% of residents live in rental housing. The opposite side of the scale is represented by poor Romania, where approximately 96% of residents live in their own flat and in Slovakia, it is around 90%. There is a lack of rental housing in these countries. That is why such type of living is quite expensive. Nowadays, the private sector is not willing to wait 20 to 25 years on return of investment in case of rental housing. Developers want the money back within five years.

Based on the experience from abroad, the developers could be motivated by application of MMC solutions that reduce construction cost as well as construction time and provide sustainability. The Institute of Construction Technology and management at the Faculty of Civil Engineering in Košice has conducted the research of improving the construction effectiveness through MMC solutions. The results of the research could be used in establishment of incentive conditions to support rental housing construction by the private sector (by developers) in cooperation with The Ministry of Transport, Construction and Regional Development of the Slovak Republic.

In Slovakia, except some small examples, the MMC solutions are not utilized in flat houses building (for rent or for private property). Based on the results of aforementioned research, just the increased construction cost compared to conventional construction systems cause disinterest in the MMC using. It does not meet the initial condition for the use of MMC solutions consisting in the fact that construction cost of MMC is lower compared to conventional construction systems. Hence, the construction cost does not compensate the risk level of the "modern" MMC solutions using. Therefore, the philosophy of MMC using abroad and analogically the possibility of the use or non-use in Slovakia is discussed in the paper.

Each presented MMC technologies can be used in the segment of flat houses as well as in family houses segment. The cost parameters of MMC technologies are derived from in real built buildings. Based on comparison of the parameters, the synthesis of lessons learned from the real cases was made. The synthesis creates a better view for selection of a construction system. The study presented in the paper has looked for the answer on question dealing with conditions under which it is possible to get benefits of MMC using and on question if any benefits for "small" investor or developer exist. Moreover, the comparison of construction cost of MMC systems in Slovakia and abroad are presented in the paper.

2. Material and methods

The MMC represent mainly production of building structures in production plants and according to foreign literature, such building structures are known as off-site technologies (Bernold, 2016; Venables et al., 2006; Mapston and Westbrook, 2010). Based on the literature (Doherty 2010, NAO), the most common classification of off-site construction methods includes construction methods of open panel systems, methods of closed panel systems, methods of hybrid systems and methods of volumetric systems.

The main classification of off-site MMC solutions:

- Panellised construction systems,
- Volumetric construction systems, and
- Hybrid construction systems (combination of panellised and volumetric).

There is also a few of on-site construction methods included in the MMC. The methods contain conventional materials that are used in some innovative way in buildings. The buildings comprising the MMC solutions (off-site and on-site) are characterised by three potential parameters: lower construction cost, reduced construction time and higher environmental protection. There are several on-site MMC solutions with reduced construction time and higher construction quality reached by the system approach into common building materials. The typical on-site MMC methods include:

- Frame construction system from wood profiles and steel profiles
- Insulated Construction Formwork (ICF) systems,
- Construction systems from precise masonry blocks connected with thin-bed mortar,
- Oak frame construction systems,
- Frame construction systems from laminated wood (plywood elements).

To compare the MMC methods based on conventional building materials, the construction system Ytong (porous-concrete blocks) and construction system Porotherm (brick) were selected.

The cost efficiency analysis of main MMC solutions is presented in the following part of the paper. As it was stated above, lower construction cost should be one from main characteristics of MMC. But it is not so clear in all situations. It is illustrated in the next section. The section has come from the results of the study conducted in the United Kingdom and dealt with the cost efficiency of MMC solutions.

The modern methods of construction as open panel systems are always slightly more expensive when comparing to conventional construction systems, but construction cost of hybrid and volumetric construction systems exceed significantly the cost of conventional construction systems (Figure 1). Significant differences in cost of MMC mean that in some projects are possible conditions when a modern method of construction could be more cost effective compared to conventional construction methods. Opinions on MMC from construction cost point of view are still contradictory. This inconsistency is presented in various research studies. One group of scientists (Doherty, 2010; Venables, 2004) claims that MMC are cost-effective, while another group of scientists (Nawi, Lee and Nor, 2011) is convinced of higher construction cost of MMC. These are subjective views on individual projects. The trend of growth or decline in the cost of MMC mainly depends on the boundary conditions of each building. There is effort to define these boundary conditions for various segments of construction.

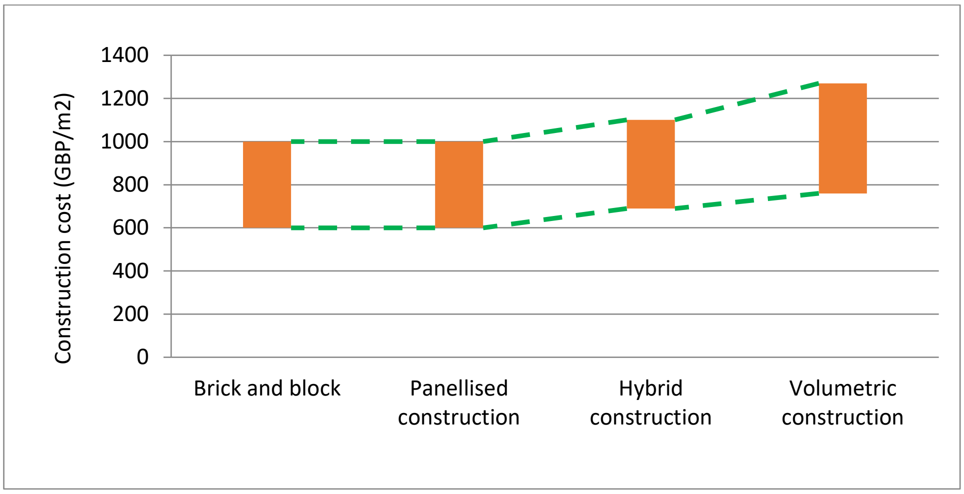

Figure 1. The average construction cost (source: National Audit Office)

Based on the cost effectiveness study (NAO), the cost of masonry constructions is comparable to cost of incomplete (open) panel construction systems. It is 520 – 880 EUR/m^2. Hybrid construction systems are by one-third more expensive when comparing to masonry and open panel construction systems. Similarly, volumetric construction systems are by one-third more expensive compared to hybrid construction systems (Figure 1). The modern methods of construction guarantee time construction reducing and on-site work reducing, but the construction cost is not always convenient for all groups of residents and for all countries. That is why the before mentioned inconsistency of opinions on cost-effectiveness of MMC still exist.

For example, the MMC are cost-effective for developers. Just the most expensive volumetric construction systems provide the highest financial benefits - around 80 EUR/m2 (Figure 2).

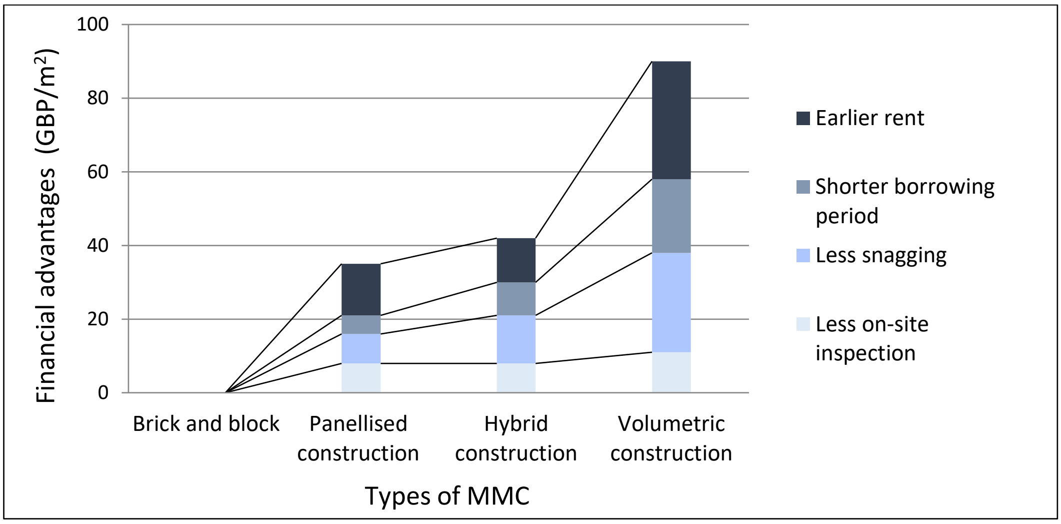

Figure 2. The financial benefits for developers in different types of MMC. Source: National Audit Office

From the Figure 2 is evident that the conventional masonry constructions are from construction cost point of view at least attractive for developers. The financial benefits for this group of construction participants come from the reasons:

- Earlier rent, earlier income from this rent due to short construction time,
- Shorter period of trusts,
- Fewer defects, as construction elements are subject to more rigorous quality control in production plants conditions,
- Declined need of on-site quality control.

3. Results and discussion

In Slovakia, the survey on MMC using was conducted too. The paper presents the results of the cost analysis of selected MMC in the segment of family houses in Slovakia. In comparison of construction cost of various MMC solutions, the reason of conventional construction systems prioritization in individual family houses construction was revealed. The studied MMC involved the construction solutions from blocks and piece parts, columnar construction systems, panel construction system and volumetric construction system. The study sample consisted of 60 buildings. The construction systems from blocks and piece parts were represented by ceramic blocks with mineral wool, polystyrene pieces with concrete core, wood chips based blocks and wooden construction system from small format blocks. The columnar construction systems involved wood-based columnar system and steel-based columnar system.

The panel construction systems included wood-based panel system, steel-based panel system, Liapor panel system and split-concrete panels with a concrete core. The volumetric construction system was represented by modular buildings with steel-based skeleton. The construction costs were estimated per 1m^2 of usable area.   The results are presented in the Figure 3. The lowest construction cost,466 EUR/m^2 of usable area, were estimated in buildings from blocks and piece parts, represented by on-site masonry construction method. The columnar construction system is by around 11% more expensive when comparing to above mentioned buildings from blocks and piece parts. The construction cost is 518 EUR/m^2 of usable area. The volumetric construction system with construction cost 713 EUR/m^2 of usable area, is by 53% more expensive compared to the cheapest variant. According to the results, the columnar construction system is the most expensive MMC in the segment of family houses in Slovakia. It is by 60% more expensive when comparing to masonry variant from blocks and piece parts, the construction cost is 750 EUR/m^2 of usable area.

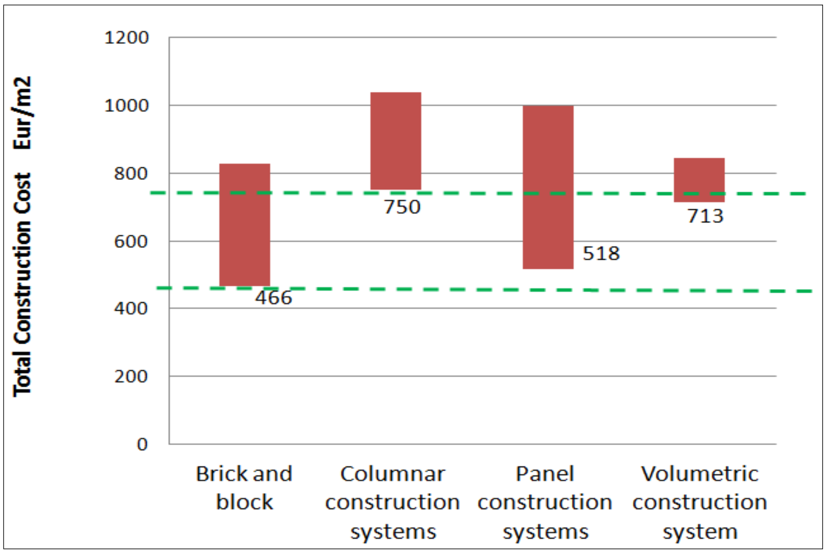

Figure 3. The average construction cost of MMC in Slovakia in the segment of family houses

Based on a case study, the comparison of construction cost of a Family House (FH) made by MMC and by conventional construction technique was conducted. The first variant was represented by double-decked family house. The house was built by ICF system – Variant Haus. The system is known as one from MMC. It is represented by neopore hollow forms made from silver-grey raw BASF – Germany. The useful area of the house is 120 m^2. The construction cost of the house is 657 EUR/m2 of useful area. The construction cost of the similar family house, built by conventional masonry technique from Porotherm construction system, with useful area 110m^2, is 696 EUR/m^2 of useful area. The construction cost of the house made from Porotherm is by 5% more expensive when comparing to variant built by MMC represented by ICF – Variant Haus. Since the system ICF- Variant Haus is still considered as unverified in Slovakia, small investors almost always prefer conventional system. In the second case, a family house was made from the system Lindab – light columnar steel-based skeleton, known as one from MMC solutions. The cost of the house was compared to the cost of house built by the conventional masonry technique from porous concrete blocks Ytong. The cost of the house from Lindab is 513 EUR/m^2 of usable area and the cost of house made by Ytong-based conventional masonry technique is 490 EUR/usable area. The conventional masonry technique is in this case by 5% cheaper when comparing to construction system Lindab (Tab. 1). In case of such comparable construction cost, considering only initial construction cost of a house, almost each investor of family house remains faithful to conventional construction methods. According to us, investors would opt some MMC solution if the construction cost of the MMC was by around 30% lower when comparing to conventional construction methods. In such situation, investors would be willing to take a possible risk of unverified MMC solutions. Otherwise, the rule is that the habit is an iron shirt.

Table 1. The construction cost of a family house built by different construction methods (source: author)

The construction system	Type of the FH (number of floors)	Construction cost of skeleton (EUR)	Useful area (m^2)	Construction cost of skeleton (EUR/m^2 of useful area)
FH – ICF - Variant Haus	2	78800	120	657
FH – conventional system Porotherm	2	76600	110	696
FH – conventional system Ytong	1	55066	112	490
FH – steel-based system Lindab	1	56415	110	513

In all cases, it was the individual construction of family house. Since there is a low demand on MMC, their construction cost is in some cases comparable to conventional systems. A similar cost analysis of MMC solutions could be made for the segment of flat houses. The analysis of benefits of MMC solutions in individual construction of family houses as well as in development construction of for rent flat houses is presented in Tab. 2.

Table 2. The analysis of benefits of MMC solutions in individual construction of family houses (source: author)

The monitored parameters characterizing the use of MMC solutions	Individual construction of family houses	Construction of for-rent flat houses through development projects
Construction time reducing	yes	yes
Construction cost reducing in general	no	yes
Cost of use reducing	yes	yes
Increased cost due to big transport distances (transport of building components)	yes	individual
Waste reducing	yes	yes
Sustainability providing	yes	yes
Feeling of the risk from new technologies testing	yes	no

In the construction of for-rent flat houses, there is a strong assumption of cost reduction regardless of the type of MMC solutions. The production lines produce serial elements and components of the same dimensions. There is no cost for the lines rebuilding. Moreover, the construction cost could be reduced in case of state incentives to support the construction of for-rent flat houses through development projects. This would solve the unfavourable situation in the number of for-rent flats in Slovakia.

4. Conclusions

The studies made by foreign scientists have shown that MMC solutions are cost-effective only in case of certain segments of buildings and only in certain boundary conditions such as state support, type of investor, segment of buildings etc.

Making the strict comparison of construction cost of buildings made by conventional and by innovative method, the innovative construction method is more expensive in certain cases. Having this knowledge, it is sometimes difficult to promote MMC solutions in individual family house construction. If the construction cost of MMC solutions was for example by one third cheaper compared to conventional construction methods, interest on MMC from investor side would be higher. But, from the long-term point of view, the buildings made by MMC report better thermos-technical characteristics. Under consideration of all benefits of innovative types o building as lower environmental impact during construction and even when used, recued construction time, lower cost of use and maintenance, it is evident that it is profitable to promote and apply the modern methods of construction despite of higher initial cost. Higher construction cost discourages investors of family houses in initial phases of construction – in the phase of cost calculating and in the phase of making decision between conventional construction method and MMC. Regarding large development projects of for-rent flat houses, the construction cost is lower in application of MMC compared to conventional construction method and the construction time is reduced through MMC solutions using.

Acknowledgements

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References

Lovell, H., Smith, S. (2010), “Agencement in housing markets: The case of the UK construction industry”, Geoforum, Vol. 41, No. 3. pp. 457-468.

Kyjaková, L., Bašková, R. (2016), “Advantages and Disadvantages of Modern Methods of Construction used for modular schools in Slovakia”, Technical Transactions Civil Engineering, Vol. 1-B/2016, pp. 35-41.

BURA Steering and Development Forum (2005), “Modern Methods of Construction Evolution or Revolution?”, British Urban Regeneration Association, London.

AMA Research Ltd., Hartley, A., Blagden, A. (2007), “Current Practices and Future Potential in Modern Methods of Construction – WAS003-001: Full Final Report”, Waste and Resources Action Programme. pp. 81.

Bernold, L. E. (2016), "Discussion of Barriers of Implementing Modern Methods of Construction" by M. Motiar Rahman", Journal Of Management In Engineering, Vol. 32, No.2. pp. 51-58.

Venables, T., Barlow, J. and Gann, D. M. (2004), "Manufacturing Excellence: UK Capacity in Offsite Manufacturing." London: The housing Forum.

Nawi M. N. M., Lee A., and Nor, K. M. (2011), "Barriers to Implementation of the Industrialised Building System (IBS) in Malaysia. " In: The Built & Human Environment Review, Vol. 4, pp.22-36.

Mapston, M., Westbrook, C. (2010), "Prefabricated building units and modern methods of construction (MMC) ", Materials For Energy Efficiency And Thermal Comfort In Buildings, No.14, pp. 427-454.

Kozlovská M., Kyjaková L., Mačková M., (2014), "Comparison of low-energy houses selected parameters made by traditional and modern methods of construction." Advanced Materials Research. Vol. 1041, pp. 51-54.

Bašková R., Spišáková M., Smrek M., (2014), "Environmental-Economic Assessment of Thermal Insulation for External Load Bearing Walls." in EnviBUILD 2014: proceedings of the International Conference, in Brno, Czech republic, 2014, pp. 113-116.

Doherty, T., (2010) "Introduction to MMC & Eco Construction", available at: HTTP://WWW. INTRODUCTION TO MMC & ECO CONSTRUCTION - TIM DOHERTY.PDF (accessed 20 April 2017).

Analysis of Modern methods of construction available at: HTTP://WWW.PARLIAMENT.UK/POST (accessed 15 April 2017).

NAO: Using modern methods of construction to build homes more quickly and efficiently. available at: HTTPS://WWW.NAO.ORG.UK/WP-CONTENT/UPLOADS/2005/11/MMC.PDF (accessed 15 April 2017).

Mass Evaluation Pilot Study as Investment Courage

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Abstract:

Mass appraisal directly depends on the quality, transparency, and efficiency of spatial planning, cadastre, and land registry records. Recent practice shows that the fair mass appraisal or evaluation systems are intended to reduce the investment risks and encourage investment climate and banks as well as other financial organizations to offer affordable financing options. In Croatia, there are initiatives to introduce such a system, but the infrastructure is not sufficiently developed to make the system in its full value. Regardless, the existing database is the most relevant for apartments, which can be analyzed as the starting point for such consideration. The authors theoretically describe basis and readiness for applying mass evaluation in Croatia, as well as its international models and experiences. The greatest benefit for investment courage would be widening mass evaluation on each type and location of buildings, but there is lots of research for choosing the right methodologies, prototypes, and impact factors to find any application in the real sector. Respecting this fact, this paper gives pilot study for further discussions and for defining new challenges regarding the theme. The main contribution of the paper is a proposed model and opportunities for mass evaluation of residential apartments and its impact on the investment climate in Croatia.

Keywords: *mass appraisal; investment climate; investment courage*

1. Introduction

It is well known that the stability of regulations, entrepreneurship, and the real estate market contribute to health progress and development of each country and promote investment activities. While Croatia is in the 74th place out of 138 regarding the Global Competitiveness Index (WEF, 2016), the most problematic factor for doing business is insufficient government bureaucracy and tax rates. The real estate market is one of the most important issues that can stimulate and awaken an economy but can also chase investors to other locations. The most worrisome fact is that lost and missed opportunities for encouraging investments are almost impossible to calculate. On the other hand, knowing the state of the real estate market, monitoring and managing it with the ambitious behaviour of clients and investors could be fundamental for appropriate planning at the national level. It could boost competitiveness and, if not increase the interest of investors, at least reduce investors running away.

Mass appraisal (MA) is the process of valuing a group of properties as of a given date and using common data, standardized methods, and statistical testing (IAAO, 2013). MA has long

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been used in many developed member states of the European Union. The main purpose of MA is to determine the market value of the property as a basis for resolving property taxes. Each country builds the property tax system in a specific way, but it is essential that such a system is in line with modern democratic and civilizational achievements. In other words, it is crucial to establish fundamental pillars of social morality: reciprocity or fairness (fair treatment) and empathy or compassion (protection of the weaker).

The morality of property tax can only be achieved if the market value of the property is used as the basis for it. Consequently, one who owns the most valuable property pays a higher tax. Regarding the earlier research results (UN Habitat, 2013), where 42 European countries were analyzed, only three (Ukraine, Poland, and the Czech Republic) use the property area as a dominant factor in calculating the tax base, not counting the countries that didn't have a certain property tax. Croatia doesn't have a practice of mass evaluation to this day, while the property tax system has recently been introduced (ZLP, 2016). This proposed system is based on the property area and doesn't fall into fair property tax systems, at least not according to the theoretical and practical known methodologies. However, according to an announcement from the Ministry of Finance, this is an interim solution that should be replaced by 2020 with a market-based system. Meanwhile, all organizational preparations should be carried out; quality property data should be provided, and the MA method (ZPVN, 2015) should be adopted.

Property taxes are not the only purpose of MA. There are many other reasons for implementing MA, such as: for estimating the real market value of property when applying for determination of ad valorem tax, for preliminary estimation of the market value before and during the sale, when assessing credit potential of the real estate portfolio or preliminary estimation of credit potential for individual real estate, for the purpose of estimating property insurance, etc.

Regardless of the MA purpose, there must be a sufficient amount of quality real estate data as a precondition for MA implementation. The procedure of selecting, data recording, and data logging is, therefore, crucial for preparedness. The paper will emphasize and select the necessary data to achieve required results. Also, a comparative analysis of the conducted research in Mostar (Žujo et al., 2013) and research for the purpose of this paper was carried out.

2. State of the art and practice

There have been many types of research and practice about MA techniques and practice (see Table 1). Today's trend is directed towards developing and applying more efficient and sophisticated hybrid techniques, which allows overcoming the shortages of the existing techniques and results that are result oriented more than ever.

Table 1. Analysis of MA techniques (source: McCluskey and Anand, 1999)

Technique	Authors	Strengths	Weaknesses
Comparative method	Wiltshaw (1991)	Ease of use; intuitive; internationally accepted method	Lacks a firm methodological structure; subjective
Multiple regression analysis	Rosen (1974); Meacham (1988); Mark and Goldberg (1988); Fibbens (1995)	Based on valid statistical assumptions; industry benchmark	Problems relate to functionality, multicollinearity, and transparency; data-hungry

Adaptive estimation procedure	Carbone and Longini (1977); Renwick and Flaherty (1996)	Iterative curve tracking process	Lacks model transparency; data-hungry
Expert systems	Scott and Gronow (1989); Nawawi and Gronow (1991); Nawawi et al. (1997)	Based on knowledge elicitation; simulation of expertise	Lacks robustness; rigidity of models
Case based reasoning	Barletta (1991); O'Roarty et al. (1997)	Reasons from past cases; objectivity; explainability	Requires considerable data; limited software availability
Artificial neural networks	Borst (1992); Evans et al. (1992); McCluskey and Borst (1997); Lenk et al. (1997)	Excels at pattern recognition; identifies underlying trends	Stability of models; functional form; black box approach; data hungry
Abductive network models	Borst and McCluskey (1996)	Can capture complex Relationships within data	Limited explainability; functional form of model; Lack of transparency

MA is used worldwide as support for determining the annual property tax, the tax on the imputed rent that owner-occupiers of residential properties pay themselves as their own landlords (which is part of income tax), the tax on landlords with ten or more residential properties, the tax on residential properties not permanently occupied by the owner, inheritance tax, and the water system charges levied by polder boards. They are the basis for setting maximum rents for social housing and are also used by notaries, banks, and insurance companies for the prevention of mortgage and real estate fraud (Kuijper and Kathmann, 2015). For those purposes, there are two common MA-selecting techniques: the method that is related to the market value and method that is based on surface area of the property. It is generally accepted that the first one has an advantage because of fair distribution of the tax burden, according to the market value, rather than the size and the area of the property unrelated to its value on the market (Uhlir & Majčica, 2016). Furthermore, it is proven that mass valuations for value-based property taxes are an important part of creating a virtuous circle in which investors have access to reliable property market data, banks are willing to release capital tied up in property, and taxpayers recognize the legitimacy of the taxes they are required to pay (Grover et al., 2015).

Mass appraisal requires complete and accurate data, effective valuation models, and proper management of resources. Valuation schedules and models should be consistently applied to property data that are correct, complete, and up-to-date (Grover et al., 2015; IAAO, 2013; Uhlir & Majčica, 2016).

Many authors point out significant cost reductions and shortening procedures after MA application (Almy, 2015; Buzu, 2015; Grover et al., 2015; Kuijper & Kathmann, 2015). Regardless of differences in defining those benefits in detail, it definitely has a positive impact on transparency and investment climate. The analysis of some years of experience shows that the appearance of the mass valuation system of land and construction structures, which was originally associated only with the real property tax reform, stimulated the interest of the society, public, and municipal institutions in values estimated by mass valuation approach (Bagdonavicius & Deveikis, 2011).

There are three most referencing challenges concerning MA: modern technology that has to support its design and application, the market (in which MA operates), and people, whose decisions directly form values and create systems from bottom up. In the process of decision making, the customer usually behaves intuitively, which is certainly not the best way to solve his housing problems (Žujo et al., 2013). But it has to be included as reality in establishing an MA system as well.

3. Research

The main research question was: *What are criteria that impact decision making when buying a residential apartment for a living?* The target group was investors and real buyers of these particular properties in Zagreb. Therefore, research was conducted through Udruženje poslovanja nekretninama (engl. Real Estate Business Association), whose representatives randomly proposed five real estate agencies for participating.

There are 44 responses in total, equally distributed by each real estate agency. Respondents were real clients that are now in the buying process and trying to find appropriate residential apartments for their living purposes. The research was conducted by interviews with only one question to answer: *"What criteria (without numerical or any other limitations), in order of importance, are important for you when deciding exactly which property to buy?"* On average, there were eight respondents from each real estate agency.

All real estate agents were given the same guidelines, not to make suggestions to respondents in any way. All respondents were in the buying process of the apartment for the purpose of resolving the housing issue. So the type of property and the region (Zagreb) for all respondents were common.

There were, on average, five criteria per respondents (average was 5,3). Only one respondent listed eight criteria. The unlimited numbers of criteria enable assuming that the listed criteria for each respondent forms 100% of the decision impact factors when buying a residential apartment. In the end, there were 20 impact factors for decision making regarding buying the apartment and two main constraints that are common for 95% of respondents: the amount of investment or price and the orderly property documentation.

There is one impact factor that has two-way meaning: *the need for renovation*. Some respondents see it as an opportunity and some as a disadvantage. The need for renovation can be positive and directly related to lower property price, which is important, as predetermined constraint with usually no flexibility. Furthermore, its benefits are manifested in the ability to arrange flooring space, furnishings, and equipment according to their own needs. Those respondents who see need of renovations as a disadvantage are those who are more concerned with finding immediately available and ready-to-move-in solutions and are compensated at a higher price. Most commonly, it is associated with the flexibility of time that they have to find an adequate solution.

Very rare criteria (quality of construction, friendly neighborhood, and existence of funds for building maintenance) are neglected from further analyses, because only 2% of respondents mentioned them, and with low priority.

Determining the weight of each particular criterion was the first issue to consider with research-collected data. As the initial and fundamental part of research, it can be set up in several methodological ways. The weight of the criteria was not in question for respondents, but the order of importance was.

The listed criteria were weighted by order of importance, assuming that the differences between the ranking criteria are determined by the number of criteria set and made 100% for each respondent separately. In other words, the ranked values are normalized to 100% by respondent. Weighted factors ($f(c_i)$) for each criterion are obtained as follows:

$f(c_i) = \frac{n+1-c_i}{1+2+..+n} * 100$, where:

$f(c_i)$ is the weighted factor for criteria c_i;

c_i is the listed criteria as a member of the whole set of proposed criteria by each respondent;

n is a number of proposed criteria by each respondent;

$\{c_1, c_2, \ldots c_i, ..c_n\}$is set of proposed criteria of each respondent.

For each respondent, $f(c_1) + f(c_2) + \cdots + f(c_i) \ldots + f(c_n) = 100(\%)$. In this way, it is ensured that formulation follows the fact that each respondent gave the whole set of important criteria, which closes 100% impact factors for decision making.

4. Results and discussion

After coding and initial data processing, two main analyses were provided: comparison with earlier research results (Žujo et al., 2013) and the statistical analysis for conducted research results. During the coding and computing of statistical data, it was important to establish a system for weighting impact factors of the proposed criteria. Descriptive analysis of results was done at the beginning of the analysis (see Table 2).

Table 2. Descriptive analysis of factors (N=44)

	Maximum	Mean		Std. Deviation
	Statistic	Statistic	Std. Error	Statistic
Location	66,67	25,4791	2,21910	14,71984
Floor plan efficiency	40,00	17,3270	2,03689	13,51121
Elevator (if applicable)	30,00	8,2257	1,48649	9,86028
Adoptation need	30,00	6,9739	1,64499	10,91161
Terrace / Balcony	30,00	6,4661	1,22619	8,13365
Property age	33,33	5,8534	1,44342	9,57457
Close to public tranport	28,57	5,6870	1,40289	9,30575
Certain floor as condition	33,33	5,2814	1,41743	9,40214
Parking	20,00	3,1402	,98657	6,54417
Quantity of light	40,00	2,6841	1,24603	8,26525
Greenery proximity	20,00	2,3268	,79208	5,25404
Orientation	19,05	2,2889	,79247	5,25664
Warehouse space existence	20,00	1,7314	,69804	4,63026
Urban morphology	23,81	1,6466	,70975	4,70798
Close to main living facilities	20,00	1,5061	,73916	4,90304
Property size	26,67	1,0607	,74913	4,96918

Positive impression (good feeling)	23,81	1,0175	,63797	4,23182
Speed marketability	23,81	,9470	,66886	4,43672
Floor plan flexibility	10,71	,7032	,39706	2,63378
Heating solution	6,67	,3032	,21187	1,40542

4.1 Comparative analysis of earlier research

A comparison to an earlier survey conducted by Žujo et al. (2013) was made to answer the research question: *Are the criteria equal to the same types of properties in all geographic regions?*

Data collection method was the same for both surveys, and the identified criteria are classified into the analog criteria groups (CG), to ensure comparison possibilities.

In earlier research (Žujo et al., 2013), four main CG were identified (location, technical quality, architecture, and living comfort). After setting the same CG for conducted research (see Table 3), there were five criteria in the CG named Location, four criteria in Technical quality, eight criteria in Architecture, and three criteria in Living comfort.

Table 3. Criteria and their CG alignment

	Group of criteria			
	Location	*Technical quality*	*Architecture*	*Living comfort*
This research	Location Close to public transport Urban morphology Close to main living facilities Marketability speed	Elevator (if applicable) Need for adaptation Property age Heating solution	Floor plan efficiency Floor plan flexibility Terrace / Balcony Certain floor as condition Parking Greenery proximity Warehouse space existence Property size	Orientation Positive impression (good feeling) Quantity of light

Earlier research (Žujo et al, 2013)	Micro-location (city centre, other urban areas, suburban areas) The position of the building within the micro-location (traffic jam, traffic noise) Insolation (per individual rooms) Utilities Public area Neighbourhood (proximity of adjacent buildings, stories of adjacent buildings)	Construction type (monolithic, semi-prefabricated, prefabricated) Building materials (natural, artificial) Building equipment (lift, antenna system, multimedia networks, computer networks, video surveillance, alarm system, blinds) Building Elements (roof, facades, windows and doors, flooring) Heating, cooling, ventilation	Rooms in the apartment (number of rooms, layout, size of the rooms, isolation) Geographic location (population density, green areas) Number of stories (number of floors in the building, the location of the apartment in the building, number of floors in the apartment) Parking space (uncovered, covered, closed)	Sound insulation (sound in the air, sound in object) Thermal insulation Natural light (per individual rooms)

Before considering weight ratio of criteria in two different regions (Mostar in Bosnia and Herzegovina and Zagreb in Croatia), it is interesting to notice comparatively equal identified criteria. CG are deployed here according to comparative study, even if the criteria are not completely equal. The original aligning criteria into CG are not considered but are retrieved to obtain comparable results. Descriptive analysis of data from conducted research is given in Table 4.

Table 4. Descriptive analysis of CG

	N	Mean		Std. Deviation
	Statistic	Statistic	Std. Error	Statistic
Location	44	35,2659	2,34091	15,52784
Technical Quality	44	21,3561	2,35432	15,61681
Architecture	44	38,0368	2,72167	18,05353
Living comfort	44	5,9905	1,72903	11,46912
Valid N (listwise)	44			

It is evident that Location is evaluated similarly in both surveys (see Table 5). *Technical quality* is also very close (4%), while *Architecture* and *Living comfort* have greater differences concerning the opinion of respondents in two comparable regions. The first one has 18% greater weight of importance in the conducted research than in earlier research, while the second one shows 14% less importance than in comparable research. Overall, it can be assumed that the importance factors vary by regions and types of properties, which can be further explored by including more regions.

Table 5. Comparison analysis results

Group of criteria	Earlier research (Žujo et al., 2013) [%]	Conducted research [%]	Difference
Location	35	35	=
Technical quality	25	21	↓ 4%
Architecture	20	38	↑ 18%
Living comfort	20	6	↓ 14%

4.2 *Interpretation of results*

Interpreting the results begins with the crucial issue of applying the research results to the whole population. This concerns criteria weights to choose an appropriate residential apartment to buy, in the region of Zagreb in Croatia. The point (see Table 2) and interval evaluation of population mean are conducted. Data distributions are analyzed, after which, the appropriate statistical methods are chosen.

The smaller the standard error is, the more confidence we can have in the mean of the sample. The standard deviation of the population is never known, and therefore, the standard error is measured. So, the standard error of mean is obtained by standard deviation of sample and sample size. The standard error depends on the standard deviation of population and sample size, while its evaluation (of standard error) depends on sample parameters instead of population:

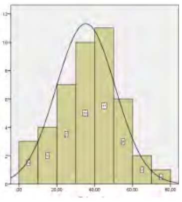
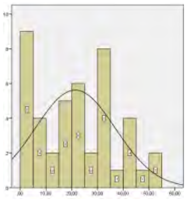
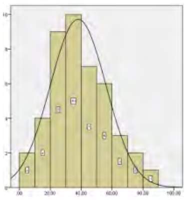
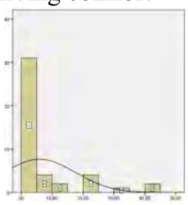
$$SE_m = \frac{S}{\sqrt{n}} \qquad (1)$$

Where SE_m is standard error of mean evaluation, S is standard deviation of sample, and *n* is the sample size.

Defining the interval of confidence is a precondition for determining the interval assessment of population mean. This interval is calculated as sample mean ± margin of error. The margin of error is a product of a certain quantization from Student's t-distribution and a standard error evaluation for the mean.

The choice of the interval of confidence depends on how much risk (α) is acceptable so as not to include in the interval. The most commonly used confident intervals are α=0,05 and α=0,01; 95% confidence interval is defined as M ± $t_{0.975}$ * SE_m; while 99% confidence interval is defined as: M ± $t_{0.995}$ * SE_m. The following table (Table 6) presents basic statistical data that can be used with 95% confidence to assess the mean of each CG in the population.

Table 6. Statistical analysis of criteria's confidence intervals and distribution

Group of criteria	Statistical parameter		Value
Location	95% Confidence Interval for Mean	Lower Bound	30,5450
		Upper Bound	39,9868
	5% Trimmed Mean		35,2257
	Median		33,3300
	Variance		241,114
	Interquartile Range		14,29
	Skewness		-,122
	Kurtosis		,244
Technical quality	95% Confidence Interval for Mean	Lower Bound	16,6082
		Upper Bound	26,1041
	5% Trimmed Mean		20,9681
	Median		20,0000
	Variance		243,885
	Interquartile Range		26,66
	Skewness		,103
	Kurtosis		-1,045
Architecture	95% Confidence Interval for Mean	Lower Bound	32,5480
		Upper Bound	43,5256
	5% Trimmed Mean		37,6624
	Median		33,3300
	Variance		325,930
	Interquartile Range		23,93
	Skewness		,350
	Kurtosis		-,430
Living comfort	95% Confidence Interval for Mean	Lower Bound	2,5035
		Upper Bound	9,4774
	5% Trimmed Mean		4,3953
	Median		,0000
	Variance		131,541
	Interquartile Range		7,92
	Skewness		2,009
	Kurtosis		3,189

It is shown that, with 95% certainty, the mean of the population for this sample is:

- Location, between 31 and 41;
- Technical quality, between 16 and 26;
- Architecture, between 32 and 43;
- Living comfort, between 2,5 and 9,4.

Those intervals mostly depend on the size of the sample and data distribution of criteria. Because of the nature of coding data, these numbers are weight values (in %) of decision-making impact criteria for buying a residential apartment in the region of Zagreb.

In order to select the appropriate statistical method for data analysis, it is necessary to verify the assumption of the data distribution normality for a population of the sample. Due to the recommended commonly known values and conditions (see Table 7), a Shapiro-Wilk's test was performed and proved that the all criteria in the sample are not normally distributed (see Table 8).

Table 7. Verifying the hypothesis of normality distribution tests

Required size of samlpe	Statistic	Value for rejecting the hypothesis
> 100	Standard skewness Standard Kurtosis	> 1,96
> 2000	Jarque-Berat stat.	> 6
> 1000	Lilieforsova mod. of Kolmogorov-Smirnovljev test	p < 0,05
> 30	Shapiro-Wilkov test	p < 0,05

Table 8. Shapiro-Wilk's test of normality

	Shapiro-Wilk	
	Statistic	Sig. (p)
Location	,974	,424
Technical_quality	,933	,013
Architecture	,969	,276
Living_comfort	,597	,000

Correlates between criteria were determined by Kendall's and Spearman's coefficients (see Table 9).

Table 9. Correlation results

			Location	Technical quality	Architecture	Living comfort
Kendall's tau b	Location	Correlation coefficient	1,000	-,205	-,234*	-,190
		Sig. (2-tailed)	-	,065	,033	,119
	Technical quality	Correlation coefficient	-,205	1,000	-,437**	-,032
		Sig. (2-tailed)	,065	-	,000	,790
	Architecture	Correlation coefficient	-,234*	-,437**	1,000	-,209
		Sig. (2-tailed)	,033	,000	-	,082
	Living_comfort	Correlation coefficient	-,190	-,032	-,209	1,000
		Sig. (2-tailed)	,119	,790	,082	-
Spearman's rho	Location	Correlation coefficient	1,000	-,295	-,320*	-,243
		Sig. (2-tailed)	-	,052	,034	,112
	Technical quality	Correlation coefficient	-,295	1,000	-,604**	-,046
		Sig. (2-tailed)	,052	-	,000	,765
	Architecture	Correlation coefficient	-,320*	-,604**	1,000	-,268
		Sig. (2-tailed)	,034	,000	-	,078
	Living_comfort	Correlation coefficient	-,243	-,046	-,268	1,000
		Sig. (2-tailed)	,112	,765	,078	-
* Correlation is significant at the 0.05 level (2-tailed) ** Correlation is significant at the 0.01 level (2-tailed)						

Based on Kendall's and Spearman's coefficients, there is a monotone correlation between CG: Architecture and Technical quality. Concerning the individual criteria, related samples of Kendall's coefficient of Concordance are conducted (Kendall's W is 0,307) and suggested to reject the null hypothesis that there is no correlation between the series of criteria ranks.

Related samples of Kendall's coefficient of Concordance for CG are conducted and suggested also to reject the null hypothesis that there is no correlation between the series of CG ranks. (Kendall's W is 0,392; degree of freedom is 3; test statistic = 51,736). Each node of the figure shows the sample average rank (see Figure 1). In a pairwise comparison of sample distributions, there is a significant difference between criteria that are marked with the yellow color and a smaller difference highlighted with the black color.

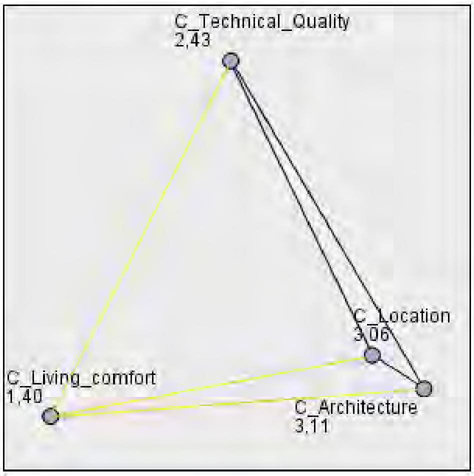


Figure 1. Pairwise comparisons of the sample's distributions: Kendall's coefficient of Concordance

The hypothesis that the distributions of categories drawn above are the same has to be rejected. This means that, in deeper analysis of the results, those criteria that are highlighted black might have analog method for analysis, but others not.

4.3 Link between MA and investment courage

The conducted research and its implications are just the beginning of a long journey to achieve the main goal: to establish a transparent and objective system for mass valuation that has a comprehensive impact. It includes investment climate impact as well. It is a long-term effect, and it should be confirmed. The authors of this paper consider that the research focus of MA should be intensified for its impact on investment climate rather than only to tax policies and amounts.

Specifically, in Croatia, the first four most problematic factors for doing business are: inefficient government bureaucracy (I=20,8), tax rate (I=15,3), policy instability (14,2), and tax regulations (11,7), which come before corruption (I=9,4) and access to financing (I=6,2) (WEF, 2016). It is obvious that MA is directly related to the first four most problematic factors for doing business, which are not followed by the appropriate attention of researchers and practitioners.

4.4 Discussion

Buyers' preferences can only be found through conversation with them. The conducted survey, which didn't impose any restrictions to respondents, indicates crucial impact factors for residential apartment purchases. Not least, it also gave secondary indicators that tell us about respondents' education and the lack of information on residential apartments in official public records.

Considering buyers' education, there is the absolute absence of energy retention as the first place that stands out. According to the survey, no prospective buyer showed interest for the energy class of the residential apartment to buy. And at the same time, it is well known that this life decision (buying an apartment) is mainly related to long-term credit lending. It can be interpreted as more efforts needed for education about the energy efficiency of Croatian citizens and the lack of awareness, regardless of the efforts made so far. Particularly, this concerns also the quality of energy efficiency certification implementation.

Declarative commitment for building energy certification and absence of: (a) Quality assurance of energy certification system, (b) Verification of ownership of it in the process of property transactions, (c) Disallowance of property transaction without proceeding energy certification system, and (d) Including required details of energy certificate in documentation (e.g., in sales contracts, with marking the particular energy class, etc.) lead to results such as observed in the survey.

Furthermore, the final list of criteria is too modest. In this part, a national programme of excellence and culture of construction, called *Apolitika*, should play a major role. Poorly educated citizens don't encourage quality, for building as well for urban and housing issues, which impacts the society as the whole.

The chronic lack of real estate data in public records is a serious obstacle to MA as well as to good quality taxes and decisions of public administration. It is apparent that a large part of the identified criteria that are interesting to the residential apartment buyers (and affect the market value of properties) are not included in e-Nekretnine (official national database, eng. e-RealEstate). Creating this database was the result of cooperation with the Ministry of Finance – Tax Administration of Croatia. They have never given priority to collecting those data. A possible solution is available at the local level, where it would be necessary to supplement the properties' records and establish a high-quality system of collecting required data. It can be recommended for further population census to re-examine, design, and conduct questionnaires about properties, in accordance with best practice of developed countries. For collecting and prepearing the missing data, it is necessery to apply the principles of the project management (control of costs, quality, and deadlines) (Uhlir & Majčica, 2016).

It is clear that there is a need for a synergy of public administration and real estate market, as the inherited state is not appropriate for the demands of the modern economy and administration.

5. Conclusion

There is a set of criteria that are repeated minimally in two surveys in a different region (Mostar and Zagreb), which plays as a decision impact factor for buying residential apartments.

If the grouping of criteria into CG is kept from the comparative research of Žujo et al. (2013), then the impact factors and their weight for the region of Zagreb are Location (35%), Technical quality (21%), Architecture (38%), and Living comfort (20%). In section 4.2 of this paper, the certainty for those numbers regarding the whole population is discussed. The main constraint of this research is related to the sample size, which was taken into account in the analyses.

This paper pointed to the lack of public records on properties, the low educational level of citizens, and their awareness regarding real estate market. Both issues are first preconditions to stop inertia and to improve doing business indicators, as the main investor courage motivator.

Further research has to be conducted to improve given grouping criteria into CG and to spread the research results to other regions and property types. Also, research methodology of defining the relative importance of each listed criteria could be discussed further.

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References

Almy, R. (2015) Property taxation and valuation in Lithuania. *Land Tenure Journal*, (2).

Bagdonavicius A. & Deveikis, S. (2011). Mass appraisal – the method and an experience in Lithuania. FIG Working Week 2011, *Bridging the Gap between Cultures*, Marrakech, Morocco.

Buzu, O. (2015) Property assessment and taxation in the republic of Moldova. *Land Tenure Journal*, (2).

Grover M.R., Tòrhönen, M.-P., Munro-Faure,P. & Anand, S. (2015) Property valuation and taxation for fiscal sustainability and improved local governance: Case studies form the ECA region, in *2015 World Bank Conference on Land and Poverty proceedings*, March 23-27 2015, The World Bank - Washington DC

International Association of Assessing Officers (IAAO) (2013) *Standard on mass appraisal of real property*.,Kansas City, Missouri, ISBN: 978-0-88329-207-5.

Kuijper, M. & Kathmann, R.M. (2015) Property valuation and taxation in the Netherlands. *Land Tenure Journal*, (2).

McCluskey W. & Anand, S. (1999) The application of intelligent hybrid techniques for the mass appraisal of residential properties. *Journal of Property Investment & Finance*, 17 (3), 218 – 239.

Uhlir, Ž. & Majčica, B. (2016) *Priručnik za procjenu vrijednosti nekretnina. Društvo građevinskih inženjera Zagreb,* ISBN: 978-953-7592-18-9, Zagreb.

UN HABITAT (2013) Property Tax Regimes in Europe. *UN HABITAT*, ISBN: 978-92-1-132565-2

World Economic Forum (WEF) (2016), The global competitiveness report 2016-2017, *Executive Opinion Survey*, Geneva, ISBN-13: 978-1-944835-04-0, pp 7, 158.

ZLP (2016) - Zakon o lokalnim porezima (NN 115/16) - Law on Local Taxes (Official Gazette 115/16).

ZPVN (2015) - Zakon o procjeni vrijednosti nekretnina (NN 78/15) - Real Estate Valuation Act (Official Gazette 78/2015).

Žujo, V., Ćećez, M., Šelih, J. & Kušar, M. (2013), Multi criteria assessment of residential units. In *Organization, Technology and Management in Construction* (OTMC 2013): proceedings of the XI International Conference in Dubrovnik, Croatia, 2013, Faculty of Civil Engineering University of Zagreb and Croatian Association of Organization in Construction, pp. 492-498.

Public-Private Partnerships on Local Level in Slovenia

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Abstract:

Public-Private Partnerships (PPP) are often perceived as a viable alternative to public debt when the need for various infrastructure is identified by the community. Use of PPPs enable the acquisition of the services necessary for the community, that can be attractive particularly for smaller public entities. However, both private as well as public partner entering the partnership need to be aware of the risks associated with this procurement model. The paper presents the benefits and risks associated with PPP for the involved stakeholders. Further, it reports on the results of the study that aims to identify the frequency of the use of the PPP procurement model on the local level in Republic of Slovenia, along with the perceived obstacles and benefits of the PPPs. Focus groups were used as the tool by which the experience and opinion of the local communities‘ representatives in the field of PPP was collected. The results of this qualitative empirical study indicate that partners entering PPP contractual model on the local community level are often not aware of the risks that may appear during PPP operation.

Keywords: *Public-Private Partnership; construction; public services; local community; focus groius; risk*

1. Introduction

Construction of large infrastructure or building systems, as well as construction of smaller ones, is often hindered by the lack of available financial means. Inadequate infrastructure constrains economic activities, and consequently also the economic growth (World Bank Group Support to Public –Private Partnerships, 2012). In such cases, a viable alternative to Public Procurement is the use of Public-Private Partnership (PPP), an alternative procurement model that can, if implemented appropriately, enable efficient construction and operation of the structures being built while maintaining sustainability of the participating public partner. Around the world, PPPs have become increasingly popular (Siemiatcky, (2012) A classical definition of PPP is provided by the Canadian Council for public–private partnerships as: '*A co-operative venture between the public and private sectors, built on the expertise of each partner, that best meets clearly defined public needs through the appropriate allocation of resources, risks and rewards'* (Ahadzi &Bowles, 2004).

The responsibilities of both partners are specified in the contract. Typically, private partner builds the facility and operates it (and receives revenue during the operation as specified in the

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contract) during the operation and maintenance phase. PPPs have been widely used in countries as diverse as Brazil, Spain, Canada, Portugal, India or The Netherlands, and have been promoted by international development agencies like the United Nations, the World Bank etc. (Siemiatycki, 2012). In addition to road and rail infrastructure, PPPs are often used for projects ranging from water treatment facilities, bridges to hospitals and prisons.

Theoretically, the use of PPP should lead to more efficient construction processes (during the construction phase), as well innovative design solutions leading to reduced construction, maintenance and operation costs; as the private partner remains involved in operation and maintaining the facility; while the public debt does not increase as the construction is not funded from the public sources. The practice shows, however, that PPPs have become lighting roads of controversy, with their pros and cons widely debated (Siemiatycki, 2012). One of the main issues is definitely the question of risks associated with these types of projects, as they typically run for at least 20 years.

Slovenia has been slow to adopt the PPP model, partly due to the fact that the legislature that enabled this procurement model, The Act on the award of concession contracts and Public-Private Partnerships was adopted only in 2006 (Pintar, 2015). Further, it was identified that the local communities (municipalities) were often successful when they applied for EU funding for the projects serving their local needs; meaning that they could carry out the necessary projects without involvement of a private partner; and that the largest investment program in Slovenia within the last decades, i.e. National Highway Construction Program (2003-2013), was based on Public Procurement contractual model. Pintar (2015), for example, claims that until 2010, only 0,5 PPPs per capita were carried out in the Republic of Slovenia.

In addition to construction projects on national level, such as the above mentioned Highway Program, the residents of Slovenia required also other facilities for public use that could not be financed exclusively from the taxpayers' money. In particular, local communities are well aware of the needs of the residents and local industry.

The aim of the research project presented in this paper was therefore to present current state of the implementation of Public-Private Partnerships in Slovenia on local level. We wish to obtain data on frequency of PPPs, contractual models used, and areas where they were implemented, as well as perceived benefits and obstacles.

2. Public-Private Partnerships on local level in Slovenia

Slovenian legislature grants a relatively high level of autonomy to the municipalities. Provided they can ensure funding, they are providing, to their residents and local enterprises, a large number of public services, ranging from pre-school children facilities, nursing homes for elderly people to sewage systems and water treatment plants. Considering the fact that there are 212 local communes (http://www.stat.si/StatWeb/en/Field/Index/20), with number of population ranging from more than 50000, to 375 inhabitants (http://www.stat.si/StatWeb/News/Index/5945), it is clear that many of them are not able to finance their communal infrastructure. Therefore, Public-Private Partnerships are a viable option for financing such projects. So far, there were no studies being carried out in Slovenia, that aimed at obtaining a comprehensive view regarding the scope and the type of PPPs on the local community level, despite the fact that considerable amounts of money are conveyed by using these procurement routes.

3. Research goal and methodology

A study carried out within the scope of the EU funded project PROFILI was therefore carried out. Its purpose was to investigate the qualitative aspects of PPPs on the local level by using the method of focus groups. The type and scope of the recent PPP projects were identified along with registering qualitative information on these projects.

Focus group (sometimes also called focus interview) is a qualitative research method often used in sociology and similar disciplines. It collects data through group interaction on a topic determined in advance by the researcher. The group needs to be composed of experts with variuos professional background, and is moderated by an experienced moderator with appropriate training (Morgan, 2014). In order to be able to compare answers provided by various participants, the conversation needs to follow the list of pre-prepared questions (questionnaire). Active participation of the participants needs to be ensured, therefore the group should not be too large; it advised that the number of participants ranges from 6 to 8.

The method clearly defines other rules, such as

- seat composition (U-shaped), to demonstrate equal importance of all participants;
- ensuring visible position of the moderator;
- appropriate professional background of the participants (they should all be relevant to the project but of different professional background). For the case presented in this paper, there should be 3 to 4 representative of relevant public offices (e.g. representatives of the bodies granting the building permits), one real estate expert, and 2 representatives of the private investors (clients);
- the moderator needs to follow the list of questions prepared in advance; and needs to have certain personal abilities, such as ability to manage diverse groups, ability to ask provocative questions (in order to initiate the conversation), and to ensure that all participants get the opportunity to present their points of view during the discussion;
- execution of the focus group is monitored by the observer, who can analyze the relationships among the group members and take relevant notes.

In the case presented in this study, i.e. implementation of PPP procurement model on the level of local communities in Slovenia, the participants were proposed by the Chamber of Commerce of Slovenia. In order to successfully carry out his/her role, the moderator had to get acquainted with the local development plans prior to the execution of the focus group, and show no bias towards proposed solutions. He/she had to ensure that all participants get involved into the discussion and discuss solutions being presented. All questions, identified in advance, needed to be addressed.

Four consecutive phases are carried out during focus group execution: (1) warming up, (2) relations. (3) enhancing relations, and (4) disaggregation of the group. Focus group meeting took typically around 2 hours: and was video-, or audio-taped, with the purpose to be able to analyze its content later on (Kuzma, 2016).

4. PPP projects in Republic of Slovenia

Public Private Partnership was employed in the Republic of Slovenia for the first time by the Municipality of Maribor in 2002. Central waste water facility was constructed (Trontelj, 2007). The duration of the concession period is 22 years, or, in other words, it will be terminated in 2024. BOT (Build-Operate-Transfer) contractual model was employed in this case. The contractual obligations of the private partner include financing, design, construction, operation and maintenance, repair and refurbishment of the waste treatment facility, as well as initial design of the mail collector that is financed, built and transferred into operation by the Municipality of Maribor (public partner). The private partner took over the business risk for the construction of the facility and its exploitation, as well as the responsibility for the execution of related Public Services (waste water treatment), with the exception of the activities related with waste mud treatment. Review of this project, carried out by the Computational Court of Slovenia concluded that the project can be considered to be an example of good practice (Computational Court of Slovenia, 2007). Many smaller projects, however, were not assessed systematically and their long-term performance or sustainability was not confirmed.

The projects identified within the scope of the PROFILI project range from Residence for seniors in Trnovo (Ljubljana) where Municipality of Ljubljana acted as the public partner providing the land, and the company DEOS as the private partner ensuring and executing the construction of the building, to General Hospital Jesenice, where construction of garage house with modern helicopter landing facility was carried out in 2010 (Smerkolj, 2016) and execution of Daycare Facility for pre-school children in Šmarje in 2015, where Municipality Slovenj Gradec published the tender on the basis of DBOT (*Design-Build-Operate-Transfer*) model (Kuzma, 2016).

5. Results of project PROFILI

Project PROFILI was financed by the cross-border cooperation program Slovenia – Italy between 2011 and 2014. The first author was one of the lead project participants. 23 focus groups were carried out within this project; 18 focus groups on local level, 2 focus groups on national level, and 3 focus groups on regional level. The meetings were recorded and archived.

According to our knowledge, this was the first time that focus groups were implemented in Slovenia. It should be emphasized that the results derived from the Focus Groups provide only partial information regarding the status of Private Public Partnership projects and accompanying actions.

Based on the analysis of the results of focus groups, the following conclusions can be derived in the field of developmental challenges of local rural communities: excessive bureaucracy, ageing of the local population, too many (small) land plots within certain areas, slow preparation of ownership documentation; and inadequate infrastructure. The advantages perceived by the participants od the focus groups in rural areas are dynamic enterprises, hard-working population, geostrategic position, advantageous location from the viewpoint of development of innovative enterprises, good infrastructure in the area of social activities; natural advantages; advantageous conditions for the development rural tourism and entrepreneurship; and development of social entrepreneurship.

The following conclusions were derived:

- the legislature dealing with PPPs is complex and sometimes ambigous;
- the process of spatial plan confirmation (required to start the construction process) takes a long time;
- the contracts related to PPPs are long-term and extend over several yearsm however they are assessed from the viewpoint of the current annual budget;
- PPP projects are often pre-labelled with the corruption;

- the majority of contracts define precisely the obligations of the partners and the timeframe of financing, however they do not address potential risks and their allocation in adequate way;
- in case of a conflict, the course of procedures is too long and can thus be fatal for the private partner;
- there is lack of good practice cases (business models) that could facilitate the application of PPP projects in practice;
- trust and stability of the public partner;
- lack of serious private investors; and different (conflicting) interests of both partners (private vs public);
- land owners are not willing to sell the land for prices that are acceptable for private and public partners;
- excessive dispersion of projects;
- lack of professional institutions that could provide help during project preparation;
- there are no guidelines, or collected good practices for individual areas where PPPs are implemented; as well as recommendations from the public sector;
- PPPs are successful only if long-term operation is a strategic goals of the private partner;
- initiatives should arise in the private area;
- private partner should be involved in the project form the very beginning;
- it is important that the rules and expectations are well defined at the onset of the of the project;
- knowledge of the private partner, related to the investment field, is crucial (expecially the knowledge related to operation phase, where the majority of costs is generated);
- communication among partners is crucial;
- initiation of a common project information platform is positive, provided that it will offer adequate information.

6. Conclusions

Results of the research conducted confirm the initial hypothesis that partners in potential PPPs enter into the partnership without using tools for comprehensive risk management. Further, the analysis of the results obtained in the field of focus group application imply that this tool is a suitable tool to enable discussion among stakeholders and that it can be executed on local as well as national level. Based on the observations in practice so far, it can be concluded that focus groups could also be employed in the process of identification of risks associated with project execution.

Further research work should be targeted into quantitative determination of probabilities associated with individual risks, and severity of their consequences.

References

World Bank Group Support to Public –Private Partnerships, https://ieg.worldbankgroup.org/Data/reports/ppp_eval_updated2_0.pdf , 2012 (retrieved March 22, 2017)

Siemiatycki, M. (2012), The Global Experience with Infrastructure Public–Private Partnerships, Planning and Environmental Law, Vol.64, No.9, p.6.

Adhazi, M., Bowles, G. (2010), Public-private partnerships and contract negotiations; an empirical study, Constr. Management and Economics, Vol.22, p.967-978.

Pintar, J. (2015), Vpliv institucionalnega okolja na razširjenost javno-zasebnih partnerstev (Influence of institutional environment on the spread od Public Private Partnerships), University of Ljubljana (In Slovenian.)

Morgan, D.L. (2007) Focus Groups, Annual Review of Sociology,Vol. 22, No. (1996), p. 129-152

Kuzma, V. (2016), identifikacija, analiza in upravljanje tveganj v projektih izgradnje na osnovi javno-zasebnega partnerstva(Iidentification, analysis and risk management in construction projects based on Public-Private Partnership), M.Sc. Thesis, University of Ljubljana, Faculty of Civil and Geodetic Engineering (In Slovenian.)

Trontelj, Ž (2007), Vpliv javno-zasebnega partnerstva na proces graditve (Influence of Public-Private Partnership upon construction process), B.Sc.Thesis, University of Ljubljana, Faculty of Civil and Geodetic Engineering (In Slovenian)

Life-Cycle Costs in Economic Analysis of Road Infrastructure Projects

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Abstract:

Projects of road infrastructure are in the most cases big projects or megaprojects of national or international importance, which consists not only in the expected benefits for the society, but also in costs connected with these projects in partial phases of their life cycle. The economic analysis of these projects evaluates the relation between costs mentioned above on the side of inputs and expected benefits on the side of outputs. This paper deals with the influence of life-cycle costs of the road infrastructure project on its total economic evaluation. There are evaluated the possibilities of the life-cycle costs assessment in the pre-investment phase and possible differences in the assessment of these costs using various approaches are identified. The importance of life-cycle costs in the economic analysis and the impact of possible changes in their assessment on the economic evaluation are presented on the case study including the set of road infrastructure projects. The objective of the paper is to evaluate the need of the detailed elaboration of the calculation of investment costs in the pre-investment phase of the life cycle of the projects for needs of the ex-ante evaluation of its economic efficiency. The output of the paper is the case study elaborated on the set of road infrastructure projects carried out in the Czech Republic.

Keywords: *Life-Cycle Costs; Transport Infrastructure; Economic Efficiency; Valuation*

1. Introduction

Construction projects in road and highway infrastructure have important impact both for the population of the country and general economic growth of the national economy. New or modernized road and highway infrastructure assures new business opportunities to partial regions; it allows better and more efficient transportation of productive factors, results of the production and people themselves. So besides the impact on businesses entities, it is necessary to highlight also the important impacts on the population providing diverse, faster and safer options to travel. According to the fact that in most cases the projects are very expensive from the investment costs point of view and moreover financed from public (national or international) sources, it is important to evaluate not only the technical side of the projects, but also their economic aspects. The main subject of the paper is to evaluate the importance of the detailed investment costs estimation in the pre-investment phase in order to evaluate the

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economic efficiency of the project together with the potential impact of changes in life cycle costs of the project (mainly investment and operational costs) on the results of the economic analysis. The results of the research are presented on case studies based on relevant projects in the road infrastructure in the Czech Republic.

2. Present state references

The economic evaluation of public investment projects in the road and highway infrastructure is based on respecting the 3E principle (Economy, Effectiveness and Efficiency) in their whole life cycle. Economy refers to efforts to minimize especially financial resources intended for the realization and the operation of investments. Efficiency indicates the use of such resources, which enable to achieve maximum volume and quality of products. In the course of economic evaluation of investment projects in the area of transport infrastructure, it is essential to respect the minimal amount of impacts of a certain project on the society as a whole. Economic impacts are usually grouped into direct economic impacts, i.e. economic costs and benefits directly related to the project, where the investment and operation costs create the most important negative economic impact and travel-cost savings form typically the most important (user) benefit category for infrastructure projects, and indirect economic benefits, the (wider) economic effects not directly related to the project but resulting from the direct impacts, e.g. productivity gains of firms and distributional effects (Geurs & van Wee, 2004). Among socio-economic impacts of transport projects are also included: environmental impacts e.g. pollution or noise (Thanos, Wardman & Bristow, 2011), (Browne & Ryan, 2011), benefits to the natural habitat (Oxman, Lavis, Lewin & Fretheim, 2009), visual intrusion, health impacts (Thomopoulos & Grant-Muller, 2013), settlement cohesion, accessibility, land use planning, agglomeration, labour displacement and habitat fragmentation and equity (Mancebo Quintana & Martin Ramos, 2010).

Cost Benefit Analysis (CBA) is currently the most popular method for assessing the economic efficiency of public projects generating particularly non-financial benefits. Use of CBA is emphasized by various authors, e.g. (Mackie, Worsley, & Eliasson, 2014), (Hyard, 2012), (Jones, Moura & Domingos, 2014), (Damart& Roy, 2009) and (Jajac, Marović & Hanák, 2014). A more detailed analysis of the benefits of investment projects in road infrastructure has been already published in the article by Korytárová & Papežíková, (2015).

In the Czech Republic the methodological materials to assess the economic efficiency of projects in the field of transport infrastructure based on CBA principle have already existed. Methodology called "The implementing instructions for evaluating the economic effectiveness of projects of road and motorway construction" by the Road and Motorway Directorate of the Czech Republic (RSD CR, 2014) is used for the projects of road and highway infrastructure, methodology called "The implementing instructions for evaluating the economic effectiveness of projects of railway infrastructure" by the Ministry of Transport of the Czech Republic (MOT CR, 2013) is used for railway infrastructure projects and "The implementing instructions for evaluating of the economic effectiveness of projects on water ways" methodology by Ministry of Transport of the Czech Republic (MOT CR, 2005) is used in the case of important transport projects in water infrastructure.

One of the key inputs entering the CBA based evaluation of investment projects in road and highway infrastructure are the life cycle costs and especially investment costs. Investment costs can be determined using detailed item budget, but in this case the detailed project documentation including drawings and technical reports is needed. However in the time of preparing of the CBA usually this detailed documentation is not available and the evaluation is usually based on the volume study. In this case the Pricing Norms, defined by the document of the Road and Motorway Directorate of the Czech Republic (RSD CR, 2016), it is possible to use.

3. Methodology

From the methodological point of view the paper can be divided into two parts. In the first part the needed detail of the investment costs, used for economic evaluation of the road infrastructure projects, assessment is discussed. The investment costs, as one of the most important inputs of the Cost Benefit Analysis, can be determined using the Pricing Norms or the detail item budget. The Pricing Norms approach follows the methodology published by the Ministry of Transport of the Czech Republic (MoT CR) and is used in the case, when the project documentation has already not been carried out in the detail needed for the item budget elaboration and is usually in the form of the frame volume study. The Pricing Norms provide the average values of costs needed for the carrying out of one kilometer of road of the specific class, one kilometer of the tunnel, one kilometer of the bridge, one crossroads etc. The prices calculated according to Pricing Norms also include the risk premium to respect possible changes and risks in the future evolution of the project. The price calculated according to the Pricing Norms includes following main parts:

- Assessment of the “Basic price” according to the Pricing Norms (main construction objects of the “A” type),
- Calculation of the price of the other objects according to the percentage rate (other objects of the “B” type),
- The expert correction of the “Basic price” according to the “Attributes”,
- Assessment of the risk premium for all construction objects (types “A” and “B”),
- Recalculation of the total price on the actual price level,
- Calculation of the total price including the VAT.

The risk premium is calculated in the form of the percentage rate from the value of the construction objects and includes:

- Risks arising from technological developments,
- Environmental risks,
- External risks,
- Legislative and legal risks,
- Economic risks.

Another possibility to determine the expected investment costs is to use the detailed item budget. However this approach requires detailed projects documentation consisting from the technical reports and drawings, which is usually not available in the time of elaboration of the CBA. The principle is based on the detailed determination of particular construction works and materials needed for the construction and their valuation using internal or official databases of prices. To prepare the detailed item budget it is possible to use appropriate software, in the Czech Republic for example Kros, Build Power, Eurocalk or ASPE.

In the second part the importance of investment costs (esp. life cycle costs) for the economic evaluation of investment projects in the road infrastructure is assessed. The importance is expressed using the sensitivity analysis. The sensitivity analysis is the analytic tool consisting in the monitoring of the relative change of the key indicator (NPV, IRR, BCR) depending on the unit change of the input parameter (investment costs, operational costs, user benefits). In the frame of the sensitivity analysis solved in this paper the dependence of the change of the Net Present Value of projects in the road infrastructure on the change of life cycle costs including investment costs and operational costs (also called agency costs) is tested.

4. Results and discussion

The investment costs are, together with operation costs and evaluated user benefits, crucial inputs of the economic analysis of investment projects and their correct determination is the basic supposition for the efficient decision. Mistakes in the investment costs valuation can have significant impact on the economic evaluation. However to determinate the accurate value of investment costs in the pre-investment phase is quite complicated, because the detailed projects documentation usually is not prepared. The subject of the first case study is the comparison of investments costs calculated according to the Pricing Norms defined by the Ministry of Transport of the Czech Republic and investment costs valuated using the detailed item budget by investor.

The case study is based on the project of the reconstruction of the road II/422 Podivín-Lednice situated in the South Moravia region (Truhlíková, 2017). The situation of the projects is displayed on the Figure 1.

Figure 1 Situation of the project of the reconstruction of the road II/422 Podivín-Lednice

The project consists in the realization of following construction objects:

- Construction object 101 Part Podivín - bridge number of evidence 422-042,
- Construction object 102 Part bridge number of evidence 422-042 – Lednice,
- Construction object 901 Temporary traffic signs,
- Construction object 201 bridge number of evidence 422-040,
- Construction object 203 most number of evidence. 422-042,
- Construction object 204 most number of evidence 422-043,
- Construction object 205 most number of evidence 422-044,

- Construction object 401 Street lamps in town Podivín,
- Construction object 402 Street lamps in town Lednice.

The total costs determined using Pricing Norms according to the Ministry of Transport of the Czech Republic and detailed item budget according to the detailed project documentation are summarized in the table 1.

Table 1 Investment costs determined using Pricing Norms and item budget

Pricing Norms				Item budget	
Costs for construction	Risk premium	Investment costs	Investment costs incl. VAT	Investment costs	Investment costs incl. VAT
79 174 432	13 301 305	93 770 397	113 462 180	76 248 719	92 260 950

The result of comparison shows similar results provided by compared approaches. If the risk premium is not considered, the results are nearly the same. The risk premium reflects the lower knowledge about the project in the pre-investment phase and the uncertainty connected with suppositions, which are, in the time of preparation of the item budget, usually confirmed and known.

The second case study presented in the paper is oriented on the determination of the importance of the life cycle costs in the economic evaluation of investment projects in the road and highway infrastructure. Life cycle costs are defined as a sum of discounted costs for investment, operation and liquidation of the project. To take into account the most usual types of projects three different types of projects were considered in the case study:

- The new construction in extravillan,
- The extension of the road in extravillan,
- The city ring road.

The new construction in extravillan is represented by the project “I/38 Jihlava – Stonařov”. The result of the economic analysis is displayed in the table 2.

Table 2 Results of the economic analysis of the project “I/38 Jihlava – Stonařov”

Lice Cycle Costs (LCC)	Present value of user benefits	Net Present Value	Internal rate of Return	Benefit-Cost Ratio
[mil. CZK]	[mil. CZK]	[mil. CZK]	[%]	[-]
2 579,431	2 841,265	261,833	5,65%	1,102

Results of the sensitivity analysis are displayed in the table 3.

Table 3 Results of the sensitivity analysis for the project “I/38 Jihlava – Stonařov”

	NPV (mil. CZK)	Change of NPV (%)	IRR (%)	Change of IRR (%)
-15%	648,748	147,77%	6,81%	20,44%
-10%	519,776	98,51%	6,40%	13,10%
-5%	390,805	49,26%	6,01%	6,31%
0	261,833	0,00%	5,65%	0,00%

5%	132,862	-49,26%	5,32%	-5,89%
10%	3,890	-98,51%	5,01%	-11,41%
15%	-125,081	-147,77%	4,72%	-16,61%

The extension of the road in extravillan is represented by the project "The extension of D1 highway in the part from flyover Kývalka to flyover Brno east". The result of the economic analysis is displayed in the table 4.

Table 4 Results of the economic analysis of the project "The extension of D1 highway in the part from flyover Kývalka to flyover Brno east"

Lice Cycle Costs (LCC	Present value of user benefits	Net Present Value	Internal rate of Return	Benefit-Cost Ratio
[mil. CZK]	[mil. CZK]	[mil. CZK]	[%]	[-]
8 194,073	20 274,831	12 080,758	12,46%	2,474

Results of the sensitivity analysis are displayed in the table 5.

Table 5 Results of the sensitivity analysis for the project "The extension of D1 highway in the part from flyover Kývalka to flyover Brno east"

	NPV (mil. CZK)	Change of NPV (%)	IRR (%)	Change of IRR (%)
-15%	13 309,869	10,17%	14,22%	14,15%
-10%	12 900,165	6,78%	13,58%	8,99%
-5%	12 490,462	3,39%	12,99%	4,30%
0	12 080,758	0,00%	12,46%	0,00%
5%	11 671,054	-3,39%	11,96%	-3,96%
10%	11 261,351	-6,78%	11,51%	-7,63%
15%	10 851,647	-10,17%	11,08%	-11,04%

The city ring road is represented by the project "I/11 – I/37 Southern conjunction Hradec Králové". The result of the economic analysis is displayed in the table 6.

Table 6 Results of the economic analysis of the project "I/11 – I/37 Southern conjunction Hradec Králové"

Lice Cycle Costs (LCC	Present value of user benefits	Net Present Value	Internal rate of Return	Benefit-Cost Ratio
[mil. CZK]	[mil. CZK]	[mil. CZK]	[%]	[-]
1 458,915	1 508,881	49,966	5,7%	1,034

Results of the sensitivity analysis are displayed in the table 7.

Table 7 Results of the sensitivity analysis for the project "I/11 – I/37 Southern conjunction Hradec Králové"

	NPV (mil. CZK)	Change of NPV (%)	IRR (%)	Change of IRR (%)
-15%	268,803	437,97%	6,85%	19,66%
-10%	195,858	291,98%	6,44%	12,54%

-5%	122,912	145,99%	6,06%	6,01%
0	49,966	0,00%	5,72%	0,00%
5%	-22,979	-145,99%	5,40%	-5,56%
10%	-95,925	-291,98%	5,11%	-10,72%
15%	-168,871	-437,97%	4,83%	-15,53%

The results of sensitivity analysis show quite equal impacts of changes in life cycle costs of the projects on their economic efficiency. It is possible to derive this conclusion mainly from impacts on the Internal Rate of Return expressing the inner profitability of the project. The impact on the relative change of the Net Present Value has in general lower informative ability, because in the case of the results round the critical value (NPV = 0) the sensitivity is very big, in the case of very good results of the project the sensitivity is lower.

5. Conclusions

The results of case studies show that the investment costs or life cycle costs estimation creates the crucial part of the economic efficiency evaluation. The research, made on case studies of transport projects of different types, shows quite equal impact of change in investment costs or life cycle costs of the road infrastructure project on the change of economic efficiency of the project represented by the Internal Rate of Return (10% change in life cycle costs causes the change of IRR approximately from 7 % to 13 %). According to the limited number of projects considered within the case study it is not possible to do general conclusion, but it is possible to form the conclusion resulting from the case study that the sensitivity of the economic efficiency on the changes in life cycle costs in the case of tested case studies is rather proportional. So it is adequate to use as an input variable of the economic analysis the investment costs estimated using price norms and not the detailed item budget, which is hardly available within this phase of the preparation of the project. This conclusion is also supported with the results of the first case study, which show similar results (different only in the size of the risk premium, which is relevant to be included in this part of the project connected with many unknowns) of Pricing Norms and detailed item budget approaches. However it is necessary to recommend to verify the results of the Pricing Norms estimation and detailed item budget calculation with really reached investment (or lifecycle) costs during the investment (or investment and operational) phase of the project within "the ex-post evaluation".

References

Browne, D.; Ryan, L. (2011), "Comparative analysis of evaluation techniques for transport policies", Environmental Impact Assessment Review. 31(3): 226–233. DOI: 10.1016/j.eiar.2010.11.001.

Damart, S.; Roy, B. (2009), "The uses of cost-benefit analysis in public transportation decision-making in France", Transport Policy. 16(4): 200-212. DOI: 10.1016/j.tranpol.2009.06.002.

Geurs, K. T.; van Wee, B. (2004), "Accessibility evaluation of land-use and transport strategies: review and research directions", Journal of Transport Geography. 12(2): 127–140. DOI: 10.1016/j.jtrangeo.2003.10.005.

Hyard, A. (2012), "Cost-benefit analysis according to Sen: An application in the evaluation of transport infrastructures in France", Transportation Research Part A: Policy and Practice. 46(4): 707-719. DOI: 10.1016/j.tra.2012.01.002.

Jajac, N.; Marović, I.; Hanák, T. (2015) "Decision support for management of urban transport projects", Gradevinar. 67(2): 131-141. ISSN: 0350- 2465. DOI: 10.14256/JCE.1160.2014.

Jones, H.; Moura, F.; Domingos, T. (2014), "Transport infrastructure project evaluation using cost-benefit analysis", Procedia - Social and Behavioral Sciences. 111: 400-409. DOI:10.1016/j.sbspro.2014.01.07.

Korytárová, J.; Papežíková, P. (2015), “Assessment of Large- Scale Projects Based on CBA” // In ProjMAN - International Conference on Project MANagement, Procedia Computer Science. 64: 736-743. ISSN: 1877- 0509. DOI:10.1016/j.procs.2015.08.602.

Mackie, P.; Worsley, T.; Eliasson, J. (2014), “Transport appraisal revisited, Research in Transportation Economics”. 47(1): 3-18. DOI: 10.1016/j.retrec.2014.09.013.

Mancebo Quintana, S.; Martin Ramos, B.; Casermeiro Martinez, M.; Otero Pastor, I. (2010), “A model for assessing habitat fragmentation caused by new infrastructures in extensive territories”, Journal of environmental management. 91(5): 1087-1096. ISSN 0301-4797. DOI: 10.1016/j.jenvman.2009.12.013.

Ministry of Transport of the Czech Republic (MOT CR) (2013), “The implementing instructions for evaluating the economic effectiveness of projects of railway infrastructure”. Retrieved from http://www.mdcr.cz/.

Ministry of Transport of the Czech Republic (MOT CR) (2005), “The implementing instructions for evaluating of the economic effectiveness of projects on water ways”. Retrieved from http://www.mdcr.cz/.

Oxman, A.; Lavis, J.; Lewin, S.; Fretheim, A. (2009), “Support tools for evidence informed health policymaking (STP) 10 // Taking equity into consideration when assessing the findings of a systematic review”, Health Research Policy and Systems. 7(1): 1-9. DOI: 10.1186/1478-4505-7-S1-S10.

Road and Motorway Directorate of the Czech Republic (RSD CR) (2014), “The implementing instructions for evaluating the economic effectiveness of projects of road and motorway construction”. Retrieved from http://www.rsd.cz/doc/Technicke-predpisy/HDM-4/provadeci-pokyny-pro-hodnoceni-ekonomicke-efektivnosti-projektu-silnicnich-a-dalnicnich-staveb.

Road and Motorway Directorate of the Czech Republic (RSD CR) (2016), “The pricing norms for road structures”. Retrieved from https://www.rsd.cz/wps/portal/web/technicke-predpisy/soupisy-a-ceny-praci.

Truhlíková, M. (2017) Finanční a ekonomické hodnocení projektů silniční infrastruktury (Financial and economic evaluation of projects in road infrastructure). Brno. 76 p., 34 p. app. Diploma thesis. Brno University of Technology, Faculty of Civil Engineering, Department of Structural Economy and Management. Supervisor Vít Hromádka.

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Economic Comparison of Construction Costs of Buildings From Renewable Natural Materials and Traditional Materials in the Czech Republic

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Abstract:

The aim of the study is to evaluate the economic benefits of construction of buildings from renewable natural materials, compared to traditional materials in the Czech Republic. The work focuses on the comparison of materials based on wood and hemp against materials based on ceramics and polyester forming the supporting structure and the thermal insulation of the building.

Comparison is made on two identical projects, with only slight differences due to technological capabilities of the materials used. To create support structures, there are considered in the first case pressed wooden joists and wooden beams, in the second case are used ceramic tiles and ceramic ceiling joists. Thermal insulation of the object is in the first case created from hemp plates and in the second case from polystyrene plates.

The work deals with the evaluation of the construction costs of buildings taking into account different input material prices, time-consumption and construction work prices. Cost comparison is made in the form of itemized budgets dividing objects into individual building constructions and works.

The conclusion is made on the basis of the obtained data Evaluation expediency of use of renewable natural materials and traditional materials, considering the current price levels in the Czech Republic. The overall assessment is also taken into account the different costs and time demands of used materials.

Keywords: *renewable, traditional, alternative, price, comparison*

1. Introduction

Money is one of many factors influencing the design of a building. Nowadays, the economic aspect is of great importance. In most cases, the investor is limited by financial resources, thereby the design of objects has to be based on it. There are a lot of ways how financial resources can be saved. For smaller scale buildings, we often see the absence documentation, technical and construction supervision, a lower level of security and safety measures, saving on the proposed quantity and quality based on drafts from a designer or a structural engineer (especially in the case of covering and protective layers), or substitution with other, and in most cases, lower quality materials. The areas where companies and investors are trying to save money are not in most cases the places where they should be trying to save. Understandably, a detached house does not need an extra person as a coordinator for safety work and the everyday presence of a technical construction supervisor,

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but skimping on the materials, for example, is often very risky and can backfire in the future in the form of the high costs of removing defects arising in connection with this choice.

One of the possible ways to make some construction savings is the use of alternative building materials. Unfortunately, these savings are not so great, because the majority of the alternative materials used today are used primarily in the process of making the "basic structure", and the greater part of the construction costs are in most cases the finishing works inside and outside of the building. However, there are still other ways that a potential investor can save. Of course it depends on what kind of works are carried out, which technologies are used, and so on. The main criterion, however, remains the type of material used, while the prices of alternative materials varies greatly. This should be taken into consideration and don't take it for granted that alternative materials are cheaper (and have lower quality).

As with conventional materials, the price and quality varies from vendor to vendor, i.e. the price difference of thermal insulations. The current prices of Styrofoam insulation with a thickness of 80 mm is around €4.4 / m2, while the pice of hemp insulation with a thickness of 80 mm is around €6/ m2. These are the prices ofthe cheapest insulation options on the market in both cases. This comparison shows that hemp insulation is not the best way to save money, but it is a natural material that is a pleasant, harmless and an environmentally friendly option for just an extra €1.6/ m2. Moreover, hemp insulation has a longer lifetime than polystyrene insulation and also retains its characteristics for a longer period, which offsets the higher price. As already outlined, it always depends on the type of used materials. If we again take into account the price of polystyrene insulation, which in this case is €3.8/ m2 for a thickness of 70 mm, and compare it to wool insulation which costs €2.5/ m2 for the same thickness (the most expensive wool insulation option costs €4/ m2) [1], then we already have a real potential for savings using alternative materials. It should be noted that wool is among the materials which meets the strict standards for thermal insulation (thermal conductivity of wool is 0.0392 W / mK).

These criteria can affect the price of objects during its construction, but also can affect an object in the next phase of the use of property. It should be noted that this phase, normally considered as 50 years, is much longer compared to the construction phase, which lasts for several months only depending on the type of material used. One can argue that operating costs are considerably lower than compared with the cost of construction, yet the maintenance costs over the considered 50-year lifetime period will significantly outweigh the costs of the construction of the building.

Heating itself is only a part of the costs associated with the phase of use of the property. A significant portion of the operating costs involved are the costs of the additional energies required to operate the building as well as maintenance costs, but this article will focus only on the cost of heating during the phase of use of the property

2. Methodology

2.1 Input data

In order to identify the differences in the costs of heating in buildings consisting of renewable and traditional materials, two identical detached house projects were created composed of different materials. For this purpose, two real detached house projects in the

Czech Republic made from wood as a supporting structure were used but the project was redesigned to use ceramic tiles for the supporting structure.

2.2 *Description of the object*

As already mentioned, in order to compare the cost of heating buildings from renewable and traditional materials, it was necessary to develop two identical projects on which it was subsequently possible to perform calculations. The default project was a detached house built in the Czech Republic with a structural system consisting of wooden beams and insulation boards composed of pressed hemp. The project was subsequently reworked with the emphasis on maintaining the highest possible authenticity into an object that uses a support system of ceramic blocks and in which the thermal insulation consists of polystyrene plates.

The building used for comparison was designed as a two-floor, single apartment without a basement. The ground floor consists of an entranced hallway with a wardrobe, connected with a utility room. There is open space in the central part of house, which consists of a living room with a high ceiling (gallery on the floor) with a kitchen and a dining room. The ground floor also has a separate study and bathroom. Access to the second floor is provided via a wooden staircase located in the living room. The living area on the second floor consists of a bedroom, two children's rooms, a bathroom and a separate toilet. The whole detached house is covered with a flat roof with a skylight over the gallery on the upper floor, which provides sunlight into the living room and the kitchen and dining room. The objects are only slightly different due to the different technologies and the materials used.

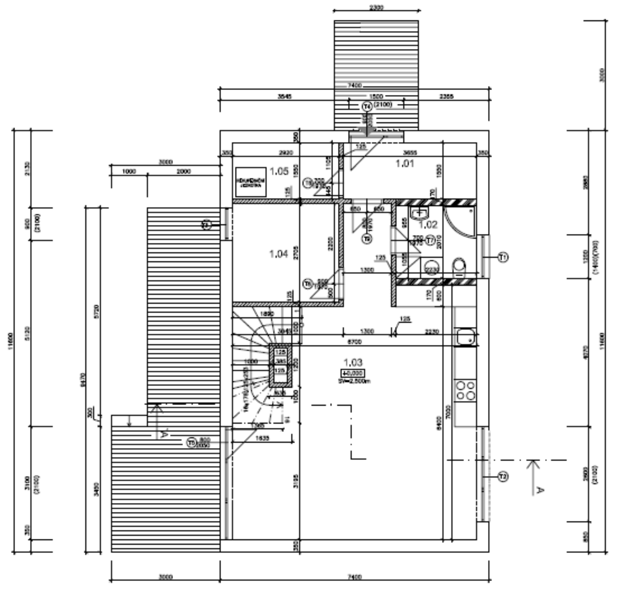
2.3 *Differences between the objects*

Due to the different technological processes and capabilities of the used materials, and despite efforts to make sure the objects were as similar as possible, there were still minor differences between the projects, namely:

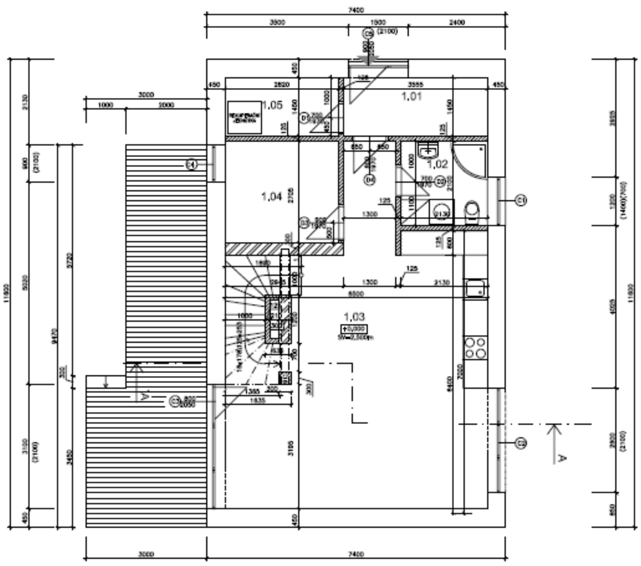
- Thickness of perimeter walls caused by thicker ceramic brickworks than wooden beams, used for walls (wooden house - 350mm, house made from bricks - 450 mm)
- Project zero at wooden house, caused by different foundations system. Wooden house is using pile foundations and house made from bricks is using foundation walls (project zero of wooden house - + 0.560 m, project zero of house made from bricks + 0.300 m)

Moreover for the detached house made from bricks:

- Coordination dimensions of structural elements were neglected in order to maintain the greatest similarity in the dimension of the objects - initial project was for a wooden house, which did not consider the coordination dimensions of ceramic tiles, so there are slight differences in sizes of rooms
- The roof structure is made from reinforced concrete and the heat-insulating boards made of polystyrene, which provides thermal insulation and also a gradient layer for the roof
- For the reinforced concrete slab over the first floor, 100 kg of steel per 1 cubic meter of concrete is calculated
- For the reinforced concrete slab over the second floor, 150 kg of steel per 1 cubic meter of concrete is calculated



Picture 2: groundfloor – wooden house



Picture 3: groundfloor - building from ceramic tiles

2.4 *Construction system*

For an objective comparison of the objects it is necessary to mention the construction systems used for both buildings.

- The wooden building was made with a columnar-frame system. The main bearing elements are “KVH” beams (structural beams). The roof and ceiling structures are also made from wooden ceiling beams. The insulating layer of the horizontal and vertical structures are combination of contact and ventiladed insulation system based on industrial hemp slabs. The foundations are made of reinforced concrete piles and bearing wooden grate

- The detached house from bricks is made of ceramic bearing masonry blocks, the ceiling structure is made of ceramic-concrete beams and ceramic “MIAKO” blocks. The roof structure consists of reinforced concrete slate. The insulation layers for the horizontal and vertical structures are made from contact insulation system based on insulation polystyrene boards. The foundations are mare from concrete foundation walls beneath the peripheral and internal support structures

Table 1. Composition of constructions – wooden house

Material	**Thickness [m]**	**λ [W/m.k]**	**Thermal resistance nstruction “U” [m2.k/W]**
Composition of walls – wooden house			
Silicone plaster	0,004	0,7	7,86
Hemp insulation “thermal-hemp basic”	0,12	0,04	
DHF board	0,015	0,15	
Hemp insulation “thermal-hemp basic”	0,14	0,04	
Vapor film	-	-	
Hemp insulation “thermal-hemp basic”	0,04	0,04	
Plasterboard	0,0125	0,15	
Composition of floor – wooden house			
Final flooring layer	0,015	0,038	7,21
Woodchip board	0,022	0,15	
Fibreboard insulation	0,04	0,046	
Fibreboard	0,018	0,15	
Hemp insulation “thermal-hemp basic”	0,22	0,04	
Diffusion film	-	-	
Wooden slats	-	-	
Cement board	0,0125	0,35	
Composition of roof – wooden house			
PVC waterproof strip	-	-	6,42
Geotextile	-	-	
OSB board	0,025	0,13	
Wooden slats	-	-	
Diffusion film	-	-	
Hemp insulation “thermal-hemp basic”	0,2	0,04	
OSB board	0,012	0,13	
Hemp insulation “thermal-hemp basic”	0,04	0,04	

Table 2. Composition of constructions – house made of bricks

Material	**Thickness [m]**	**λ [W/m.k]**	**Thermal resistance of construction “U” [m2.k/W]**
Composition of walls – house made of bricks			
Stucco	0,015	0,1	1,67
Ceramic tile “Porotherm 44 P+D”	0,44	0,3	
Stucco	0,015	0,1	
Composition of floor – house made of bricks			
Final flooring layer	0,015	0,038	5,45
Concrete screed	0,08	1,5	
Separation foil	-	-	
Thermal insulation – EPS boards	0,2	0,04	
Hydro isolation	-	-	

Composition of roof – house made of bricks			
PVC waterproofing strip	-	-	5,21
Catchment boards	-	-	
Thermal insulation – EPS boards	0,2	0,04	
Separation foil	-	-	
Reinforced concrete slab	0,2	3,5	
Stucco	0,015	0,1	

2.5 Material characteristics

During the assessment of the differences between the objects it is necessary, in addition to the technological, environmental and economic measures, to also take into account the different physical properties of the materials (especially density, strength, resistance to fire and thermal conductivity).

- Materials for a wooden house
- wooden “KVH” beams
- density - 350 kg / m3
- compressive strength perpendicular to the fibre - 21MPa
- hemp insulation

- Materials for a house made of bricks
- ceramic tiles
- density - 750-790 kg / m3
- compressive strength - 8 - 15MPa
- thermal conductivity - 0.13 to 0.155
- polystyrene insulation

3. Results

On the basis of the created projects two itemized budgets were compiled. The resulting values are shown in the table below (Table 1), where the resulting amounts are divided into objects as structural systems and components according to the price levels in the Czech Republic.

Table 3. Comparison of results

Number	**Component**	**Structural construction**		**Finishing works**	
		HTM[€]	**WH [€]**	**HTM [€]**	**WH [€]**
1	Earthworks	1 338	371	-	-
2	Foundations and special foundations	5 546	6 859	-	-
3	Vertical and complete constructions	18 251	-	-	-
4	Horizontal constructions	12 678	-	-	-
61	Surfacing – interior	7 614	-	-	-
62	Surfacing - exterior	11 457	11 234	-	-
63	Floors and floor constructions	1 570	-	-	-
64	Openings	6 467	6 839	-	-
94	Scaffolding and construction elevators	1 757	-	-	-
95	Finishing constructions	1 367	1 512	-	-

711	Water isolation	-	-	2 282	-
712	Bituminous	-	-	2 903	2 504
713	Thermal insulation	-	-	3 792	12 607
762	Carpentry constructions	-	-	-	36 801
764	Plumbing constructions	-	-	1 864	1 808
765	Hard coverings	-	-	-	436
767	Locksmith constructions	-	-	-	2 455
771	Flooring tiles	-	-	1 964	2 010
775	Parquet flooring	-	-	2 656	2 796
784	Paintings	-	-	762	723
Total		**68 045**	**26 815**	**16 223**	**62 140**

Note: HTM - house from traditional materials, WH - wooden house

The price comparison shows us that a traditional brick building costing €84,268 is cheaper than a wooden building with hemp insulation that comes in at €88,955. However, the difference is not so great as to be the main reason to select a building system. Also, it is necessary to take into account the minor differences between the items that moderately affect the final price that are listed above.

We can see the biggest difference in the prices is between insulations, which is due to the higher price of hemp insulation and also because of the much higher amount of insulation required due to the requirements of the used construction system. The difference in the prices of insulations is €8,815. Due to the higher amountof insulation, which is directly connected with a lower heat loss than in the case of a house made from traditional materials, another question arises. What is the difference between operating costs and whether this difference in prices "pay" operating objects (it should be noted that an object made from traditional materials hasn´t got insulated vertical walls).

It is still necessary to keep in mind that "minor deviations" are possible, but after considering the previously described facts it is possible that the prices of objects from traditional and alternative materials in the Czech Republic are comparable.

4. Conclusion

Cost optimization has been and always will be one of the great themes in almost all sectors of human activity. In addition, the situation is much more specific in the construction sector, since the entire industry mainly operates on the principle of "contract prices", thus the fixed price quoted in the contracts work is often an unrepeatable result of negotiations between the investor and the contractor. The fair value of the work is also very difficult to determine because the implementation process enters many variables that may impact the price, so even the most experienced price estimator is often not able to determine the exact final cost of the work and the calculation of the price of work must therefore always be taken with a certain detachment.

These examples, however, show that the use of alternative materials for the sole purpose of reducing costs is not so easy. This is confirmed by the price of a straw house in Kruplov, a small village in the Czech Republic, built in 2011 that cost €74,074 [2]. Since price levels are slightly changing (rising) from year to year, we have to recount the price of that house according to the development of prices of constructions in the Czech Republic between 2011 and 2017, which is around 14.3% (according to information from the Czech Statistical Office). So nowadays, the same house would cost €84,667. Also in this case, the cost of construction of the same object from traditional materials would be comparable. There is also a difference in carpetnery works and foundations. Difference in carpetnery works is caused by the fact that whole wooden house is made from wood, so there is way bigger amount of carpetnery works than in case of house made from bricks. Difference in price of foundations is caused by difference in used foundation systems. There should be also mentioned a difference in construction price, which is already counted in total prices of both buildings. According to data obtained from construction company, construction time of wooden house was 5 months and according to data obtained from PC software Kros+, construction time of house made of bricks is 8 months. With average labor cost 8€ per hour, 8 working hours per day and average number of 4 laborers cost of construction time of wooden house is 25 600€. Construction price of house made of bricks with same number of laborers, working hours and 8 months is 40 960€.

We can say that the prices of traditional and alternative materials are comparable and we can´t look at alternative materials in the conditions of the Czech Republic as a clear way to reduce construction costs. With these materials, it is necessary to work at an early design stage and not just include them as an alternative for savings, since in most cases it requires special design solutions (an example could be a wall made of clay, when unburnt clay could serve as a supporting element, but could be used as a filler for wooden substructures, and can respectively be used for creating partitions and other non-bearing structures). However, if we regard alternative materials as a "cheap alternative" and an opportunity to reduce construction costs, then we can enjoy the benefits of an environmentally friendly, non-toxic, gentle nature, and last but not least in the Czech Republic, still unconventional housing means that meets the criteria of sustainable construction.

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References

Tepelná izolace z ovčí vlny - výroba, použití. *EnviWeb* [online]. Redakce EnviWeb, 2011 [cit. 2017-04-05]. Dostupné z: http://www.enviweb.cz/clanek/staveni/88994/tepelna-izolace- z-ovci-vlny-vyrobapouziti

NĚMEČKOVÁ Alena. *Dům ze slámy a bez hřebíků*. Doma, 2011, roč.1, č.1, s. 20-23.

ISSN neuvedeno

LABUDEK, Lukáš. *Technické, cenové a ekologické porovnání alternativních stavebních materiálů*. Brno, 2013. 53 s.,50 s. příl. Bakalářská práce. Vysoké učení technické v Brně, Fakulta stavební, Ústav stavební ekonomiky a řízení. Vedoucí práce doc. Ing. Alena Tichá, Ph.D..

CHYBÍK, Josef. *Přírodní stavební materiály.* Praha: Grada, 2009. Stavitel. ISBN 978-80- 247-2532-1.

Capability Strings – Building Fast Relational Capabilities through Set of Cross-Organizational Threads in Industrial Construction

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Abstract:

In industrial project development, one can witness an existence of sets of joint activities and policies between the Client and Contractor. These activities joined together in a row as temporary cross-organizational threads allow considerable lateral exchange of information as well as problem solving actives between client and contractor. Absence of such threads increase potential risk in engineering, procurement and construction services. Therefore, in this research we focus on the most comprehensive contracting model called EPC or Turnkey. We collect and compare activities in a single EPC case. Comparative analysis is focused on cooperative processes, resources and activities by EPC project Client and EPC Contractor. Data collection is done by activity, resource and process mapping and results are shown in integral comparison table. Findings show that Clients and Contractors perceive differently their cooperative activities. Further, findings show that in this case Contractor has displayed much more readiness for cooperative actions by developing an offering of joint activities with the Client that we call capability strings. These strings act as platform for joint capability for EPC service delivery through reducing risk of budget overrun and minimize dispute. In addition, this paper concludes that building Client capabilities for EPC procurement requires organizational adjustments and pairing of processes policies and routines with the Contractor.

Keywords: *project, capabilities, epc, contractor, client, engineering, procurement, construction, large, organization;*

1. Introduction

Civil and construction services are procured by clients in non-sequential and time distant periods. In that sense, clients usually approach engineering and construction investment as off-shelf procurement product. Latent risks in construction and sophisticated commercial arrangements require Clients to approach carefully when procuring engineering and building services. Often, when project requires lot of industry specific knowledge, Clients ask external help from consultants to act on their behalf in project management. On the other hand, Contractors have developed unique processes and activities for their internal use with aim to reduce commercial or technical risks. While such organizational design is beneficial regarding production risks, Contractors often require intense interaction with Clients as a way of solving problems and possible disputes on time. Due to often limited capacity for construction management, Clients choose contract arrangements that induce as minimal risk as possible for

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them. Such contract is called turnkey or EPC contracts. By choosing EPC contract Clients often reduce resources required for engagement with the Client thus reducing number of interface levels as well as frequency of interaction. It is a natural response to reduce resources when project risks are reduced. EPC contractors often argue such policy due to complex and changing nature of the construction project as well as Client's lack of understanding of course of engineering and construction in relation to the project environment. In that sense, Contractors tag a risk level on Client based on their capability to cope with the project. This paper is part of an ongoing research into Client's capabilities to procure engineering and construction services. In this paper we take a single case of EPC procurement and collect empirical data within Client and Contractor with focus on planned processes and activities that act as interface platform for information sharing, planning and decision making. We map interface platforms i.e. processes, events, digital connections or other activities where Client and Contractor engage resources to reduce risks, adapt to new environmental requirements and transfer information or knowledge.

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2. Literature review

Due to often limited capacity for construction management, Clients choose contract arrangements that induce as minimal risk as possible for them. Such contract is called turnkey or EPC contracts. Investigating phenomenon of client capability remains a truly challenging ground for management science and organizational studies. As literature remains vague on client capabilities it does a lot on contractor capabilities or developers. In that sense, here we bring in the definition of contractor capabilities as counter term to client capabilities. Hampson and Brandon say that contractor capabilities are to "*design, construction and operation of facilities that truly reflect the present and future needs of the project initiator, future owners and tenants, and aspirations of stakeholders [and] ... have developed develop better systems for capturing client requirements*" (Hampson & Brandon, 2004 and 2005). Meeting client needs is thus considered critical to the success of construction projects and for the construction industry overall. While there may be many participants involved in a construction project, this research aims to define strings of attachment between client and contractor. Client is considered as organization that procures/orders design, engineering and construction service. Client in that sense is a project stakeholder that is required to decide upon project delivery system, clearly define building requirements, provide basic data to the design or construction contractor and take over the building after completion. According to ASCE (American Society of Civil Engineers), Project Delivery Systems describe how the project participants are organized to interact, transforming the owner's goals and objectives into finished facilities. During that period, Client can face numerous challenges generated by the changing environment, lack of vague design, commercial interest of contractor or another stakeholder. Importance of Client capabilities is indirectly pointed in numerous researches. Yaxin (2012) indicates that *problems related to client, human resource and financial capability have significant impacts on the EPC project implementation.* Zheng (2010) lists Client as one of the EPC project risks. Pearson and Skues (1999) analyze specific approach to monitoring and control of EPC projects. Most EPC contracts are large industrial or infrastructure contracts. In infrastructure, as Molenaar and Songer (1999) point out a dominance of public Clients.

Due to infrequent exercise of such procurements, Client often engages consultants for project management services on their behalf as well as may engage in contractual arrangements where most of the project risk is transferred over to the contractor. In complex construction undertakings, such scenarios are supported by FEED services followed by EPC/Turnkey contract types. EPC is the abbreviation for Engineering Procurement Construction. EPC is one of the global construction contracting models, and it is also known as the turnkey project service. It is a type of contract typical of industrial plant construction sector, comprising the provision of engineering services, procurement of materials and construction. The term “turnkey” indicates that the system is delivered to the client ready for operations. The outstanding feature of the EPC is that the ultimate price and time of the project have a great degree of certainty. The project is largely Contractor managed and the cost risk and control are weighted towards the Contractor and away from the Owner. And while EPC contracts are drafted to lift the project weight off the client, numerous reports indicate that a cooperative approach to construction delivers real benefits to all the parties. The Latham report (1994) indicates partnering and alliance contracting as a way forward to improve efficiency and profitability. Egan expanded on this concept to recommend integrated supply teams and long-term client/construction team relationships to allow lessons learned to be incorporated into the next project. However, these models do reduce Client’s chance to exercise market behavior and reduce construction costing. Long term contracts in large industrial projects are expensive to implement, therefore focus on bespoke contracts, arrangement and team support activities, focused team building exercises and the like remain as only viable solutions.

In that sense, lack of Clients risk raises perceptions that managing EPC contract may be effortless. Therefore, client PMs often face scarce resource base and must display in advance all necessary resources and it can be seen that resources required and in excess due to oversimplified perception of contract management. This is where experience, informal hierarchies and trust become relevant in securing minimum resources for property project engagement by the Client.

3. Method statement

This paper is a part of an ongoing research into Client capability in EPC Contracts. This part focuses on strings of interaction between Client and Contractor. By term strings we acknowledge processes and policies that act as interface between Client and Contractor. Focus is drawn on information sharing, synchronizations, decision making as well as joint actions. We compare the sheer existence of such processes and policies as well as resources that they allocate. This paper reports findings from a single EPC project case that is used as a sampling test for a larger data gathering. In this case Client has procured a FEED service for construction of large industrial plant for production of product that will comply with new industry standard. For the FEED and EPC procurement, Client has hired an experienced consultant to provide education and advise during procurement rather than to act on their behalf. Consultant claims to have developed a world class solution for the Client. Data is collected in time frame after the FEED is delivered and before EPC contract is awarded. Client has provided contact with selected bidder and data was collected separately in the Client office as well as the Company with most competitive bid. An open-end questionnaire is dispatched to both respondents. Respondent at the Contractor side was Project Controls manager. On the Client side data was collected from the Head of Investment Division. First step of data collection was done by one-on-one conversation. This was followed by structuring of data. Data was structured by categorization of processes, policies or routines that support interaction between Client and Contractor. Second step was as done through mail. List of strings was set out to both Client and the Contractor to confirm existence of the specified processes, policies or routines. Questionnaire collected strings for bidding, execution and project close out phases. Questionnaire is dealing with organizations liabilities toward the project, project performance increase, reduction of risk, contract awareness, consensus and dispute avoidance, dynamics monitoring and milestone performance, service price and commercial matters, supply chain management, health and safety and other administrative aspects. These components were grouped in five parts i.e. Bidding stage, Project execution (i.e. kickoff, contract administration and other project functional interface) and Project close-out.

4. Empirical analysis and findings

Data collection was performed according to the above described research plan. In the first step, Contractor has identified 22 processes or combination of processes and policies that he has implemented or plans to implement in the project. Interview with the Client has resulted in 8 policies and processes that Client planes to implement in the project. In the second step, a confirmation was sought from both respondents. A whole list of processes and activities has been dispatched to respondents to either confirm or dismiss individual processes or activities as bundles of processes. Both respondent returned their answers out of which Contractor list of processes stayed the same while Client added two more activities as planned. In the end, empirical sample consist of 32 data out of which Client has displayed 10 and Contractor 22 policies, processes or activities that are displayed in table 1 below.

	Activities and policies planned in EPC engagement	EPC contractor	EPC client
BIDDING PHASE	Review of Contract Terms (legal issues - indemnities, liabilities, law provisions, and others) and their associated risks to the project with individual bidders		
	Review of Technical Terms (FEED inputs) and their associated risks to the project with individual bidders		
	Review of the Contract's commercial requirements, such as payment and extra work exhibits, project reporting exhibits, schedule dates and others		
	Consolidation of the exceptions and clarifications made to the Contract (technical, commercial, legal) during contract negotiation and until project award		
	Negotiating the Contract with the EPC contractor		
	Compartmentalization - Controlled distribution of parts of Contract within the PMT (priced and unpriced copies) and integration of Client and Contractor professionals responsible for specific deliverable		
	Engage PMT in Contract awareness discussion and achieve a consensus towards the interpretation and application of the Contract – colocation and scenario workshop		
EXECUTION PHASE	Identify the Contract conditions and their application in mitigating project risks		
	Identify the Contract conditions and their application in exploiting project opportunities		
	Establish a working relationship with the Client's contract management team including contractual matters reporting and exchange		
	Issuance of the Contract project set up documents such as insurances, financial bonds, and others		
	Implement a comprehensive Contract communication process for correspondence, notices, interface documents, notices, and others		
	Execute a robust project change management process, which covers the creation of customer change orders, status submission and tracking, and negotiation.		
	Technical – acquire an awareness of the project technical and operation work elements		
	SCM – communicate all Contract requirements for cascade to suppliers		
	Project Forecast – obtain and review cost information during project change order creation, and provide updates on EPC service performance changes		
	Planning – integral planning platform for Client and Contractor - converse on Contract completion dates and schedule float impacts due to project change orders		
	Document Control – monitor the conformity with the Contract requirements i.e. timely document reviews, etc. and raise changes in cases of non-compliance		
	Project Management – attend all project commercial meetings and actively safeguard the project Contract rights and obligations		
	Dispute Management – engage as project liaison with the Legal team during Project Contract disagreements.		
CLOSEOUT	Ensure all technical contract completion conditions are met and issues resolved.		
	Probing digital as-build data with real works, shared testing and startup processes		
	Ensure all commercial contract completion conditions are met and issues resolved.		

Table 1. *Comparative table of Contractor and client perspective for EPC project – comparison based on planned activities*

In table 1. one can find list of activates that are planned by the Contractor and the Client for their EPC project. Each activity belongs to one of three phases of project i.e. Bidding, Execution and Closeout. By looking at columns 3 and 4 one can see that Client does not expect as much joint activities as the Contractor does. Client plans its resources and capabilities accordingly and in that sense project misses out substantial number if interactions.

In the bidding phase, Client does not recognize Contractor's readiness to engage in review of contract terms i.e. legal issues related to indemnities, liabilities, law provisions, and others with the Client. Contractor considers this activity to be highly influential on the price of service and by getting involved Contractor can get better perception of project risks regarding customs, supply chain and other features relevant to pricing. Further, Client's procurement plan excludes joint review of technical terms (based on FEED inputs) while Contractor perceives this activity as opportunity to display custom solutions thus reducing offer price. Another highly important activity not previewed by the Client is review of the Contract's commercial requirements, such as payment and extra work exhibits, project reporting exhibits, schedule dates and others. In this activity Contractor seeks to develop a working relationship with Client's personnel and get a grasp on Client's planning and reporting expectations. In this activity, Contractors collects data on Client for risk assessment model and respectively offer price. Contractor points that comprehensive distribution of work packages and Client's awareness of the supply chain management Contractor applies, is important for good relationship and is a baseline for communication policy and processes between numerous project stakeholders. Further on, Contractor stresses the added value of contract awareness discussion. Such activity is based on temporary co-location of Client and bidding contractor staff where Contractor collects risk management data on various project scenarios thus allowing more precise estimation outcome. This activity results in a baseline document valuable in the execution phase as it prevails to be a first jointly made document between Client and Contractor.

In execution phase Contractor expects to work closely with the Client in exploring technical and commercial opportunities. In this reengineering phase, Contractors explores simplifications, cost reduction and reengineering of specific parts of the project thus allowing saving to be made for the Client and the Contractor. Further on, Client does not expect to get involved in daily correspondence across technical issues but rather delegated PM to handle daily routine. On the other hand, Contractor express readiness to inform and confirm technical and commercial activities on daily basis. This is also visible in planning activities where Client does not recognize integral planning platform benefits as well as project change management. In that sense, Contractor recognizes an importance of robust project change management process, which covers the creation of customer change orders, status submission, tracking and negotiation. Based on their previous experience, Contractor stresses that early Client's engagement in planning activities and change management allows continuous beneficial working relationship with the Client.

In the closeout phase, Contractor expects the Client to join the probing of digital as-build data with real works, shared testing and startup processes as it is important for later handover process. On the other hand, Cient expects a shared activity where pending issues will be resolved and commercial contract completion conditions are met.

The above empirical data shows that the balance of expected activities rests on Contractors side. It is visible that Contractor plans more shared activities with the Client in bidding and execution phase of the project. This research is a first step in displaying asymmetries between Client and Contractor thus allowing alignment of processes and creation of cross-organizational threads of interaction.

5. Conclusion

Client capabilities have so far been overlooked by the literature. Contraction industry provides service where Client plays important and active role. Client readiness for engagement in construction project remains uncontrolled part of the building process. Industry faces more and less experienced clients thus adding risk margin to overall service price. To reduce number of risks, Contractors have developed a number of processes and practices to support collaborative approach to project bidding and execution. Such collaborative actions help Contractor to prepare for the project but, as Contractor's stress out, increase Client's readiness for its role in the project. There are many project delivery systems with clear risk bearing levels for Clients. EPC stands and a contractual arrangement with lowest level of responsibility for the Client thus being favorite in complex industrial projects. This research examines interaction opportunities between Client and Contractor in EPC project. Empirical experiment is set to analyses process and activity plans of both contractual parties and bay comparing the two display asymmetries in expectations in EPC project delivery system. It is important to stress that none of the activities monitored are contractually obliging in case of EPC and rest in voluntary part of project activities. For empirical examination, a EPC project case is selected in early bidding stage. Client has procured FEED input for the plant and is in process of evaluation of bids for EPC contract award. Most competitive Contractor was approached for data gathering. Based on open end interview as a first step and confirmatory poll as second step we have found out that Contractor outnumbers Client in processes and activities that allow interaction between the two. Findings show that Contractor is interested to engage as comprehensively as possible with the Client. Yet, at the same time, Client is not planning to mobilize resources for so many activities as Contractor expects them to. In that sense, it is obvious that Contractor's effort in building fast relational capabilities through set of cross-organizational threads in industrial construction remains a single side effort. Clients still face challenge of justifying resource engagement in EPC project due to higher project delivery price as well as lower levels of risk exposure This research is part of an ongoing research into Clients capabilities in EPC contracts and remains as an important evidence of asymmetry of project stakeholder expectations.

References

Hampson, K.D. and P. Brandon. (2004) Construction 2020: A vision for Australia's property and construction industry. Brisbane: Cooperative Research Centre for Construction Innovation, Icon.Net Pty Ltd.

Hampson, Keith D., Brown, Kerry A., & Brandon, Peter S.(2005)Clients driving construction innovation : mapping the terrain; Cooperative Research Centre for Construction Innovation, Brisbane.

Molenaar, K. R., & Songer, A. D. (1999). Public-Sector Design/Build Evolution and Performance. Journal f management in Engineering, 15(2), 54.

Person, M., & Skues, D. (1999). Control of projects implemented through design and build contracts, Seminar Proceeding on Design and Build Procurement System, Construction Industry Training Authority(pp. 9-60). Hong Kong

Yaxin X. (2012) Improving the performance of Chinese construction firms on EPC projects in China, Doctoral dissertation at NUS- National University of Singapore

Zheng, J. H. (2010). Simple Analysis on EPC Turnkey Project Construciton Risk Management. Value Engineering, 29 (21), 85-86.

Mapping the Issue of Water Supply Network and Sewerage System in the Czech Republic

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Abstract

The article discusses the issue of construction and operation of water supply network and sewerage system in the Czech Republic. Until the early 1990s, the technical infrastructure throughout the state was centralized. Unlike the other network sectors, such as gas or electricity, water supply sector does not have one owner and independent regulator. Currently there is a large number of owners and operators of water supply network and sewerage system in the Czech Republic. Part of the water supply networks is owned by municipalities; however, some municipalities have sold their network. Other municipalities have kept the network and have rented the operating part to the private sector. This is related to the emergence of problems both with financing the operation and reconstruction of technical infrastructure and drawing of European grants. The presented article maps the solutions to these problems in the Czech Republic and examines in detail the involvement of voluntary associations of municipalities operating in the South Moravian Region. The analysis of the current state of water supply and sewerage system of municipalities in the South Moravian Region was elaborated with the support of the extensive recherché and marketing survey. Based on the obtained findings was, in the frame of the research project, finalized still incomplete public database and detailed maps showing the involvement of voluntary associations of municipalities in the complicated issue of water supply network and sewerage system in the South Moravian Region of the Czech Republic.

Keywords: *water supply network, sewerage, municipalities, associations of municipalities, management, funding*

1 Introduction

Providing the construction and operation of water supply network and sewerage system in the Czech Republic has completely changed during the past twenty-five years. Until the early 1990s the technical infrastructure throughout the state was centralized. Unlike the other network sectors, such as gas or electricity, water supply sector does not have one owner and independent regulator. Currently there is a large number of owners and operators of water supply network and sewerage system in the Czech Republic. Part of the water supply networks is owned by municipalities; however, some municipalities have sold their network. Other municipalities have kept the network and have rented the operating part to the private sector. This is related to the emergence of problems both with financing of operation and reconstruction of technical infrastructure and with drawing of European grants.

Area of technical infrastructure, i.e. municipalities facilities as water supply network, sewerage (WSN) and a waste water treatment plant (WWTP), proved to be the most important area for realization of construction investments. Many municipalities in the Czech Republic implement

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it through participation in voluntary association of municipalities. Firstly the development of technical infrastructure and its operators since 1990s up to now in the Czech Republic has been mapped for the purposes of the research in this area. Due to the extent of the issue in this area, detailed research was focused on the situation in the South Moravian Region.

Analysis of the current state of water supply provision and sewerage system of the municipalities in the South Moravian Region was elaborated with the support of the extensive recherché and marketing survey. Based on the obtained findings was, in the frame of the research project, finalized still incomplete public database and detailed maps. Theese maps show the involvement of voluntary associations of municipalities in the complicated issue of water supply network and sewerage system in the South Moravian Region of the Czech Republic.

Great experience with municipal cooperation can be seen in Israel. Findings suggest that regional cooperation can be an efficient tool in promoting advanced wastewater treatment, and has several advantages: an efficient use of limited resources (financial and land); balancing disparities between municipalities (size, socio-economic features, consciousness and ability of local leaders); and reducing spillover effect (Hophmayer-Tolkich, Kliot, 2006).

The results of empirical analysis which was conducted among a sample of very small municipalities indicate that small towns that cooperate incur lower costs for their waste collection service. Cooperation also raises collection frequency and improves the quality of the service in small towns (Bel, 2009).

2 Methodology

To obtain the necessary data for the research, various recherché from many published sources were initially used. Subsequently a relatively detailed marketing research focused on the situation in the South Moravian Region was carried out. The functionality of associations of municipalities operating in the South Moravian Region and their usefulness for the purposes of the research was examined. A questionnaire survey was carried out; the results were analyzed and assessed from the point of view of their possible marketing use and practical application in the building and public sectors.

Although the voluntary associations of municipalities are compulsorily registered in the public register of the relevant regional authority, the need to supplement the information and update on further geographic, demographic and economic data have arisen. Therefore, in the frame of the research a relational database of voluntary associations of municipalities in the South Moravian Region was created with the use of software Acces tool. Database contains extremely detailed information on individual associations and was further used for the creation of the map documentation. Maps of water supply network and sewerage system in the South Moravian Region were incorporated using a geographic information system. Both also include a detailed plotting of the municipalities and voluntary associations of municipalities which are connected to the infrastructure.

3 Development of the technical infrastructure and its operators

Water supply network, sewerage system, waste water treatment plants and gas pipeline create the content of the concept of technical infrastructure. The article focuses on the issues related to the operation of this infrastructure (except for the gas pipeline).

In the Czech Republic, the development of sewerage system and building of waste water treatment plants was considerably delayed compared to the water system network in general. Permanent water supply system began to be built in the cities as late as in the 19^{th} and 20^{th} centuries. Only 7% of the population was connected to the sewerage system in the early 20^{th} century. After the end of WW2 Czechoslovak Republic had only 51 functioning waste water treatment plants (Chromec, 2012). Between 1950s and early 1990s a total of 11 state-owned enterprises were established in the Czech Republic (9 regional and 2 in Prague). Theese enterprises operated 44,907 km of water supply network and 17,495 km of sewerage system and were in charge of the reconstruction and development of water infrastructure (Broncová, 2002).

The change in the ownership structure of water supply network, sewerage system and waste water treatment plants was made possible by the change in legislation in early 1990s. Based on the transformation law and government resolutions, the privatization of the existing owners of technical infrastructure began in 1991. The original state water management organizations and national committees performing their administration were transformed to public and private entities. The organizational framework became the "Principles for the privatization of state enterprises of the public water supply and sewerage system" developed by the Ministry of Agriculture of the Czech Republic. Even that they included: *"Expertises of foreign consulting firms and experience from the operation of public water supply and sewer system in the developed countries of Europe confirming the benefits of the existence of larger organizational structures which are able to provide better and cheaper services for the operation and development of this field to users, particularly for citizens" (*Transparency International, 2009), the already existing functional structure of water supply and sewerage system (WSN) and waste water treatment plants (WWTP) was replaced by the emergence of new water management companies (WMC) in the first half of the 1990s. Approximately 40 district and more than 1,200 small operators with different form of ownership infrastructure were created. These 40 district waterworks owning the infrastructure ensured supply of water for more than 90% of the Czech population at the same time. The remaining 10% of the water market was provided by small operators who originated from municipalities that chose not to deposit their property into the district WMC. , In spite of that fact they operate the assets separately, or entrust its management to the private operating company in which the municipality had business interest or their representatives in the institutions of the company."

Approved privatization projects allowed towns and municipalities to establish new companies, mostly joint-stock companies. Subsequently the state transferred all the water supply network and sewerage system including waste water treatment plants to their property free of charge.

The very concept of privatization allowed creating one of the two forms of water management companies (Transparency International, 2009). Either a mixed water management companies (WMC) which had to own and operate the infrastructure and solve their possible relationships by contracts according to a business law or a separate WMC., It was supposed separation of operations department including the development of water supply system which should be provided through other persons, whether natural or legal. Subsequent privatization of water management companies was, however, made impossible by policy contained in privatization projects. They were called "golden shares" through which the state could block adoption of inconvenient or undesirable changes to the water management company. In towns and municipalities which owned nearly 90% of all shares, these shares were transferable only with the consent of the general meeting of the town or municipality and only among already existing shareholders.

In the first privatization phase, state property was transferred to three big cities: Ostrava, Brno and Prague. In the second phase, assets worth approximately 41 billion CZK were privatized. Municipalities received assets worth 25.4 billion CZK by free of charge transfers. Assets worth 16.2 billion CZK werre transferred to the mixed joint-stock companies majority-owned by towns and municipalities and the remaining 0.3 billion CZK were sold directly (Department of Agriculture, 1992).

Some large water management companies such as: Prague water supply network and sewerage system, Inc., Brno water supply network and sewerage system, Inc., Ostrava water supply network and sewerage system and North Bohemia water supply network and sewerage system were privatized in a different way. Their share on the operating companies was offered for direct sale or public competition allowing the entry of foreign companies into this sector. Foreign investors were allowed to purchase up to 20% of the shares of operating companies from the State Property Fund (Broncová, 2002). That was the initial impulse for the foreign companies to buy shares from the towns and municipalities during the following period which enabled them to finally control the operating companies. It also contributed to a fragmentation of multiplicity entities active in this field. Currently, the existing structure has been represented by 6,433 owners of water supply network and sewerage system and 2,745 operators (Duda et al., 2015).

Table 1 Drinking water supply, sewerage system and waste water treatment plants in the Czech Republic 1990 – 2015 *(Department of Agriculture,2005, 2010, 2015)(Czech statistical office, 2017)*

	u.m.	1990	1995	2000	2005	2010	2015
NUMBER OF RESIDENTS							
Czech Republic	ths.	10,364	10,331	10,273	10,234	10,517	10,543
South Moravian Region	ths.	1,143	1,141	1,135	1,130	1,164	1,179
DRINKING WATER SUPPLY							
Length of water supply network	ths.	47,723	46,071	53,288	69,358	73,448	77,146
Population supplied with water from water system (whole Czech Republic)	ths.	8,624	8,860	8,952	9,376	9,787	9,929
Proportion of the population on the total number	%	83.2	85.8	87.4	91.6	93.1	94.2
In the South Moravian Region	km	78.1	80.2	82.5	93.6	94.9	95.3
SEWERAGE SYSTEMS							
Population living in houses connected to the sewerage system (whole Czech Republic)	ths.	7,522	7,559	7,685	8,099	8,613	8,882
In the South Moravian Region	ths.	1,474	1,279	1,495	936	1,018	1,055
Proportion of the population on the total number	%	72.6	73.2	74.8	79.1	81.9	84.2
In the South Moravian Region	%	71.6	72.7	73	83.1	88.3	89.9

WASTERWATER TREATMENT PLANTS							
Number of WWTP (whole Czech Republic)	p.	626	783	1,055	1,994	2,139	2,456
In the South Moravian Region	p.	12	124	157	175	198	230
Total capacity of WWTP's (whole Czech Republic)	ths.m^3/day	2,667	3,314	3,926	3,736	3,798	3,916
In the South Moravian Region	ths.m^3/day	181	530	361	315	325	333

Table 1: The development of water supply from public water supply networks and connection of the population in the Czech Republic and in the South Moravian Region in the period from 1990 to 2015.

Table 1 above also shows the increase in the number of population supplied by water from public water supply network and those living in houses connected to public sewerage system. This trend is due to the construction of new water supply network and sewage systems. During the observed period the increase reached 15%, which are nearly 1,305,000 inhabitants. Increasing trend can also be observed in the Length of water supply network marker. Specific development was observed in Share of the population supplied from water supply systems in the South Moravian Region marker where this indicator exceeded national average by 2%, in 2005 and keeps the current trend.

For sewerage system, the increasing tendency was observed in Population living in houses connected to sewerage systems marker which increased by 18% during the observed period and represents an absolute increase by 1,360,000 people. This indicator is also higher among residents living in houses connected to the sewerage system in the South Moravian Region by 4% in 2005 compared to the national average and it maintains its increasing tendency. Construction of new and intensification of existing waste water treatment plants helps to achieve a high proportion of treated waste water.

4 Voluntary municipal associations as owners and operators of technical infrastructure

In parallel with the privatization of water supply network and sewerage system, legislative changes in the status of towns and municipalities which enabled transformation of property rights and services occurred.

Since 1990, municipalities have become independent legal entities with their own property and the right for economic, social and cultural development. Act no. 367/1990 Coll., enabled them to establish and set up various organizations and facilities serving for meeting the needs of their citizens. Since the beginning of 1992, towns and municipalities could join together to create a voluntary association of municipalities (VAM). They have been granted the status of an independent legal entity created under concluded contract and approved internal rules embodied in the statutes. Their organizational structure is diverse because they can choose the form of their arrangement. They have their own property and property provided by associated towns and municipalities. They are subject to mandatory registration with the relevant regional office. Central records and statistics of voluntary associations of municipalities in the Czech Republic are conducted.

In the South Moravian Region there are 127 voluntary associations of municipalities, representing 17% of the total of 747 registered ones by the Ministry of Finance (ARES, 2016).

The following chart Figure 1 shows how municipal associations were created in individual years.

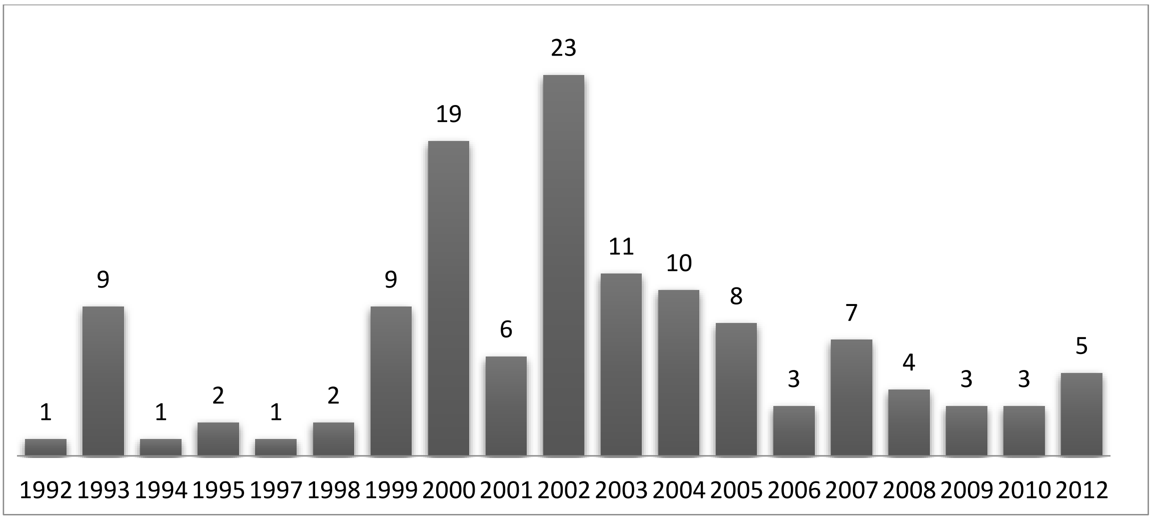

Fig. 1 Number of created associations of municipalities in individual years *(authors 'own work)*

Voluntary associations can develop their activities in various fields, such as education, social and health care, culture, municipality cleanliness, removal and disposal of wastes, management of local roads, forests, houses and flats, the operation of quarries, sandpits, equipment for mining and processing of raw materials, air protection and last but not least, water supply, sewerage system and waste water treatment plants operation.

The possibility of establishing voluntary associations and municipalities also in the area of water supply network, sewerage system and waste water treatment plants broadens the ownership and operational structure of water and sewerage system by another important entity despite the fact that in the South Moravian Region a large water supply company operates as is Brno water supply and sewerage system company, Inc., Water supply joint stock company, Ltd., Břeclav water supply and sewerage system company, Inc., Hodonin water supply and sewerage system company, Inc. and Vyškov water supply and sewerage system company, Inc., the activity of VAM in this field is not negligible.

From a total of 747 (ARES, 2017) voluntary associations of municipalities, 127 of them were created in 2016 in the South Moravian Region (Association of Municipalities Index, 2017) i.e. 16, 4%. Of these, more than a half (71 VAM) was created to operate water supply network, sewerage system and waste water and treatment plants. Some voluntary associations of municipalities focus its activities solely on the operation of water supply network (8 VAM), others on sewerage system and waste water treatment plants (25 VAM) or only on waste water treatment plants (4 VAM).

5 Research results

For the research, the relational database that facilitates working with data and enables to create necessary outputs in the form of charts, tables and calculations, was created. Technical infrastructure area seems to be the most important area for further construction investments. A substantial part of associations of municipalities was established for the construction and operation of the water supply network and sewerage system. Therefore, the subsequent research focused on the technical infrastructure. The result of the research in this field was creation and updating of maps of municipal facilities for water supply, sewerage and waste water treatment plants in the South Moravian Region and a design of the solutions for those municipalities and associations of municipalities that do not have the complete infrastructure.

The obtained results were plotted into the updated maps of associations of municipalities dealing with water supply network. For each association, its identification number which allows its search and link to other information contained in the created database, was stated.

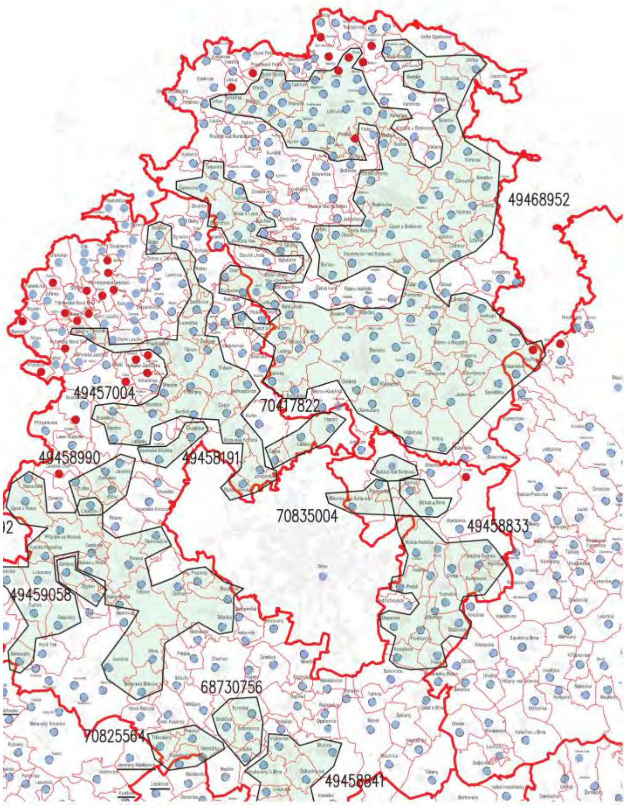

Fig. 2 The updated situation of water supply network *(authors' own work)*

Voluntary associations of municipalities which operate public water supply network were plotted into the updated maps. Colour distinguishes those municipalities that already have built a water supply network as well as those that are currently building it including those municipalities that have not built it yet.

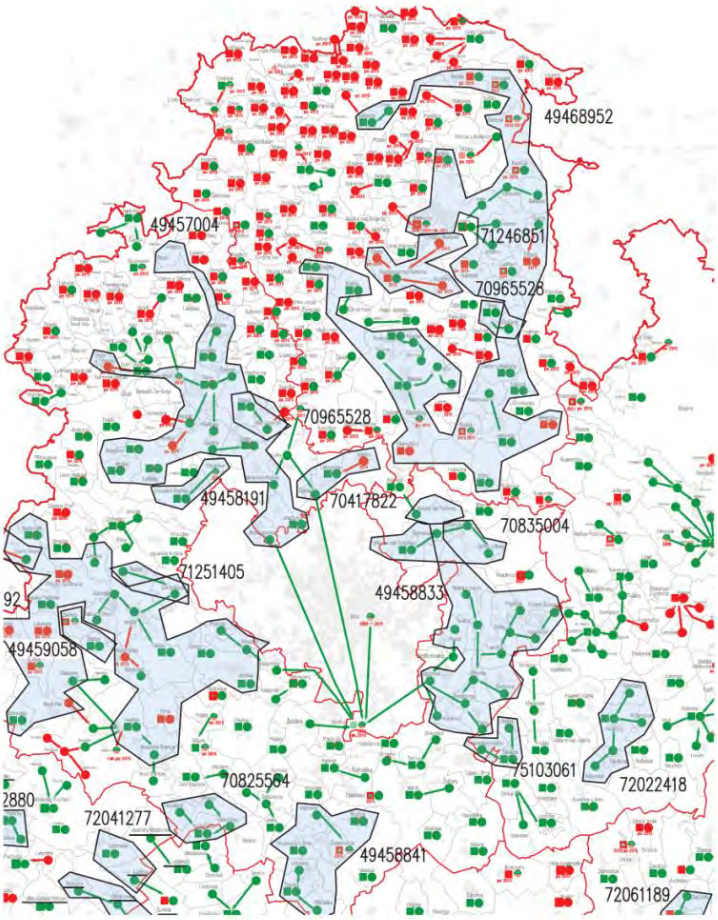

Fig. 3 Updated situation scheme of sewerage system *(authors' own work)*

In the case of sewerage system, the map was updated by associations of municipalities operating sewarage systems and waste water treatment. Plotted into the map and distinguished in colour were those municipalities that already have this infrastructure, those that are currently building it and those that want to build it within five-year horizont. This identification enabled to identify those municipalities which still do not have this infrastructure.

6 Conclusions and Recommendations

South Moravian Region is the fourth largest and the third most populated region of the Czech Republic. There are 647 municipalities in the region, of which 47 towns including the second largest city of Brno. In terms of administrative organization it consists of seven territorial units called districts.

Of the total of 14 regions, the South Moravian Region with 95.3% of the population supplied with water from public water network holds the sixth largest proportion. 89.9% of the population live in the houses connected to the sewerage system which represents the fourth highest share within other regions.

Despite this, there are still municipalities that have not had the public water supply network and sewerage system until now. In the area of public water supply network this deficit concerns a total of 42 municipalities. However, the situation is worse in the case of connection to a sewerage system and waste water treatment where a total of 170 municipalities have no sewerage system and waste water treatment plant connection.

Table 2 Overview of the number of municipalities without built water supply network by *(SPF Group a HOPE GROUP, 2015).*

Name of the district	Number of municipalities without public water supply	Number of municipalities without public sewerage system
Blansko	9	10
Brno-country	19	35
Břeclav	0	24
Hodonín	5	4
Vyškov	3	73
Znojmo	6	14
Total	42	170

The following table shows the percentage share of population connected to technical network.

Table 3 Proportion of the population with access to the technical infrastructure *(SPF Group a HOPE GROUP, 2015)*

	Proportion of the population with access to water supply	Proportion of the population with access to sewerage system
Czech republic	99.73%	77.37%
South Moravian Region	99.70%	82.55%
Brno – city district	99.46%	58.40%

As one of the possible solutions to the current situation for the municipality is to join already existing close voluntary association. It has also complete the new infrastructure through grants by the Ministry of Agriculture and Ministry of Environment or the "Integrated territorial investment" programme. These have been announced for the period 2014 - 2020 and also concern the Brno metropolitan area. They are co-financed from EU structural funds. Brno metropolitan area (BMA) includes 167 municipalities. 78 of them are already members of voluntary associations of municipalities and their activity is focused on the sewerage system. If the case of water supply, there are 82 municipalities. In terms of the number of municipalities BMA, the involvement of municipalities in VAM with the activities of the technical infrastructure is below 50%. Therefore, this programme aims to build a sewerage system for 40% of the population of the Brno metropolitan area. Sewerage system for around 20% of municipalities where it is completely absent (SPF Group a HOPE GROUP, 2016).

7 References

*Administrativní registr ekonomických subjektů (Ares) (*Administrative Business Register, in Czech) [online database]. Praha: Ministerstvo financí ČR, 1999 [cit. 2017-03-18]. Available from: http://wwwinfo.mfcr.cz/

*Administrativní registr ekonomických subjektů (Ares) (*Administrative Business Register, in Czech) [online database]. Praha: Ministerstvo financí ČR, 1999 [cit. 2016-05-20]. Available from: http://wwwinfo.mfcr.cz/

Bel, G. 2009. Intermunicipal cooperation, privatization and waste management costs: Evidence from rural municipalities. *Waste Management* [online]. 29(10), 2772–2778. [cit. 2016-10-31]. DOI: 10.1016/j.wasman.2009.06.002.

Broncová, D., 2002. *Historie kanalizací: dějiny odvádění a čištění odpadních vod v Českých zemích (*History of sewers: the history of the collection and treatment of waste water in the Czech Lands, in Czech), Praha: MILPO MEDIA.

Czech statistical office, 2017. *Water Supply Systems, Sewerage and Watercourses – 2015.* [online] Praha .[cit. 2017-03-03] Available from: https://www.czso.cz/csu/czso/vodovody-kanalizace-a-vodni-toky-2015

Department of Agriculture, 1992. *Vodovody a kanalizace Českére publiky: Výroční zpráva (*Water and sewage systems of the Czech Republic: Annual Report, in Czech), Praha: Ministerstvo zemědělství ČR.

Department of Agriculture, 2005. *Vodovody a kanalizace Českére publiky: Výroční zpráva (*Water and sewage systems of the Czech Republic: Annual Report, in Czech), Praha: Ministerstvo zemědělství ČR.

Department of Agriculture, 2010. *Vodovody a kanalizace Českére publiky: Výroční zpráva (*Water and sewage systems of the Czech Republic: Annual Report, in Czech), Praha: Ministerstvo zemědělství ČR.

Department of Agriculture, 2015. *Vodovody a kanalizace Českére publiky: Výroční zpráva (*Water and sewage systems of the Czech Republic: Annual Report, in Czech), Praha: Ministerstvo zemědělství ČR.

Duda, J. a kol*.,* 2016. *Vodovody a kanalizace ČR (*Water and sewerage of the Czech Republic, in Czech). Praha: Ministerstvo zemědělství České republiky.

Hophmayer-Tolkich, S., Kliot, N. 2006. Inter-municipal cooperation for wastewater treatment: Case studies from Israel. *Journal of Environmental Management* [online]. 0802, 86(3), pp. 554-565 [cit. 2016-10-10]. DOI: 10.1016/j.jenvman.2006.12.015.

Chromec, T., 2012. *Transformace odvětví vodárenství po roce 1989 (geografická analýza)* (Transformation of the water sector in 1989 (geographical analysis), in Czech) [online]. Olomouc. [cit. 2017-03-31]. Available from: http://theses.cz/id/8x22xm/. Bachelor thesis. Univerzita Palackého v Olomouci, Přírodovědecká fakulta. Supervisor Doc. RNDr. Zdeněk Szczyrba, Ph.D..

Law no. 302/1992 Coll., Supplementing Law no. 367/1990 Coll., On municipalities of § 20a - § 20d

Law no. 367/19990 Coll., On municipalities, § 20a-§20d

Rejstřík svazku obcí (Associations of Municipalities Index in Czech). In: *Portál Jihomoravského kraje* [online]. Brno: Jihomoravký kraj, 2014 [cit. 2017-03-31]. Available from: http://www.kr-jihomoravsky.cz/Default.aspx?ID=221102&TypeID=61.

SPF GROUP a HOPE GROUP, 2015. *Integrovaná strategie rozvoje brněnské metropolitní oblasti pro uplatnění nástroje integrované územní investice (ITI)*. Brno.cz [online]. Ústí nad Labem a Brno: SPF Group a HOPE GROUP [cit. 2017-04-10]. 276 s. Available from: http://www.brno.cz/fileadmin/user_upload/sprava_mesta/Strategie_pro_Brno/dokumenty/iti/ISR_BMO_ITI_final_rijen.pdf

Transparency International, 2009. *Privatizace vodárenství v České republice: kam odtékají zisky? (*Privatization of water supply in the Czech Republic: where do the profits flow?, in Czech), Praha: Transparency International – Czech Republic.

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Use of voluntary associations of municipalities in the Southern Region for the technical infrastructure.

Is Ethical Behavior Profitable in Construction? A Theroretical Framework

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Abstract:

There are two main competing theories concerning relationship between business ethics and profit. According to Nobel prize-winning economist Milton Friedman, managers should not take care about business ethics at all. Their only duty is to maximize profit. In contrast, according to the theory of "school of enlightened selfishness", the manager is responsible not only to shareholders but also to the wider community. In other words, according to this theory, the manager should take care about business ethics. Accordingly, the main purpose of this article is to apply these two theories on construction business and to check validity of these theories in construction. Or, in short, the main question is whether is it better for a civil engineer to follow the principles of business ethics or not. This analysis will be based on the game theory and rational choice theory. The main conclusions are, first, that an ethical behavior is profitable in situations when a long term cooperation with business partners, workers, customers and wider community is expected. However, second, construction business also provides many incentives for an unethical behavior that could be very lucrative. This article will explains under which circumstances one may expect an unethical behavior in construction. In the final part, this article will outline methods for empirical research about profitability of ethical behavior in construction.

Keywords: *business ethics; profit; ethical theories; construction; game theory; prisoners' dilemma; tragedy of commons.*

1. Introduction

Jones (2004, 45) defines ethics as a set of moral principles and beliefs about what is right or wrong. Thus, business ethics is a set of our beliefs about what we consider as moral and immoral business. There are three main sources of business ethics. The first source is the professional ethics. The second source is social ethics. Each community has its own general moral norms, which in turn affects the way people behave at the workplace. So, for example, education that an individual acquires in the family will have a significant impact on his behavior at the workplace. If the family fosters authoritarian behavior, then that behavior will prevail in business organizations. If, at the society level, none cares about the vulnerable groups (for example, there is no universal health care), then the business organizations will probably also lack the spirit of solidarity. And economic situation in the country affects business ethics. It is

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hard to expect that people will follow the highest ethical standards if they have to fight for their mere existence. Surely, it is easier to insist on respecting business ethics if people have a good income, than if they cannot live from their own salaries. However, whether the standards of business ethics will be respected, depends on each individual. Therefore, the third source of business ethics is individual ethics. The owner of the construction company has to decide whether to offer a bribe to get a job, and at the same time the person who was offered the bribe must decide whether to violate business ethics.

2. Business ethics and profit

Business has never been based solely on ethical judgments. The primary motive of almost every employer is profit. Thus the question arises: what to do if someone has to choose between lucrative earnings - which can be achieved by disrespecting business ethics - and ethical business, which in a certain situation will not result in a lucrative profit? Neither economists nor theorists of business ethics have a unique answer to the question. Nobel prize-winning economist Milton Friedman argues that managers should take only the logic of profit. And the title of his famous article - The Social Responsibility of Business is to Increase its Profits (2000) - presents his basic argument (in Dienhart, 2000). Why should managers, as agents of the owner's company, care only about profit? Friedman explains this by the fact that the company owners invest their own money, and is therefore in their interest to make as much profit from the investment. Indeed, imagine that one have sold his/her own home and invest his/her money in construction business. Would he/she be interested in anything else other than to return the invested money and, possibly, to get profit? However, the question arises: what if his/her company pollutes the environment? Does this person need to take care of the people who live near his/her company? Or he/she should continue to think only about the profit? Friedman's response would be positive. It is not your obligation to care about the environment, unless the law forces you to do so. Friedman believes that it is not the duty of a businessperson to take care of the common good. It is state's responsibility. So, if the government has been negligent and has not passed legislation on environmental protection, the entrepreneur has the right to pollute. In other words, the entrepreneur does not need to be "more Christian than the Pope." The entrepreneur has the right, under existing legislation, to maximize the profit.

However, such Friedman's attitude raises many doubts. Suppose that the fines for polluting the environment are small, and setting the air and water purifier is very expensive. Is one allowed to violate the law in this case, regularly pay the fines and thus increase one’s profits? If profit is your sole responsibility, why should the law be above your profit? Another example: You own a private clinic that performs heart surgery. A patient, to whom another doctor recommended a risky heart surgery, comes to you. You, as a surgeon and the owner of the clinic know that this risky operation is not needed, but you can earn 100,000 Euros from this operation. Legally you cannot have a problem because you can always present documentation from doctor who recommended surgery. Do you need to follow Friedman in this case, who says that profit (and possibly the law) is the only thing you need to take into account? Would you, if you were the patient, forgive the doctor who unnecessarily did the surgery (of course, if you survived the operation)? If one believes that a doctor cannot operate due to ethical reasons, it is logical to expect that the construction company should install filters that would prevent the pollution of the environment, even if the law does not require it (because pollution can also be dangerous for health)? So, should logic of profit be above the norms of business and professional ethics?

Not all theorists share Friedman's opinion. Edward Freeman (2006) states that managers are responsible not only to the owners of shares but also to the local community, suppliers, customers and employees in the company. Marianne Jennings (2003, 46-7) calls this theory "school of enlightened selfishness" and says: "In line with this school, the manager is responsible not only to shareholders but also to the wider community. Enlightened egoism is based on the notion that socially responsible business is in long term more profitable than traditional egoism." School of enlightened selfishness would argue that it is in the building contractor's self-interest to protect the environment, even when the law does not require it from him, because if local people see that he pollutes the environment, they would boycott his products, the entrepreneur would get a bad reputation, and he would not succeed at the market. Also, the owner of the clinic would also bankrupt if it becomes known that patients were operated even when it was not needed, just to make more money. In other words, enlightened egoist is also partly an altruist because he/she cares about long-term clients, assuming that he/she would earn more on the basis of ethical behavior than by intentionally deceiving clients in order to get profit as soon as possible. Of course, there are some other reasons for acting morally - a sense of satisfaction due to honest work and absence of fear that immoral or even illegal actions will eventually be discovered and punished. Therefore, many companies are trying to take care not only of the clients and the local community but also of their own employees. So they build free kindergartens which are incorporated in the company, co-finance summer vacations of their employees, help them when the employees relocate, etc. That ethical behavior is often very profitable confirms the fact that Microsoft is one of the most successful companies in recent decades, known for giving large donations to various humanitarian projects. Obviously, a good image of the company has a positive effect on its business operations. However, that does not mean that it is always easy to respect business ethics when the logic of profit conflicts with business ethics.

3. Game theory and business ethics

So, is it profitable to respect business ethics? To answer this question, we will provide an example from related sciences. In political science and economics there is a very popular theory - game theory. One of the most popular games is the "prisoner's dilemma" which is based on the following story. A policeman catches two burglars, but there is not enough evidence against them. So, he says to both of them, (prisoners are not allowed to communicate and do not know whether the other one will confess the crime): "If both of you admit that you committed a crime, you will receive up to five years in prison. If you confess and your colleague does not, you will be acquitted for cooperating, and your colleague will get six years in prison. But if he confesses, and you do not, you will go to six years in prison, and he will be acquitted. Finally, if neither of you admit committing the crime, you will each get one year in prison for unauthorized possession of weapons." Graphically, proposal can be presented like this:

	A admitted the crime	A did not admit
B admitted	A5, B5[2]	A6, B0

[2] Years in prison.

B did not admit	A0, B6	A1, B1

So, if A confesses, he can get five or zero year in jail. If he does not admit the crime, he can get six or one year imprisonment. If A is an egotist, it is better for him to confess. The same applies to B. However, if both are egoists, they will both end up five years in prison, and if they are both altruists, they will be in jail for only a year. "Prisoner's dilemma" illustrates why ethical behavior can be useful - if one does not watch only one's own interest all parties are better off. If the above prisoners behave ethically towards each other (forget for a moment the broader community and the fact that they came into prison for burglary), then they will be better off than to think only about one's self. There is a similar situation in the society. Egoistical factory owner can benefit if he releases toxic chemicals into the river (because he would have a higher profit) than if he installs expensive waste water purifier in the plant. However, the waste in water can cause cancer to people who live along the river. Therefore, the benefit of the individual, the factory owner, is paid with the huge expense of the community - deaths and serious illnesses. The situation becomes unbearable if everyone behaved like factory owner, who also may develop cancer because other plants may discharge toxic gases in the city where the owner lives. Thus, the community has a lot more overall benefits from ethical behavior than unethical.

Ethical behavior reduces what is in economics called transaction costs, namely the costs of control. For example, imagine that in our own apartment we constantly live in fear that our housemates are going to rob us and we constantly have to hide our money. Such a life would be a constant source of stress and frustration. So a quality civil engineer will rather work for a company where the owner will never deprive him of his salary, or vacation or treat him unethically. Thus, the Mayo's experiments have shown that humane and ethical treatment of employees can often achieve better business results than unethical conduct (see Miller and Form, 1966). We would rather do business with a partner whom we consider fair, and who will not deceive us, than with a person who is dishonest. Therefore, adherence to business ethics simplifies our work as well as family ethics (not stealing each other's money) makes our lives easier.

Respect for business ethics affects the reputation. For example, if we bought a product which broke down and a salesman is immediately ready to replace the product purchased, we will rather buy products from this salesman than from the one who will try to convince us that the product was functioning, but that we simply did not know use it properly. So, the salesman who replaces a product acquires a good reputation and the individual will not only buy from him but he will also recommend him to his close friends. In this case, the benefits of compliance with business ethics will be mutual, because both of them, the buyer and the seller, will be satisfied.

There is also the immaterial reward for ethical business, and it is a feeling of satisfaction that pervades the man whose honest work enabled him and his family to have a decent living. Of course, even a thief can get rich, but nevertheless, he is still haunted by the fear that his thievery will eventually be discovered. Moreover, it is a quite different feeling when people get rich by writing and selling their own quality books, than getting enriched from robbery. Wealth gained through honest work causes a higher self-esteem and respect for others, while the wealth gained through disgraceful conduct often causes contempt of others, and unethical person can feel remorse.

However, it is important to note that the state of law, which punishes violations of the law, is a prerequisite for the development of business ethics. If those who violate moral and legal rules are constantly avoiding punishment then more and more people resort to unethical business. In every society some criminals succeed to conceal the traces of their crimes, but there is a big difference between a society in which a success of an unethical individual is an exemption and the society in which majority of reach people are those who do not respect business ethics at all.

4. Business ethics in construction

By now, a general theory about the relationship between profitability and business ethics was presented. But, do we have some peculiarities in construction business? Is relationship between business ethics and profit different than in others branches of economy? In order to answer this question, we will return to game theory. It was presented above that common interest of two players is to cooperate. In this case, their over result would be better (they will spend less years in prison). However, from individual point of view, it is better to cheat (not cooperate). In this case, one may spend less year in prison or even be released from prison. The same imagined situation can be transferred to environment in construction business. If a construction company wins a tender for refurbishing tunnels on a highway - as a result of bribe offered to some politicians - the common interest will be in jeopardy, because taxpayers will have to pay more than in situation in which a tender is transparent and without corruption. However, the very construction company would earn more because bribed politicians would ensure that this company wins in competition with others and that this company is payed more than other companies that participate in the tender. In other words, an individual player may earn more by not cooperating (by cheating).

Experiments, conducted on the basis of prisoner's dilemma, showed that cooperation is profitable in iterated games: i.e., if people work together for a long time they will earn more by ethical behavior than by cheating each other. For example, one would rather give job to a construction company that fulfill all the obligation, stated in a contract, that to a company that tries to avoid its obligations. In addition, a skilled worker would rather work for a company that always give salary on time that for a company that tries to cheat its own workers. Furthermore, local government would prefer a construction company that does not pollute environment. In short, trust enhance profit in construction projects (Cerić, 2016).

However, in spite of all these obvious advantages of ethical behavior, one can find examples of unethical behavior in construction business almost on a daily basis. It is enough just to read newspapers and one will find plentitude of examples in which, construction companies, for example, did not pay their workers. Or, examples in which a company wins a tender in spite of the fact that other company offered much better contract. According to *Construction Sector Transparency Initiative (CoST)*, the value of losses through corruption in construction is, globally, between one and three trillion dollars a year (10 to 30 percent of the value of global construction output). CoST also provide very plausible explanation why the scale of corruption is so high in construction business. They cite 13 important reasons but five of them are the most important ones:

1. Uniqueness: No two construction projects are the same making comparisons difficult and providing opportunities to inflate costs and conceal bribes.
2. Complex transaction chains: The delivery of infrastructure involves many professional disciplines and tradespeople and numerous contractual relationships that make control measures difficult to implement.
3. Work is concealed: Materials and workmanship are often hidden, e.g. steel reinforcing is cast in concrete, masonry is covered with plaster and cables and pipes enclosed in service ducts.
4. Official bureaucracy: Numerous approvals are required from government in the form of licenses and permits at various stages of the delivery cycle, each one providing an opportunity for bribery.
5. The scale of infrastructure investments: Investments in economic infrastructure such as dams, airports and railways can cost tens of billions of dollars making it easier to conceal bribes and inflate claims.

So, why unethical behavior is spread in construction in spite of the fact that, in long term, ethical behavior is more profitable? From the analysis above, it is obvious that one of the most important reasons for unethical behavior in construction, from the standpoint of game theory, is *uniqueness*. Robert Axelrod (2006) explains why it is very important whether one has just one contact with another player, in prisoner's dilemma, or these two people play itinerated games. Let us assume that above mentioned prisoners face possibility for an award instead of prison. For example, they should choose between sharing an award or to take everything for himself/herself. If both players want to share they would get, for example, $5,000. If both want just for himself/herself they would get just $1,000. However, if one says that he/she wants to share and another player says that he/she wants everything for himself/herself this egoist gets $6,000 and another player gets nothing. So, what would be the best answer? If they take into account their common interest, the best strategy is that both of them want to share. Their common award would be, in this case, $10.000. However, from individual standpoint, it is better to demand everything for himself/herself. In this case possible awards are $1.000 or $6,000. If he/she wants to share, possible awards are $ 0 or $ 5,000.

	A wants to share	A wants everything for himself/herself
B wants to share	A $5,000 B $5,000	A $6,000 B $0
B wants everything for himself/herself	A $0, B $ 6,000	A $1,000 B $1,000

So, if this game is played just ones, it is more profitable not to cooperate (to play egoistically). But what if this game is played several times, with same players? Is egoism still the best strategy? The answer on this question is negative. After several repetition of this game, both players would conclude that they earn, together, just $2,000 in every itineration instead of earning $10,000. In this case one may earn more by playing egoistically just if the other player does not retaliate. If first player is always egoist and another always altruist, the first player would earn $6,000 each time and another would earn nothing. However, it is very likely that the second player would stop playing altruistically, seeing that altruism does not bring him/her any award and he/she would, most likely, also start to play egoistically. After several itineration, both would conclude that it is better to cooperate and they would start to play altruistically (following their egoistic interests). In short, itinerated games force egoists to behave altruistically in order to maximize their profits. Accordingly, types of business in which people interact frequently stimulate altruistic behavior. If one has a grocery store with regular customers, it is in his/her interest to be altruistic toward his/her customers. For example, if one regular customer wants to return certain product, it is wise for owner of this grocery store to accept this demand of the customer knowing that, in long run, he would earn much more by satisfying customer's needs than by trying to earn refusing demands of the customer. From the viewpoint of game theory, business in a grocery store is an itinerated game.

In contrast, construction industry is frequently prisoner's dilemma game with just one interaction. Here, as it was explained above, egoism is more profitable than altruism. If one entrepreneur thinks that he/she will build just one house for a certain customer, it might be profitable to spare during the process of building this house in order to decrease the cost and in order to increase the profit from this one project. As a result, the quality of this house could be lower than it is expected. This is especially true if we know that it is relatively easy to conceal work in construction (see point number 3 above). In short, unethical behavior can be profitable more frequently in construction than in other businesses, which is in accordance with the game theory.

There is an additional rational choice explanation for unethical behavior in construction business – the tragedy of commons. According to William Forster Lloyd (1833) this is the situation where individual users acting independently according to their own self-interest behave contrary to the common good. A classic example is situation when cattle herders share a common parcel of land. All herders have interest to use the common land as much as possible because profit from herd would be individual but cost of using the land will be paid by the entire society. As a result, the common parcel could be depleted or even destroyed, to the detriment of the entire society. Similarly, large-scale infrastructural projects are frequently financed by entire society but private companies build this infrastructure. Hence, there are many possibilities for bribe because construction companies can earn a fortune participating in this projects. Furthermore, politicians pay this projects not with their own money but from money collected by taxes. Therefore, they are tempted to take the bribe. Or, to use rational choice theory, their self-interest motivate them to behave contrary to the common goods. Once again, construction industry provides more incentives for unethical behavior than other businesses.

Does it mean that ethical behavior is not profitable in construction? It would be too hastily to make this conclusion. Cerić's book (2016) shows that trust in construction (and trust is based on ethical behavior) increases profit. According to one respondent in the survey for this book,

> reputation is the most important strategy since a contractor with a good reputation to complete the project on time and with minimum problems will definitely minimize the risk for the project owner. It is the same for the contractor. A reputable project manager will definitely be much more predictable for the employers than any other. So the risk is minimized (p. 77).

However, reputation is important in, to use the terminology of the game theory, itinerated games and in situation where it is not possible to take common goods for your own sake. Accordingly, an appropriate legal framework should prevent unethical behavior. In other words, ethical behavior and trust can prevail if cost of unethical behavior becomes too high.

This article is a theoretical analysis of motivation for ethical and unethical behavior in construction business. However, every theory should be empirically tested in order to prove its validity. Recently, we have a plethora of empirical research about corruption in construction. It would be out of the scope of this article to present all works that deal with this topic. Nevertheless, this article will, at the end, present some articles that are connected with the theoretical analysis above, especially those articles that propose some possible solutions that may prevent unethical behavior in construction.

Bowen at al. (2016) analyzed corruption in the South African construction industry, on the basis of an opinion survey of clients and construction professionals, and concluded that corruption is perceived to be widespread, what is in accordance with our prediction based on game theory. Furthermore, the authors found out that government officials (as clients) are most involved in corrupt activities, which is in accordance with the theory of the tragedy of commons. Bowen et al. suggest the inclusion of ethics topics in tertiary education and training curricula as one of the possible remedies for corruption. Patrick Zou (2006) found that corruption is also widespread in construction in China. He concluded that two most important measures for prevention of corruption in construction are development of appropriate organizational culture and severe punishment and prosecution of corrupt personnel, especially personnel that work for state bureaucracy. Finally, Glavinja et al. (2017) found many similarities in patterns of corruption in the United Kingdom and Croatia. Furthermore, more than 90 percent of respondents in Croatia believe in frequent occurrence of corruption in construction. In addition, 70 percent of respondents believe that corruption occurs at the level of local government and 60 percent of respondents claim that corruption also happens on the state authority level which is also in accordance with the rational choice theory (tragedy of commons).

All the articles presented above have one thing in common – they claim that corruption is widespread in construction business almost everywhere in the world. They differ in proposed remedies. Zou (2006) claims that solution is severe punishment for corruption but other authors emphasize more organizational culture and education as remedies. Furthermore, empirical findings in these articles support theoretical analyzes in this article. Simply saying, game theories and rational choice theory help us explain why corruption occurs more frequently in construction than in majority of other branches of economy.

At the end, it is important to present possibilities for further research in this field. This research applies game theory and rational choice theory in explanation of possible causes of widespread corruption in construction but just on theoretical basis. Many articles and books analyze corruption in construction business empirically, checking game theory just indirectly. Some of these works are presented above. However, it might be important to check game theory and rational choice theory in construction business directly. For example, it would be interesting to compare presence of ethical behavior between business partners in construction who have frequent business interactions with presence of ethical behavior in situation where business partners (subcontractors, for example) interact only once. Our hypothesis is that the more business partners interact the higher is probability for ethical behavior. Second, in order to check applicability of "tragedy of commons", it would be interesting to compare probability for ethical behavior when one business partner is state bureaucracy with probability for ethical behavior when both (or all) business partners are private companies. Here, our hypothesis is that unethical behavior is more likely to occur when private companies deal with state bureaucracy (this was one of the arguments for comprehensive privatization of state companies). However, both hypotheses should be checked empirically. The very fact that people try to hide corruption would be the main obstacle for this type of analysis, similarly like in any other type of research about corruption.

5. Conclusion

After presenting theoretical arguments about relationship between business ethics and profit, this article applied game theory for analysis about profitability of ethical behavior in construction business. The main conclusion is that, from the prospective of game theory and rational choice approach, construction business provides more incentives for unethical behavior than majority of other brunches of economy. There are two main reasons for it: uniqueness (reputation is less important in situation when business partners interact only ones) and "tragedy of common", which means that public finance of big infrastructural projects provides many opportunities for bribery. Empirical research should further test these theoretical assumption about applicability of game theory and rational choice approach in the analysis of profitability of ethical behavior in construction.

6. References

Axelrod, R. (2016), The Evolution of Cooperation, Basic Book, New York.

Bowen P., Edwards P. and Cattell K. (2012), "Corruption in the South African construction industry: A mixed methods study", in: Smith, S.D. (Ed), Procs 28th Annual ARCOM Conference, 3-5 September 2012, Edinburgh, UK, Association of Researchers in Construction Management, 521-531.

Cerić A. (2016), Trust in Construction Projects, Routledge, London and New York.

Construction Sector Transparency Initiative (2016), This is why construction is so corrupt, https://www.weforum.org/agenda/2016/02/why-is-the-construction-industry-so-corrupt-and-what-can-we-do-about-it/ (Accessed 3/5/2017).

Freeman, E. E. (2006), "A Stakeholder Theory or the Modern Capitalism", in Jennings, M. M., Business Ethics: Case Studies and Selected Readings, Thomson, Mason, pp. 63-8.

Friedman, M. (2000), "The Social Responsibility of Business is to Increase its Profits", in Dienhart, J. W., Business, Institutions and Ethics: A Text with Cases and Readings, Oxford University Press, Oxford, pp. 233-7.

Glavinja, Cerić A. and Nahod M. (2017), "Corruption in the construction industry: Comparison of survey results in Croatia and in the United Kingdom", CIB 2017.

Jennings, M. M. (2003), "Schools of Thought on Social Responsibility", in Jennings, M. M. (ed.), Business: Its Legal, Ethical and Global Environment, Thomson, Mason, pp. 46-7.

Jones, G. R. (2004), Organizational Theory, Design, and Change: Text and Cases, Pearson Education International, Upper Saddle River.

Lloyd, W. F. (1833), Two lectures on the checks to population, Oxford University, https://archive.org/details/twolecturesonch00lloygoog (Accessed 6/5/2017).

Miller, D.C. and Form, V.H., 1966, Industrijska sociologija, Panorama, Zagreb.

Zou, P. X. W (2006), "Strategies for Minimizing Corruption in the Construction Industry in China", Journal of Construction in Developing Countries, Vol. 11, No. 2. pp. 15-29.

Impact of ERP Systems on Cost Reducing in Construction Project Management in Slovakia

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Abstract:

Currently period is characterized as a period of dynamic progress and expanding use and implementation of information communication technology generally. Data and information requirements in the knowledge society heads grow every day. Several studies suggest that the use of Enterprise Resources Planning systems contributes on cost reducing of project and enterprise management. However, these studies also indicate that their use in small and medium sized enterprises is low. Several surveys have been carried out abroad on this issue. The exploitation of advanced technologies to support management in many enterprises is a priority and one of the main steps and procedures to successfully manage enterprises and projects. Enterprise Resource Planning systems are one of the possible solutions for cost reducing. Article discusses issue of implementation and use of Enterprise Resources Planning in Slovak construction industry from various point of view. The main objective of this article is to confirm impact of implementation and use of Enterprise Resource Planning on cost reducing in construction project management. Enterprise size, enterprise owner, participant of construction project and SK NACE classification present important factors for selection of research groups.

Keywords: *Enterprise Resource Planning systems, cost reducing.*

1. Introduction

The cost reducing of construction companies depends on several factors. A lot of competition, pressure to revenue increasing and wide availability are the merits of the need to address the issue of cost reducing in selected sectors (Radziszewska-Zielina, 2016). This opens up a number of questions how to reduce the cost of companies and what factors affect it. The issue of cost reduction is a very timely topic. The last period is often argued about the impact of innovation in information and communication technologies on the cost reducing of companies, generally. It is very necessary to monitor the impact of these advanced technologies on the cost reducing in construction companies (Zima, 2015). New innovations and trend (for example new ICT tools) support management control (Bleijenbergh, 2015).

Powerful project management software has become a prerequisite to manage the projects more efficiently and effectively, and aid the project managers in their decision-making (Kikoy, 2012). The job does easily, quickly and accurately can constitute a competitive advantage. This

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may also be in the use of technologies for information exchange, document management, and construction project management. Progress of information and communication technologies (ICT) is undeniable in every field. That means hardware and software that contains various essential software, application software and development resources (Thomas, 2007).

The use of ERP systems is wide. There are used by enterprises in various fields, including construction enterprises. Enterprise Resource Planning or ERP is a system that incorporates internal management information with the external management information that covering the sales, accounting and finance, manufacturing and customer care (OECD, 2007). ERP systems in the U.S. rank among the most popular instrument, which can improve business processes. Most companies from Fortune 500, including large construction companies applied ERP systems already in the 90th years of 20 century (Mutesi and Kyakula, 2011). Gradually, small and medium-sized enterprises adopt and accept ERP systems, too.

This topic was subject of research in more publication. But in condition of Slovak construction industry it didn´t. These is purpose of this research. Selected researches in this issue are named in table 1.

Table 1. Review of selected ERP researches

Tittle of publication	*Year of publication*	*Authors*	*Country*
Use of ICT for e-procurement in the UK construction industry: a survey of SMEs readiness	2004	*Wong and Sloan*	*United Kingdom*
Implementation of enterprise resource planning ERP) systems in the construction industry	2003	Ahmed et al.	N/A
Exploitation of semantic web technology in ERP systems	2007	Anjomshoaa et al.	N/A
The Impacts of Enterprise Resource Planning Systems on Firm Performance: An Empirical Analysis of Chinese Chemical Firms	2010	Liu, Miao and Li	China
Promoting the use of ICT in the construction industry: Assessing the factors hindering usage by building constractors in Ghana	2012	*Sekou*	Ghana
The Impact of Enterprise Resource Planning (ERP) System on the Cost and Price of Auditing–Auditor's Perspective	2013	Azaltun et al.	Turkey
The Impact of ERP Systems on Business Decision-Making	2013	Lečić and Kupusinac	Serbia
Impact of enterprise resource planning systems on management accounting	2014	Ponoricá, Al-Saedi and Sadik	N/A
Application of ICT in the construction industry in Kampala.	2014	Mutesi and Kyakula	Kampala
Factors for the acceptance of enterprise resources planning (ERP) systems and financial performance	2015	Bazhair and Sandhu	N/A

Enterprise resource planning systems and the effects on management control	2016	Cuppen	N/A

Ahmed et al. discussed the issue of implementation of ERP systems in construction enterprises. Already in this research, the question has been raised for the first time about the impact of ERP systems on the costs of construction enterprises (Ahmed et al., 2003). Another research discussed about the impact of ERP systems on business performance. Business performance has also addressed the issue of cost reducing. Next researches were talking about impact of ERP systems on decision-making (Lečić and Kupusinac, 2013). Enterprise resource planning systems and its impact on management accounting are described by other authors (Ponoricá et al, 2014). Vice versa, next research shown the impact of financial performance on ERP systems (Bazhir and Sandhu, 2015). What is the impact of ERP systems also solved another survey conducted in Turkey (Azaltun et al., 2013). However, any of these studies directly discussed the impact of ERP systems on cost reducing in construction project management. No research has been found to investigate the issue in Slovakia in the detailed investigation of other sources. Therefore, the question arises: What is impact of ERP systems on cost reducing in construction project management in Slovakia? And what are differences between differently research group by enterprise size, enterprise owner, participant of construction project and other.

2. Methodology and aims of research

1.1 Research questions and aims

The research issue is based on several, mainly foreign sources and studies. Based on the evaluation of the current state mostly abroad it was set basic research questions and the research conducted in Slovakia. Their version is as follows:

- What is impact of ERP systems on cost reducing in construction project management in Slovakia?

- What are the differences based on some groups companies divided for impact of ERP systems on cost reducing?

Based on the determination of research questions have been set research aims. The main aim of this research was confirming the claim that ERP systems have an impact on the cost reducing in Slovak construction companies. Another aim of this paper was confirming different exploitation impact of ERP systems between research group divided by factors like enterprise size, enterprise owner, participant of construction project and SK NACE classification. Other words, previously factors (company size, company owner, participant of construction project and SK NACE classification) have an impact on cost reducing of Slovak construction companies.

1.2 Data collection and research sample

Data collection was conducted by the questionnaire. Questionnaire was designed and distributed in electronic form. Questionnaire was produced by online platform FORMEES in electronic form. The research sample was approached by e-mail with the request to participate in the research. Total were interviewed 1276 of respondents (construction companies in Slovakia). It participated in the questionnaire survey 85 respondents. It represents a return of 6.66%. Generally, it is possible to return to the level of 4.31% is considered as good.

The questionnaire questions are provided in the appendix. There are selected questions for this research of hypotheses. There are partial research questions and results of one major research focusing on the use of ICT in Slovak construction industry and its impact on cost reducing.

Research sample represents research group divided by choose factors like company size, enterprise owner, participant of construction project and SK NACE classification. The most important divided is according to company size. The company size is probably the most important factor from view of ERP exploitation.

Table 2. Research sample

	Number of respondents	**Respondents in %**
Divided according to company size		
Large enterprises	7	8.24%
Medium sized enterprises	23	27.06%
Small enterprises	27	31.76%
Microenterprises	28	32.94%
Divided according to participant of construction project		
Main contractor	31	36.47%
Sub-contractor	23	27.06%
Investor/developer	12	14.12%
Designer	19	22.35%

1.3 Data processing and research hypotheses

Achieved data were evaluated based on several statistical methods through software MS Excel and STATISTICA version 12. Due to the nature of the problem and the main aim of the paper it was selected appropriate statistical methods that can detect and analyses relationships between research groups - Kruskal-Wallis test. Arithmetic average of the selected areas, we get peace. To determine the answer was used "Likert scale ranging" from 1 to 5 on the basis of fixed values has been done the arithmetic average of the values for the selected area under consideration. It means cost reducing in construction companies. 1 - is very low level of cost reducing and 5 - is the very high level of cost reducing. Research of exploitation was done in similar principle. That means it used Likert scale for level of exploitation (exploitation rate) in construction companies (1 - very low impact rate and 5 - The highest impact rate or level). . This data was comparison with companies that they use ERP systems and companies don't use ERP systems. Based on research issue, foreign studies, research questions, it was set hypotheses.

$H1_1$: ERP systems have significant impact on cost reducing in construction project management.

That means, that companies with extremely used ERP systems achieve higher value (more than 3.5) and this claims will be confirmed by Kruskal- Wallis test. Cost reducing in construction companies used ERP system is higher, like construction companies don't used ERP system.

In contrast, the hypothesis is constructed as follows:

$H1_0$: ERP systems don't have significant impact on cost reducing in construction project management.

Next hypotheses are extended this main hypothesis about some factors as enterprise size, enterprise owner, participant of construction project and SK NACE classification and differences between them.

$H2_1$: The use of ERP systems has a significant impact on cost reducing in construction project management in differences from company size.

$H3_1$: The use of ERP systems has a significant impact on cost reducing in construction project management in differences from company owner.

$H4_1$: The use of ERP systems has a significant impact on cost reducing in construction project management in differences from participant of construction project.

$H5_1$: The use of ERP systems has a significant impact on cost reducing in construction project management in differences from SK NACE classification.

On the other hand, it was set following hypotheses:

$H2_0$: The use of ERP systems don't has a significant impact on cost reducing in construction project management in differences from company size.

$H3_0$: The use of ERP systems don't has a significant impact on cost reducing in construction project management in differences from company owner.

$H4_0$: The use of ERP systems don't has a significant impact on cost reducing in construction project management in differences from participant of construction project.

$H5_0$: The use of ERP systems don't has a significant impact on cost reducing in construction project management in differences from SK NACE classification.

3. Results and discussion

The advantages of ERP systems are indisputable. Their implementation is on the rise for the last period. Their benefits are often a topic for discussion. What are the benefits of ERP systems for construction companies or construction project management? What is the most important from an economic point of view for construction project management? According to our other researches and results from them, one of the most important advantage of using ERP it is cost reducing. The question is follow: Do ERP systems have significant impact on cost reducing in construction project management? And how much is this impact? It was the subject of hypotheses 1. Level of cost reducing is in results (Figure 1).

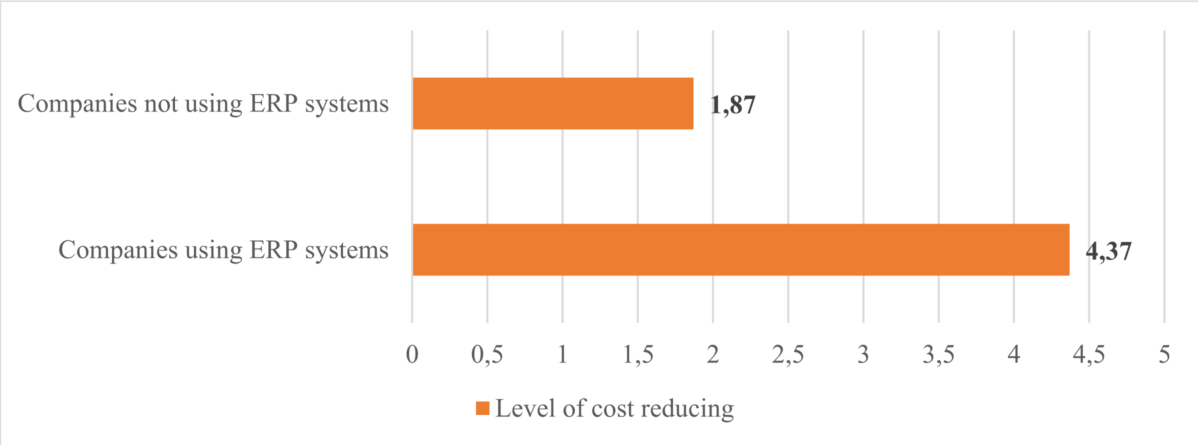

Figure 1. Level of cost reducing in construction project management in Slovakia

In a research group, where companies are using ERP systems in construction project management permanently, it achieved level of cost reducing at 4.37. It means very high level and it confirms the importance of using ERP systems in construction project management. On the contrary, companies aren´t using ERP systems achieved level of cost reducing only at 1,87, what represents very low effect. The final statement, that ERP systems have significant impact on cost reducing in construction project management was confirmed by Kruskal-Wallis test. This test shown the differences in the results between the individual research groups and based on the statistical significance of 0.05 and the probability $p = 0.0136$ we can confirm the hypothesis 1: ERP systems have significant impact on cost reducing in construction project management.

Next research questions are about quantifying impact of ERP systems on cost reducing in differences groups. The point of view was set based on company size, company owner, participant of construction project and SK NACE classification.

Degree of impact (impact rate) of ERP systems on cost reducing for construction project management in large companies is 3.79 (Figure 2). It represents a significant impact. Medium-sized enterprises recorded the impact of ERP systems on cost reducing for construction project management at the level of 3.39. Small enterprises achieved value of impact rate at 2.99 and micro-enterprises achieved value of impact rate only 2.62. ERP systems are used mainly in large companies. The reason of this statement it can be fact that ERP systems demands a lot of finances for implementing.

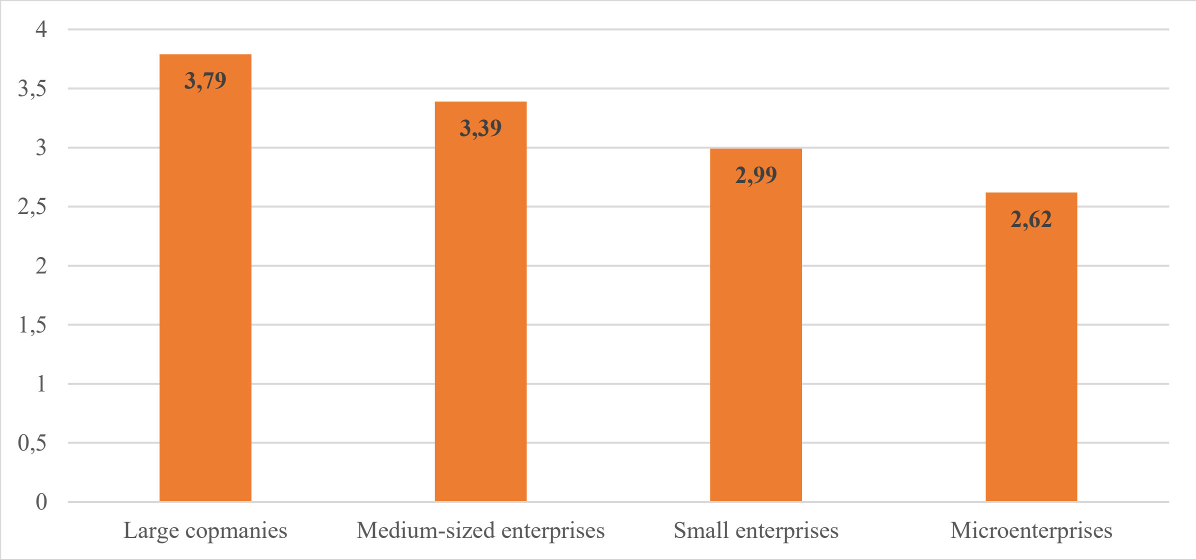

Figure 2. Impact rate of using ERP systems on cost reducing (divided based on company size)

Table 3 describes the Kruskal - Wallis test for statistical significance examining the impact of ERP systems to cost reducing in differences from the company size. ERP systems to achieve the above-mentioned test, p = 0.0246. Based on these results, in all study areas it confirms the statistical significance, and therefore may be a confidence level of α = 0.05 to accept the hypothesis $H2_1$: The use of ERP systems has a significant impact on cost reducing in construction project management in differences from company size.

Impact level of ERP system to cost reducing reached value 3.69 for construction companies used foreign private equity (Figure 3). Compared to the enterprises using solely on Slovak private capital to represent a significant difference. Value if impact level in construction companies using foreign capital represents a significant impact on cost reducing. It was again confirmed impact of foreign capital and pressure of management to adopt and implementation of new ICT and upgrade efforts to automate routine processes and thus effectively cost reduce construction project management.

Figure 3. Impact rate of using ERP systems on cost reducing (divided based on company owner)

Table 3 describes the Kruskal - Wallis test for statistical significance examining the impact of ERP systems to cost reducing in differences from the company owner or using of foreign private equity. ERP systems to achieve the above-mentioned test, $p = 0.0413$. Based on these results, in all study areas it confirms the statistical significance, and therefore may be a confidence level of $\alpha = 0.05$ to accept the hypothesis $H3_1$: The use of ERP systems has a significant impact on cost reducing in construction project management in differences from company owner.

The biggest impact level of ERP systems to cost reducing in construction project management in Slovakia achieved investors and this value was 3.47. This value is not significant. Other participants achieved lower values of impact level to cost reducing. Designers achieved value of impact level of ERP system using to cost reducing at 3.33 and sub-contractor only 2.93. The lowest value achieved main-contractor, only 2.87.

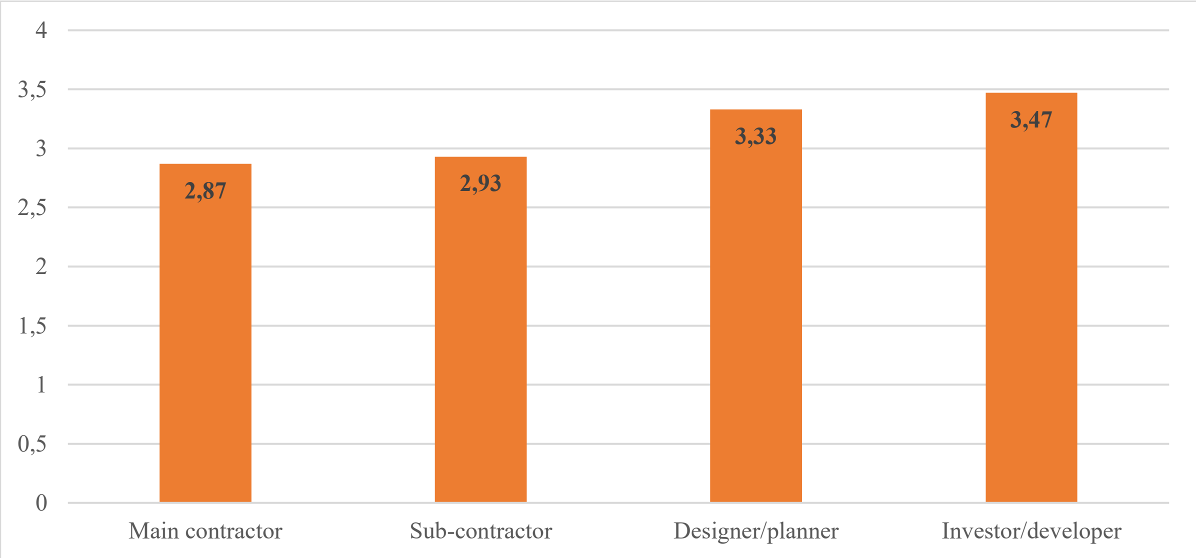

Figure 4. Impact rate of using ERP systems on cost reducing (divided based on participant of construction project)

Table 3 describes the Kruskal - Wallis test for statistical significance examining the impact of ERP systems to cost reducing in differences from participant of construction project. ERP systems to achieve the above-mentioned test, $p = 0.5618$. No value has not exceeded the level of impact to cost reducing divided of the research group, according participant of construction project in Slovakia over 3.5. Based on these facts it shows that in all tested areas it cannot be confirmed the statistical significance confidence level of $\alpha = 0.05$ and it hypothesis $H4_1$ is rejected to reject. Therefore, accepted is hypothesis $H4_0$: The use of ERP systems don't has a significant impact on cost reducing in construction project management in differences from participant of construction project.

Similar situation is in results based on divided according to SK NACE classification. The highest impact on cost reducing achieved group of engineering buildings. It represented 3.54 impact level. Building construction achieved impact rate only 2.76, it means lowest impact. Specialized construction works achieved impact rate 3.13.

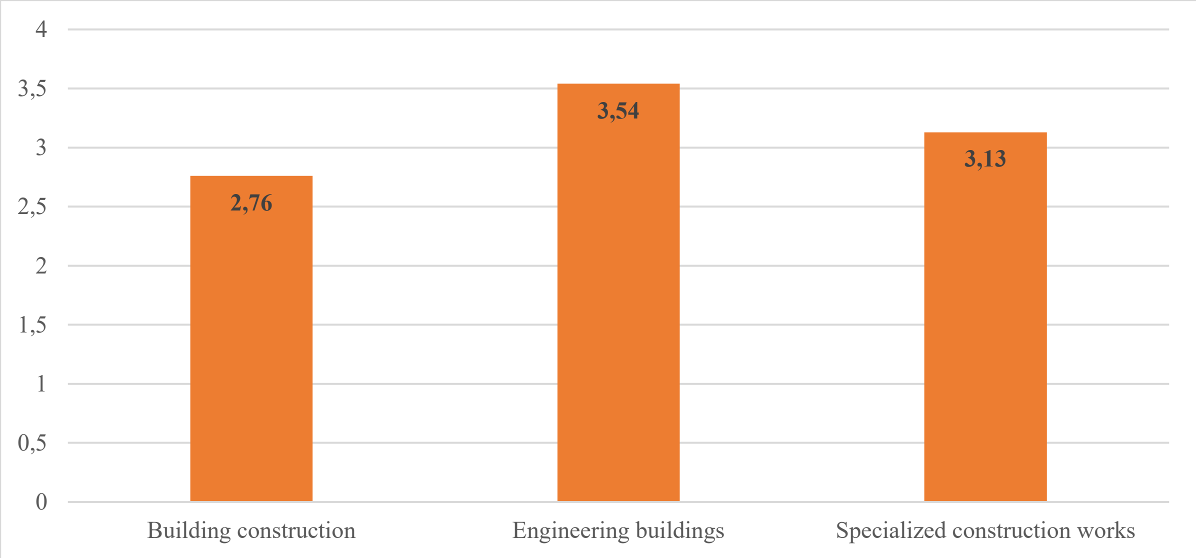

Figure 5. Impact rate of using ERP systems on cost reducing (divided based on SK NACE classification)

Based on Kruskal-Wallis test, where p= 0,1895 I is not possible confirmed $H5_0$, The use of ERP systems don't has a significant impact on cost reducing in construction project management in differences from SK NACE classification. Vice versa, we can confirmed $H5_0$:The use of ERP systems don't has a significant impact on cost reducing in construction project management in differences from SK NACE classification.

Next table presents results of all Kruskal-Wallis tests for all hypotheses and final statement of acceptance or rejection. From 5 hypotheses was confirmed three. Last two hypotheses were rejected, because based on Kruskal-Wallis test it was not confirmed these statements.

Table 3. Final results of Kruskal-Wallis tests

Hypotheses	*Factor*	*K-W Anova (p)*	*Acceptance/rejection*
$H1_1$: ERP systems have significant impact on cost reducing in construction project management	Use or not ERP		**Accepted**
$H2_1$: The use of ERP systems has a significant impact on cost reducing in construction project management in differences from company size	Company size	0.0346	**Accepted**
$H3_1$: The use of ERP systems has a significant impact on cost reducing in construction project management in differences from company owner	Company owner	0.0413	**Accepted**
$H4_1$: The use of ERP systems has a significant impact on cost reducing in construction project management in differences from participant of construction project	Participant of construction project	0.5618	Rejected
$H5_1$: The use of ERP systems has a significant impact on cost reducing in construction project management in differences from SK NACE classification	SK NACE classification	0.1895	Rejected

Research shown that ERP system has a significant impact on cost reducing in construction project management. Results of research indicates differences between research group based enterprise size and owner on cost reducing in construction project management. It's logical, because based on more other own research large enterprise invests more financial resources like medium-sized and small enterprises. Enterprise owner recorded the same results in breakdown of research sample. Impact of foreign private equity and abroad know-how is significant for implementation of ERP systems. Pressure from foreign owner to implement new ICT tool is generally. It is probably reason, why it is so big differences between these groups. The most important finding is about generally impact of ERP systems on cost reducing in construction project management. Every construction enterprises in Slovakia confirm higher level of cost reducing after implementation of ERP system. In comparison results before and after implementation, it's clear shown differences value of impact rate. In discussion with more managers in these enterprises, they confirm hypothesis, that implementation of ERP system it's main reason of cost reducing in contraction project management too. Vice versa, last two hypotheses were not confirmed. Probably SK NACE classification and participant of construction project are not significant factors for implementation a exploitation of ERP system and it's reason, why results of impact of ERP system are not so clear and different.

4. Conclusion

The issue of ERP systems is very actual topic. Using ERP systems in construction project management increasing and pressure on construction companies to implementing these systems is relatively high. This research shown impact these tools on cost reducing, what presents one of the biggest advantage of ERP system. Based on research results and Kruskal- Wallis tests were accepted three from five hypotheses. ERP systems have significant impact on cost reducing in construction project management, the use of ERP systems has a significant impact on cost reducing in construction project management in differences from company size and the use of ERP systems has a significant impact on cost reducing in construction project management in differences from company owner. On the other site, Kruskal-Wallis test didn´t confirm two hypotheses and these hypotheses were rejected. There are hypothesis 4 and 5. These results shown importance of ERP using in construction project management. ERP systems have significant impact on cost reducing. All construction companies achieved cost reducing after implementation of ERP system. Cost reducing level in companies using ERP was higher than companies not using ERP. Next both factors were confirmed. Company size and company owner. Research group divided by these factors shown differences in impact rates on cost reducing. This statement was confirmed by Kruskal-Wallis test in both cases. Vice versa, participant of construction project and SK NACE classification are not very important for level of Impact on cost reducing. These research were different impact rates, but Kruskal-Wallis didn´t confirm this results with statistical significant more than 5 %. Form these reason, it didn´t possible accepted these hypotheses. Generally, ERP systems are very important and their impact on cost reducing is significance in construction project management. As important factor for results are company size and owner. Participant of construction project and other are not very important, but their impact were not confirmed.

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References

Ahmed S.M., et al. (2003) "Implementation of enterprise resource planning ERP) systems in the construction industry" Construction Research Congress 2003

Anjomshoaa, A. et al. (2007), " Exploitation of semantic web technology in ERP systems", 2007

Azaltun M., et al. (2013), "The Impact of Enterprise Resource Planning (ERP) System on the Cost and Price of Auditing–Auditor’s Perspective", Journal of modern accounting and auditting, 2013, vol. 9., no. 4, pp. 497-504

Bazhair, A. and Sandhu, K. (2015), "Factors for the acceptance of enterprise resource planning (ERP) systems and financial performance", Journal of Economics, Business and Management, 2015, Vol. 3, No. 1, pp. 1-10

Bleijenbergh, I. (2015). "Kwalitatief onderzoek in organisatie "(2nd edition). Den Haag: Boom Uitgevers, 2015

Cuppen, J. (2016), "Enterprise resource planning systems" 2016

Kikoy. H. (2012), "What is an ERP software and how can it help your business. 2012 [on-line], Available: http://www.herbertkikoy.info/2012/05/erp-software-and-your-business/

Kruskal; Wallis. "Use of ranks in one-criterion variance analysis.", Journal of the American Statistical Association. vol. 47 (260), pp. 583–621

Lečić, D. and Kupusinac, A. (2013), "The impact of ERP systems on business decision-making", TEM Journal, 2013, Vol. 2, No. 4, pp. 323-326

Lee. S. and Yu. J.H. (2012) “Success model of project management information system in construction” ,Automation in construction. 2012, pp. 82-93

Liu, L., Miao, R. and Li, C. (2010), "The Impacts of Enterprise Resource Planning Systems on Firm Performance: An Empirical Analysis of Chinese Chemical Firms"

Markechová, D., Tirpáková, A., and Stehlíková, B. (2011), "Základy štatistiky pre pedagógov", UKF Nitra, 2011, ISBN 978-80-8094-899-3

Mesároš. P. (2013) “Manažment znalsotí v praxi slovenských stavebných podnikov”, Košice: VÚSI, spol. s r.o. 2013. 182.s. ISBN 978-80-89383-28-3

Mutesi, E.D. and Kyakula, M. (2011), "Application of ICT in the construction industry in Kampala", Second International Conference on Advances in Engineering and Technology. 2011. pp. 263-269

Mutesi, E.T. and Kyakula, M. (2014), "Application of ICT in the construction industry in Kampala" Second International Conference on Advances in Engineering and Technology. 2014. Vol. 2. pp. 263-269

OECD Organization For Economic Co–Operation and Development (1997), "Main economic indicators – Sources and methods: labour and wage statsitics. Paris : OECD Publishing, 1997. 72. p.

Ponoricá, A.G., Al-Saedi, A.H.J. and Sadik, H.H. (2014), "The impact of enterprise resource planning systems on management accounting", 2014

Sekou, E.A. (2012), "Promoting the use of ICT in the construction industry: Assessing the factors hindering usage by building constractors in Ghana", 2012

Thomas, W. S. (2007), "Achieving success through adoption of prise resource planning (A quantitative analysis of sap users in North and South America)", California: ProQuest Information and Learning Company, 2007, ISBN 48106-1346

Wong, C.H. and Sloan, B. (2004), " Use of ICT for e-procurement in the UK construction industry: a survey of SMEs readiness", 20th Annual ARCOM Conference, 2004, Vol. 1, pp. 620-8.

Zima, K. (2015), "The use of fuzzy case-based reasoning in estimating costs in the early phase of the construction project.", AIP Conference Proceedings. 2015, Vol. 1648, ISBN: 978-073541287-3 333333333

Appendix

Structure and questions in questionnaire:

Generally information:

1. How big is your construction enterprise?

a.) Large enterprise (more than 250 employees)

b.) Medium-sized enterprise (50 - 249 employees)

c.) Small enterprise (10 - 49 employees)

d.) Microenterpise (0 - 9 employees)

2. Does your company have some foreign owner? (In other words, does your construction company use foreign private equity or know-how?)

a.) No, my company uses only Slovak private equity (only Slovak owner)

b.) Yes, my company uses foreign private equity (not only Slovak owner)

3. What are you mainly participant of construction project?

a.) Main contractor

b.) Sub-contractor

c.) Investor/developer

d.) Designer

4. What is your NACE classification number?

Research information

Please, in all answers select values from 1 to 5, where 1 means a minimal effect - low level of cost savings and 5 means the maximum level of cost savings.

1. What is your level of cost reducing in your construction company now?

2. What was your level of cost reducing in your construction enterprise before implementing of ERP systems? (It answers only construction enterprise that implemented ERP systems)

The Application of Design Science Approach to AEC Research

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Abstract:

There is relatively little engagement between research and the AEC industry to improve research impact on the society. Design Science Research (DSR) approach offers a better alternative to the traditional behavioral science research paradigm commonly used in the AEC disciplines employing quantitative and qualitative methods. DSR approach can connect real world problems with research processes by creating new and innovative artifacts that have a purpose and utility. There is no established framework for applying Design Science in AEC and the analysis of how existing DSR frameworks are feasible for AEC is considered a gap in knowledge. The aim of this article is to analyze, from a theoretical viewpoint, the existing DSR frameworks in the IS field; and systematically examine their applicability in AEC discipline research. The analysis is complemented with an AEC case example in which DSR has been applied to develop an ex-post evaluation tool for Public-Private Partnership projects (PPP). The use of DSR results in a tool that is designed by the researchers, tested using experts' inputs, and applied in real PPP projects. The article is significant because it provides to AEC researchers a framework that can be used to conduct DSR. It concludes that IS DSR is applicable to AEC and can impact its research by changing the trend of the current research themes and by creating research studies that, from their conceptualization, are intended to solve a real problem in the industry.

Keywords: *AEC; DSR; design science; research, ex-post evaluation; project management; public-private partnership; information system.*

1. Introduction

In Architecture, Engineering and Construction (AEC) field, there is relatively little engagement between research and the industry to improve research impact on society. According to Leiringer and Dainty (2017) AEC research lacks problem-solving studies with the dominance of perception studies, especially in recent years. Design science approach is presented here as a new way of doing research that can better connect the academia with the needs of the AEC industry.

The design science (DS) approach is based on the seminal work of Simon (1969) "the science of the artificial". He argues that science can be separated into two main forms: (1)

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Understanding nature or the behavior of nature, and (2) designing artifacts that can change nature. Physics and biology, among others, are "natural sciences" disciplines because their main concern is about "truth" and "necessity" (Hill, 2009). In contrast, artificial sciences such as engineering, medicine, law, architecture, and business concerns "usefulness" and "contingency". Design science research (DSR) offers a better approach for connecting real world problems with research process by creating new and innovative artifacts that have a purpose and utility for the end users. DSR has the clear objective of solving an existing problem by employing essentially a design and evaluation cycle to search for the solution.

While the existing frameworks for performing DS research are specifically developed for certain disciplines, the theoretical foundations of DS, developed by Simon (1969), are applicable to all kind of research disciplines. One of the main structured bodies of knowledge developed for applying and employing DS is in the Information System (IS) discipline. Hevner, March, Park, and Ram (2004) proposed a methodology for DS research (DSR) in the IS field, using the essential conceptualization of Simon (1969). That article is considered a starting point for the creation of a DSR branch within the IS field.

In AEC, the design concept is well employed and known; design science has been used to perform research (Voordijk, 2009); and in technological themes (i.e. BIM) AEC is combined with other "design disciplines" such as Information Systems (IS) and Computer Science. However there is no established framework for applying Design Science in AEC. The use of DSR is relatively little when compared with the IS field. The analysis of how existing DS frameworks are feasible for AEC and what are their limitations is considered a gap in knowledge. Therefore, the aim of this article is to analyze, from a theoretical viewpoint, the existing DSR frameworks in the IS field; and examine their applicability in AEC discipline research. The analysis is complemented with an AEC case example in which is currently being applied.

2. Methodology and Structure

The analysis of the literature is conducted using an inductive process (Johanson & Williamson, 2013) to develop an argument by combining and contrasting existing theory with logic and practice. This leads to a reflective process for proposing how a DSR theoretical framework in the IS field can be applied to AEC context. The literature search was done using a combination of keyword search and non-systematic snowball approach starting on existing Design Science general reviews.

The article has three main sections apart from the introduction, methodology and structure, discussion, and conclusion. The first section analyses five themes of IS DSR frameworks and assess the possibility of extending the use of the frameworks to AEC field. The second section describes an AEC case example in which DSR is currently being applied. The research case example is the design of an "ex-post evaluation tool for public-private partnership projects". The third section assesses the preliminary results of the research case example.

3. Design Science Frameworks: An analysis

Design Science is employed in many disciplines, such as education, management, engineering, medicine, law, and information systems (Aken, 2004). However DSR in Information systems is very well developed, providing structured frameworks to guide the research process. These frameworks can be divided into five themes:

- Definition of artifact
- Hevner's (2004) IS DSR framework as an iterative process
- Peffer's (2007) IS design science methodology
- Hevner's (2004) IS design science guidelines
- Gregor and Hevner's (2013) DSR contribution framework

These themes are analysed to determine their applicability to AEC field. A summary of the analysis is presented in Table 2 (discussion section).

3.1 Theme 1: Definition of artifact

The term artifact refers to a creation that is made by humans, and therefore is considered artificial. This is opposite to something that occurs naturally (Simon, 1996). The artifact should provide a solution to an existing problem in the real world, but also it should solve the problem in an efficient manner providing utility to the user (Hevner and Chatterjee, 2010, p. 2). March and Smith (1995) defined artifacts as:

- Constructs (vocabulary and symbols)
- Models (abstractions and representations)
- Methods (algorithms and practices)
- Instantiations (implemented and prototype systems)

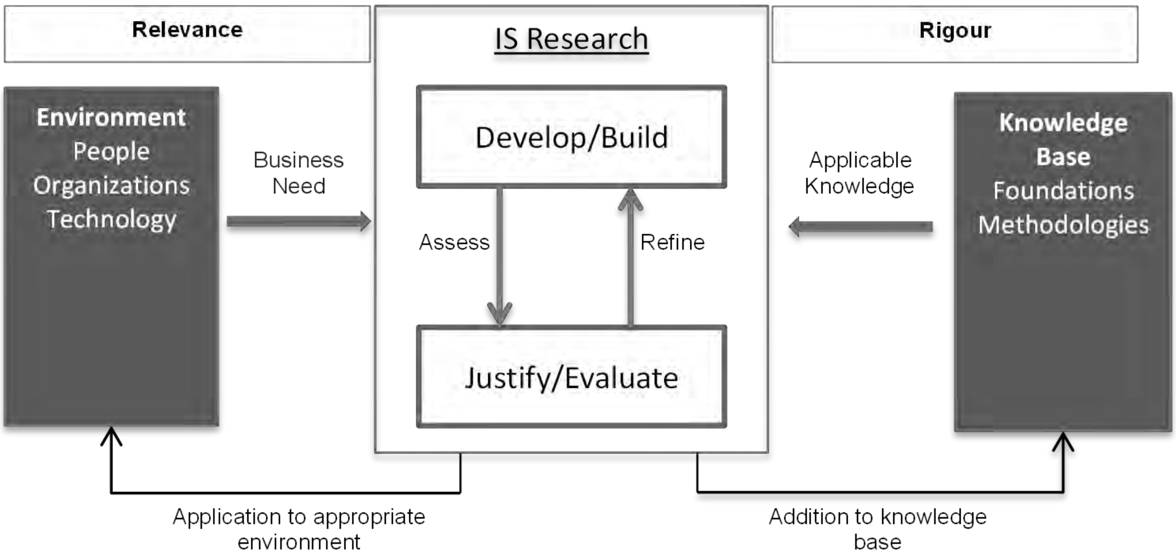
The different kind of artifacts, described mainly for IS are considered not exclusive of the IS field. Several artifacts can be found in the literature for each of the descriptions, even though they were not a result of a DSR process. "Technical drawing" is a set of vocabulary and symbols created to communicate ideas; it can be defined as a construct. "Porter's five forces" for strategic planning is an abstract model that supports decision making. Critical path method is the starting point of the project management discipline; therefore, essentially an artifact. And the "concrete conveyor" is undoubtly an artifact that is implemented in the construction industry. All of the provided forms and examples of artifacts have the following characteristics (1) are artificial (human made), (2) solve an existing problem in the real world, and (3) provide utility in an efficient manner to the user. Consistent with Simon, they can be characterized in terms of function, goal, and how they adapt to the environment.

3.2 Theme 2: Hevner et al. (2004) IS DSR Framework as an iterative process

Hevner et al. (2004), based on March and Smith (1995), state that the basic process of design science is the iteration between a develop/build process and a justify/evaluate process (Figure 1). The build/develop process has the aim of developing an artifact based (1) on a business need (that comes from the environment), and (2) on existing knowledge that can be applied to the new design. The 'justify/evaluate' process assesses what was done in the built/develop process, completing the iteration. After a number of iterations the research present two main outcomes: (1) solve the problem originated in the environment (making the research to be relevant); and (2) contribute to the existing knowledge base, requiring the research to be rigorous (differing from a pure design process).

Even though Hevner et al. framework is developed for IS research, none of the components of the framework are exclusive to the IS field. However, to apply it to AEC, two changes must be considered. First, "nature" must be added to the environment, expanding the spectrum of possibilities in which artifacts can solve problems (i.e. infrastructure to solve desertification impacts or an engineering method to address a natural disaster). Second, assuming that a "business" is a kind of organization, "business needs" should be replaced by "organization's needs"; representing not only businesses, but any kind of organization made by one or more people, public, private, or non-profit.

Figure 1: DSR framework for Information System (Adapted from Hevner et al., 2004)



3.3 Theme 3: Peffers at al. (2007) IS design science methodology

Peffers, Tuunanen, Rothenberger, and Chatterjee (2007) proposed a structured methodology for performing DSR in IS field. It includes six steps: (1) problem identification and motivation, (2) definition of the objectives for a solution, (3) design, and development, (4) demonstration, (5) evaluation, and (6) communication.

Even though the framework was made for IS, the six steps are considered very general and with no specific focus on IS field. Steps 1 and 2 are identical to any behavioral approach. Steps 3, 4, 5 and 6 are limited to design science, but they are not exclusive to IS.

3.4 Theme 4: Hevner's (2004) design science guidelines

Hevner et al. (2004) proposed seven guidelines which are meant to help the DS research process in the IS field. However, each guideline can be applied to AEC disciplines.

<u>Guideline 1 - Design as an artifact:</u> DSR should produce a viable artifact that solves a real problem from the environment.

<u>Guideline 2 - Problem relevance:</u> The relevance of the problem is related to the community (organization) that has the need. In IS, it is the community of practitioners which need IT solutions for their problems. The underlined principle for determining the relevance is the assessment of the utility of the solved problem and the comparison with the cost or the opportunity cost of solving it. In other words, a problem is relevant in AEC when (within other requirements) it has a good cost/benefit ratio for the problem-owner.

Guideline 3 - Design evaluation: The evaluation of artifacts, according to Hevner, must be rigorous in terms of quality, utility, and efficacy; using evaluation methods to demonstrate those attributes. As an artifact that will be used in the real world, appropriate metrics should be considered to evaluate it. The description of the evaluation process and the methods are not considered to be limited to IS field and can be applied to any artifact that is created in any research field.

Guideline 4 - Research contribution: Three contributions of DSR for IS have been identified: (1) the artifact that solves the identified problem, (2) the contribution of the theory that was invented or adapted, forming the basis of the artifact, and (3) the contribution of new methodologies that were employed to design or to evaluate the artifact. DSR in AEC can also contribute with artifacts to solve a problem, formulate theory to contribute to AEC field as well as develop and validate methodologies that can be used in the AEC domain.

Guideline 5 - Research rigor: Rigor in behavioral sciences refers mainly to data collection and analysis techniques. In design science it refers to the formalism that describes the design of the artifact and the evaluation methods. The scientific rigor is applicable and relevant to AEC research.

Guideline 6 - Design as search: The iterative process is the essence of design science and is defined by Simon (1996) as a Generate/Test cycle. Applicable to AEC, Hevner's framework of DSR is explained as a search for alternatives, testing them against the laws and constrains that characterize the problem.

Guideline 7 - Communication of research: In IS, the communication of the research should be done to two audiences: technological and management. The former is interested in the process of designing the artifact, while the latter is interested in the cost/benefit analysis in order to build or purchase the artifact. To apply guideline 7 to AEC, technological audience can be replaced by a generic "design-oriented" audience; and management audience can be generalized to "user-oriented" audience.

3.5 Theme 5: Gregor and Hevner's (2013) DSR contribution Framework

The contribution to knowledge of a DSR project depends on the type of artifact developed. Gregor and Hevner (2013) state that DSR should have artifacts at different levels, from an instrument that solves a specific problem, to an abstract theory that supports the development of that instrument and also other future artifacts that can solve similar problems. They also analyzed the contribution in terms of solution maturity and application domain maturity recognizing four types of contributions: Routine design, improvement, exaptation (adaptation), and invention.

Gregor and Hevner (2013) discussed the contribution of DSR without restricting it to IS. However all the examples provided are from the IS field. Nevertheless, the theory can be applied to AEC.

After the review of the five themes of IS DSR, a case study is now presented describing the DSR application in the AEC field.

4. Example: Ex-post evaluation tool for public-private partnership projects

An ex-post evaluation tool for public-private partnership projects is an artifact in the AEC field, and in the public policy domain. The tool has been developed using a design science approach and it will be described employing Peffer's et al. (2007) methodology for DSR. This methodology is consistent with AEC field and involves 6 steps: (1) problem identification and motivation, (2) definition of the objectives for a solution, (3) design, and development, (4) demonstration, (5) evaluation, and (6) communication.

4.1 Problem identification and motivation

Public-private partnership (PPP) model of procurement is a way to deliver public infrastructure using private funding and managing risk for public purposes.

From a taxpayer point of view, the impact of PPP projects, like any kind of public investment, should be assessed and analyzed; especially if a private company is making profit with it. One relevant instrument to protect the taxpayers' interest is an ex-post evaluation. The difficulty of evaluating PPPs is due to (1) the mix of stakeholder's interests and power (2) the time frame (25+ year contracts) and (3) the political and ideological frame (public interest). Despite the difficulties, an impact assessment is relevant in PPPs because (1) future PPPs can be improved through the generations of lessons learn from existing PPP projects; and (2) the outcome of PPP assessment can contribute to the discourse in practice and academia about the use of PPPs as a procurement method.

The problem to be addressed by this research is the lack of a method to assess the impact of the delivery and the outcome of a social infrastructure PPP project on stakeholders. The arguments that support the problem are (1) the existing criticism of PPPs about their performance for achieving public welfare; (2) the nonexistence of a PPP ex-post evaluation method, and (3) the existing gap in knowledge regarding the use of project success framework as a basis for PPP impact evaluation.

4.2 Definition of the objectives for a solution

To solve the problem, an ex-post evaluation tool that can assess, specifically, PPPs must be designed.

The research question is: How can the impact of a social infrastructure public-private partnership project on stakeholders be assessed ex post?

The objective of the research is to apply the theory of project success as a basis for evaluating a PPP, and create a systematic procedure to gather and analyze the impact of a PPP project from multiple perspectives.

4.3 Design and Development of the tool

An extensive literature review in fields of project management, performance measurement systems, public-private partnerships, evaluation theory, and public policy has been done. According to Gregor and Hevner (2013), to start a DSR the first question to answer is what do we know already? From what existing knowledge can we draw?

The research has four main stages: (1) development stage, (2) prototype stage, (3) testing stage and (4) validation stage (Figure 2). Each stage has a 'develop/build' process and a 'justify/evaluate' process (from Design Science approach in Figure 1).

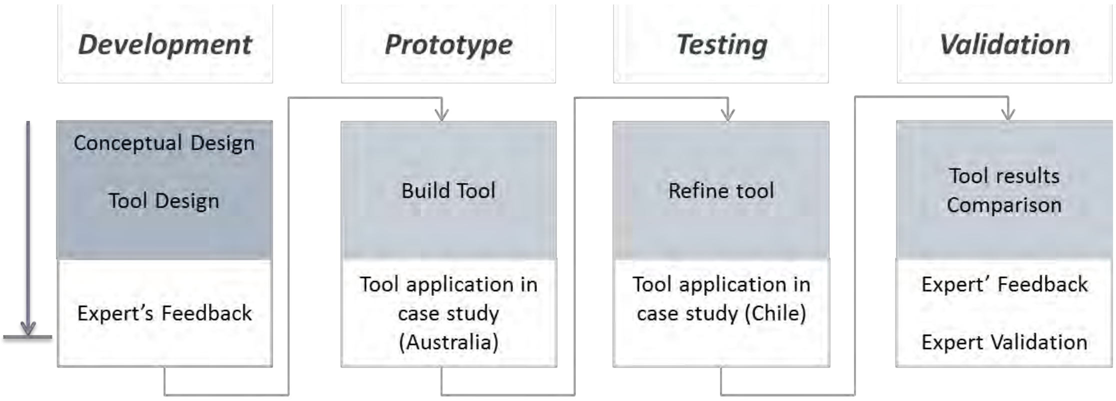


Figure 2: PPP Ex-post evaluation tool Research Strategy

The first proposed artifact is a conceptual framework called Project Success Evaluation Pyramid Model (PSEPM) as a basis for developing the PPP evaluation tool (figure 3). The design is grounded on the project management discipline and the project success concept; a project will be successful if all the stakeholders' expectations are met. With this definition as a starting point, the conceptual framework argues that there is a big spectrum of success criteria from each specific stakeholder by which they make their own judgments about the project. Therefore, it is necessary to employ a set of principles to converge the multiple perspectives.

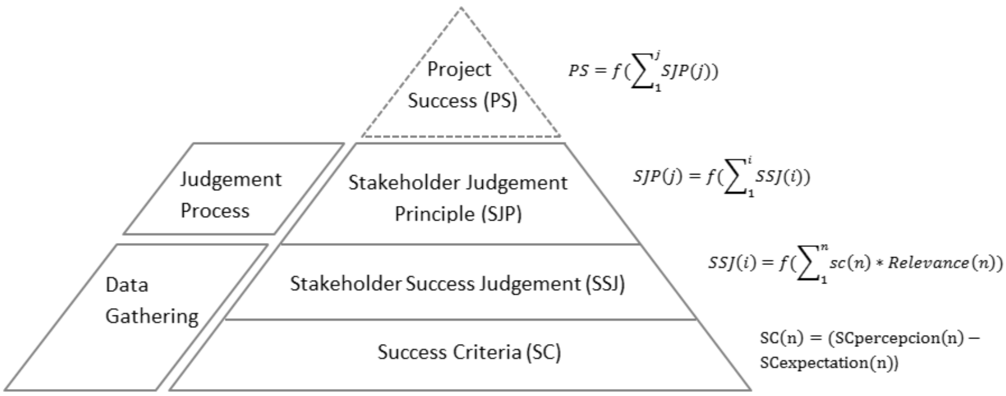


Figure 3: Project Success Evaluation Pyramid Model (PSEPM) (Author's)

Based on the development of the conceptual framework (PSEPM), the evaluation tool architecture has been designed. The tool is a 9 steps procedure, specifically for infrastructure PPP projects, to be followed by the stakeholder interested in performing an ex-post impact evaluation (figure 4). This approach is new and different from existing evaluation methods, which have the pattern of including only the criteria that concerns the evaluation team, without addressing, in a systematic way, the complexity of PPPs.

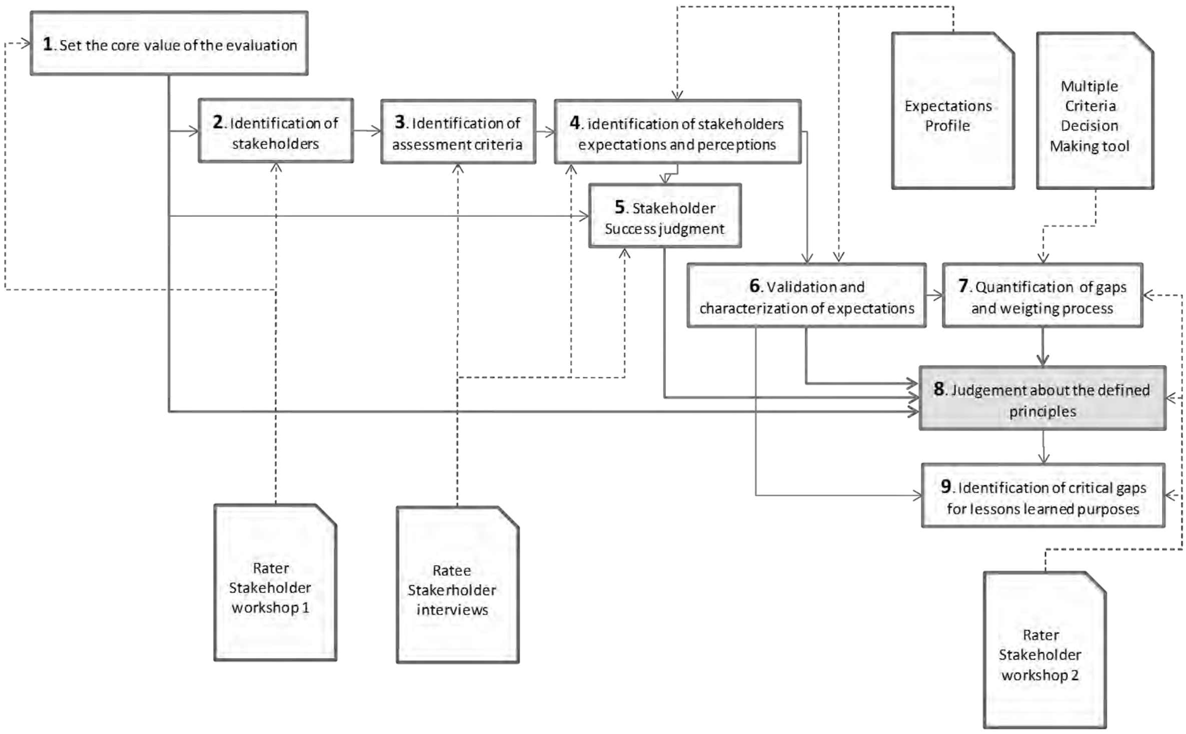


Figure 4: PPP ex-post evaluation tool architecture (Author's)

Both, the conceptual framework and the tool architecture have been presented to experts from the public and private sector in Chile and Australia (Development Stage). The feedback provided by them is being considered for the redesign of the procedure in the subsequent stages. This article does not provide a full description of the artifacts, nor the supportive theory; it is not the aim of the article to explain in detail the outcome of the case study, but the method employed to design it.

4.4 Demonstration of the tool

To test and refine the evaluation tool, two "test cases" were selected. It is important to clarify that they are not case studies; the main purpose is not to study the cases, but to study the tool performance in the cases. The selection of the test cases is affected by four variables: (1) availability of stakeholders, (2) expertise of the researcher, and (3) similarity between cases. The researcher has a deep understanding of social housing PPP projects in Chile. Then, an Australian social housing Project has been selected to be the prototype test case; this is to help refine the tool faster and sooner. The case in Australia is the 59 units Drill Hall social housing redevelopment project in the city of Melbourne and in Chile the 233 units "United by a Dream" social housing new project in the City of Concepcion. For each case, the selection of the stakeholders is based on the generic characterization of (1) public authority, (2) private entity, (3) end user, and (4) society. However, the inclusion of them will be re-evaluated, as the identification of stakeholders is one of the tool's steps. With each test case, the refinement process will be based on observation (data collection) and Functional black box testing (data analysis).

4.5 Tool Evaluation

For each test case, the result will be obtained in the form of an evaluation report. These results will be presented to experts, and they will be asked to compare it with other types of evaluations that have similar purposes, such as PPP UN approach (Lund-Thomsen, 2007), beneficiary assessment (World Bank, 2016), Post occupancy, etc. The tool is evaluated, based mainly on its utility, because the nature of the problem is considered of public interest. To represent public interest a group of expert in the private and public sector, academic and non-academic was selected to evaluate the tool. The main metrics that they will use to assess the tool is utility (how useful is the tool to evaluate), efficiency (resources and time consumption when evaluating) and applicability (what kind of projects can be evaluated). The evaluation will be done in a relative scale (not absolute scale), comparing those metrics against other types of evaluations using the pair wise comparison technique (David, 1963).

4.6 Communication of the research and the tool

The research is being communicated to the design-oriented audience (academic community) by conference and journal articles. It will also be communicated to the user-oriented audience (mainly in the public sector) by providing the tool as a documented procedure with a web-based computer interface using a web portal.

5. Evaluation of the DSR Process

The DSR example "ex-post evaluation tool for PPP projects" presented in the previous section employing Peffer's (2007) methodology, is also consistent with Hevner et al. (2004) DSR guidelines. The case study fulfils the 6 guidelines stipulated by Hevner et al. – Table 1. The 6 guidelines are the assessment criteria for validating a DSR project, i.e. (Hill, 2009).

Table 1: Case study analyzed with Hevner et al. (2004) DSR Guidelines

Guidelines	Explanation
Design as an artifact	The research is the design of a conceptual model and an evaluation tool (procedure).
Problem relevance	A PPP is relevant to the taxpayer and then to the whole society, validating the problem of evaluating the impact of this procurement method
Research contribution	This research project provides the three kinds of contribution, named, (1) the artifact (ex-post evaluation tool) that solves a problem in real world; (2) the theory behind (project success evaluation pyramid model) that is a contribution to knowledge; and (3) the methodology, which in this case has the novelty of using the IS framework in the AEC field.
Research Rigor	The process for designing the artifact involves: (1) an extensive literature review, (2) involved experts from the private and public sector, and (3) a testing process with two case studies.
Design as search	Each of the four stages of the research is an iteration process of building, evaluating, and refining the artifact
Communication of research	The result will be presented to an academic (technological) audience and to the public (user) domain.

6. Discussion

6.1 Applicability of DSR framework to the AEC field

The DS frameworks developed for IS were analyzed to examine how they can be applied to AEC field. In doing so, the existing DS literature in IS has been reviewed and structured in five themes: (1) The definition of artifact, (2) Hevner's (2004) IS DSR framework as an iterative process, (3) Peffer's (2007) IS design science methodology, (4) Hevner's (2004) IS design science guidelines, and (5) Gregor and Hevner's (2013) DSR contribution framework. Table 2 shows the applicability to AEC of each component of the frameworks; highlighting how they can be adapted to suit AEC research.

Table 2: Summary of IS DSR frameworks analysis

Theme	Component	Applicable to AEC
Definition of artifact	Construct, model, method, Instantiation	Yes
Hevner's (2004) IS DSR framework as an iterative process	Develop/Build and Justify/evaluate process	Yes
	Relevance and rigour	Yes
	Environment	Not applicable: Add "nature" as part of the environment
	Existing knowledge	Yes
	Business needs	Not applicable: Extend "business need" to "organisation's need"
	Applicability to knowledge and Environment	Yes
Peffer's (2007) IS design science methodology	Problem identification and motivation	Yes
	definition of the objectives for a solution	Yes
	Design, and development	Yes
	Demonstration	Yes
	Evaluation	Yes
	Communication	Yes
Hevner's (2004) IS design science guidelines	Design as an artifact	Yes
	Problem relevance	Not applicable: Generalise the relevance of the problem: Employ a cost/benefit analysis
	Design Evaluation	Yes
	Research Contribution	Yes
	Research Rigour	Yes
	Design as search	Yes
	Communication of research	Not applicable: Generalise audiences: Design-oriented and user-oriented audiences
Gregor and Hevner's (2013) DSR contribution framework	Contribution type	Yes
	Solution/Application-domain Maturity	Yes

The analysis concluded that only four components needed minor changes within the five themes of the IS DSR. These changes can enable the AEC to adopt the existing DSR frameworks.

6.2 Impact of design science in AEC

Behavioral sciences are well recognized and employed in the AEC. There are several studies that use mathematical models and predictive analytics in AEC field. The use of surveys for gathering data and describing a certain events using quantitative models is also well known in this research field. Even though the behavioral sciences are employed in most research studies, they still propose some artifacts that can be helpful for practitioners, and consequently, impact positively the society. However, behavioral sciences are not structured to solve a real problems; their objective is to understand a phenomenon, not to change it. Therefore, some of the artifacts that are obtained with this approach might lack of relevance, as they do not have a clear "environment" and an "organization need" (from IS DSR taxonomy).

The problem of relevance of AEC research has been recognized in the editorial of one the reputable journals in AEC: Construction Management and Economics.

"...In recent years, we have seen a marked decline in empirical research and papers that observe, measure and study practice. Instead, we have seen a proliferation of papers where the research is seeking the opinions of respondents, typically through surveys or interviews. And so what we know about construction is largely framed by what practitioners tell us about it, and not what we observe in and through our engagements... we would very much like to reinvigorate the empirically driven problem-based research that once defined our field," (Leiringer & Dainty, 2017)

Different from behavioral science approach, DS requires the initial contact with the "environment" because the core objective is to solve "someone's problem" with an artifact. It is an approach that allows AEC research to have ready-to-go knowledge that can be applicable to the industry, including, as an essential requirement, the validation and the testing process.

The use of DSR can impact AEC research by changing the trend of the current research themes. This change is relevant because a lack of research application affects the potential performance of the industry, creating no positive impact on the society, which in many cases funds research projects through taxes.

6.3 Design science research case example

The presented case example is currently being developed employing the DSR approach and confirms that the frameworks that were analyzed from IS are applicable to AEC. The artifact is intended to solve a real problem within public-private partnership projects, differing from a traditional "descriptive" research.

7. Conclusion

The article has addressed three issues in the context of architecture, engineering and construction field: (1) the use of design science as an alternative research approach (2) the use the IS frameworks as a basis for DSR in AEC and (3) a real application of the DSR in the case example "ex-post evaluation tool for PPP projects".

Design science is presented as an alternative approach for the traditional behavior science approach. One of the main attributes of DS is its problem-solving objective through the creating of an artifact. AEC is recognized as a research field that needs more engagement with the industry in order to provide real solution of problems. Ergo, it can be concluded that DSR is not only an alternative approach, but a better approach.

The analysis of the five themes in which the IS DSR body of knowledge was structured shows that, with minor changes, they are completely applicable to AEC research field.

One relevant insight from the presented example is that the outcomes of the research are two artifacts: one created to solve a real problem in the defined environment, and another to contribute to the existing knowledge in the construction and project management discipline.

Further research needs to be developed to explore the particularities of design science in AEC. Also, systematic literature review is necessary to examine which topics are most likely to be suitable for design science. Finally and most important, more DS research projects need to be developed and published in order for AEC researchers to increase knowledge and the application of DS to solving real world problems.

8. References

Aken, J. E. v. (2004), “Management research based on the paradigm of the design sciences: The quest for field-tested and grounded technological rules”, Journal of Management Studies, 41(2), 219-246, doi:10.1111/j.1467-6486.2004.00430.x

David, H. A. (1963), “The method of paired comparisons”, (Vol. 12): DTIC Document.

Gregor, S., & Hevner, A. R. (2013), “Positioning and presenting design science research for maximum impact”, MIS Quarterly, 37(2), 337-355.

Hevner, A. R., & Chatterjee, S. (2010), “Design Science Research Frameworks”, Design Research in Information Systems, 23, available at https://ezp.lib.unimelb.edu.au/login?url=https://search.ebscohost.com/login.aspx?direct=true&db=edb&AN=76830821&site=eds-live&scope=site

Hevner, A. R., March, S. T., Park, J., & Ram, S. (2004), “Design science in information systems research. MIS Quarterly, 28(1), 75-105, available at https://ezp.lib.unimelb.edu.au/login?url=https://search.ebscohost.com/login.aspx?direct=true&db=bth&AN=12581935&site=eds-live&scope=site

Hill, G. (2009), “A framework for Valuing the Quality of Customer information”, (Doctor of Philosophy), University of Melbourne, Melbourne, Australia, available at http://ghill.customer.netspace.net.au/docs/summary.html

Leiringer, R., & Dainty, A. (2017), “Construction Management and Economics: New Directions”, Construction management and economics, 35(1-2), 1-3, doi:10.1080/01446193.2017.1275159

Lund-Thomsen, P. (2007), “Assessing the impact of public-private partnerships in the global south”, United Nations.

March, S. T., & Smith, G. F. (1995), “Design and natural science research on information technology”, Decision Support Systems, 15(4), 251-266. doi: http://dx.doi.org/10.1016/0167-9236(94)00041-2

Peffers, K. E. N., Tuunanen, T., Rothenberger, M. A., & Chatterjee, S. (2007), “A design science research methodology for information systems research”, Journal of management information systems, 24(3), 45-77, available at https://ezp.lib.unimelb.edu.au/login?url=https://search.ebscohost.com/login.aspx?direct=true&db=bth&AN=28843849&site=eds-live&scope=site

Simon, H. A. (1969), “The sciences of the artificial”, Cambridge, MA.

Simon, H. A. (1996), “The sciences of the artificial (3rd ed.)”, MIT press.

Voordijk, H. (2009), "Construction management and economics: the epistemology of a multidisciplinary design science", Construction management and economics, 27(8), 713-720, doi:10.1080/01446190903117777

World Bank (2016), "Beneficiary Assessment", available at http://web.worldbank.org/WBSITE/EXTERNAL/TOPICS/EXTSOCIALDEVELOPMENT/EXTPCENG/0,,contentMDK:20507670~pagePK:148956~piPK:216618~theSitePK:410306,00.html (accessed 7 May 2017)

A Comparative Analysis of the Croatian System of Energy Efficiency Measures

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Abstract:

In accordance with Directive 2012/27 / EU on energy efficiency, every three years, each Member State of the European Union is obliged to draw up its own national action plan for energy efficiency, being proposal of measures through which it plans to achieve Kyoto protocol commitments.

In Croatia, the Third National Energy Efficiency Action Plan for the period 2014-2016 is still in effect. The necessity to adopt a new national Action Plan lays a claim to re-evaluate success of previous measures. Consequently, the initial research objective of this scientific paper is to compare Croatian experiences in implementing energy efficiency measures, in relation to selected countries of the EU. The paper uses primarily scientific methods of analysis and comparison because, in addition to the relevant literature research, it uses data from MURA and ODYSEE, the most complete European databases on energy consumption, energy efficiency measures and their energy and environmental impacts.

Given that Croatia is late with development and adoption of the new action plan for commenced time period, the results of this research could give valuable guidance in this regard, stemming not only from the review of performance of the previous national Action Plan but also from the lessons learned from testing the applicability of abroad used measures. The results suggest that Croatia is successful in achieving its energy policy goals, but certain measures could be restructured – for example providing tax relief and introducing more informative and promotional measures, as well as further reduction of targeted consumptions in terms of focusing on heating.

Keywords: *energy efficiency; measures; action plan; MURE; ODYSEE*

1. Introduction

By entering the European Union, Croatia has taken, among others, obligations defined in Kyoto Protocol (NN 5/07). The core purpose of undertaken obligations is recognition of the problem of global warming, but also taking an active stand regarding its settlement. Based on the fact that the global warming is not geographically limited, i.e. that the reduction of emissions has a global impact regardless of the place of its origin, Kyoto Protocol enabled the signatory countries to choose whether they will meet the obligations through the application of their own measures or by using the Kyoto Protocol Mechanism. The Mechanism enables assessing the costs of implementing projects of emissions reductions nationally or in another country, with

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the purpose of technology transfer to regions in which those projects would be the most cost-effective.

In order to achieve the undertaken commitments, Croatia has launched a series of measures and activities that are being carried out at the national level. If achieved results would be better than defined by undertaken commitments, there is a possibility to offer the surplus to less successful countries and thus gain certain revenue.

Implementation strategy of energy efficiency projects at European and global level is recognized as the key in terms of achieving the effects of climate change, energy security and economic development, i.e. as the most relevant factor of fulfilling the commitments undertaken by Kyoto Protocol (Bukarica and Tomšić, 2017). However, although the implementation of energy efficiency projects is generally accepted as a model through which it is possible to carry out the undertaken commitments, the implementation rate is still lower than expected. Analysis of this problem in previous studies suggests the reason might be in inadequate understanding of the energy market, as well as the lack of knowledge about the impact of measures and activities (potential and actual) (Bukarica and Tomšić, 2017). In order to solve the problem, measures and activities should be adapted to market conditions and directed to eliminate the barriers or strengthen the areas in which the output is realized. Because of that it is necessary to evaluate the existing measures and activities, so it could be decided which measures to keep and which to abandon. Such an evaluation should not be based on simple savings analysis, without taking into consideration reasons of success/failure of specific measures and activities.

Appreciating all of the above said, it can be resumed that an underlying assumption of obligations fulfilling is efficient planning. Therefore the next chapter shall provide a relevant theoretical framework regarding planning. Only after that, the empirical part of our research shall be presented, too. It will disclose comparison of energy efficiency measures planned and implemented in Croatia and its peer countries. Final remarks are provided in conclusion.

2. The role and importance of planning programs and energy efficiency projects

In the era of globalization, when changes are frequent, creation of energy efficiency programs and planning documents is a challenge, which is manifested in several basic assumptions:

- The time frame of globalization with continuous changes makes the long-term planning more complex,
- The realization of the set goals in a certain period of time, in the context of constant changes,
- Active involvement of individuals and legal entities which are influenced by the government only through legislative measures
- The area of energy efficiency is a multidisciplinary field, which is itself complex
- Lack of collection systems for data on energy consumption, etc. (Styblinkas and Čandrlić Dankoš, 2013).

Design and creation of planning documents is always a challenge, and their importance is particularly highlighted where there is no planning or it is not sufficiently developed. This can be illustrated on the Swedish case, in which the lack of a systematic strategy, especially in terms of defining the target group to which the program seeks to influence as well as in terms of insufficient impact assessment, resulted in a misunderstanding of measures holders, what became an obstacle of wind energy usage as the bottom line (Åstrand, 2003).

Recognizing the problem of lack of knowledge regarding planning in this complex area of energy efficiency, led to research conducted both by scholars and professionals, focused on the formulation of theoretical models that should provide a greater level of effectiveness.

One of the most appreciated such models have been created in Guidelines for monitoring, evaluation and design of energy efficiency policies (Khan et al. 2006), within the project Intelligent Europe. The Guidelines define the workflow toward policy formulation and implementation as presented in Figure 1. Evidently, operational model based on indicators is in the middle of the process. This model suggests planning based on the identification of causes and effects, with each step determining its target, but also determining the relationship between the expected effects and invested resources. Thus the model includes not only the final outcome, but the series of indicators of the planned measures and activities of the energy efficiency policy. This concept allows us to understand the reasons of success (or the lack of it) and decide on necessity of the policy adjustment or redesign.

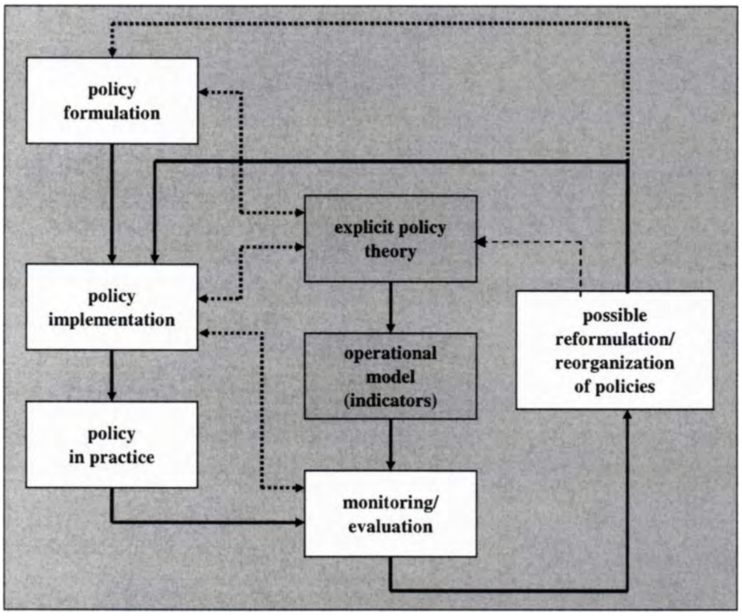


Figure 1 Outline of the policy cycle and the role of the program theory in the policy cycle (source: Khan, J. et al., 2006: 4)

In order to fulfill the undertaken obligations, signatory countries have the freedom to prescribe energy efficiency measures within their own national programs and plans. Before those national documents get to be ratified in Parliament, they are being controlled at the European level. Those programs and plans represent comprehensive documents of national policies in the energy segment, including analysis of the current situation, measures and activities, financial resources as well as performance indicators.

In order to assure an equal approach to creating a model for the planning of measures and activities of energy efficiency, European Commission has created "Guide and template for the preparation of the second national energy efficiency action plans". This document defines the content of national energy efficiency plans within the European Union, so it was the base for creation of „Drugi nacionalni akcijski plan energetske učinkovitosti Republike Hrvatske za razdoblje do kraja 2013. godine“ (2013), too. This Croatian national plan included measures of primary energy savings, measures to improve energy efficiency and energy savings in direct consumption.

The experience of acting upon this Guide imposed the changes in the methodology which led to creation of Guidance for National Energy Efficiency Action Plans (2013). This guidance was the base for “Treći nacionalni akcijski plan energetske učinkovitosti za razdoblje 2014. – 2016“ (2014), written in Croatia. „Treći nacionalni akcijski plan“ analyzed the results of the first two national action plans and defined the measures for energy savings. The structure of this action plan is in compliance with European guidance and as such is consisted of 7 categories of measures:

- Horizontal measures,
- Energy efficiency measures in buildings,
- Energy efficiency measures in public sector,
- Energy efficiency measures in industry,
- Energy efficiency measures in transport,
- Promotion of the efficient heating and cooling,
- Energy transformation, transmission, distribution and response to demand,

As part of the Annex there are also following measures:

- primary energy savings,
- primary energy savings as a result of energy savings in final consumption,
- energy efficiency measures in production, transmission and distribution of electric power
- savings measure in direct consumption

Identical methodological framework for the creation of program and planning documents enabled the comparison of these documents at the EU level, unified procedures for savings calculations and made the role of countries in achieving undertaken obligations transparent. In the same time, monitoring of the realization of the planned activities and measures additionally emphasized the importance of planning process.

Furthermore, the literature (Škrabalo et al., 2010) suggests that, before creation of planning documents in the manner of relevance, implementation effects, acceptability and consistency, also the following information should be analyzed and acknowledged:

- solutions implemented in other countries, especially the ones have proven successful,
- solutions that have been used in previous years, with respect to the gained know-how about their feasibility and efficiency,
- solutions that have been used in other forms of public planning, especially the mechanisms of monitoring and implementation,
- propositions of professionals and non-governmental sector involved in this area,
- pilot projects whose results have been awarded a positive review.

Following these recommendations, hereafter presented shall be the results of the comparative analysis of Croatian and chosen foreign energy efficiency measures.

3. Comparison of Croatian energy efficiency measures with those in peer countries

The empirical part of this paper is based primarily on scientific methods of analysis and comparison. Method of analysis was used in order to perceive the overall energy efficiency system through its relevant components and thus create a precondition for the cognition through comparison. Regarding the comparison itself, the method was used to generate the new insights by considering two or more individual characteristics (as opposed to e.g. the induction method, in which individual variables lead to the general knowledge), thus enabling the identification of similarities and differences among those comparable variables.

Croatian chamber of economy, Croatian Bureau of Statistics and Croatian National Bank very often use the European Commission's criteria in their analysis, meaning they compare Croatia with 10 new member countries to the European Union after the year 2004[1]. As this approach has proven to be successful, we decided to use it also in this paper. Therefore we compared Croatian energy efficiency system with the one in peer countries: Cyprus, Czech Republic, Estonia, Lithuania, Latvia, Hungary, Malta, Poland, Slovakia and Slovenia.

As the main source of primary data, authors have used ODYSSEE and MURE, the most comprehensive European data basis in the context of energy efficiency (CO2 indicators, energy consumption and energy policy measures as well as their energy and ecological effects).

European Union member countries have adopted three national energy efficiency plans from 2008 until today. In our research, we conducted the analysis of the type and frequency of the relevant energy efficiency measures undertaken in Croatia and the peer countries. For the observation period of our research, we have chosen the period of the first national action plan from 2008 - 2010, the period of the second national action plan from 2011 - 2013 and the period of the third national action plan from 2014 - 2016.

In the evaluation of energy efficiency measures we relied on scoring methodology[2] used by the MURE data base for monitoring the success of energy policy measures and activities in EU28. The scoring methodology is designed in a way that higher score indicates the better result in achieving the set energy policy goals. Through such record of the each member country's contribution, this base enables identification of the most efficient measures and activities as well as monitoring of the portion of realization of the obligations undertaken by signing the Kyoto protocol.

We have primarily focused on three different criteria defined in the MURE data base[3]:

- Output-based scoring, based on energy savings – it uses information on energy savings which are described as the "policy output", and compares those savings with final energy consumption in different consumption sectors, in defined time frame. Perhaps it should be elaborated that final energy consumption includes energy for industry, transport, households, services and agriculture, excluding consumption in the process of the energy transformation and in the energy industry itself[4]
- Output-based scoring, related to energy efficiency potentials of measures and activities – it uses data on achieved energy savings and current energy policy, comparing the potential with current savings up till the year 2030
- Output-based scoring, related to 2020. energy efficiency targets – it uses data on savings and compares them with the set goals.

The results of our analysis are shown in Table 1, in which columns 1, 2 and 3 represent three different output-based scoring criteria types described above. It is evident that the most important sector of energy savings from 2008-2010 was the transport sector, while in later periods households and other sectors became more important. Furthermore, the most successful countries in that period were Poland, Slovenia and Latvia. By becoming the EU member state, i.e. by adopting the second and the third national action plan, Croatia increased the number of energy efficiency measures and their effectiveness. In both of those periods, 2011-2013 and 2014-2016, Croatia's energy efficiency scoring was high so it was ranked as the second or the third in comparison with the peer countries.

Table 1 Output-based scoring ranks (Source: authors' analysis based on the data from MURE database)

POLICY SCOREBOARD- OUTPUT BASED SCORING (NEEAP 1. mesaures 2008-2010.)																	
Based on energy savings						Related to energy efficiency potentials						Related to 2020. energy efficiency targets					
Country	Tot	H	Ter	I	Tr	Country	Tot	H	Ter	I	Tr	Country	Tot	H	Ter	I	Tr
Poland	3	0	0	1	2	Poland	13	0	0	3	10	Slovenia	7	4	0	3	0
Slovenia	2	1	0	1	0	Slovenia	10	4	0	6	0	Poland	7	0	0	2	5
Estonia	0	0	0	0	0	Latvia	4	3	0	0	1	Latvia	2	1	0	0	1
Cyprus	0	0	0	0	0	Croatia	0	0	0	0	0	Croatia	0	0	0	0	0
Latvia	0	0	0	0	0	Cyprus	0	0	0	0	0	Cyprus	0	0	0	0	0
Croatia	0	0	0	0	0	Czec Rep	0	0	0	0	0	Czec Rep	0	0	0	0	0
Czec Rep	0	0	0	0	0	Estonia	0	0	0	0	0	Estonia	0	0	0	0	0
Hungary	0	0	0	0	0	Lithuania	0	0	0	0	0	Lithuania	0	0	0	0	0
Lithuania	0	0	0	0	0	Slovakia	0	0	0	0	0	Slovakia	0	0	0	0	0
Malta	0	0	0	0	0	Hungary	0	0	0	0	0	Hungary	0	0	0	0	0
Slovakia	0	0	0	0	0	Malta	0	0	0	0	0	Malta	0	0	0	0	0

POLICY SCOREBOARD-OUTPUT BASED SCORING (NEEAP 2. measures 2011-2013)																	
Based on energy savings						Related to energy efficiency potentials						Related to 2020. energy efficiency targets					
Country	Tot	H	Ter	I	Tr	Country	Tot	H	Ter	I	Tr	Country	Tot	H	Ter	I	Tr
Poland	4	1	1	1	1	Poland	24	6	6	6	6	Poland	16	4	4	4	4
Croatia	3	0	0	0	3	Croatia	9	0	1	0	8	Croatia	8	0	1	0	7
Estonia	2	0	0	0	2	Estonia	8	0	0	0	8	Estonia	5	0	0	0	5
Czec Rep	0	0	0	0	0	Lithuania	5	5	0	0	0	Hungary	1	0	0	0	1
Cyprus	0	0	0	0	0	Hungary	2	0	0	0	2	Czec Rep	0	0	0	0	0
Hungary	0	0	0	0	0	Czec Rep	0	0	0	0	0	Cyprus	0	0	0	0	0
Latvia	0	0	0	0	0	Cyprus	0	0	0	0	0	Latvia	0	0	0	0	0
Lithuania	0	0	0	0	0	Latvia	0	0	0	0	0	Lithuania	0	0	0	0	0
Malta	0	0	0	0	0	Malta	0	0	0	0	0	Malta	0	0	0	0	0
Slovakia	0	0	0	0	0	Slovakia	0	0	0	0	0	Slovakia	0	0	0	0	0
Slovenia	0	0	0	0	0	Slovenia	0	0	0	0	0	Slovenia	0	0	0	0	0

POLICY SCOREBOARD - OUTPUT BASED SCORING (NEEAP 3. measures 2014-2016)																	
Based on energy savings						Related to energy efficiency potentials						Related to 2020. energy efficiency targets					
Country	Tot	H	Ter	I	Tr	Country	Tot	H	Ter	I	Tr	Country	Tot	H	Ter	I	Tr
Czec Rep	4	2	1	1	0	Czec Rep	18	9	2	6	1	Czec Rep	12	6	3	3	0
Croatia	1	0	1	0	0	Latvia	7	5	2	0	0	Latvia	4	1	3	0	0
Latvia	1	0	1	0	0	Croatia	3	1	1	0	1	Croatia	2	0	2	0	0
Cyprus	0	0	0	0	0	Poland	3	0	0	3	0	Poland	2	0	0	2	0
Estonia	0	0	0	0	0	Slovenia	2	0	0	2	0	Slovenia	1	0	0	1	0
Hungary	0	0	0	0	0	Cyprus	0	0	0	0	0	Slovakia	0	0	0	0	0
Lithuania	0	0	0	0	0	Slovakia	0	0	0	0	0	Cyprus	0	0	0	0	0
Malta	0	0	0	0	0	Malta	0	0	0	0	0	Estonia	0	0	0	0	0
Poland	0	0	0	0	0	Hungary	0	0	0	0	0	Hungary	0	0	0	0	0
Slovakia	0	0	0	0	0	Lithuania	0	0	0	0	0	Lithuania	0	0	0	0	0
Slovenia	0	0	0	0	0	Estonia	0	0	0	0	0	Malta	0	0	0	0	0

Tot = Total; H = Household; Ter = Tertiary; I = Industry; Tr = Transport

The greatest number of different measures and activities was applied in the second period, from 2011-2013. After that, enough experience had been gained to eliminate the measures and activities which did not justify their purpose. Such downsizing with purpose of quality increase was faced in all observed countries, and total number of measures is presented in Figure 2.

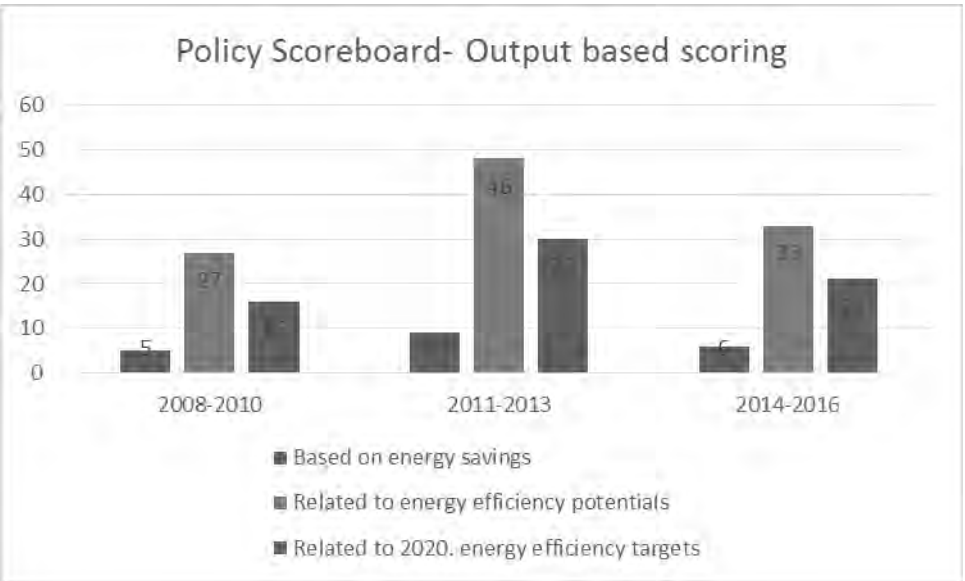


Figure 2 Number of total measures and activities, differentiated upon 3 different output-based criteria, recorded in MURE data base (source: authors' analysis based on the data from MURE data base)

Further analysis, dealing with structure of prescribed measures in terms of sectors, is presented in Figure 3. The figure shows that the largest number of measures in the first two periods (the first two national action plans) was implemented within the transport sector. This clarifies the most significant impact of those measures detected in Table 1. Transport sector measures included, for example, the introduction of European standards, information campaigns on energy efficient behavior in transport, promotion of sustainable transport systems and efficient use of fuel as well as promotion of “cleaner” cars. Impact of those measures has been significantly decreased in the third observed period, as they fulfilled their purpose. By that time, importance of measures in households, tertiary sector and industry increased. As previously in transport sectors, these sectors first introduced regulatory and information measures, which are a natural precondition for implementation of any other measure. Although this kind of measures does not imply direct energy savings effects, they are a presumption of future achievement of energy policy objectives. Thereby, regulatory measures are used by the government to impose certain standards, whilst all other measures are used to collect resources needed for meeting those standards. Again, the Figure shows aggregate numbers for all observed countries.

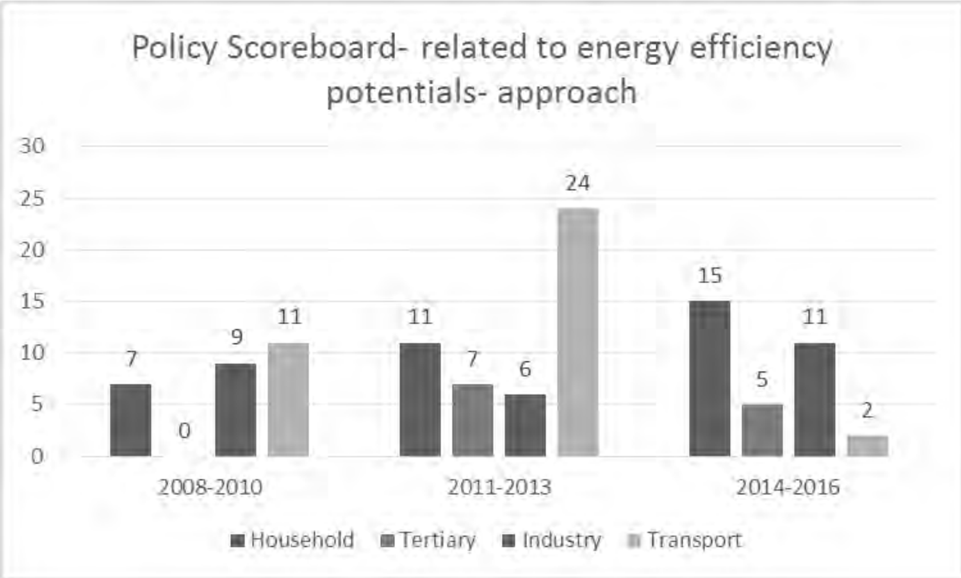


Figure 3 Distribution of energy savings measures among different sectors (source: authors' analysis based on the data from MURE data base)

We found it interesting also to analyze measures in terms of targeted end users, and our findings are presented in Figure 4. This analysis shows that there are 11 different types of end users targeted by European energy policies:

- Building professions
- Landlords
- Owner-occupiers
- Tenants
- General public
- Low-income households
- Researchers
- Housing associations
- Manufacturers
- Retailers
- Not specified

Additionally, this analysis identified that, among those peer countries who recorded their data in MURE data base, the most directed their measures toward a wide range of end users. Croatia and Czech Republic, as the first two countries in the output based scoring table, focused their efforts towards only three categories. Croatia chose: general public, building professions and housing associations.

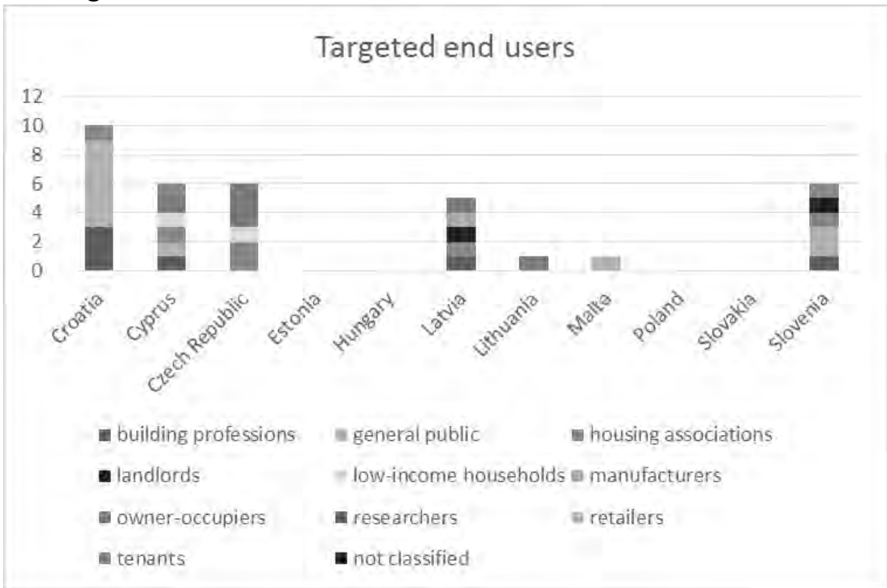


Figure 4 Targeted end users (source: authors' analysis based on the data from MURE and ODYSEE data bases)

Analysis of the measures according to the type of measures defined in the last, third national action plan, shows that the most important measures in that period were financial, fiscal and legislative/informative measures. Results of this analysis are presented in the Figure 5. In this respect Croatia does not deviate from the European average, since we also used mainly financial measures (co-financing of energy restoration, investments in renewable energy sources, encouraging the purchase of more efficient equipment as well as energy efficiency improvements projects.

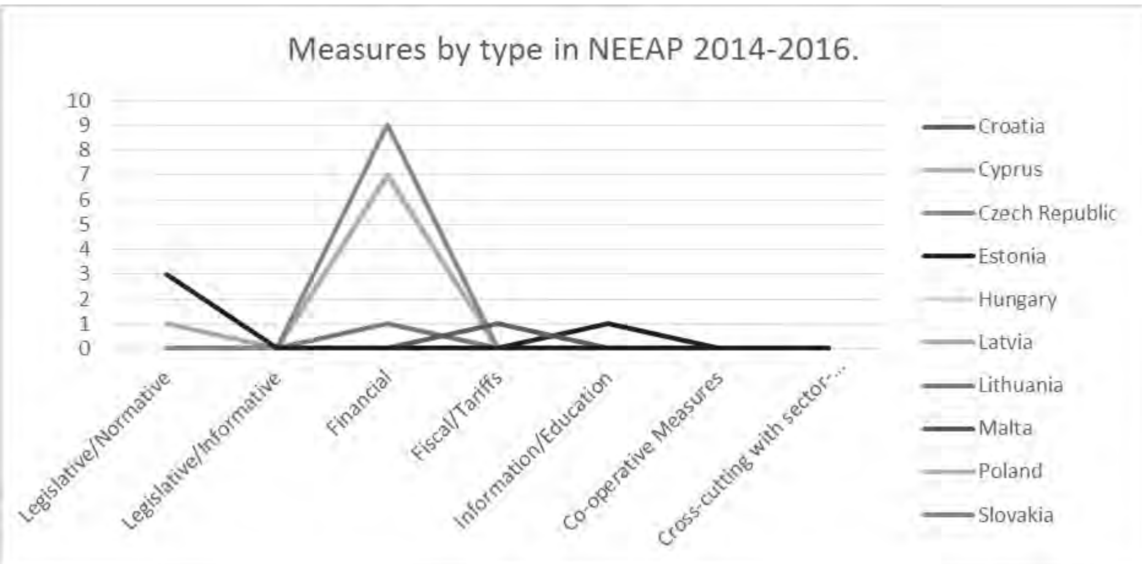


Figure 5 Energy efficiency measures by type (source: authors' analysis based on the data from MURE data base)

As it can be seen from the Figure 6, comparative analysis of measures according to targeted consumption detected that Croatia mostly directs energy efficiency measures toward total final consumption, total electric consumption, space heating, hot water and other targeted uses. Such distribution suggests that Croatian measures are intended toward uses with the biggest energy consumption, allowing the assumption that also the effects should be the biggest. In the same time, it could be noted that Czech Republic, as the most successful country, chose only one consumption target for its measures – space heating, in the last period. On the other side, Cyprus is the country with most of selected targeted consumptions, which did not pay off very well in the last period, since it is one of the poorly ranked countries in the output based scoring table. None of the countries targeted cooking, probably because these potential energy savings were not perceived as interesting.

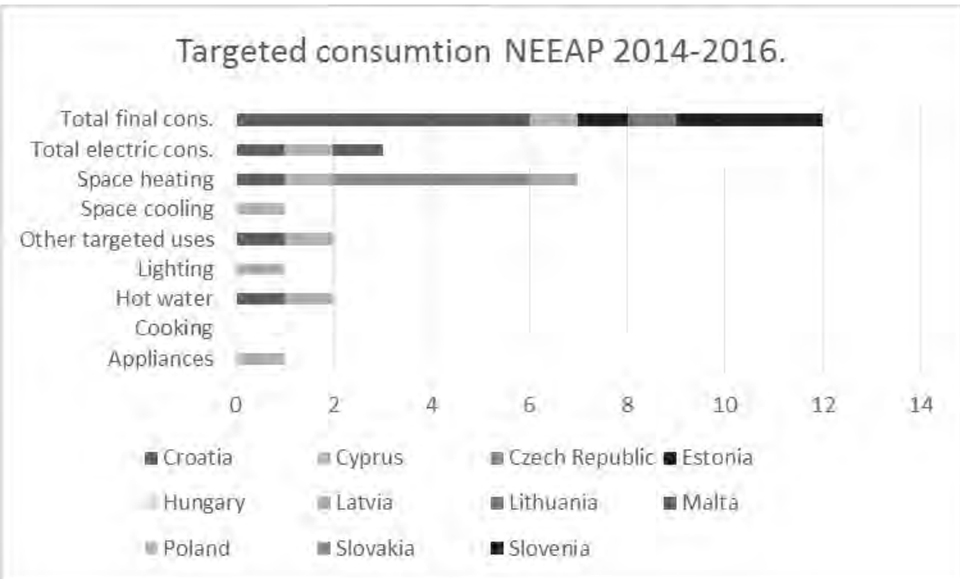


Figure 6 Measures according to targeted consumption (source: authors' analysis based on the data from MURE data base)

Not all of the observed countries have recorded their data on energy efficiency measures' actors to the MURE dana base, but comparative analysis of those who did suggests extremely significant role of the government, both central and local. This is visible in Figure 7. The same figure also identified Croatia as the country with most actors. Although there is no scientific proof that number of actors has a direct positive influence on country's energy efficiency improvement, it seems reasonable to assume so. At least, such a wide distribution of actors indicates improvements in appreciating and involvement in this complex topic, which should result in better planning and implementation of energy efficiency projects.

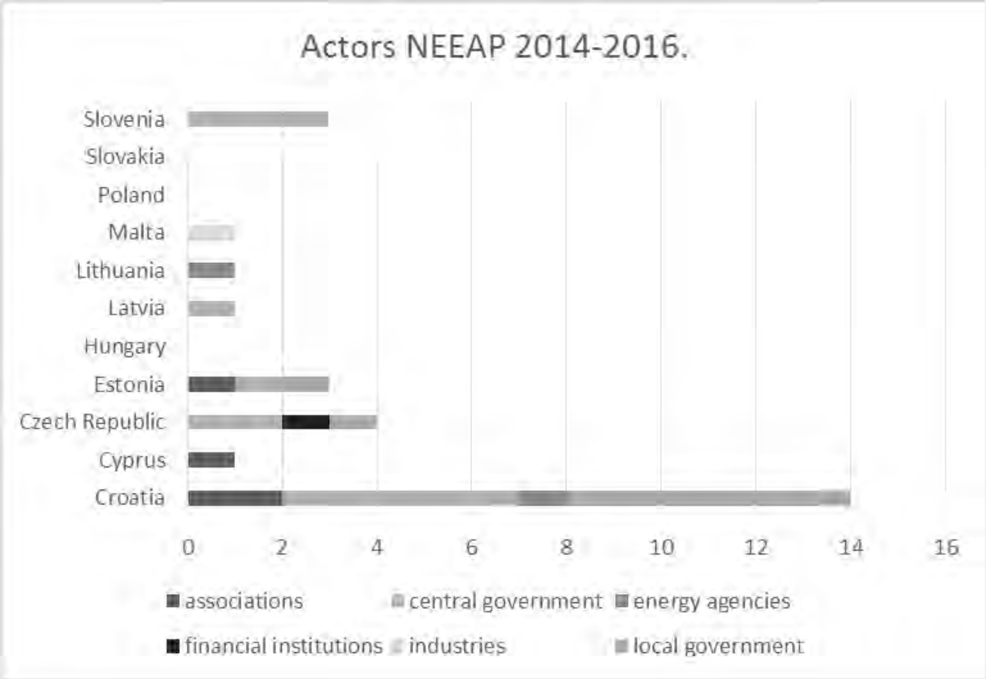


Figure 7 Energy efficiency measures according to actors (source: authors' analysis based on the data from MURE data base)

Beside in the above presented analysis, Croatian status in comparison to other European countries is indicated also in Report from the Commission to the European Parliament and the Council assessment of the progress made by member states towards the national energy efficiency targets for 2020 and towards the implementation of the Energy Efficiency Directive 2012/27/EU[5]. The Report stated that there is an evident progress in reducing energy consumption at the European level: from 2005 till 2013 final energy consumption was decreased for 7%. Consumption of primary energy was decreased for 8%. The Report confirms the above analyzed Croatia's efficiency in planning and implementing energy efficiency measures, but in the same time sheds a somewhat different light on that success. Namely, the Report finds Croatia's goals not ambitious enough and therefore relatively easy to be achieved! Croatia has set its energy efficiency goals significantly lower than other successful countries like Czech Republic or Poland. So, although data recorded in ODYSEE data base indicates Croatia will fulfill its goals by 2020., the question is should we be satisfied with that?

4. Discussion and conclusion

Comparative analysis of Croatian energy efficiency system showed that Croatia as well as the analyzed peer countries reported the trend of efficiency increase in the second (2011-2013) and the third (2014-2016) observed period. All of them applied downsizing of the measures introduced during the first action plan (2008-2010) in order to be more focused and efficient. In that sense the application of a joint Guidance for National Energy Efficiency Action Plans certainly fulfilled its purpose.

There are other common features of applied energy efficiency measures among the observed countries, too. All of them put emphasis on transport sector during the first energy efficiency action plans. By the time of the third national action plans, primate was taken by measures intended for households, industry and tertiary sector. Such a trend can be expected also in the newly-started period. Furthermore, analysis of energy efficiency measures by type showed that all countries introduced primarily financial, fiscal and legislative measures. Interpretation is self-evident if taken into account that energy efficiency measures imply the collection and redistribution of significant resources. However, although the role of these measures is unavoidable also in the future, we think the new action plan should consider certain tax relief, especially for small and medium enterprises. Together with some more informative and promotional efforts, such an approach might motivate and additionally activate the private sector in implementation of energy efficiency measures.

On the other hand, while the majority of observed peer countries directed their energy efficiency measures toward wide range of end users, Croatia targeted only 3 end users' categories: general public, building professionals and housing associations. Since such the approach proved to be smart in terms of output based scoring both for Croatia and Czech Republic as the best ranked country, it can be expected that both the number and the structure of end users shall not be increased in the future.

Additionally, differences have been identified regarding targeted consumption, too. Our comparative analysis shows that countries which targeted several consumptions in the same period have ended poorly ranked on the output based scoring list. Croatia targeted only a few consumptions, but the example of Czech Republic as the best ranked country, who chose only heating for its targeted consumption, might lead to further decrease of chosen consumptions in Croatia. Heating is one of the biggest energy consumption costs[6] in Croatia. But beside its cost significance, heating is equally important due to its social role, too – its role in the context of fighting poverty is inevitable. Due to all that, we find repositioning of targeted consumptions in terms of putting more emphasis on heating worth considering.

Based on the results presented in this paper, we think that, currently, one of the strongest Croatia's advantages is the number of actors covered by its National energy efficiency action plan. All countries recorded significant role of government (both central and local), but unlike other countries, Croatia included many other actors in implementation of energy efficiency measures, too. This is considered a key of overall appreciation of energy policy goals.

In the end, it can be concluded that Croatia is successful in fulfilling undertaken obligations and achieving the set energy efficiency goals. However, after the relevant results have been highlighted and thoughts on possible improvements presented, also some open questions as suggestions for future research must be outlined. Croatia is no exception in setting energy efficiency goals not overly ambitious, in order to be sure to achieve them. Namely, exceeding the goals provides the opportunity to market the surplus and thus generate an input to national budget. This is more appealing than having elusive goals which would lead to financial sanctions. Such an approach is additionally supported by the expected[7] lower oil and gas prices, which shall reduce the motivation for investing in energy efficiency projects in the future. But, the question whether the potential generated through implementation of energy efficiency projects is sufficiently exploited deserves a future research. That research should build on existing knowledge about stimulating impact of energy efficiency measures and projects on general economic growth.

References

Åstrand, K. (2003) „Methods for evaluation of technology and market development of wind power“, In: Energy Program Eevaluation Conference, Seattle, USA. pp. 237-248

Bukarica, V., Tomsic, Z. (2017), „Design and Evaluation of Policy Instruments for Energy Efficiency Market“, IEEE Transactions on Sustainable Energy, Vol.8 No.1, pp. 354-362.

„Drugi nacionalni akcijski plan energetske učinkovitosti za razdoblje do kraja 2013.“ (2013) available at: http://www.mgipu.hr/doc/EnergetskaUcinkovitost/II_NAPEURH_2013.pdf (accessed: 15 December 2016)

„Guidance for National Energy Efficiency Action Plans“, (2013), available at: https://ec.europa.eu/energy/sites/ener/files/documents/20131106_swd_guidance_neeaps.pdf (accessed: 16 December 2016)

Khan, J., Harmelink, M., Harmsen, R., Irrek, W., Labanca, N. (2006) Guidelines for the monitoring, evaluation and design of energy efficiency policies - How policy theory can guide monitoring & evaluation efforts and support the design of SMART policies. Active Implementation of the European Directive on Energy Efficiency, Utrecht, The Netherlands, available at: https://ec.europa.eu/energy/intelligent/projects/sites/iee-projects/files/projects/documents/aid-ee_guidelines_en.pdf (accessed: 9 February 2017)

Styblinkas, M., Čandrlić-Dankoš, I. (2013) „Challenges of making the program and plans of energy efficiency in final use od Osijek-Baranjy County“. In: (Anka Mašek Tonković, Ed.) 2nd International scientific symposium economy of Eastern Croatia – yesterday, today, tomorrow, pp. 171-177

Škrabalo, M., Branković, N., Kulić, S., Somun-Krupalija, L., Pašagić, E., Šuškić-Bašić, S., Traljić, S., Vežić,A. (2010) "Priručnik za razvoj javnih politika za državne službenike u BiH", UNDP Bosnia and Herzegovina

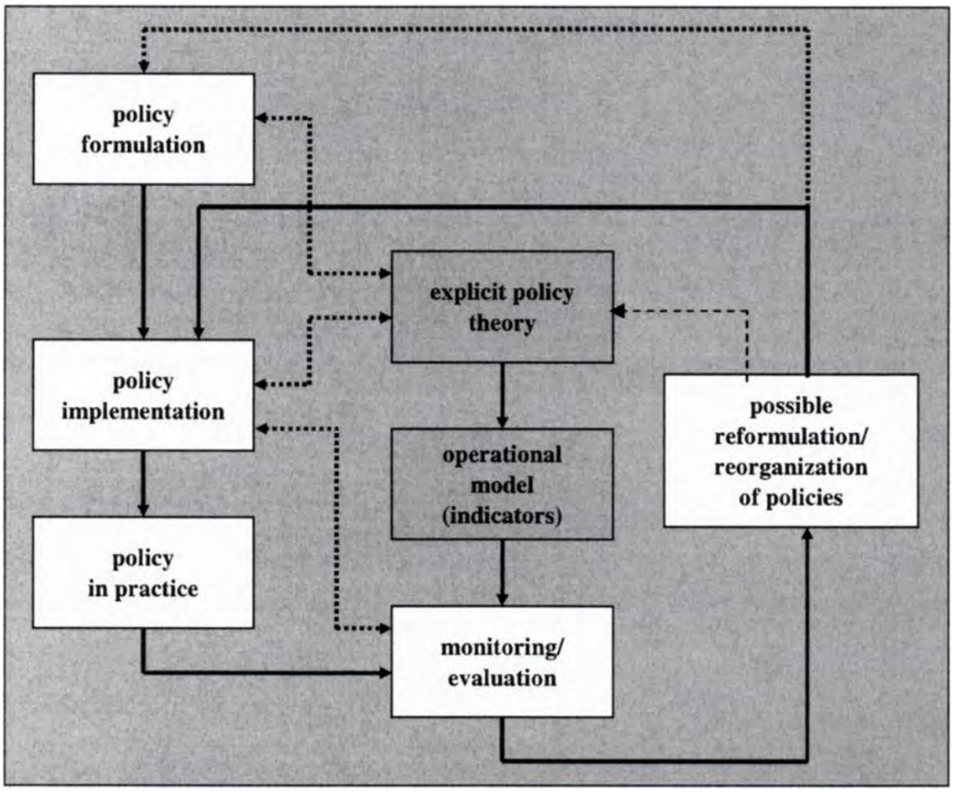
„Treći Nacionalni akcijski plan energetske učinkovitosti RH za razdoblje od 2014. do 2016.“ (2014), available at: http://www.mgipu.hr/doc/EnergetskaUcinkovitost/ III_NAPEU_2014-2016.pdf (accessed: 16 December 2016)

„Guide and template for the preparation of the second national energy efficiency action plans ", (2010) Europska komisija i Zajednički istraživački centar, Ispra, Italija available at: https://www.energy-community.org/portal/page/portal/ENC_HOME/DOCS/1790177/0633975ABC597B9CE053C92FA8C06338.PDF (accessed: 19 December 2016)

(2007), Zakon o potvrđivanju Kyotskog protokola uz okvirnu konvenciju Ujedinjenih naroda o promjeni klime, NN 5/07, Međunarodni ugovori

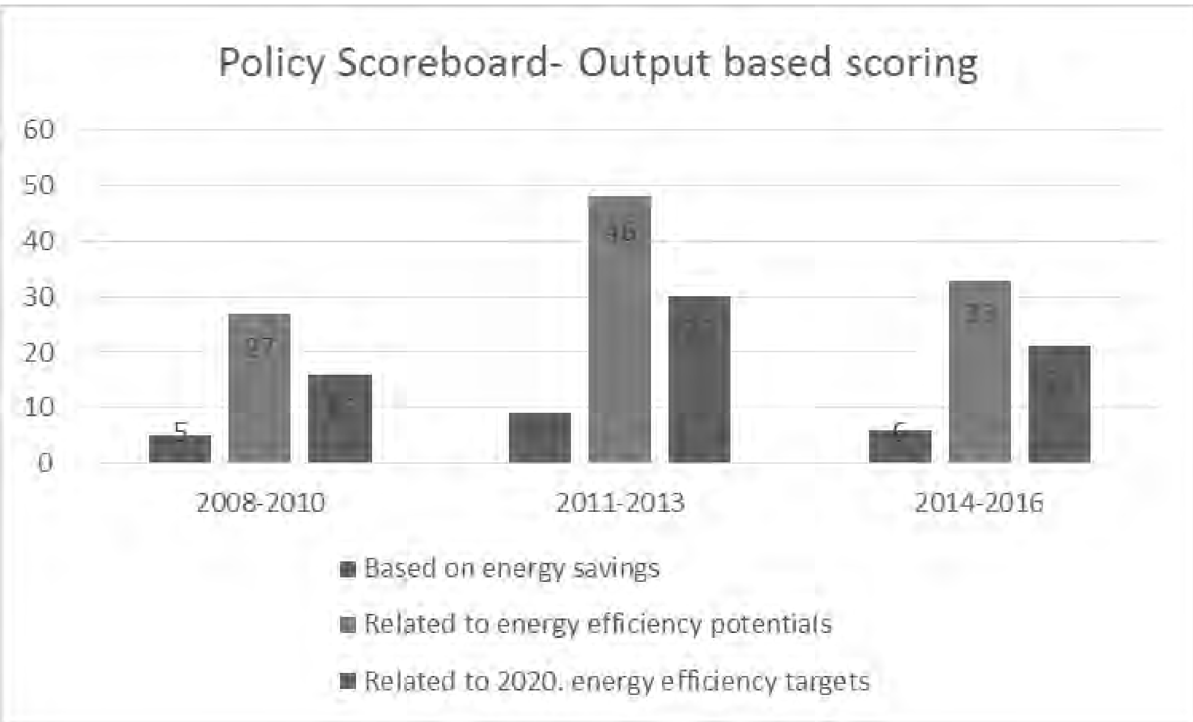
Figures separately

Figure 1 Outline of the policy cycle and the role of the programme theory in the policy cycle



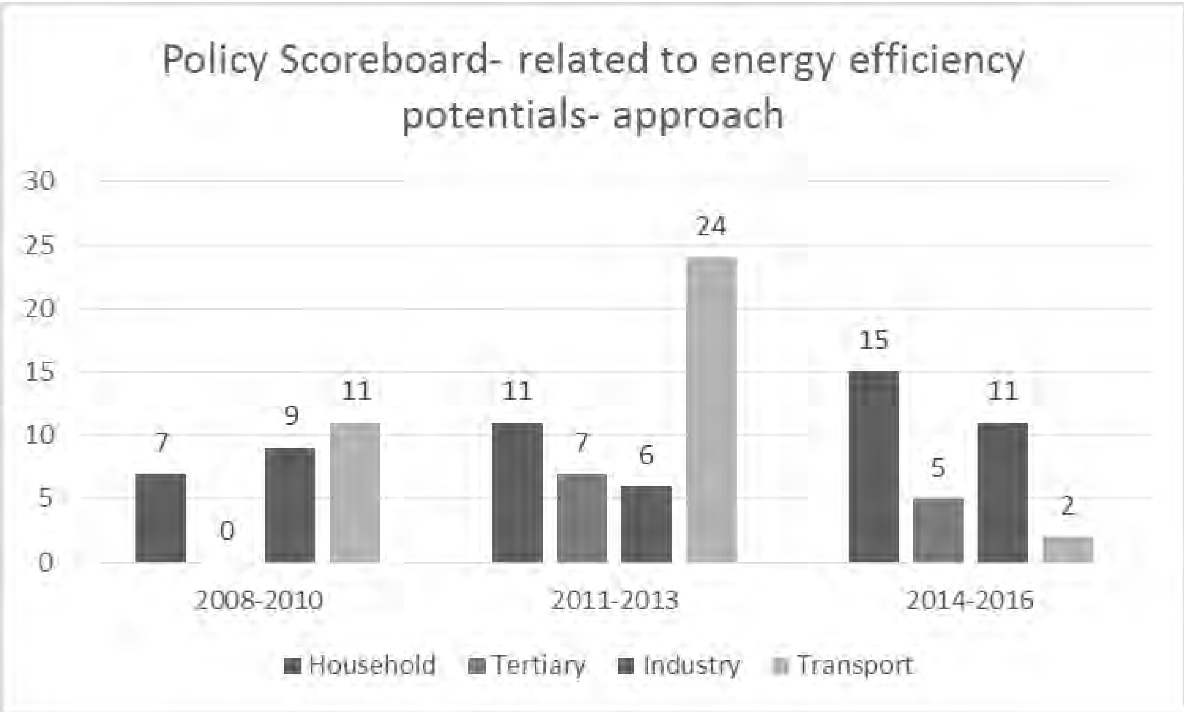
Source: Khan, J. et al., 2006: 4

Figure 2 Number of total measures and activities, differentiated upon 3 different output-based criteria, recorded in MURE data base



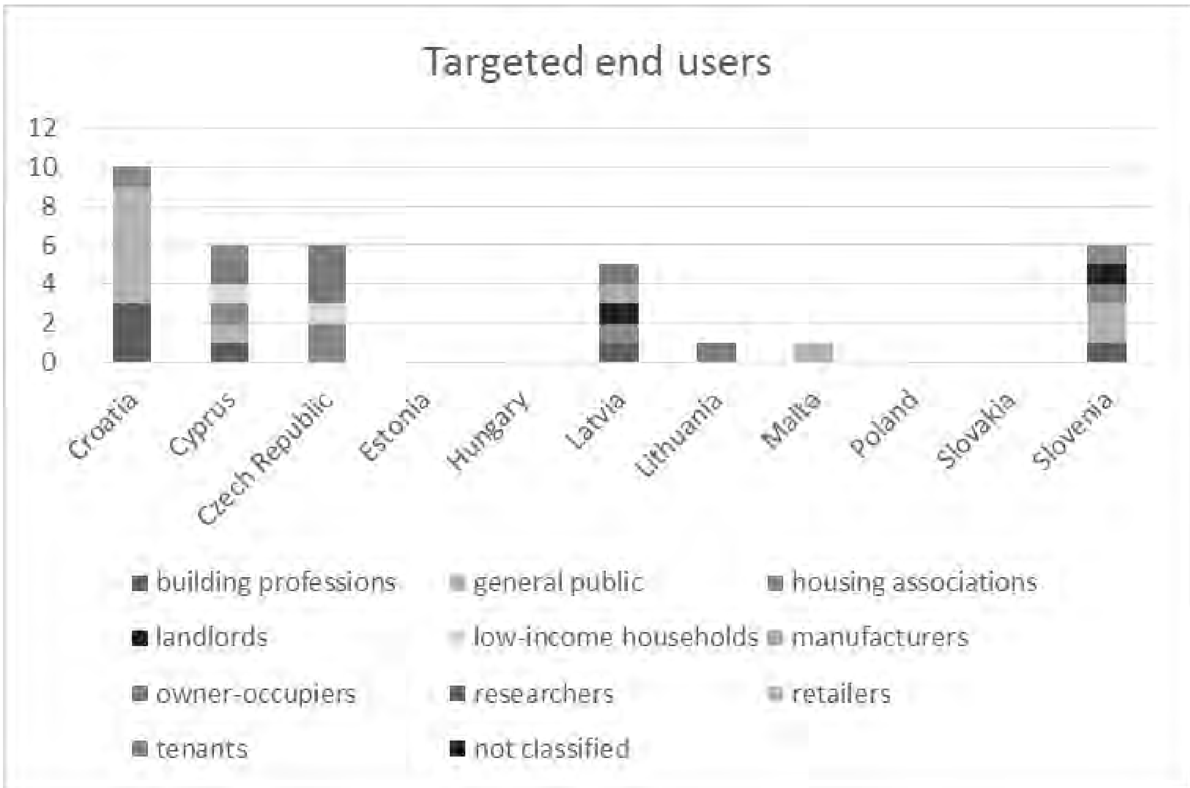
Source: authors' analysis based on the data from MURE data base

Figure 3 Distribution of energy savings measures among different sectors



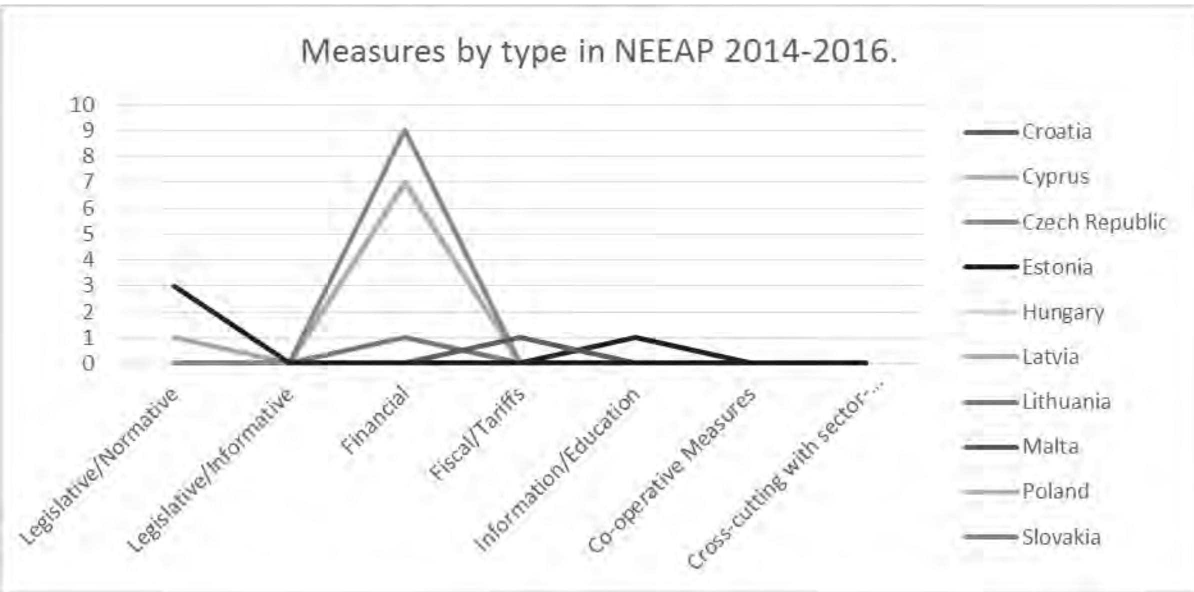
Source: authors' analysis based on the data from MURE data base

Figure 4 Targeted end users



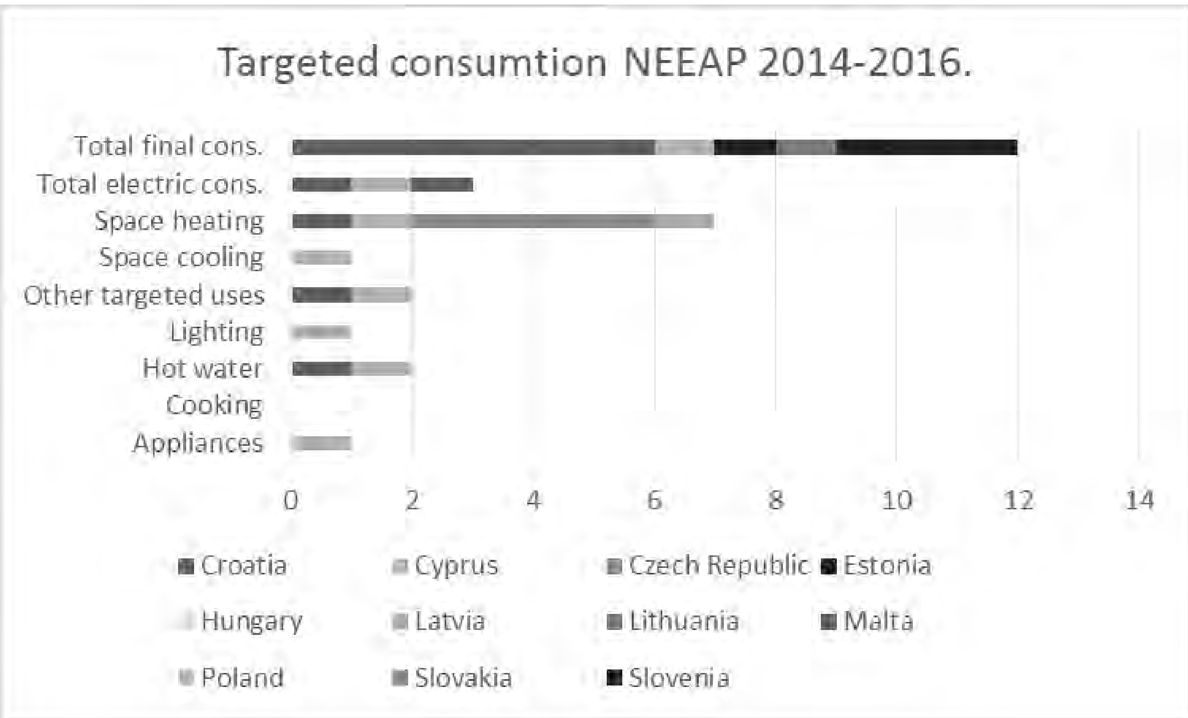
Source: authors' analysis based on the data from MURE and ODYSEE data bases

Figure 5 Energy efficiency measures by type



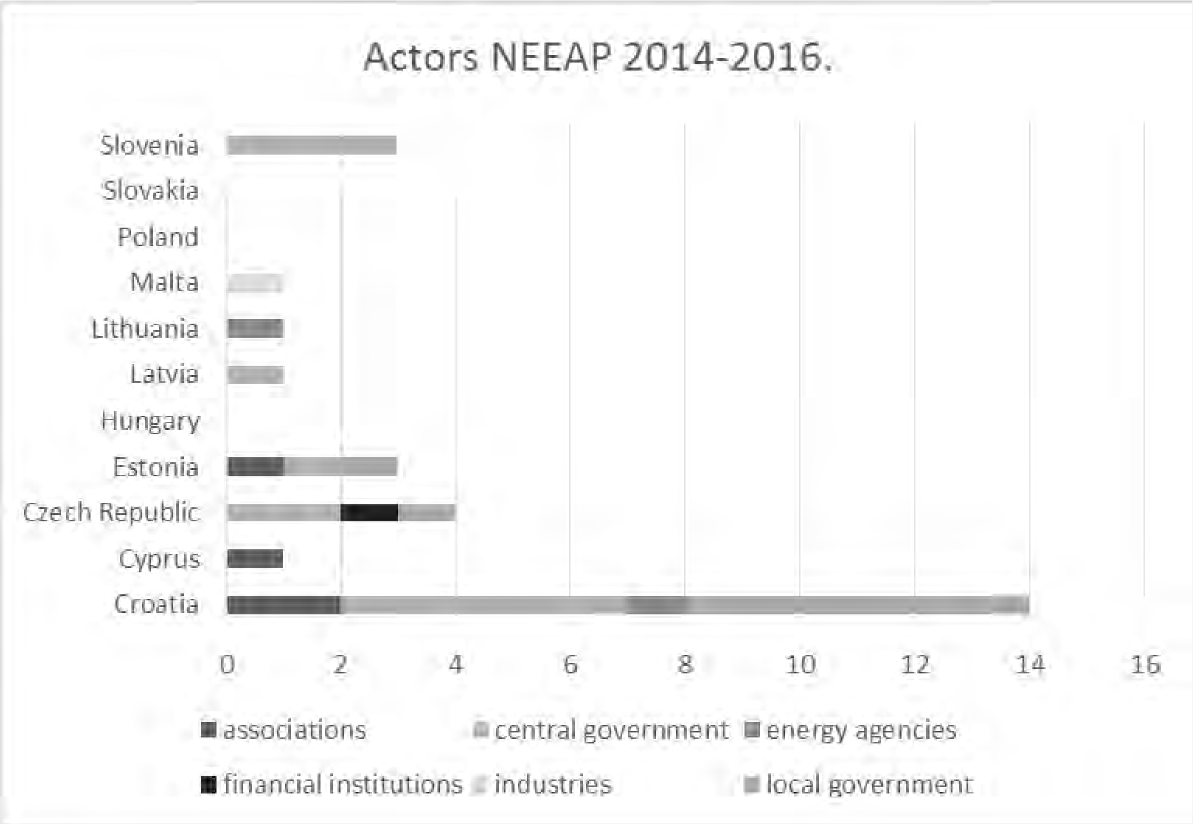
Source: authors' analysis based on the data from MURE data base

Figure 6 Measures according to targeted consumtion



Source: authors' analysis based on the data from MURE data base

Figure 7 Energy efficiency measures according to actors



Source: authors' analysis based on the data from MURE data base

[1] Prognoze hrvatskog gospodarskog rasta, (2016) Hrvatska gospodarska komora, Sektor za financijske institucije, poslovne informacije i ekonomske analize, available at: http://www.hgk.hr/documents/prognoze-hrvatskog-gospodarskog-rasta580f48a4caf16.PDF

[2] http://www.measures-odyssee-mure.eu/MureScoreboardMethodology.pdf

[3] http://www.measures-odyssee-mure.eu/scoreboard-energy-efficiency-policy.asp

[4] Direktiva o energetskoj učinkovitosti, (2012), 2012/27/EU available at: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2012:315:0001:0056:EN:PDF

[5] Report from the Commission to the European Parliament and the Council assessment of the progress made by member states towards the national energy efficiency targets for 2020 and towards the implementation of the Energy Efficiency Directive 2012/27/EU available at: http://eur-lex.europa.eu/legal-content/HR/TXT/PDF/?uri=CELEX:52015DC0574&from=EN

[6] Energija u Hrvatskoj – godišnji energetski pregled (2015), Ministarstvo zaštite okoliša i energetike, http://www.eihp.hr/wp-content/uploads/2017/03/EUH2015.pdf

[7] Report from the Commission to the European Parliament and the Council assessment of the progress made by member states towards the national energy efficiency targets for 2020 and towards the implementation of the Energy Efficiency Directive 2012/27/EU available at: http://eur-lex.europa.eu/legal-content/HR/TXT/PDF/?uri=CELEX:52015DC0574&from=EN

International Performance of Croatian Construction Companies

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Abstract:

The intensification of the process of globalization and international competition increases the number of companies that weight internationalization of its business. Therefore internationalization of construction firms gets more importance and comes into focus of research interest, so it represents a major challenge for managers and owners of construction companies (primarily due to the specifics of the construction industry). The paper presents the results of surveys conducted among construction companies that have their income realized abroad. Research has shown how much experience Croatian construction companies have in international markets, on how many foreign construction projects they were involved, in which countries, in what kind of projects were involved. The subjects also evaluated their performance in foreign markets using the following indicators: organizational performance, market performance and customer satisfaction. Furthermore, the importance of increasing international performance and the suggestions for further research in the field of international construction are presented at the end.

Keywords: construction industry, internationalization, performance, Croatian construction companies

1. Introduction

At one point of time every company is considering the possibility of winning new markets. Internationalization is the process of ever-increasing connectivity of countries and dissemination of interdependent technological, production, trade, traffic, communication and other relationships between them (Economic lexicon, 2011). The international construction sector is an important part of Global economy. There is an increasing need for domestic construction companies to expand their business to overseas markets. After the "golden age" of the Croatian construction industry for about seven years, in 2008 the global economic crisis expanded to Croatian construction. This is primarily expressed in reduced real estate sales, smaller investments in shopping centers and business premises, as well as in the reduction of infrastructure projects. Today a survival strategy for all businesses, especially for construction companies is coming out to global markets.

At the time of globalization and increasingly competitive environment, measuring performance has become crucial for successful strategic business management. Organizational

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performance represents the business image of the organization today (Vukomanović and Radujković, 2011). Performance management is a discipline that emerged in the nineties of the last century because of the unsatisfactory use of financial measures in monitoring business performance. Primarily because of availability of financial information after management actions and decisions, and also over a certain accounting period, but managers need information immediately - currently, up-to-date, mainly non-financial information (Bassioni et al., 2004).

The paper begins with a definition of a performance and an international performance founded in the literature. Then it presents the research design and methodology and after that presents the results of conducted survey. The paper concludes with a discussion of the study's findings and suggestions for further research in the field of international construction.

2. International performance

The importance of measuring performance as a tool for assessing the management of executing and implementing the company's strategy has risen backwards for 20 years both in academic and business circles within different industries. The importance of identifying an organization's performance is evident throughout the markets worldwide, the results of which are to attract future investment, to increase share value and to attract high caliber employees (Kagioglou et al., 2001). In construction, the measuring performance is even more expressed in terms of its specificity, simultaneous implementation of various projects and control of a large number of input resources (Yu et al., 2007).

As a result of the research on the topic international business, it's shown that the performance was also a crucial variable that many researchers were interested in. Hult et al. (2008) investigated and summarized all the research and studies published in 96 papers from international journals in the period from 1995 to 2005, which concerned the ways of measuring performance in the context of international business. Their research was based on Venkatraman and Ramanujam's (1986) performance measurement framework. They evaluated the ways of measuring performance through three dimensions:

- Data source types (primary or secondary)[2],
- Measurement methods (financial, operational and overall effectiveness) and
- Level of analysis (at enterprise level, strategic business unit or inter-organization).

Until now the conducted research on this topic has covered two areas: 1. Measuring performance of construction companies (mainly focusing on domestic construction companies market) and 2. Internationalization of construction companies (Jin et al., 2013). There are too little research and literature devoted to measuring performance of international construction companies. The most significant research on this topic was conducted by Jin et al. (2013) who

[2]According to Venkatraman and Ramanujam (1986), primary data implies subjective information, and secondary objective.

investigated the performance of international construction companies considering international business and domestic support. They developed a model for measuring performance of international construction companies based on the Balanced Scorecard (BSC) model.

Business performance measurement (BPM) using various sets of financial and non-financial measures. The most important performance indicators used in this research are organizational performance, market performance and customer satisfaction.

2.1 Business performance

Business (Organization) performance can be measured by subjective manager's estimation and / or by analysis of financial statements, such as balance sheet and profit and loss account. Dees and Robinson's Studies (1984), Fynes et al. (2005) and Venkatraman and Ramanujam (1986) have shown that the manager's expert assessment about company's business results does not deviate significantly from the indicators obtained from the company's financial statements. In favor of using organizational performance indicators as a measure for performance evaluation there is also a fact that until recently measuring performance in the construction industry was dominantly focused on project performance and neglected the organizational level. Today, however, management performance and performance measurement at the organizational level is gaining increasing importance.

2.2 Market performance

The second group of performance indicators refers to market performance. According to Jin et al. (2013) market performance is a unique dimension used for measuring international companies' performance, and chosen based on literature reviews and studies in the field of international construction. The market performance measurement mostly focuses on management of construction companies in different foreign markets. Using expert assessments of managers to evaluate market performance (eg. market share) is better accepted than the use of financial indicators (Franco-Santos et al., 2007).

One of the reasons is that market performance indicators, such as market share, do not necessarily need to give a result in a favorable financial outcome (Norreklit, 2000). The market share is usually considered from a customer / client perspective (Kaplan and Norton, 1996b) and relates to their satisfaction and retention, and hence increased revenue. However, according to Jin et al. (2013) this method of market performance measuring is not suitable for the construction industry due to its low concentration ratio (large number of small and medium-sized construction companies on the market).

2.3 Customer performance

Customer satisfaction measurement is an indispensable part of company's measuring performance. These indicators are chosen based on theoretical implications that strengthening customer value leads to greater customer connectivity and ensuring high quality business, especially in the construction industry (Jin et al., 2013). It is considered that every successful company owes its long-term success to the superior fulfillment of customer needs and expectations (Mueller and Srića, 2005).

Since the construction industry is characterized by the participation of different stakeholders with different goals, the use of the above-mentioned models is justified for measuring performance of the construction companies, and their constituent part is customer satisfaction measurement of construction projects. In this paper, customer satisfaction will not be measured using common categories (such as cost, time, and quality), but will be used by expert evaluators of value-added managers, customer relationships, and overall customer satisfaction.

3. Research method

In this paper the research was conducted by serious and detailed interviews with 35 experts from Croatian construction companies who participated in foreign construction projects, either as contractors or as consultants. All respondents participated in the decision-making process on internationalization of their business operations and on the choice of strategy for foreign markets. In the first part of the interview, respondents answered to general questions about the international projects they participated in, while in the second part of the interview they expressed their views about the international performance of their companies so far. The attitudes of the respondents were measured by the average ratings of the corresponding statements, using the Likert scale, determined by a 5-degree scale.

2.1 Performance indicators

Performance indicators of the international business of construction companies are based on the model developed by Jin et al. (2013). They based their model on the Balance Score Card model, which initially consists of 4 dimensions: financial measures, customer satisfaction, internal processes, learning and development. Subsequently, they extended it for two other dimensions: market performance and stakeholder satisfaction.

Three dimensions (shown in Table 1) were selected for the purpose of this research, which will measure the performance of international business operations of Croatian construction companies: Business Performance - BP, Market Performance - MP and Customer Performance - CP.

Table 1. Performance indicators

	INDICATOR	AUTHOR
	BUSINESS PERFORMANCE	
BP-1	Corporate income growth	Morgan et al. (2012)
BP-2	Providing business profitability	Styles (1998)
BP-3	Defined strategy acts on foreign markets	Cadogan et al. (2009)
BP-4	Foreign income	Cadogan et al. (2009)
BP-5	Share of foreign income in total income	Jin et al. (2013)
BP-6	Reputation / image (good references) of a company	Jin et al. (2013)
	MARKET PERFORMANCE	
MP-1	Strategic position on the Global market	Zou and Cavusgil (2002)
MP-2	Market share in foreign markets	Cadogan et al. (2009)
MP-3	Improve market share in foreign markets	Cadogan et al. (2009)
MP-4	Satisfaction with performance in overseas markets back 3 years	Cadogan et al. (2009)
	CUSTOMER PERFORMANCE	
CP-1	Client's satisfaction	Krohmer et al. (2002)
CP-2	Retaining existing clients	Krohmer et al. (2002)
CP-3	Collaboration with clients	Jin et al. (2013)
CP-4	Attracting new clients	Krohmer et al. (2002)

4. Results

As it’s mentioned, there are 35 Croatian construction companies, with experience in international business that has participated in the survey. The distribution of the surveyed enterprises by size[3] is given in Table 2.

Table 2. Distribution of enterprise from sample by size

		Frequency	Percent	Cumulative Percent
Valid	Small	16	45.7	45.7
	Medium	5	14.3	60.0
	Large	14	40.0	100.0
	Total	35	100.0	

In the sample of this study there were 16 (47.1%) small construction enterprises, only 5

[3]The number of employees as a criterion for company's size:

- small company– from 10 to 50 employees
- medium - sized company– from 51 to 250 employees
- large company – 251 and more employees

medium - sized (14.7%) and 14 large (38.2%).

By analyzing the experience of companies operating in foreign markets, the tested companies were distributed as shown in Table 3.

Table 3. Business experience of a company from a sample on a foreign market (number of years)

		Frequency	Percent	Cumulative Percent
Valid	1 – 5 years	5	14.3	14.3
	5.1 – 10 years	7	20.0	34.3
	10.1 – 20 years	10	28.6	62.9
	More then 20 years	13	37.1	100,0
	Total	35	100,0	

As can be seen from Table 3, 12 companies with less than 10 years of experience in foreign markets (around 35%) participated in the survey, while 10 companies have experience between 10 and 20 years (28.6%). More than 20 years of work experience in foreign markets have 13 (35.3%) of construction companies from the sample.

The number of countries involved in this study is shown in Table 4. The largest number of construction companies from the sample participated in foreign projects in 5 to 9 countries (42.9%, 15 of them). In 10 and more foreign countries, 9 sampled companies (25.7%) participated.

Table 4. Number of countries where Croatian construction companies from the sample participated:

		Frequency	Percent	Cumulative Percent
Valid	1 – 4	11	31.4	31.4
	5 – 9	15	42.9	74.3
	10 and more	9	25.7	100.0
	Total	35	100,0	

With regard to the number of foreign projects where the construction companies from the sample participated, the average number of projects is 42. Only eight companies have so far participated in less than 10 projects (of which one company is on one project). More than 50% of respondents participated in 10 to 20 foreign projects (18), while 25.7% (9 of them) participated in 21 and more foreign projects (Table 5).

Table 5. Number of projects where Croatian construction companies from the sample participated

		Frequency	Percent	Cumulative Percent
Valid	Less then 10	8	22.9	22.9
	10 – 20	18	51.4	74.3
	21 and more	9	25.7	100.0
	Total	35	100,0	

The largest number of projects, analyzed by this survey, was for the public investor (65.7%, 23 of them). Also there were 8 (22.9%) private projects and 4 (11.4%) of the public-private partnership projects.

Table 6. Distribution of project types on a foreign market of companies from sample

		Frequency	Percent	Cumulative Percent
Valid	Public	23	65.7	65.7
	PPP	4	11.4	77.1
	Private	8	22.9	100.0
	Total	35	100,0	

The countries where the observed foreign projects are realized are presented in Table 7.

Table 7. Distribution of countries where the projects from the sample are realised

		Frequency	Percent	Cumulative Percent
Valid	Albania	2	5.7	5.7
	Algeria	4	11.4	17.1
	Arabaian penisnula	2	5.7	22.9
	Austria	1	2.9	25.7
	Bosnia & Herzegovina	5	14.3	40.0
	Montenegro	2	5.7	45.7
	India	1	2.9	48.6
	Ireland	1	2.9	51.4
	Kosovo	2	5.7	57.1
	Hungary	1	2.9	60.0
	Germany	2	5.7	65.7
	Qatar	1	2.9	68.6
	Russia	2	5.7	74.3
	Slovenia	3	8.6	82.9
	Serbia	5	14.3	97.1
	Sudan	1	2.9	100.0
	Total	35	100.0	

Table 7 shows that the observed projects were realized in 16 different countries. The largest number of projects covered by this survey was conducted in Bosnia and Herzegovina and Serbia (14.3%, 5 of them). Than Algeria, 4 projects (11.4%) and Slovenia, 3 projects (8.6%), Albania, the Arabian Peninsula, Montenegro, Kosovo, Germany and Russia with 2 projects (5.7%) and At the end with only one project in Austria, India, Ireland, Hungary, Qatar and Sudan (2.9%).

Finally, it is interesting to note that 25 sampled companies already had experience in projects participating in the country where the project was monitored, later even 29 companies concluded new jobs and continued their business in that country.

Company performance results across three dimensions: business performance (BP1 - BP6), market performance (MP1 - MP4) and customer performance (CP1 - CP5). The average rating of the respondent on the statement of performance of his/her company is shown in Table 8.

Table 8. Respondets' attitude about company performance

Indicator	**Intensity in %**					**Average rating**
	1= Totally disagree	**2**= mostly disagree	**3**= neither agree nor disagree	**4**= mostly agree	**5**= totally agree	
BP-1	2.9	2.9	28.6	34.3	31.4	3.89
BP-2	0.0	8.6	22.9	4.0	28.6	3.89
BP-3	2.9	14.3	17.1	20.0	45.7	3.91
BP-4	8.6	25.7	22.9	25.7	17.1	3.17
BP-5	5.7	17.1	25.7	22.9	28.6	3.51
BP-6	0.0	20.0	14.3	34.3	31.4	3.77
MP-1	25.7	25.7	31.4	14.3	8.6	2.74
MP-2	20.0	25.7	31.4	14.3	8.6	2.66
MP-3	11.4	17.1	28.6	31.4	11.4	3.14
MP-4	17.1	22.9	20.0	25.7	14.3	2.97
CP-1	5.7	0.0	20.0	42.9	31.4	3.94
CP-2	8.6	0.0	17.1	45.7	28.6	3.86
CP-3	5.7	5.7	14.3	48.6	25.7	3.83
CP-4	5.7	11.4	25.7	42.9	14.3	3.49

According to the presented results, it can be concluded that all respondents are mostly satisfied only with the claims about realized customer performance on foreign markets. More than 50% of the respondents are largely and completely in agreement with the CP-1 claims - that their company meets the interests of customers on the foreign market (average rating 3.94), CP-2 - that their company retains existing customers on the foreign market (average grade 3.86), CP-3 - that their company has good cooperation with its clients on the foreign market (average rating 3.83). The lowest average rating (3.49) has the CP-4 claim - that their company is attracting new clients to foreign markets, which is justified by the recession and the unpredictable period in both Croatian and world construction.

Mostly respondents agree with their business performance claims on the foreign market, arguing with BP-4's claim - their company is satisfied with foreign revenues, which they do not agree with or disagree with (estimate 3.17). Observing the other claims of this group, BP-3 claims are best evaluated - that their company has a strategy on foreign markets (average grade 3.91), followed by BP-1 claims - to provide revenue growth and BP-2 - company ensures its profitability (average ratings 3.89).

Respondents neither agree nor disagree about the company's market performance claims. Looking at the average ratings, the highest rating has MP-3 claim - the company continuously improves its market share in foreign markets (average rating 3.14).

5. Conclusion

This paper analyzes the results of a survey with aim to explore situation within Croatian construction companies and their international performance. Today entering global markets is increasingly becoming a survival strategy for all companies, especially for construction companies, because domestic construction companies have become much too small, and regional, even European, companies are in the same or similar stagnation or decline. Participation in international business makes it necessary to adopt new marketing principles, new technologies and educate personnel.

There are respondents from 35 Croatian construction companies who participated in the survey, mostly having more than 10 years of experience in the international market and most of them participated in more than 10 international projects. Most international projects have been implemented in the countries of the region, Bosnia and Herzegovina and Serbia, followed by Algeria. It is indicative that projects in the Middle East and other countries were conducted 10 years ago or even more, as well as that very few projects and operations were conducted in European countries.

Respondents were asked to evaluate claims regarding the performance of their companies in inexperienced markets and these results showed that respondents of Croatian construction companies are most satisfied with the achieved customer performance, followed by business performance and at least with marker performance (e.g., Market discipline in certain countries or its strategic position in foreign markets). These results gave a good insight into the situation of Croatian companies on the international construction market and their performance, as well as the need to improve this position and develop a clear strategy and support for future non-national business as one of the key models of recovery and competitiveness of Croatian construction industry. But, it is undisputed that Croatian construction companies should concentrate on exporting their knowledge and experience on civil engineering projects. Entering foreign markets with well-defined business and well thought-out marketing strategies should be an essential factor in the successful project management of domestic construction companies on the large global market. We believe that this study opens up an opportunity for further research. Further research might give guidelines for increasing business performance of Croatian construction companies in foreign markets.

References

Bassioni, H., Price, A. and Hassan, T. (2004) Performance Measurement in Construction, Journal of Management in Engineering, 20 (2), 42–50.

Dess, G. D. and Robinson, R. B. (1984) Measuring Organizational Performance in the Absence of Objective Measures: The Case of the Privately-Held Firm and Conglomerate Business Unit, *Strategic Management Journal*, 5 (3), 265-273.

Cadogan, J. W., Kuivalainen, O. and Sundqvist, S. (2009) Export market-oriented behavior and export performance: Quadratic and moderating effects under differing degrees of market dynamism and internationalization, *Journal of International Marketing*, 17(4), 71-89.

Ekonomski leksikon (2011) Leksikografski zavod Miroslav Krleža, Zagreb (Digital Edition/CD)

Franco-Santos, M., Kennerley, M., Micheli, P., Martinez, V., Mason, S., Marr, B., Gray, D. and Neely, A. (2007) Towards a definition of a business performance measurement system, *International Journal of Operations & Production Management*, 27(8), 784-801.

Fynes, B., Voss, C. and Búrca, S. D. (2005) The impact of supply chain relationship dynamics on manufacturing performance, *International Journal of Operations & Production Management*, 25 (1), 6-19.

Hult, G. T. M., Ketchen, D. J., Griffith, D. A., Chabowski, B. R., Hamman, M. K., Dykes, B. J., Pollitte, W. A. And Cavusgil, S. T. (2008) An assessment of the measurement of performance in international business research, *Journal of International Business Studies*, 39 (6), 1064–1080

Jin, Z., Deng, F., Li, H. and Skitmore, M. (2013) Practical Framework for Measuring Performance of International Construction Firms, *Journal of Construction Engineering and Management*, 139 (9), 1154–1167.

Kagioglou, M., Cooper, R. and Aouad, G. (2001) Performance management in construction: a conceptual framework, *Construction Management and Economics*, 19, 85–95.

Kaplan, R. S. and Norton, D. P. (1996) Using the balanced scorecard as a strategic management system, *Harvard Business Review*, 74(1), 75–85.

Krohmer, H., Homburg, C. and Workman, J.P. (2002) Should Marketing Be Cross-Functional? Conceptual development and inernational empirical evidence, *Journal of Business Research*, 55 (6), 451–465.

Morgan, N. A., Katsikeas, C. S. and Vorhies, D. W. (2012) Export marketing strategy implementation, export marketing capabilities, and export venture performance, *Journal of the Academy of Marketing Science*, 40(2), 271–289.

Mueller, J. and Srića, V. (2005) *Upravljanje odnosom s klijentima*, Delfin razvoj managementa, Zagreb

Norreklit, H. (2000) The balance on the balanced scorecard—A critical analysis of some of its assumptions, *Management Account. Research*, 11(1), 65–88.

Venkatraman, N. and Ramanujam, V. (1986) Measurement of business performance in strategy research: A comparison of approaches, *Academy of Management Review*, 11 (4), 801–814.

Vukomanović, M. and Radujković, M. (2011) *Poslovna izvrsnost u građevinarstvu RH*, Sveučilište u Zagrebu, Građevinski fakultet i Hrvatska udruga za organizaciju građenja, Zagreb

Yu, I., Kim, K., Jung, Y. and Chin, S. (2007) Comparable Performance Measurement System for Construction Companies, Journal of Management in Engineering, 23 (3), 131–139.

Zou, S. And Cavusgil, S. T. (2002) The GMS: A broad conceptualization of global marketing strategy and its effect on firm performance, *Journal of Marketing*, 66 (4), 40-56.

Improving Performance of Building Construction Projects: A New Approach of Labor Productivity Benchmarks

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Abstract:

Labor productivity is one of the main factors directly affecting a construction firm's profitability in building projects. The purpose of this paper is to evaluate construction projects' productivity and to demonstrate conceptual benchmarking principles, implementing a widely applied theoretical model with a supplement of a simple statistical procedure. A new approach for estimating baseline productivity and determining the abnormal workdays for common construction activities is introduced, with the application of a process control chart using statistical analysis. The proposed method is combining the baseline subset concept with control limits and is considered to be more simple and appropriate for benchmarking labor productivity records. Benchmarks, in the form of indices, such as the Disruption Index, the Performance Ratio and the Project Management Index were calculated from in-situ daily measurements for two different plastering techniques, applied in two similar building construction projects in the region of Thrace, Greece. Findings revealed that construction workers' productivity performance varied according to innovation in construction techniques, taking into consideration the type of the activity carried out and the surrounding work environment.

Keywords: *labor productivity; internal/external plastering; variability; benchmarking; productivity indices*

1. Introduction

Labor productivity is one the most discussed and debated topic in construction, with multiple levels of approach, since it is among the critical factors contributing to the profitability of most construction projects and one of the most commonly used performance indicators to assess their success. The main question of why the construction sector is considered problematic when it comes to productivity was provided with different answers by many authors and researchers. However, it should be recognized that the comparison of construction with other sectors is rather unfair. The automotive industry, for example, well known for its efficiency, can be rather easily standardized while much less stakeholders are involved and furthermore, weather dependency is almost out of question. On the other hand, construction industry includes many stakeholders, a great amount of trades, colliding interests and further social dependencies. More specifically, Greek construction sector is based on concrete and ceramic masonry, while timber is very limited and not widely used. Structures are more reinforced and demanding, since earthquake probability is relatively high. Hence,

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buildings are less flexible and more focused on constructability. Despite these differences, the Greek construction sector has recognized the need for improvement in its productivity.

Yi and Chan (2014), attempting a systematic review on literature upon labor productivity in the construction industry, identified baseline/benchmarking construction labor productivity as a major research area among the related topics. Focusing on the realistic approach of productivity measurement on the building construction site, this paper reviews a number of benchmarks that can be used for labor productivity improvement in construction projects, as an extension of a previous study (Manoliadis, 2011), applying a slightly altered version of the well-established theoretical model of Thomas and Zavrski (1999a,b) and utilizing data of daily reported productivity rates of construction activities. In addition, the proposed approach uses an alternative methodology of calculating the baseline productivity, based on similar statistical techniques reported in the literature, by the definition of the baseline subset and the estimation of abnormal workdays employing a control chart with average productivity and standard deviation of daily recorded measurements. The method is tested in labor productivity benchmarking, with a case study of mortar plastering for a traditional and a modern plastering technique.

2. Literature review

2.1 The concept of construction productivity

Construction productivity, like productivity in general, can be viewed as a measure of outputs obtained by a combination of inputs. Number/balance and motivation of labor force were identified by Horner (1982) as critical factors, among others, that affect construction productivity. Olomolaiye *et al.* (1998) also identified labor skills and training as an internal factor affecting construction productivity performance. Construction productivity depends heavily on human effort and performance, since labor is one of the main productive resources, thus labor productivity is considered to be a critical productivity index in construction.

The main focus of most authors regarding the ways to increase productivity is waste elimination, mainly through benchmarking. Benchmarking, a systematic and continuous measurement, comparison and improvement process, consists an important lean construction principle (Koskela, 1992; Ballard and Howell, 1994;1998).

Thomas and Završki (1999b) defined the “ripple effect”, a common phenomenon on site, as a highly disrupted project where the work of a crew is affected daily, often by the work of others, and the loss of productivity cannot be related to a specific event. They pointed out that poorly performing projects have much higher variability than do projects that perform well. Therefore, reducing variability is a factor that leads to less waste, hence higher productivity levels.

2.2 Studies of benchmarking construction labor productivity

Several attempts have been made over the last decades to model construction labor productivity (Adrian, 1987; Abdel-Razek and McCaffer, 1990; Thomas and Zavrski, 1999a,b; Abdel-Hamid *et al*., 2004). Among them, Thomas and Zavrski (1999a,b) are considered to be the first to develop a conceptual, site-based framework specifically for benchmarking labor productivity of construction activities. Their model, known as "*Theoretical Model for International Benchmarking Labor Productivity*", was widely applied to establish the basis of benchmarking labor productivity by first determining certain project attributes (total work hours and quantities; cumulative and baseline productivity; abnormal workdays) and then calculating different project benchmarks in the form of indices, namely the Disruption Index (DI), the Performance Ratio (PR) and the Project Management Index (PMI). They also deployed the concept of Work Content which represented the complexity of each activity incorporated in their method, essential for confirming the application of the model according to the working conditions.

Enhassi *et al.* (2007), adopting Thomas and Zavrski's model, measured and compared masonry labor productivity across nine different construction projects located in Gaza Strip, Palestine. Accordingly, Abdel-Razek *et al.* (2007) calculated the same three indices as benchmarks of construction labor productivity using data from masonry activities on eleven building projects in Egypt and concluded that the three benchmarks of labor productivity were reliable indicators of project labor performance. Sweis *et al.* (2008) using the same method conducted a comparative study on factors affecting masonry labor productivity in U.S., U.K. and Jordanian construction projects, by quantifying and comparing the baselines among the three countries. Their results revealed that the quantified differences in the baseline values could be mainly attributed to skills and work methods used.

2.3 Methods of identifying baseline productivity

The identification of productivity baseline was treated in many different ways in the related literature by various researchers. Adopting the original measured mile method for lost construction productivity calculation, Thomas and Zavrski (1999a,b) were the first to introduce the *"baseline"* concept to deal with projects with unclear un-impacted sections, considering it as the best labor productivity level reached from a contractor in a single project, but using arbitrarily as a baseline subset *"the n workdays, approximating the 10% of the total workdays, that have the highest daily production or output"*.

Even though a large number of latter studies followed this approach as a practical method (Enhassi *et al.*, 2007; Abdel-Razek *et al.*, 2007; Sweis *et al.*, 2008), Ibbs and Liu (2005) had already argued that the baseline method was highly subjective, since there could be no evidence that 10% of the whole daily productivity is a reasonable or well-accepted percentage to represent the best performance a contractor could achieve. They introduced a new method called *"K-means clustering"* for baseline productivity calculation, trying to overcome this weakness, based on good contractors performance and related impact.

Assuming baseline as the labor productivity level that reflects a contractor's normal operating performance, Gulezian and Samelian (2003) proposed a general, measurement-based, objective approach for establishing a productivity baseline, upon the measured mile method. Introducing the concept of variation in individual productivity values, they explicitly considered variability with the use of a process control chart, a graphic diagram with limits, in order to uncover unusual productivity values and to isolate those representing the normal performance of the contractor. Their control chart comprised of three lines, a center line corresponding to the average or arithmetic mean productivity level and an upper/lower control limit, set at three standards deviations above/below the mean, respectively. To determine the productivity baseline they applied their control chart successively to the productivity values, eliminating at each stage the values that fall outside of the control limits. When no additional values existed out of control, then they estimated the baseline productivity as the arithmetic mean of productivity values left within control limits.

A similar method was introduced by Zhao and Dungan (2014) where they also adopted the basic principle of labor productivity loss calculation and defined the baseline subset as the section of work in which productivity reflects the constructor's normal operating performance, although not necessarily continuous in time. After segregating the productivity data into the un-impacted/lightly impacted (good) and the heavily impacted (bad) productivity group using the overall average productivity, they determined the baseline subset by eliminating extreme values from the good productivity group, also applying a control chart technique. Their technique was differentiating from the one by Gulezian and Samelian in that it was applied only to the good productivity group, rather than the whole set of values, and it was revised so to use the average productivity of the good group only as the center line of the control chart, instead of the arithmetic mean of the individual productivity values. The baseline productivity was then calculated as the average productivity of the baseline subset.

3. Methodology

3.1 Activity attributes and definitions

Activity attributes for estimating cumulative productivity are following the logic of the initial Thomas and Zavrski's model, as also applied by Enhassi *et al.* (2007) and Abdel-Razek *et al.* (2007). A slight differentiation from the aforementioned studies is in productivity calculation, with productivity rates measurements considered according to the general formula of productivity:

$$\textit{Productivity} = \textit{Output Quantity} / \textit{Input Quantity} \tag{1}$$

Outputs, depending on the worker's trade and the type of activity carried out, were measured as produced and finished quantities, while inputs were measured by the total man-hours, in other words the total hours consumed by the construction workers in order to achieve the output. This definition implies that higher rates values correspond to higher productivity.

The definitions of the activity attributes are considered as the following:

- <u>Total Workhours (TWH):</u> the sum of daily work hours consumed in each activity
- <u>Total Quantities (TQ):</u> the sum of daily quantities produced for each activity
- <u>Cumulative Productivity (CP):</u> the compilation of the completed quantities to date, given the workhours charged to the activity, calculated with the following equation:

$$CP\ (m^2/hr) = TQ\ (m^2)\ /\ TWH\ (hr) \tag{2}$$

Baseline productivity is referring to a project or an activity where the organization and construction plan is adequate and materials' or equipment's flows are properly scheduled, so the baseline concept is inevitably connected to best levels of performance. Yet, the proposed method is in part differentiating from the baseline subset approach of Thomas and Zavrski's model, adopting a combination of a subset consisting of above-average productivity values with a control chart procedure similar to those of Gulezian and Samelian (2003) and Zhao and

Dungan (2014). The approach used for anomaly data detection (Goldman and Cohen, 2004) applies successively the Lower Control Limit, through iterations, in order to determine the baseline subset content and identify the abnormal days.

- Control Limit: Disruptions are associated with lower productivity, however, the baseline is unaffected by disruptions. The boundary for this range is the Lower Control Limit (LCL), which can be calculated with the following equation:

  $$LCL = \bar{X} - 3\sigma \quad (3)$$

  where:

  - $\bar{X}$ is the overall average daily productivity for each activity, calculated as:

    $\bar{X} = \frac{\sum_{i=1}^{n} x_i}{n}$, with x_i the daily productivity values and n the number of working days

  - σ the standard deviation of the daily productivity, calculated as:

    $$\sigma = \frac{\sum \sqrt{(x_i - \bar{X})^2}}{n}$$

  The productivity values are divided to those worse than LCL (Group F), which represents abnormal days, and the remaining ones (Group R). This data separation process is demonstrated mathematically below:

  $X = (x_1, x_2, ...x_m)$, where *X:* the whole set of productivity values, and x_i: the *m* values of set *X*, with *i=(1,2,3,…,m),*then:

  - Group F is defined as: F=$\{x_i \mid x_i < \bar{X} - 3\sigma, \forall i\}$ (4)
  - Group R is defined as: R=$\{x_i \mid x_i \geq \bar{X} - 3\sigma, \forall i\}$ (5)
- Baseline subset: The final Group R is determined through an iteration process, when no additional productivity values remain under LCL. Then the baseline subset consists of all the values that are above the average productivity of the final Group R.
- Abnormal Workdays: Abnormal workdays refer to days with productivity significantly below average CP. Based on the above criteria, an abnormal (disrupted) workday is defined as any workday where the daily productivity value is below LCL, in each one of the iterations.
- Baseline Productivity (BP): Having the baseline subset defined, the two methods for calculating the BP for an activity in a project is the median (Thomas and Zavrski, 1999a,b; Sweis *et al.,* 2008) and the average (Enhassi *et al.,* 2007; Abdel-Razek *et al.,* 2007) of the productivity values in the baseline subset. In the proposed method, the average, meaning the arithmetic mean, of the values included in the baseline subset is used for the estimation of BP
- Expected Baseline Productivity: In the case of comparing labor productivity of identical construction activities between a number of projects, the expected BP was determined as the average BP value for all the examined projects (Thomas and Zavrski, 1999a,b; Enhassi *et al.,* 2007; Abdel-Razek *et al.,* 2007). In the proposed method, since the productivity of certain construction activities is examined individually in single projects, reported production rates representing the ideal or highest labor performance possibly

achieved, for such activities, are used to assess the expected BP. Such records can be found in data bases or portals of established and recognized organizations or associations in the field of construction.

The graphical representation of the process control chart for the identification of the abnormal days, the determination of the baseline subset and the calculation of BP is given in Figure 1.

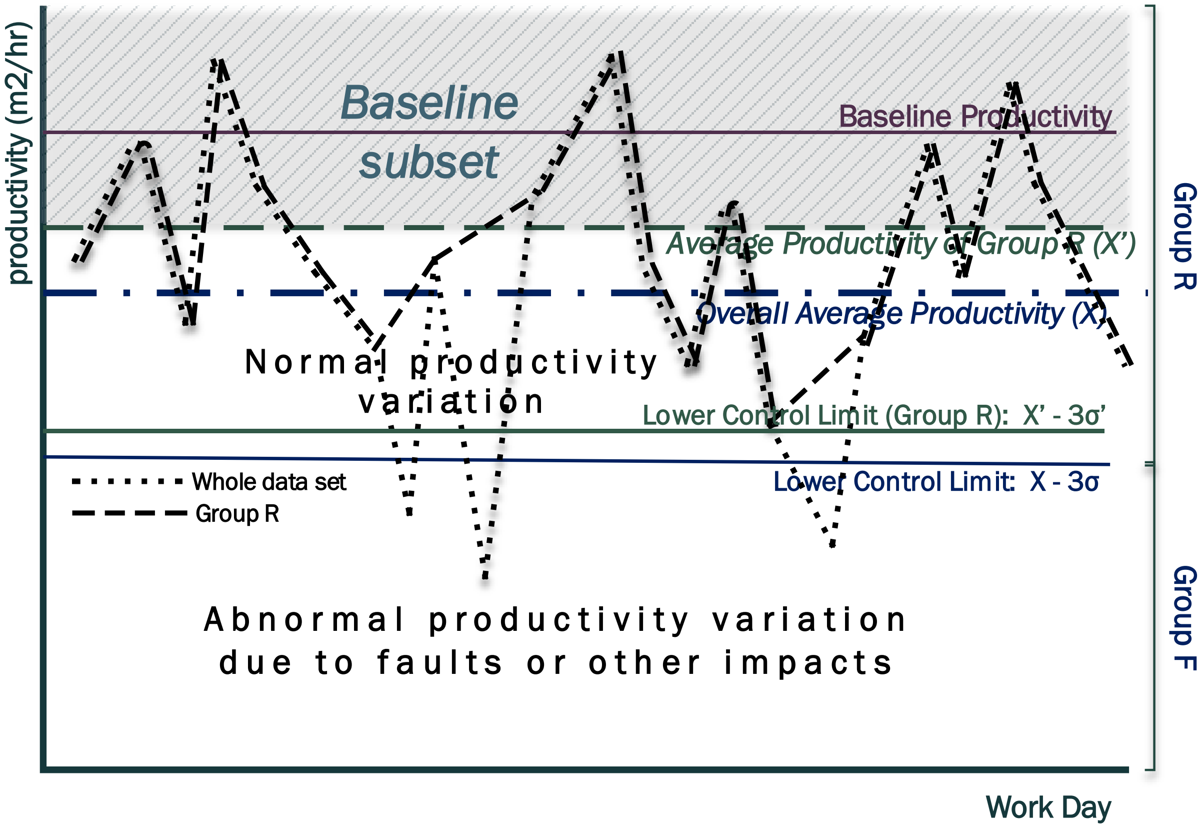

Figure 1: Process control chart

The steps of the iteration process of the proposed approach, for the identification of abnormal workdays and determination of the baseline subset, and finally the calculation of the Baseline Productivity, are presented below:

- The first step is to calculate the overall average productivity ($\overline{X}$) and standard deviation (σ) of the whole set of daily productivity values, in order to define LCL.
- The next step is to identify abnormal days, if any, so to determine Group R and then recalculate $\overline{X}$ and σ using Group R:

$$\bar{X} = \frac{\sum_{i=1}^{n} x_i}{n}, \quad \sigma = \frac{\sum \sqrt{(x_i - \bar{X})^2}}{n}, \quad x_i \exists R$$

in order to define the new LCL of Group R.

- If after the first iteration, values corresponding to abnormal days are still included in the Group R data set, a second iteration should be run, and so on.

- The last step, when no abnormal days are left in Group R, is to define the baseline subset from the average productivity of Group R and calculate BP.

The flow chart of the iteration process is presented schematically in Figure 2.

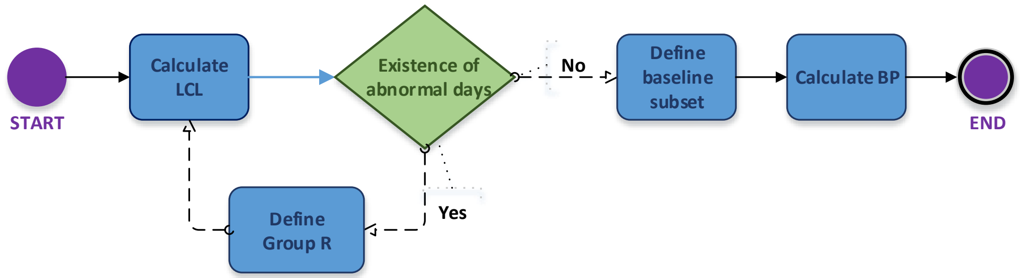

Figure 2: Flow chart of the iteration process

3.2 Indices calculation

Based on the above attributes, indices such as the Disruption Index (DI), the Performance Ratio (PR) and the Project Management Index (PMI), serving as benchmarks, can be calculated as introduced in the Thomas and Zavrski's model and employed in other similar studies (Abdel-Hamid *et al*., 2004; Enhassi *et al.,* 2007; Abdel-Razek *et al.,* 2007; Sweis *et al.*, 2008).

- Disruption Index (DI): A first indicator for benchmarking labor performance, representing a metric of the productivity disruption for an activity within a single project, expressed as the percentage of the abnormal days in the total number of workdays. It can be calculated by the following equation:

  $$DI = Number\ of\ abnormal\ workdays\ /\ Total\ number\ of\ workdays \qquad (6)$$

  The values of DI can range from 0.0, for an activity without abnormal days, to 1.0, for an activity with all the workdays abnormal. Higher values of the DI imply more disrupted activities, experiencing more abnormal workdays.
- Performance Ratio (PR): This ratio gives a general measure of the overall productivity performance, representing the comparison of the actual obtained productivity with the productivity considered as ideal or best, and is calculated with the following equation:

  $$PR = CP\ (unit/hr)\ /\ Expected\ BP\ (unit/hr) \qquad (7)$$

  Given the adopted definition of CP (Eq. 2), higher values of PR correspond to better labor performance for the construction activity. Based on the concept of the expected BP adopted, as presented in subsection 3.1, values of PR could only exceed 1.0 for exceptionally good performing activities, executed in ideal conditions, so values slightly below 1.0 should also correspond to good performing activities. Consequently, PR values below 0.5 indicate poorly performing activities.
- Project Management Index (PMI): A dimensionless parameter which reflects the project management contribution on the cumulative labor performance of the activity, comparing the actual CP to BP. This index provides a measure of the impact of poor material/equipment utilization, or inappropriate project planning, on performance and is

also used as a measure of waste. The definition of CP (Eq. 2), along with the proposed methodology for the determination of the baseline subset and the calculation of BP, makes clear that the BP value will be in any case higher than the CP one, so the calculation of PMI is conducted with the following equation:

$$PMI = (BP - CP)\ (unit/hr)\ /\ Expected\ BP\ (unit/hr) \qquad (8)$$

Obviously, improved project management's influence on the overall performance leads to decreased PMI values. The lower the PMI values the better the overall activity performance.

4. Case study

4.1 Data collection process

Labor productivity data of plaster workers, regarding two plastering activities (one traditional and one modern using gypsum), performed by separate work crews, each consisting of a tradesman and a laborer, were collected from daily in-situ measurements, in order to benchmark labor productivity for block mason and plaster mason. The plastering activities were carried out in two residential building projects in the region of Thrace, Greece, constructed at the same period and sharing similar characteristics in scope, size, specifications, quality requirements and design features.

The measurements for the two plastering activities referred to:

- Gypsum plaster mason of 12 mm on block work, for internal plastering, where the amount of plastered area is expressed in m^2/hr
- Plaster mason of external plastering, where the amount of plastered area is expressed in m^2/hr

Data collection focused on quantity of work done by mason, time required to complete that particular work and also document factors that may affect the work of each crew in a daily productivity sheet. Measurements of work quantity on a particular day were recorded once daily, at the end of the workday.

4.2 Results and discussion

Daily productivity values for the two plastering activities were recorded for the time period each activity lasted and their respective activity attributes, namely the Overall Average and the Cumulative Productivity and the Lower Control Limit, were calculated in order to investigate the existence of abnormal workdays and the definition of the baseline subset, consequently. The daily productivity measurements and the calculated activity attributes, for the whole set of productivity values, for both plastering activities, are reported in Table 1. Their process control charts are depicted in Figures 3 and 4 respectively.

Table 1: Daily productivity values and activity attributes for the whole data set

Gypsum Plastering			Plaster Mason of external plastering		
Work Day (A/A)	***Daily Productivity (m^2/hr)***	***Day characterization***	**Work Day (A/A)**	***Daily Productivity (m^2/hr)***	***Day characterization***
1	4,22	normal	1	3,48	normal
2	4,78	normal	2	3,32	normal
3	3,53	normal	3	3,57	normal
4	3,80	normal	**4**	2,34	***abnormal***
5	3,67	normal	5	3,00	normal
6	4,07	normal	6	3,32	normal
7	3,27	***abnormal***	**7**	2,36	***abnormal***
8	3,60	normal			
9	3,80	normal			
Cumulative Productivity (CP)	3,860		**Cumulative Productivity (CP)**	3,056	
Overall average productivity	3,860		**Overall Average Productivity**	3,056	
Standard Deviation	0,140		**Standard Deviation**	0,180	
Lower Control Limit (LCL)	3,440		**Lower Control Limit (LCL)**	2,516	
Abnormal days	1 (No7)		**Abnormal days**	2 (No 4,7)	

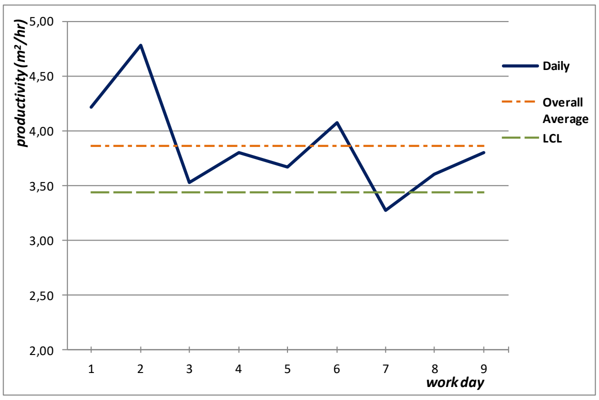

Figure 3: Process control chart for Gypsum Plastering

Figure 4: Process control chart for Plaster Mason

The results presented in Table 1 and in the two control charts, Figures 3 & 4, reveal the existence of one abnormal day for Gypsum Plastering (Workday No 7) and two for Plaster Mason (Workdays No 4 & 7). The procedure is repeated, excluding the abnormal days from the productivity values for the two activities, using Group R, where:

- Gypsum Plastering: Group R = Workdays 1, 2, 3, 4, 5, 6, 8, 9
- Plaster Mason: Group R = Workdays 1, 2, 3, 5, 6

Results for the activity attributes of both plastering activities, after the 1st iteration of the procedure, are reported in Table 2, while the process control charts are depicted in Figures 5 and 6 respectively.

Table 2: Daily productivity values and activity attributes after 1st iteration

Gypsum Plastering				**Plaster Mason of external plastering**			
Work Day (A/A)	***Daily Productivity (m^2/hr)***	***Day characterization***	***Baseline subset***	**Work Day (A/A)**	***Daily Productivity (m^2/hr)***	***Day characterization***	***Baseline subset***
1	4,22	normal	***Yes***	1	3,48	normal	-
2	4,78	normal	***Yes***	2	3,32	normal	-
3	3,53	normal	No	3	3,57	normal	-
4	3,80	normal	No	**5**	3,00	***abnormal***	-
5	3,67	normal	No	6	3,32	normal	-
6	4,07	normal	***Yes***				
8	3,60	normal	No				
9	3,80	normal	No				
Group R average productivity			3,934	**Group R average productivity**			3,338
Standard Deviation			0,137	**Standard Deviation**			0,087
Lower Control Limit (LCL)			3,524	**Lower Control Limit (LCL)**			3,077
Abnormal days			-	**Abnormal days**			1 (No 5)
Baseline Productivity (BP)			4,357	**Baseline Productivity (BP)**			-

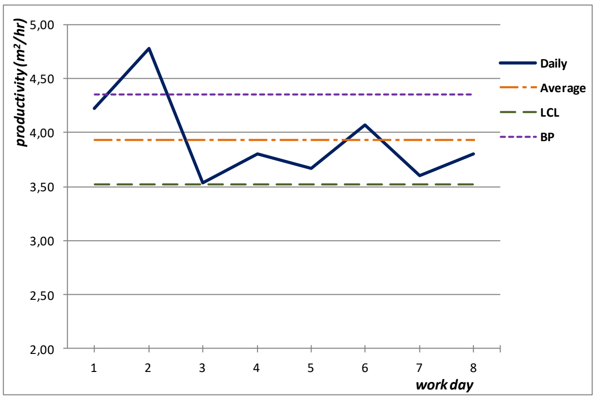

Figure 5: Process control chart for Gypsum Plastering after 1st iteration

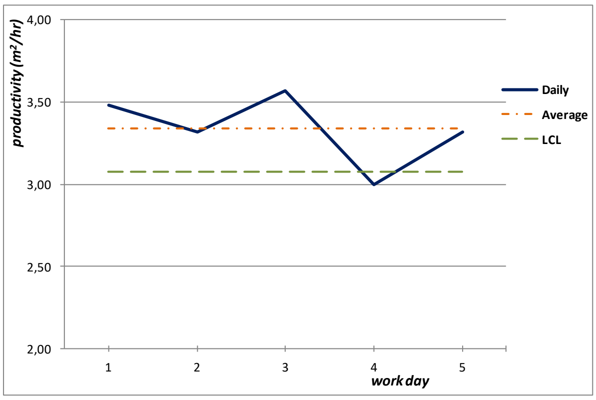

Figure 6: Process control chart for Plaster Mason after 1st iteration

After the first iteration of the procedure, no abnormal days for Gypsum Plastering are included in Group R, as observed from the results of Table 2 and the control chart of Figure 5, so the baseline subset and the BP for the specific activity can be calculated, as depicted in Figure 5. On the contrary, the respective results of Table 2 and Figure 6 for Plaster Mason reveal one abnormal day still included in the productivity values (Workday No 5). In this case, a 2nd iteration is executed with the new Group R, where:

- Plaster Mason: Group R = Workdays 1, 2, 3, 6

The results for the activity attributes of Plaster Mason after the 2nd iteration are reported in Table 3, while the process control chart is depicted in Figure 7.

Table 3: Daily productivity values and activity attributes after 2nd

Plaster Mason of external plastering			
Work Day (A/A)	***Daily Productivity (m^2/hr)***	***Day characterization***	***Baseline subset***
1	3,48	normal	***Yes***
2	3,32	normal	No
3	3,57	normal	***Yes***
6	3,32	normal	No
Group R average productivity		3,423	
Standard Deviation		0,054	
Lower Control Limit (LCL)		3,262	
Abnormal days		-	
Baseline Productivity (BP)		3,525	

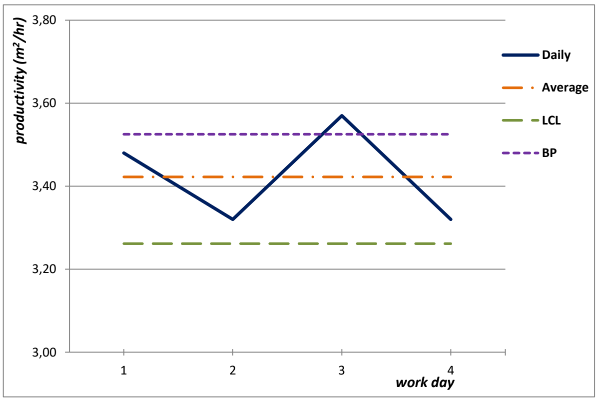

Figure 7: Process control chart for Plaster Mason after 2nd iteration

Table 3 results and the control chart of Figure 7 indicate that, after the 2nd iteration for the productivity values of Plaster Mason, no more abnormal days are included in the remaining set of values (new Group R), so the baseline subset and the BP for Plaster Mason can be calculated, as depicted in Figure 7.

For the identification of the expected BP, productivity rates for plastering construction activities, reported on a web site portal designed for the construction industry, were considered (Methvin estimation software). The expected BP value for the traditional plastering technique (Plaster Mason) was set to 5.200 m^2/hr, as the mean of the top plastering production rates for the tasks of browning as an undercoat (3.100 m^2/hr) and skimming as a topcoat (7.300 m^2/hr), in internal walls of common height. The respective value for the modern plastering technique (Gypsum Plastering) was estimated by raising the above value by 20%, set to 6.240 m^2/hr.

Having both plastering activities' attributes (abnormal days, CP and BP) calculated, after the completion of the two iterations procedure, as well as the two expected BPs defined, the values of DI, PR and PMI can be calculated, with the use of Equations 6, 7 and 8, respectively. Table 4 summarizes the activity attributes and the three productivity indices (benchmarks) for Gypsum Plastering and Plaster Mason.

Table 4: Productivity attributes and benchmarks for Gypsum Plastering and Plaster Mason

Activity	**Total work days**	**Abnormal days**	**CP** *(m^2/hr)*	**BP** *(m^2/hr)*	**Expected BP** *(m^2/hr)*	**Benchmarks**		
						DI	**PR**	**PMI**
Gypsum Plastering	9	1	3,860	4,357	6,240	0,111	0,619	0,080
Plaster Mason	7	3	3,056	3,525	5,200	0,429	0,588	0,090

The DI values for the two plastering activities reveal that Plaster Mason (DI=0.43) experienced more disruptions than Gypsum Plastering (DI=0.11). The small DI value for Gypsum Plastering (DI≈0.1) indicates a not disrupted and presumably good performing activity. On the other hand, the higher value for Plaster Mason (DI>0.4) should be considered as a sign of a highly disrupted and poorly performing activity.

The two PR values were significantly below 1.0 (PR≈0.6), implying that the overall performance of the two plastering activities cannot be considered sufficient, with the Gypsum Plastering performance appearing slightly better. Regarding the last index, both PMI values are notably low (PMI<0.1), signifying that the two activities performed extremely well. The paradox of the presence of very low PMI values (below 0.1), indicating exceptional performance, at the same time with medium PR values (near 0.6), indicating poor or in the best case moderate performance, could be attributed to the high expected BP rates employed, using data for plastering construction activities that corresponds to top performance.

By examining the three benchmarks together for the two plastering techniques, we can conclude that Gypsum Plastering exhibited better overall performance than Plaster Mason, since all three indices reported better values for Gypsum Plastering and more specifically: a significantly lower DI value (0.111<0.429), a slightly higher PR value (0.619>0.588) and even a marginally lower PMI value (0.080<0.090).

5. Conclusions

The paper proposed an alternative approach for identifying the baseline subset and calculating the baseline productivity, in benchmarking construction project productivity performance. The proposed method is integrating Thomas and Zavrski's baseline productivity (as the best performance achieved by a contractor for a construction activity) and the process control chart technique of Gulezian and Samelian (2003) (where upper and lower control limits were applied successively to eliminate extreme values). In doing so, it employs only the Lower Control Limit (LCL) to estimate abnormal days through iterations, thus not excluding productivity data with *"abnormal"* high values. In addition, the method is adopting the statistical technique of Zhao and Dungan (2014) with the average productivity and the standard deviation, grouping the productivity data into two productivity groups, a good and a bad one, for the determination of the baseline subset.

To illuminate the proposed method, labor productivity measurements were recorded for two different plastering techniques, carried out in two residential building projects in the region of Thrace, Greece. Three performance productivity benchmarks, the Disruption Index, the Performance Ratio and the Project Management Index were calculated.

The presented technique can be implemented as a practical tool supporting benchmarking in construction labor productivity and used not only for the assessment but also for the control of construction projects. Construction managers may take advantage of such benchmarks to gather useful information for evaluating and improving labor productivity performance of construction activities.

References

Abdel-Hamid, M., Elshakour, H. A. and Abdel-Razek, R. (2004), “Improving construction labor productivity in Egypt using benchmarking”, Banha Higher Institute of Technology, Banha.

Abdel-Razek, R.H. and McCaffer, R. (1990), “Evaluating variability in labor productivity”, In: Proceedings of the 3rd International Symposium of the International Project Management Association (IPMA), Egypt, pp. 527-550.

Abdel-Razek, R., Elshakour, H. A. and Abdel-Hamid, M. (2007), “Labor productivity: Benchmarking and variability in Egyptian projects”, International Journal of Project Management, Vol. 25, pp. 189-197.

Adrian, J.J. (1987), Construction Productivity Improvement, Elsevier Science Publication Co., New York, NY.

Ballard, G. and Howell, G. (1994), “Implementing Lean Construction: Improving Downstream Performance”. In: Proceedings of the 2nd Annual Conference of the International Group for Lean Construction (IGLC), Santiago, Chile.

Ballard, G. and Howell, G. (1998), “Shielding Production: Essential Step in Production Control”, ASCE Journal of Construction Engineering and Management, Vol. 124 No. 1, pp. 11-17.

Enhassi, A., Mohamed, S., Mayer, P. and Abed, K. (2007), “Benchmarking masonry labor productivity”, International Journal of Productivity and Performance Management, Vol. 56 No. 4, pp. 358-368.

Goldman, A. and Cohen I. (2004), “Anomaly detection based on an iterative local statistics approach”, Signal Processing, Vol. 84, pp. 1225-1229.

Gulezian, R. and Samelian, F. (2003), “Baseline determination in construction labor productivity-loss claims”, Journal of Management in Engineering, Vol. 19 No 4, pp. 160-165.

Horner, M. (1982), The Control to Productivity, Chartered Institute Of Building (CIOB), Technical Information Service, No 6.

Ibbs, W. and Liu, M. (2005), “Improved measured mile analysis technique”, ASCE Journal of Construction Engineering and Management, Vol. 131 No 12, pp. 1249-1256.

Koskela, L. (1992), Application of the production philosophy to construction, CIFE Technical Report #72, Stanford University, CA, USA.

Manoliadis, O. (2011), “Labor Productivity Benchmarking in Greek Projects”, Organization, Technology and Management in Construction: An international Journal, Vol. 3 No 1, pp. 221-226.

Methvin estimation software, “Plastering Production Rates”, available at: https://www.methvin.org/construction-production-rates/building-constants/masonry/plastering-production-rates (accessed at 10 September 2017)

Olomolaiye, P.O., Jayawardane, A.K.W. and Harris, F.C. (1998), Construction Productivity Management, Longman, Harlow.

Sweis, G.J., Sweis, R.J., Abu Hammad, A.A. and Thomas, H.R., (2008), “Factors Affecting Baseline Productivity in Masonry Construction: A Comparative Study in the US, UK and Jordan”, Architectural Science Review, Vol. 51 No 2, pp. 146-152.

Thomas, H.R. and Završki, I. (1999a), “Construction Baseline Productivity: Theory and practice”, Journal of Construction Engineering and Management, Vol. 125 No. 5, pp. 295-303.

Thomas, R.H. and Zavrski, I. (1999b), Theoretical Model for International Benchmarking Labor Productivity, Technical Report No. 9913, Pennsylvania Transportation Institute, University Park, PA.

Yi, W. and Chan, A.P.C. (2014), “Critical Review of Labor Productivity Research in Construction Journals”, Journal of Management in Engineering, Vol. 30 No 2.

Zhao, T. and Dungan, J.M. (2014), “Improved Baseline Method to Calculate Lost Construction Productivity”, ASCE Journal of Construction Engineering and Management, Vol. 140 No 2.

Building Information Modeling

Conceptual Elaboration of a Construction Site Diary in Electronic Form

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Abstract:

The idea of keeping a construction site diary on an electronic device as an application that the user can have on his mobile device or tablet and facilitate his daily entry of data has been developed. The software environment in which the application was developed was an Android studio and a mobile device was used to start the application. Further cooperation with the programming engineer can give a good result of this conceptual application.

Keywords: *Android studio, application, construction site diary*

1. Introduction

Today it is impossible to imagine life without mobile devices, which is especially evident after the invention of smartphones. Users of smartphones and other mobile devices are of all ages, which is another factor that contributed to their large prevalence. It features an open architecture with specific relations between the application and the display and the possibility to change any common application that comes with the operating system, which speaks of the flexibility it provides. Google Android is the first operating system for mobile devices with open source, which means that its source is fully available to programmers and may be modified in any way without the need for licensing.

While performing any construction project, it is necessary to conduct a construction site diary. It is led in the form of a double-page book (original and copy) where copy can be torn out and original can be given to the investor who needs to keep track of the project progress. Sometimes problems arise due to the search for signatures of supervisors,

This paper presents the idea of developing the application for keeping a construction site diary that the user can have on his mobile device or tablet, which facilitates his daily entry of data. The main objective of the application is to enable the user to keep the site diary electronically and automatically send data to the investor. With this modern way of writing a construction site diary with which it is easier to handle, the everyday entry of permanent general data would be solved. By automatically storing data and networking with everyone who keeps a diary, it's easier for a supervisor to work with simple control on your device and by signing it by sending direct data to the investor. Given the clear visibility of the signature date and the entered data, the investor can immediately control the state of the project's progress. The

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application should simplify data entry and eliminate everyday writing. The data that the application displays are stored in XML format and organized saving is required for their use.

2. Development of the idea

A construction site diary is a document on the course of works which, among other, proves the compliance of terms and methods of construction, i.e. the execution of individual works with the presumptions and requirements from the main design, detailed design, regulations and standards [1]. Participants in keeping the construction site diary are the contractor, the person responsible for conducting the construction (main site engineer, site engineer, and construction manager), supervising engineer and / or main supervising engineer.

The development environment Android Studio was used for preparing the application. The Android Studio recognizes the source of the program and helps the user by giving him templates. It is easy to use and allows quick navigation. The architecture of the Android operating system is based on Linux 2.6 kernel which is used as a Hardware Abstraction Layer - HAL. The reason for the use of the Linux operating system kernel is its proven driver model, the ability to manage memory and processes, proven security model, network connectivity, robustness and constant development and improvement of this operating system [2]. The program source is written in Java programming language, and a mobile device was used to launch the application. The application has the same result on a tablet which would be more favorable for the entry of performing a construction project on the site, primarily because of its size and the width of the screen, as well as better orderliness of the application itself. Each screen of the user interface is presented by the class *Activity.* The application consists of one or more activities. It is important to note that an application is not the same as a process and this significantly affects the behavior and life cycle of the application. This section describes the proposed development of the application itself, which in reality has not been completed. Based on the idea itself, interfaces and their interactions were performed and the plan and program for further development were laid out.

We have chosen the platform API 15: Android 4.0.3 (IceCreamSandwich) covering approximately 90.4% of devices active in Google Play Store. To simplify the creation of such an idea and testing, the aforementioned platform is used. For now, it is irrelevant which Android is used and in which version because it is given here only the idea of possible creation of such an application that is not yet in use. When creating such an application, it's easy to upgrade the platform version. The first application interface is shown in Figure 1, i.e. this *activity* is added to the initial *activity* and such design is valid for the entire application.

Figure 1. The first application interface

The icon was made in PhotoScape program that enabled merging of two frames downloaded for free use from the internet site http://www.iconarchive.com/. The application is simply "downloaded" from the Android Market after being put there by the software developer. Android Studio was chosen precisely because of this simple and smooth "put-download" of applications. The application itself has the ability to rotate the screen, and thus leave the user the choice of input. In further examples the rotation is adjusted to certain topic, depending on the desired display.

The aim of the application is an easy way to enter data in the construction site diary. Figure 2 shows a graphical representation of merging the class windows using the application. It shows the branch of opening new windows. There are also labels for return which mostly lead to the window *activity_postojeci_projekti.xml (activity_existng_projects.xml)*.

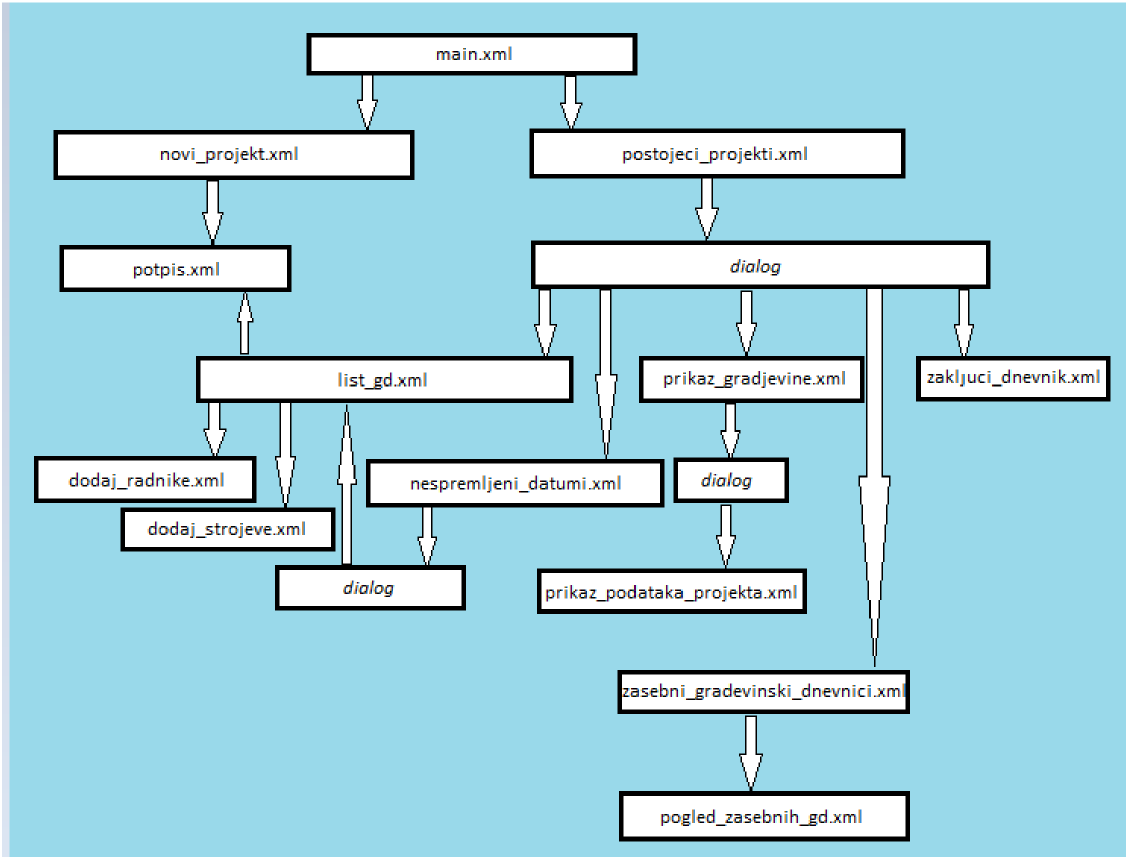

Figure 2. Merging of classes using the application

The first window that opens when the application is activated is *main.xml*, shown in Figure 1. Therefore, when a user runs the application, the first activity with the name of the application *Gradevinski dnevnik (Construction site diary*) (due to the impossibility of writing in Latin script, certain letters had to be replaced by the English alphabet) is displayed on the screen. Two labels are placed here; one to open the new project *activity_novi_projekt.xml* (*activity_new_project.xml)* and the other to open all existing projects *activity_postojeci_projekti.xml* on the device. At the bottom is a link for downloading the Rules for writing a construction site diary on the electronic device in pdf format. *Activity_novi_projekt.xml* is the window for entering a new project with its data (Figures 3 and 4), which allows the user to write the data about the selected contractor (name, address and place). Such data are also entered for the investor and the structure for which the project is being done. The name of the structure is the name of the project that we want to store in the memory and call it every time we want to enter the data in the construction site diary. In addition to information about the structure, data on the building permit are also entered (class, order number, date and place of issuance of building permits).

Figure 3. **T**he first part of *activity_novi_projekt.xml*

The presented Figure 3 was made in Photo Scape by *screenshotting* the screen of the application on the mobile phone and incorporating it into a single image for better orderliness of the application contents. The application itself has the ability to *ScrollView* in any direction that the device is turned

Figure 4. The second part of *activity_novi_projekt.xml*

The remaining part of this window opens the possibility of entering the names and surnames of the responsible person conducting the construction, as well as data on technical inspection, consisting of supervising engineers and chief supervisory engineer. Data about the Act of their appointment is also entered. Each of them must sign their name and a click on *Potpis* (*Signature*) opens a new activity, *activity_potpis.xml* (*activity_signature.xml)* shown in Figure 5. Here, the user signs his name and by pressing the label below, saves his signature confirming which user he is.

Figure 5. Example of signature

For this idea of recognition a data base with all the employees of a particular company is proposed with the ability to recognize the signature on the basis of the one entered and stored in memory. This example shows a signature that is upon storing returned to *activity_novi_projekt.xml*.

In the new project, data about the beginning of the application and start of the construction are entered. Both labels at the bottom *Izadji* i *Spremi novi projekt (Exit and Save new project)*, take us back to the first activity from where we choose a destination. *Spremi novi projekt* (*Save the new project*) saves the project and creates it in the list printed in the new activity *activity_postojeci_projekti.xml*. When the label *Postojeci projekti* is pressed, this window opens. By adding a new project, the list is regenerated and all projects stored in the memory are retained. This layout is shown in Figure 6.

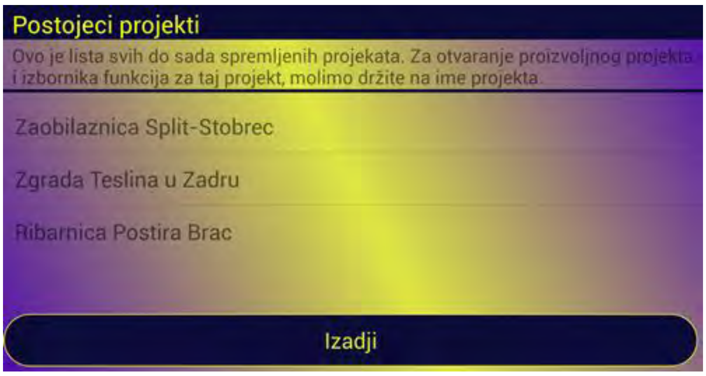

Figure 6. Activity*_postojeci_projekti.xml*

As the note indicates, selecting the project name opens a menu as shown in Figure 7. If we just click on the project, *Toast* with the full name of the project is displayed.

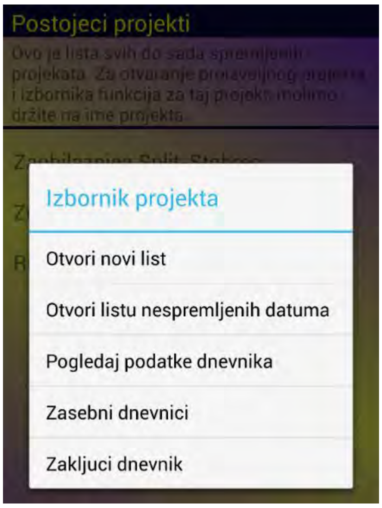

Figure 7. Project menu

As for the menu for the project, it contains the displayed addresses for further use of the site diary. *Otvori novi list* (*Open a new sheet*) opens a new window *activity_list_gd.xml (activity_sheet_gd.xml)* whose content can be seen in Figures 8 and 9.

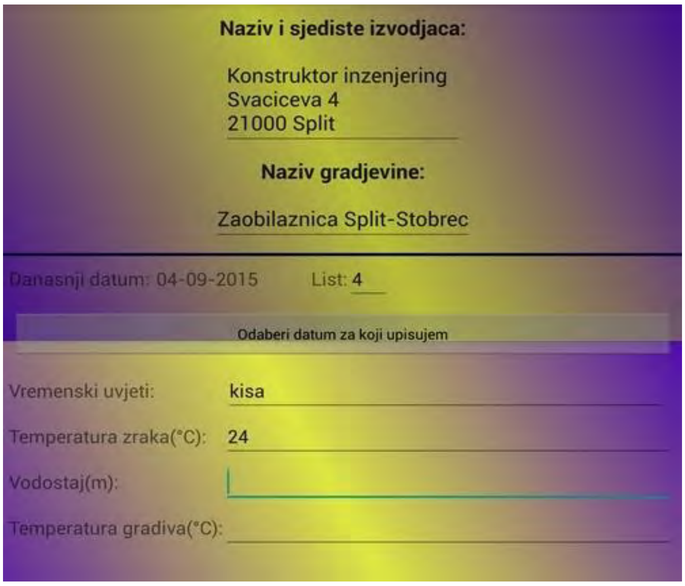

Figure 8. Beginning of the window of the Construction site diary sheet

With each new entry by date in the site diary menu message *Otvori novi list* (*Open new sheet*) is entered. As shown in the first picture, the name of the project and the name and address of the registered office of the contractor is automatically displayed, as well as the number of pages upon opening a new sheet that are based on the already stored pages. The current date is also automatically displayed, which does not have the option of changing. Below that is a label called *Odaberi datum za koji upisujem* (*Select the date of entry*) which serves the user to select the desired date, i.e. select the date of entering and storing this sheet. This greatly helps the user, as he doesn't have to repeatedly enter the same data in the site diary, which can often be exhausting for the person entering data in the construction site diary. Another problem is that, for example, the contractor does not enter data in the site diary daily or that the supervising engineer is not present, so the idea is that by such entry of the date and automatic date which is immediately displayed, the entries in the site diary are controlled.

Figure 9. The last part of the window - entry of a new sheet of the site diary

If we look at the section Structure of employees and machinery, we see that it shows only the note with the possibility of selecting the label underneath. If we do that, it opens up the whole menu with listed employees or machinery, depending which label we choose. Such entering a new activity opens *activity_dodaj_radnike.xml* or *activity_dodaj_strojeve.xml* (*activity_add_employees.xml* or *activity_add_machinery.xml*). By simply selecting employees or machinery and selecting *Dodaj* (*Add*), the data are returned to the window *activity_listGD.xml*. Now we have the listed marked items and can add their number, quantity. Example is shown in Figures 10. and 11.

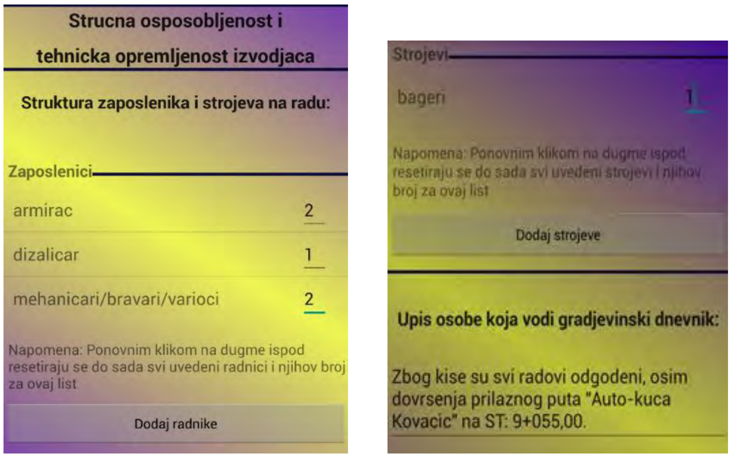

Figure 10. Stored employees

Figure 9 shows a section for the entry of the person who keeps the construction site diary. He signs his name in the same way upon finishing the entry by selecting *Spremi danasnji list (Save today's sheet*) by which the previously entered data about the structure are saved on that day and a list by dates is created by the *dialogue*. The section displayed after the entry of the supervising engineer and others is significant for its automatic date which is recovered when the supervising engineer wants to enter his part. Finally, by choosing *Spremi* (*Save*) the site diary entries of that day are completed. This operation is possible only after entering and saving the entry of the responsible person.

Therefore, when the person responsible for the works saves his part, a list in a new window is created, as shown in Figure 11. This window can be accessed by selecting *Otvori listu nespremljenih datuma (Open list of unsaved dates*) from a predefined dialogue.

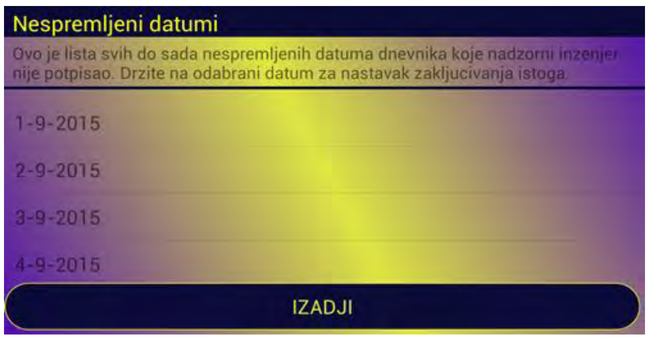

Figure 11. *activity_nespremljeni_datumi .xml*

As said in the note, for conclusion of a specified date, the date should be selected where a small *dialogue* is opened with the message *Zavrsi ovaj dnevnik* (*Conclude this site diary*). Choosing this message the supervising engineer now re-enters the activity with the list where all the contractor's data are entered, stored and confirmed and that part cannot be updated. The supervising engineer can now add his text, sign and save it. As stated, this date is then deleted from the cache and only the list of project dates that the supervising engineer did not save remains. This stored date, along with other stored dates, is located in a separate list in the activity *activity_prikaz_gradjevine.xml*. (*activity_display_structure.xml*). This application activity allows an insight into the project and all the data entered when creating the project. Below these data is a list of all previously stored dates for the project. The selection of date is accessed through a small new *dialogue* with the message *Pogledaj ovaj datum* (*View this date*). This opens a new window, *activity_prikaz_podataka_projekta.xml* (*activity_show_data_project.xml*). It only provides printing of data by dates. We cannot go ahead from this activity. Only by selecting *Izadi* (*exit)* we can return to *activity_postojeci_projekti.xml.* (figures 12. and 13.).

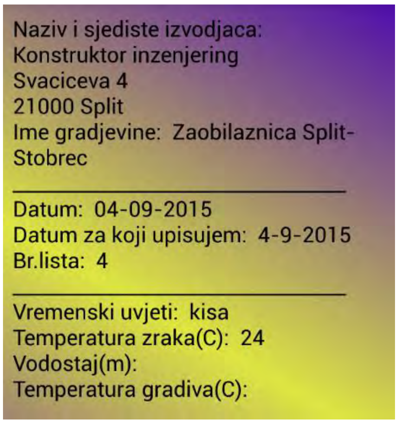

Figure 12. Data print by dates, part one

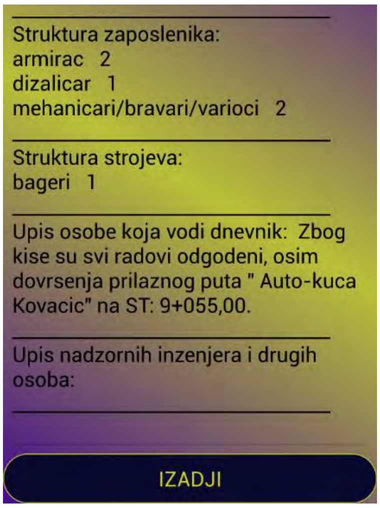

Figure 13. Data print by dates, part two

From the window in which all projects are printed, as has been said, when they are selected the window with *dialogue* opens. If we select the message with the name *Separate site diarys,* a new activity opens, *_zasebni_gradevinski_dnevnici.xml* (*activity_separate_construction_site diarys.xml*). The layout is shown in Figure 14.

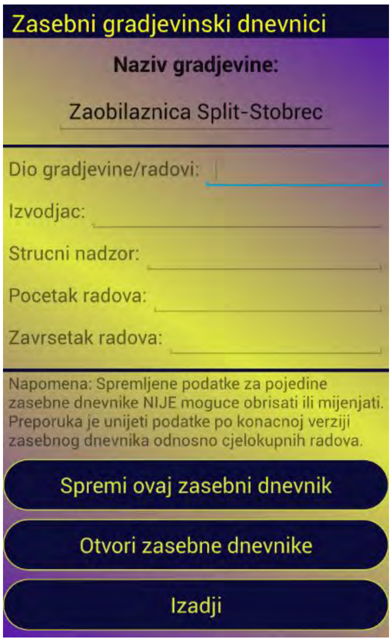

Figure 14. Activity*_zasebni_gradevinski_dnevnici.xml*

The name of the project for which separate construction site diaries are printed is displayed. It is also the name of the structure. Below the user has the option of entering data, such as part of the structure/works, name of the contractor, who is the technical supervisor and the beginning and end of the works. There is a note to be known that when a user enters the data and pushes *Spremi ovaj zasebni dnevnik* (*Save this separate site diary*), the data cannot be changed. This of course is not more difficult than it was when printed on paper, as the whole site diary cannot be deleted or changed. It can only be amended by a new entry.

The last option given to the user related to a specific project is to conclude the site diary. In this activity the project data is once more opened. The activity in question is *activity_zakljuci_dnevnik.xml (activity_conclude_site diary.xml)*. Here we have the possibility of concluding the site diary, after which site diary data cannot be entered. The key *Datum zakljucivanja dnevnika* (*date of concluding the site diary*) opens the possibility of easier selection of the entry date, as we used in the activity *activity_list_gd.xml*.

At the conclusion of the diary it is proposed that the site diary be deleted from the application and to be sent over the Internet to a particular medium with the ability to preview in a text format. For further development of the application, with the expertise of programmers, detailed storing of all project data can be programmed and data automatically sent to the supervising engineer so that he could conclude the site diary on time and send the finished data to the investor to follow up on the performing of works. Detailed storing and the way to automatically send data necessary for people or businesses should be additionally considered in conjunction with programmers who could easily make the final first version of this application. It is important to know the way to connect all entered data on the device with automatic transmission to a device where they can be read or even printed. For now, only the idea of application operation is given, along with everything that the current application has. Upon completion of the application operation it must be put on the Android Market from where it could easily be downloaded and used.

3 Conclusion

Android is an operating system that has completely changed the mobile phone industry and had a huge success. The fact that allows Android such fast progress is a good organization that uses the open source system. This approach leaves a lot of space for innovation and creativity, which is necessary for success in today's world.

To create high-quality applications it is not sufficient to know only the Java programming language and the Android interface, but it should be taken into account that mobile devices are limited in their memory and speed of application performance, so the programmer must make sure that the application takes up less memory and has only those functionalities it truly needs. It should also be considered that these devices differ in screen size, physical keys and the like. The application design must be simple yet attractive and interesting to the user. Therefore, before creating applications, the requirements that the applications must meet should be thoroughly studied

An idea has been developed, according to which the construction site diary was in function for data input and kept entirely in electronic form. In cooperation with a programming expert, the application could quickly be made a prototype and given to the user. For the whole area of the program source it is necessary to thoroughly resolve the rest of the programming of the possible application and at the same time take into consideration the currently set law for the future use of such applications on an electronic device.

The most demanding part is data storing where further cooperation with the programming engineer is required. Thanks to the openness of the program source, the programmers were given access to an existing application and source samples. On the Internet it is possible to find examples of different applications and pieces of source that are complemented with the comments of other programmers. The main advantage compared to previous keeping of a construction site diary is easier entry of the necessary data that are not repeated every day, which constituted unnecessary work to the contractor. The application should automatically enter some necessary data and immediately update them for other employees. Construction works should also be checked regularly. Also, the site diary can be kept on-site, because the electronic device is easily portable. Further cooperation with the programming engineer can give a good result of this conceptual application.

4 Literature

[1] Radujković, Mladen i suradnici; Organizacija građenja. Zagreb: Sveučilište u Zagrebu, Građevinski fakultet, 2015.

[2] Head First Android Development (http://www.it-ebooks.info/book/644/)

[3] IconArhive (http://www.iconarchive.com/)

BIM Educational Activities on Civil Engineering Faculty Technical University of Košice

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Abstract:

Idea of Building information modelling (BIM) concept consist on creating and managing data of whole building lifetime cycle in virtual model, where all information are stored. Benefits of BIM tools and techniques are already demonstrated on big commercial buildings projects and infrastructure projects and they are still more and more accepted for managing medium and small projects. In this article is introduced modern history of acquiring knowledge about BIM on Civil Engineering Faculty on Technical University of Košice. Presented are actual activities, which allow transfer BIM technologies into educational process. Aim of this research was to find out actual level of knowledge about BIM technologies and level of skill in working with BIM software, which future graduates of first and bachelor of masters study programs Architectural Engineering acquired during study.

Keywords: *Building information modelling (BIM); university education, lifelong learning, civil engineering faculty*

Introduction

Building information modelling (BIM) represents digital model of physical and functional characteristics of building and its facilities, which creates source of shared knowledge and its base for information exchange. This creates solid base for decision making through whole lifetime cycle of building, from first idea to the demolition (Sinclair, 2012). By Eastman (Eastman et al., 2011) BIM is not only a change of technology, not only a thing or software type, but human activity, which obtain large changes of processes in building design, construction and facility management. Virtual model of building provides platform for all aspects of construction products and process, what allow simulate and optimize not only a building design and construction, but processes in lifetime cycle of building too. Virtual "intelligent model" also contain tools, which allow automatic correction of building or process virtual model in case that partial change are made. Due to these facts BIM provides base for understanding building aspects of building, significantly exceeds 3D modelling. One of main benefit of BIM technology is lower investments costs and operating costs in building construction and facility management.

European directive in public procedure (EUPPD), encourages member states to support, specification or regulation of BIM usage for construction projects financed from public funds

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in the European Union since 2016. Nowadays many states of EU supports or even require use of BIM for public projects and is only a matter of time, when Slovakia react on initiative EUPPD. It is excepted that Slovakia will in 2017 adopt three European standards within CEN 442 Building Information Modelling (BIM):

- EN ISO 12006-3:2016 (WI=00442003) Building construction - Organization of information about construction works - Part 3: Framework for object-oriented information (ISO 12006-3:2007) into Slovak system of national standards was in 1.2.2017 added standard STN EN ISO 12006-3:2017 (739015) released in English language.
- EN ISO 16739:2016 (WI=00442002) Industry Foundation Classes (IFC) for data sharing in the construction and facility management industries (ISO 16739:2013).
- EN ISO 29481-2:2016 (WI=00442001) Building information models - Information delivery manual - Part 2: Interaction framework (ISO 29481-2:2012).

Benefits of BIM technology have effect on thinking not only a public client, but on private client too. Because of that there is demand on new standards and new type of work. Current labour market offers jobs for civil engineer, who not only has technical knowledge about building and construction process, but also shows skills with work in BIM software tools. Current issue is how to train current and future graduates of civil engineering faculties to use BIM technology in their future jobs.

1. Research and educational activities in BIM

For 40 years Civil Engineering Faculty, Technical University of Košice (CEF TUKE) provides university education and prepare students for construction industry. Through these 40 years educational activities were adapted to the needs of construction market. Contents of teaching in study programs on first, second and third degree level were permanently actualized. Transition from 2D CAD environment into completely different platform, as 3D BIM environment, is not an easy task. Research and educational projects aimed on BIM technologies preceded educational activities. Main promoter of BIM technologies on CEF TUKE is team of employee and PhD students from Institute of Construction Technology and Management (ICTM). This team is led by prof. Ing. Mária Kozlovská, PhD. in its long-term research activities focused on BIM issues and findings were applied into educational process.

1.1 Research and educational projects aimed on BIM technology

The institute ICTM solve since 2010 projects focused on innovative approaches to design and management of construction projects based on use of digitalization information. The institute ICTM is involved in two specific projects financed from EU structural funds:

- ITMS 26220120018 Support the development of IKT for research of effectiveness of building construction, materials and technology with emphasis on increase the competitiveness of economy (2009-2010) and;
- ITMS 26220120037 Excellent research of building construction using virtual reality with emphasis on increase the competitiveness of economy (2010-2013);

allow to equip laboratory of digital research of building construction by hardware and software tools. Equipment of laboratory consists of 10 performing workstation for construction virtual design including program suite for 3D modelling and IKT server, 3D prototyping printer, software for nonlinear static, dynamic, shear and shape analysis, software for managing and measurement special climate box, software for simulate heat transfer and so on.

Since 2014 is institute involved in University Scientific Park TECHNICOM for innovative application with support of knowledge technology, within which was purchased 3D laser scanner FARO FOCUS 3D X130 for the purpose of research into the principles of reverse engineering. Within Scientific Park we are focused, also on applied research in area of use real-time dynamic visualization for project design and delivery.

One of the first educational project aimed on BIM technology was project KEGA-124-038TUKE-4/2010 Skills development for virtual design and management of construction based 5D technologies (2010-2012). In this project was created basic study materials for solving engineering tasks were created in Revit Architecture, AutoCAD Civil 3D, IDA Climate and Energy, MS Project and Cenkros Plus. One of project output was creation of “construction projects storage”. In this storage from 2012 are regularly stored building documentation of diploma works of students of the Architectural Engineering study program. Documentation of building project in storage can be used as input to solving case studies, or for solving specific goals in bachelor's and master's thesis in other study programs as Technology and Management in Civil Engineering or Environmental Structures.

The next project activity VEGA 1/0840/11 Multi-dimensional approaches supporting integrated design and management of construction projects (2011-2013) was focused on exploring opportunities and limitations of BIM technology. Were examined new approaches to increase quality and efficiency in the design phase and management of construction work, taking into account the global research platform developed under the name Integrated Design and Delivery (Kozlovská and Sabol, 2010; Šoltés and Kozlovská, 2013), opportunities for the development of tools enabling the design and management of construction projects in other dimensions - time, budget, quality, safety, equipment, site, facility management (Kozlovská et al., 2014; Podmanický and Hyben, 2013), options and design of concepts for integrating time (Bašková and Krajňák, 2013), concepts for integration of cost parameters in design of building projects (Mesároš et al., 2014; Talian, 2011) or opportunities, results and conceptions the safety of buildings (Struková and Kozlovská, 2013).

Institute ITCM get also international project ERASMUS IP - 12203-0915/KOSICE03 Integrated design and management of construction projects (2012 – 2013), which allow developing BIM in student’s and teacher’s international environment from Cracow University of Technology and University of Zagreb.

Current on CEF TUKE are ready and submitted several educational projects that starts in 2017, which aim to innovate educational process and allow student to get knowledge and skills in use BIM technology in each phase of lifelong cycle of the building.

1.2 Lifelong learning courses in BIM

Lifelong learning courses organized by TUKE track two main goals. First is increase educational and practice competences of own education employee. Second is to provide opportunity to increase knowledge and skills for construction industry workers.

Within one of abovementioned project was provided opportunity to attend free courses on purchased software such as Revit Architecture, AutoCAD Civil 3D; Revit MEP; Revit

Structural; Robot Structural Analysis... for education of employee on CEF TUKE. Main goal of courses was to support skills in use of BIM software tools especially those staff who are involved on civil engineering to lead design subjects. Goal of these courses was to erase subjective barriers, which should slow down use of progressive software technology directly in educational process. Course was attending by 18 educational employees and 20 PhD students of CEF TUKE.

In 2017 CEF TUKE filled for accreditation the educational lifelong learning program focusing on BIM technology. Within 16 program modules focused on special BIM software, every lasting for 12 – 36 hours, absolvent can get skill and knowledge about 3D (4D, 5D) modelling. Since 2012 institute offer educational program Preparation and management of construction projects (accreditation number 3213/2012/63/1) focused on principles in time and costs management of construction project, including basic information about BIM and supported activities.

Lifelong learning for designer, subcontractor, developer, building owner and facility manager offer another organization and training centre too. For example BIM association Slovakia (BIMAS, created in 2013) offers courses and trainings in design in BIM software, work with projects in BIM technologies and analysis appropriateness of modelled project or already build construction.

1.3 Student activities, competitions and events focused on BIM

Computer companies developing BIM software allow students to have 1 – 3 year student license. Students of any school can use these software for education purpose for free. Whether student will spend study period to acquire not only knowledge but skills in work with BIM software, it is on student personal judgement. On other side is in teacher hand to orientate and motivate students to use BIM software in subjects of every study program. CEF TUKE is member of BIMAS and together organizes events for students aimed to propagate BIM technology. On these events specialists from practice inform students about positive experience with use of BIM technology in specific projects. In following events are this subject rise an interest among teachers, who can significantly affect on students and their approach to BIM technology.

BIMAS is one of lead organizer of competitions in BIM technology in Slovakia. For the second year it organizes BIM Challenge, where students from all over Slovakia competed in speed of design in BIM. Within competitions is BIM workshop ongoing, which provided different view to BIM with practical example. Interest of students from every civil engineering faculty in Slovakia about competition in work with BIM software is an indicator about level of education in BIM environment on specific university. One student on the first year and two students on the second year represented CEF TUKE in BIMAS competition. Lack of interest of TUKE students to participate on BIM Challenge is alarming.

2. Current state survey of knowledge and skills in BIM within study programs

The Civil Engineering Faculty TUKE provides relevant bachelor, master and doctoral level of the university study (table 1). The studies in all study programs are compatible with reference to the Association of European Civil Engineering Faculties.

Survey of knowledge and skills in BIM within study programs is based on analysis of the thematic focus of the completed final theses on bachelor and master studies in previous academic years. In the academic year 2016-2017, the level of knowledge and skills of students in BIM technologies was assessed of study programs Architectural Engineering.

Table 1: The study programs of Civil Engineering Faculty TUKE

Level of study programs	**Indicated in article**	**The study programs**
Bachelor study programs	B1	Architectural Engineering
	B2	Structural and Transportation Engineering
	B3	Realization of Transportation Structures
	B4	Technology and Management in Civil Engineering
	B5	Environmental Structures
Master study programs	M1	Architectural Engineering
	M2	Building Services
	M3	Building Structures
	M4	Structural and Transportation Engineering
	M5	Realization of Transportation Structures
	M6	Technology and Management in Civil Engineering
	M7	Environmental Structures
Doctoral study programs	D1	Theory of Architectural and Indoor Engineering
	D2	Theory and Design of Engineering Structure
	D3	Theory of Technology and Management in Civil Engineering
	D4	Environmental Engineering

Bachelor and master theses in Architectural Engineering programs (B1, M1, M2, M3) are mostly thematically focused on architectural and construction solution of building. Although there was no bachelor or master thesis about BIM technology last year, students from Architectural Engineering study program have a choice in which software the thesis will be processed and submitted. Analysis of projects shows that project documentation for master thesis from Architectural Engineering study programs are usually created in 2D software. In 3D software are only architectural visualization models. The occurrence of project design in software support BIM technology is unique. Current status is complicated by fact that in last two years was most of master thesis submitted in “pdf” format, this making difficult to identify in which software was project documentation created. This 2D documentation cannot be used for solution of tasks in specific area of BIM.

Students from Structural and Transportation Engineering study programs (B2, B3, M3, M4, M5) got thesis focused on construction solution of engineering buildings or on building construction static assessment. Mostly used BIM tool in educational process is Tekla Structure, SCIA and AutoCAD Civil 3D, which supports BIM for civil engineering design and documentation for transportation, land development, and water and wastewater projects. Active use of software tools for solution of assigned tasks within technical subjects is good basics for use of BIM technology in thesis.

In Technology and Management in Civil Engineering study programs (B4, M6) was main motivation for bachelor and master thesis focused on BIM technology, solution of PhD thesis regarding with themes of research projects on ICTM. In table is information, which area of BIM (table 2) was main aim in solution of bachelor and master theses.

Table 3 and 4 show the number and proportion of bachelor and diploma works of students of the Technology and Management in Civil Engineering study programs (B4, M6) which focused on BIM technology for last 6 years. Analyzes show that most of the BIM work is on these programs.

Table 2: BIM areas for theses solved on Institute of Construction Technology and Management

Area of Building information modelling	
A	Building design with use of BIM technology (3D model of selected construction and building equipment).
B	Time-space planning of resource and time simulation of construction (4D construction model).
C	Modelling of construction process condition (3D, 4D and 5D modelling of construction site)
D	Calculation of building construction costs from virtual model (quantity takeoff from 3D model, 5D modelling)
E	Facility management (3D model of exists building construction and technical equipment of building)
F	Planning and managing of construction process (work with projects in BIM environment)
G	Modelling and simulating of virtual model parameters from different views

Table 3: Number and percentage of thesis focused on BIM technology in Technology and Management in Civil Engineering bachelor study program

Academic year	Number of students	Bachelor theses in BIM		Area of BIM (by table 2)
		number	%	
2015/2016	29	-	0	-
2014/2015	39	-	0	-
2013/2014	35	1	2,9	D
2012/2013	55	-	0	-
2011/2012	95	3	3,2	E; F; F
2010/2011	32	-	0	-

Table 4: Number and percentage of thesis focused on BIM technology in Technology and Management in Civil Engineering master study program

Academic year	Number of students	Diploma theses in BIM		Area of BIM (by table 2)
		number	%	
2015/2016	33	4	12,1	A-B; A-B-F; C; E
2014/2015	54	3	5,6	B; F; A-G
2013/2014	36	2	5,6	B; B
2012/2013	26	-	0	-
2011/2012	28	3	10,7	A-C-D; D; A-F-G
2010/2011	35	3	8,6	A-B-D; C; C-D

BIM technology, in whole building lifetime cycle uses building 3D virtual prototype. Future graduate of CEF TUKE in study program Architectural Engineering need to realize that skills and knowledge in design 3D building model is crucial for achieving competence of construction engineer in work with BIM technology. Next are shown results from survey, with the participation of students in final year of bachelor and master degree in academic year 2016/2017 of Architectural Engineering study programs (B1, M1). In survey were participating 33 bachelor degree students (45.2% of total 73) and 23 master degree students (41.81% of total 58). Results show that only 2 students (2.74% of students participating on survey) of bachelor degree and only 5 students (8.62% of students participating on survey) of master degree in their thesis create project as 3D information virtual model. In most theses is 3D model created only to visualize architectural design of building (35.15% of students participating on survey). In figures (Fig. 1, Fig. 2) are answers of bachelor and master degree students in question: *"Know you what is BIM?"* and *"Is your master or bachelor thesis related to BIM technology?"*

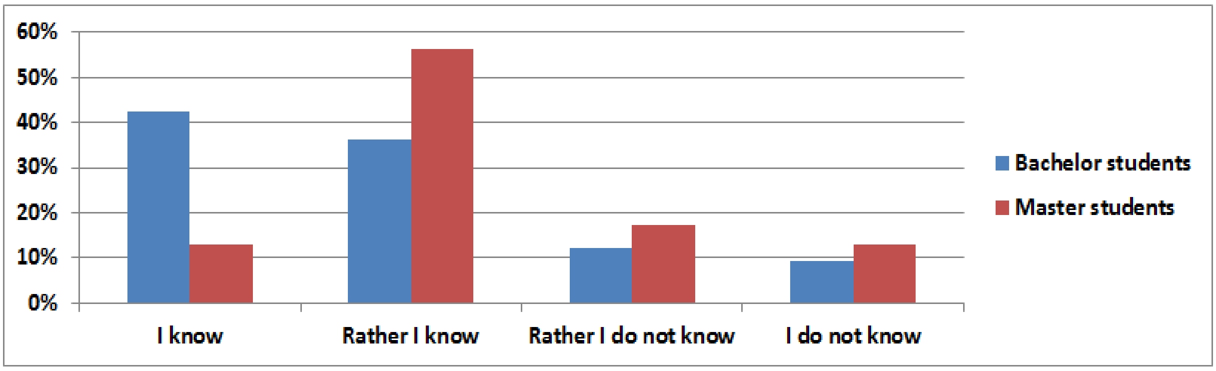

Fig. 1 The answers to the question *"Know you what is BIM?"*

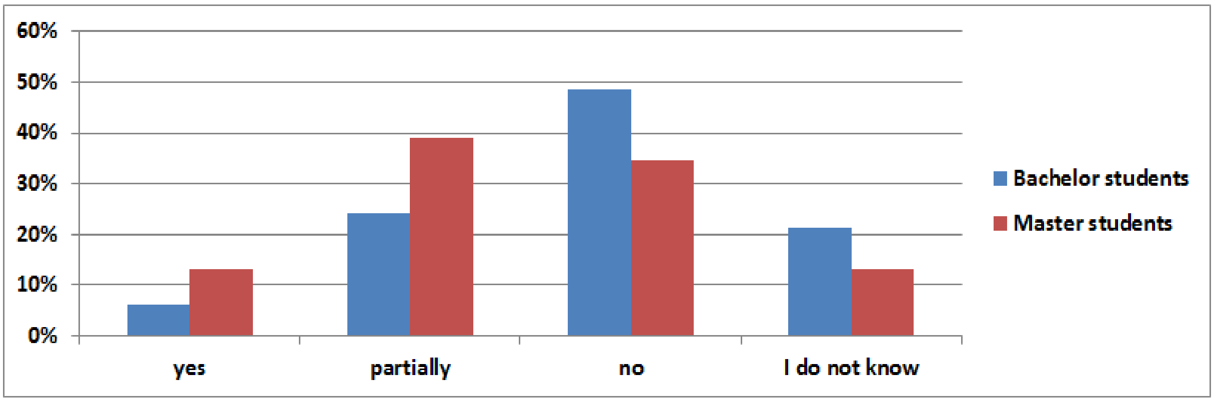

Fig. 2 The answers to the question *"Is your bachelor or master thesis related to BIM technology?"*

Students answer to question *"Where did you get information about BIM technology?"* too. Most of answers were: CEF TUKE and internet. Next question was *"On which subject on CEF TUKE you get information about BIM?"* Most of answers were: construction atelier. Goal of this survey was to find out current state of knowledge and skills in BIM technology of CEF TUKE students. Is very important to more and more bachelor and master theses will be created in BIM platform. These theses can be used for another study programs and to solve problems within whole building lifetime cycle.

Conclusion

Slovak construction industry do not solve a question "yes or no?" to use BIM technology, but question "when?". Answer depends on specific knowledge and skills of construction engineer and competence to transform progress in BIM technology. In this article are tracked activities in BIM on civil engineering faculty TUKE from three different views. First is preparation, solving and results of scientific and educational projects. Second view is supported activities in lifelong learning of educational staff and representative of construction industry. Third view consists of joining students in computer competitions as well as in topics of bachelor, master and PhD theses. Change and pprogress in the construction industry must change educational process on university too, but results of survey show that students of CEF

TUKE have not enough knowledge and skills in term of BIM technology. This situation is partly caused by lack of teacher interest about BIM environment. Teachers must realize that firstly they must be educated in BIM technology and then pass that knowledge to students.

Acknowledgement

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References

Bašková, R. and Krajňák, M. (2013) Automation of the scheduling in construction. In: Integrated design and management of construction project. Košice, TUKE, 2013, p. 168-178 ISBN 978-80-553-1426-6

Eastman, C., Teicholz, P., Sacks, R. and Liston, K. (2011) BIM Handbook (Second Edition), Wiley, NJ.

Kozlovská, M., Čabala, J. and Struková, Z. (2014) The Methodology of Interactive Parametric Modelling of Construction Site Facilities in BIM Environment. In: SSP - Journal of Civil Engineering, Selected Scientific Papers. Vol. 9, No. 2 (2014), s. 85-96. ISSN 1336-9024

Kozlovská, M. and Sabol, L. (2010) Using of the newest CAD/BIM tools in construction projects. In: Design, technology, refurbishment and management of buildings: 37th IAHS World Congress on Housing , Santander (Spain). University of Cantabria, 2010, p. 1- 6. ISBN 978-84-693-6657-8

Mesároš, P., Talian, J. and Kozlovská, M. (2014) Methodology design for automated cost estimating of construction projects. In: CTM 2014: Construction Technology and Management, International Scientific Conference, September 09 - 11, 2014, Bratislava, Slovakia. Bratislava, STU, 2014, p. 327-335. ISBN 978-80-227-4243-6

Podmanický, P. and Hyben, I. (2013) Adopting building information modeling for facility management. In: Visnik Nacionaľnogo universitetu Ľvivska politechnika: teorija i praktika budivnictva. No. 756 (2013), p. 228-234. ISSN 0321-0499

Sinclair, D. (Ed.) (2012) BIM Overlay to the RIBA Outline Plan of Work Royal Institute of British Architects, RIBA, RIBA Publishing, London

Struková, Z. and Kozlovská, M. (2013) Skills development for construction safety risks prevention through BIM based tools. In: Journal of Safety Research and Application. Vol. 6, no. 3-4 (2013), p. 1-7. ISSN 1803-3687

Šoltés, T. and Kozlovská, M. (2013) Methodology of experimental research in the field of BIM technology adoption. In: Multi-dimensional approaches supporting integrated design and management of construction projects. Proceedings of scientific papers 2013. Košice, TUKE, 2013, p. 89-95. ISBN 978-80-553-1546-4

Talian, J. (2011) Making a building budget in Building Information modeling system. In: Geodesy, architecture and construction 2011: proceedings of the 4th international conference of young scientists: November 24-26, 2011, Lviv, Ukraine. Lviv, Publishing House of Lviv Polytechnic, 2011, p. 18-19. ISBN 978-617-607-159-4

Applicability of BIM kiosk on Construction Sites

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Abstract:

There is a poor implementation of BIM at the construction phase, especially on the site where traditional way of working with paper drawings is still popular. A literature identifies several major shortcomings of using this approach on the site: poor portability and inadequate handling of drawings; problems related to readability of drafts; insufficient and not enough detailed information. Nevertheless, the idea of bringing digital design information on the site is not quite new. There were several studies of implementing digital equipment (e.g.laptops) on the site with possibility to navigate, review and collect specific project information. One of the popular ways of bringing BIM to the site is via BIM kiosks - rough computing system built for construction site personnel. The purpose of BIM kiosks is to enable workers/engineers to review the model and thus get on-site access to the update design information. This paper seeks to bring BIM closer to the site via theme of BIM kiosk as a means of site personnel for the extraction of all needed project information. What is a BIM kiosk, what benefits does it brings, how to use it and implement on the site, those are the questions this paper is being focused on. Research has shown how BIM kiosk could be applicable to the Croatian construction projects and that it would be mostly useful for contractors. The benefits of BIM kiosk are recognized, especially benefit of brining up-to-date project information on site. Results and comments of respondents welcome BIM kiosk on construction sites.

Keywords: *BIM; construction; site; BIM-kiosk*

1. Introduction

BIM is being rapidly adopted in the countries worldwide. Leaders in the BIM implementation, according Smart Market Report (McGraw Hill Construction, 2013), are France, Germany and United Kingdom. This are the countries that are continuously developing, controlling and monitoring BIM implementation in all project phases. Croatia, on the other hand, is still hard to adopt changes caused by BIM (Kolarić et al., 2016). According to their research, only 0-25% of construction companies use BIM in their business.

Also, literature shows that BIM is being implemented mostly in the design and pre-construction phase - which means the insufficient use of BIM and BIM benefits, especially in terms of time and cost reduction. One of the famous tools that brings BIM to the construction site is BIM kiosk – an on-site ICT system that allows participants in construction to be in constant relation with up-to-date information and to better visualize project and project tasks. This paper seeks to identify factors for a quality and better implementation of BIM in a

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construction phase. This paper explains the idea of BIM kiosk and seeks to find potential benefits of its usage, barriers of implementation on the construction site, the impact on the specific project stakeholders and the key parts of the BIM kiosk (in the terms of software, hardware and required information). These questions are being processed through the paper which is divided into several parts: literature review, methodology, research results, discussion and conclusion.

2. Literature review

Today BIM is being used mostly in a design phase, while for a phase of construction the traditional way of working is still popular –usage of drawings in a paper form (Bråthen and Moum, 2016). Bråthen and Moum (2016) has shown that construction workers experience paper drawings as insufficient and as a form of project information that is not providing enough detailed information.

Although BIM is mostly used in a design and preconstruction phase, the idea of bringing BIM on a construction site is not new at all (Kimoto et al., 2005). Literature shows studies of implementing BIM on construction site by bringing a physical tools that is a source of information on the site. For example, Hewage and Ruwanpura (2009) mentioned in their research the term of "Information booth" – as a form of information desk with a big screen and plotter. This "Information booth" was tool that helped construction workers to access to the latest, updated drawings and project information.

Literature also provides researches and the testing of usage different kind of digital equipment on the site – for example, electric pocketbooks, computers, laptops and so on (Yeh, Tsai and Kang, 2012), (Kimoto et al., 2005), (Sacks, Radosavljevic, Barak, 2010), (Kim, Park, Lim, Kim, 2013). For example, Sack et al (2010) tested the usage of big touch screen on the site and concluded that this kind of approach provides the possibility of getting online feedback and that is suitable for more workers / engineers to simultaneously review project information. Davies and Harty (2013) had conducted an empirical study of implementation BIM on the site by using the term "BIM-site" that provides construction workers to manage with a various information via tablets. They noticed how IT skills of construction workers were developed through social relations and informal arrangements rather than through formal processes. van Berlo and Natrop (2015) analyzed the concept for the construction workers where the BIM is being used for generating the drawings for a particular task, with an idea to provide workers with the information they really need. Results showed that this kind of a concept brings to the better communication between workers and construction manager. Another research of BIM implementation on site was provided by Merschbrock and Nordalh-Rolfsen (2016). They were analyzing the usage of BIM at particular task on the site – installation of reinforcing bars. Workers had got access to the advanced virtual model via iPad, and the final result was positive - workers noticed the great benefits of using the model in relation to the previous use of traditional drawings. The conclusion of this research was that bringing BIM to the construction site increases the productivity of the construction process.

Considering the examples above, it can be concluded that the importance and benefits of BIM kiosks are extremely high. BIM kiosk is robust computer system built for construction staff (Eriksen Hellum, 2015). The purpose of BIM kiosk is to provide the ability to review BIM models and thus to get on-site access to the final design details and project information of the planned building for construction engineers and workers (Bråthen and Moum 2016).

There are several reasons why a information system on the site should be used (Wang and Love, 2012): (1) the interdependence; (2) relation between digital and physical; (3) synchronization of mental models for communication, project control, monitoring and feedback: built vs. planned; (4) procurement: managing and monitoring of material flow; (5) project life cycle (from design to production): gaps in the visualizations; (6) site schemes and storage.

Example the US patent of BIM kiosk is presented in Figure 1.

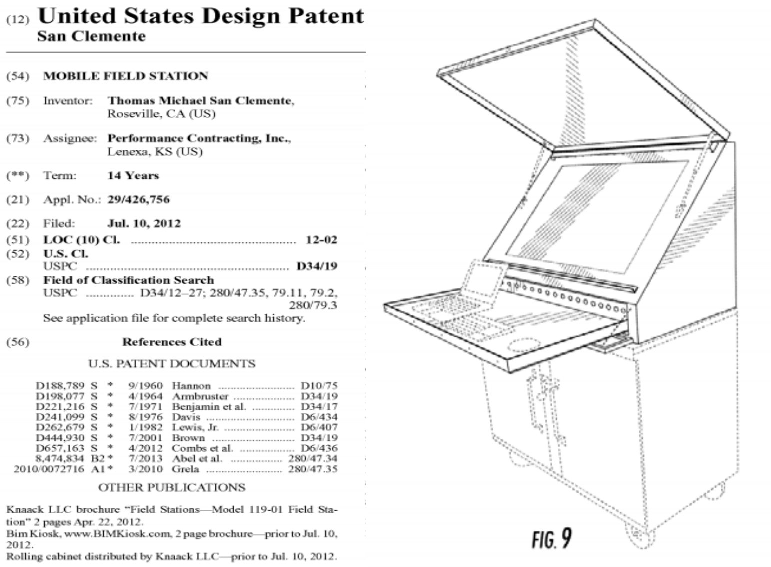

Figure 1: Example of mobile information station – BIM Kiosk. The patent by Thomas Michael [14]

3. Methodology

The research "Applicability of BIM kiosk on Croatian construction sites" has been conducted. The research had been guided with a survey that was contained of 24 questions divided in sections:

- Introduction to the term BIM kiosk - part in which the brief description of idea and functionality of BIM kiosks has been given. Main purpose of this section was to simplify and to bring closer BIM kiosk to the respondents.
- Survey - part with the 24 questions about applicability of BIM kiosk on the Croatian construction site.

Survey was sent by electronic way through the Google Forms system in a period from January to April 2017, to the participants who partly or in a full-time work on the construction site. Survey was consisted of questions diverse type: 2 question with answers in the text form, 10 questions with multiple choice, 2 questions pairing with the number of points on the scoring scale 1-6 (given scale; 1-minimum value of the offered answers; 6-highest value to an answer) and 10 with a single choice. The survey required the average filling of approximately 7 minutes.

Survey respondents were investors (4,35% of respondents), project managers (8,15%), design engineers (44,57%), contractors (25,00%), supervising engineers (14,13%), consultants (1,63%) and other respondents with specific roles on the project (2,17% of respondents).

The research was conducted by quantitative approach and the data were processed by descriptive statistical method-using statistical logic, formulas, symbols, and numerous mathematical operations and mathematical reasoning methods. Part of the research analysis was based on the Relative Importance Index (RII), by formula (1):

$$RII = \Sigma w \,/\, (A \times N) \tag{1}$$

where ∑w represents the summary assessment of the participants of the survey; A, the highest score given by the participants while N is the total number of survey's respondents

4. Results

4.1. Sample specifics

The respondents to the survey were participants in construction: investors, project managers, design engineers, supervising engineers, contractors and consultants who partly or in a full-time work on the construction site. 53,98% of respondents work on structural projects, 22,57% on architectural projects, 11,50% work on project of mechanical engineering and 9,73% are part of electrical engineering on the project. The 2,21% cover special disciplines on project - such as IT or project management. 15,93% of respondents cover more than one (1) discipline on the project (e.g. structural and mechanical engineering). (Figure 2)

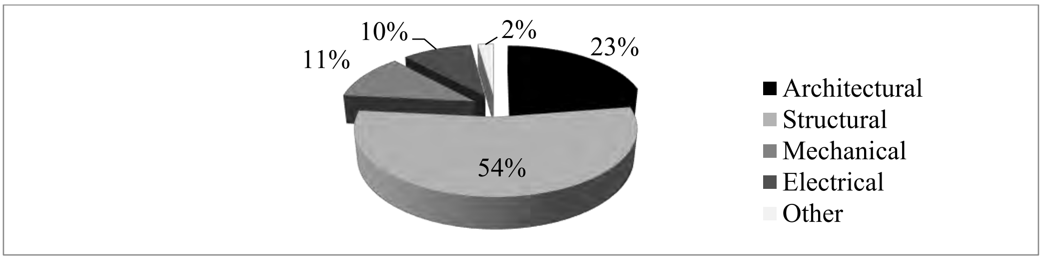

Figure 2: Respondents professional role on the project

Most of the respondents work on the projects of residential buildings, industry buildings and warehouses, office buildings and hotels. Minor of the respondents work on railroad infrastructure projects, airport infrastructure (roads etc.), religious buildings and power providing buildings (Figure 3).

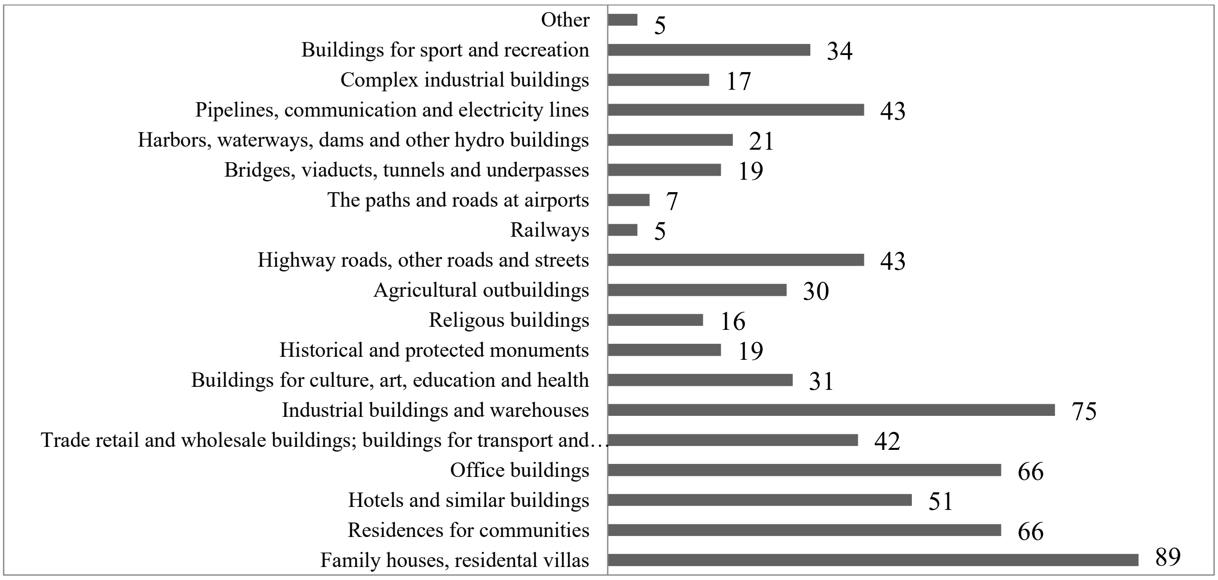

Figure 3: Type of project respondents were involved

The majority of respondents work on projects in the Croatia and South Eastern Europe - countries that are at the stage of increasing awareness and initial implementation of BIM technology (Figure 4).

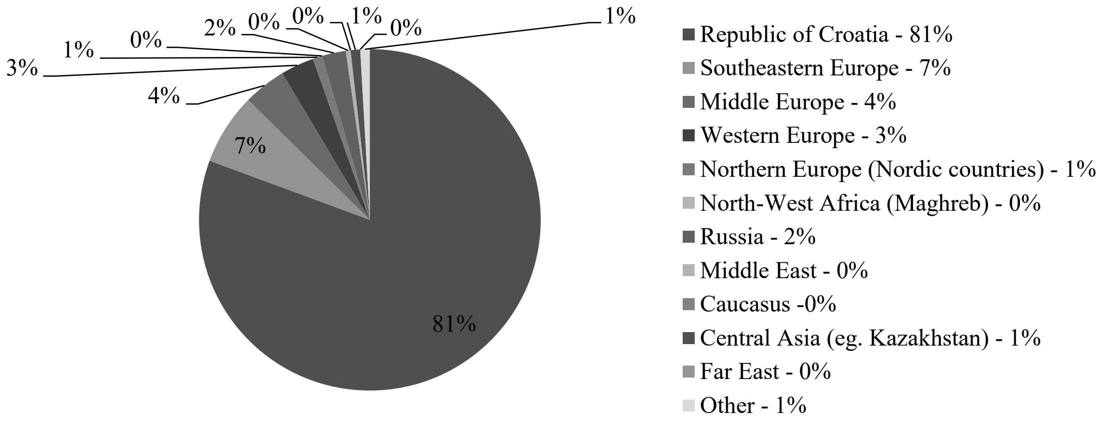

Figure 4: Geographical area of respondents activity on projects

4.2. Current practices on construction sites

Most of respondents work on construction sites with no specific requirement, i.e. at accessible or not isolated terrain. The term inaccessible and isolated site consider terrain with difficult geographical and meteorological conditions, with poor telecommunication signals and/or conditions that make it difficult to communicate with co-workers outside the site. Also, most of respondents pointed out they use digital equipment and Mobile Internet (Wi-Fi, 3G, 4G, etc.) on construction sites. (Figure 5, 6 and 7)

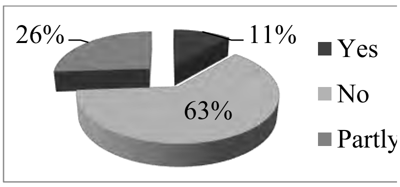

Figure 5: Ratio of respondents who work on inaccessible and isolated site

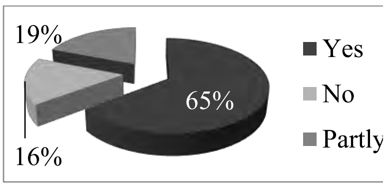

Figure 6: Usage of digital equipment on the construction site

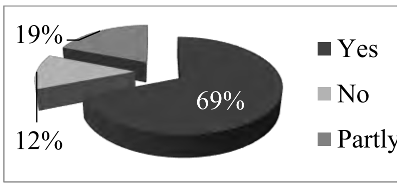

Figure 7: Usage of Mobile Internet on the construction sites

44,02% of respondents have rated with the highest grade (6 from 1-6 scale) the importance of usage of digital equipment on the site, and 48,91% gave highest rate (6) to the importance of using mobile Internet on the site. The average rate of all answers on importance of usage digital equipment is 5,04 (RII= 0,84) and mobile Internet is 5,08 (RII=0,85), which indicates that respondents are aware of the importance and the need for up-to-date and instant availability of information. Today real-time information are required for continuity of the project.

4.3. Awareness and usage of BIM technology on Croatian construction market

Almost half of the respondents (47,28%) still do not use BIM technology on their projects. 22,28% of them use BIM, and 14,67% are not even familiar with the term and concept of BIM. These results are real representation of the current situation of BIM implementation in the Republic of Croatia- it is in initial phase and currently, focus of academic institutions and chambers is to increase awareness of BIM processes, functions, benefits and disadvantages. (Figure 8)

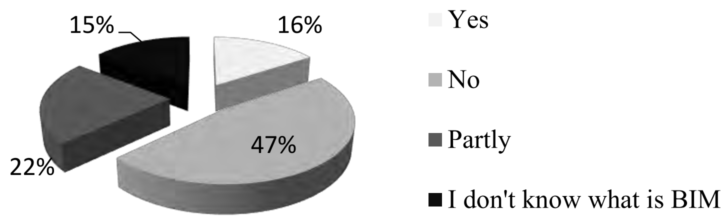

Figure 8: Usage of BIM technology in Croatia

When asked about awareness of BIM kiosk, 80,43% of respondents answered that, before this survey, they had never heard about the term of BIM kiosk. Only 13,04% of respondents had heard about BIM kiosk, mostly via Internet search or when participating on BIM conferences, presentations or trainings.

4.4. Applicability of BIM kiosk on construction sites

After short introduction and description of BIM kiosk at the beginning of the questionnaire, respondents were asked to give their opinion about applicability of BIM kiosk on Croatian construction projects. More than 50% of respondents believe that the BIM kiosk is applicable on Croatian projects (Figure 9) and more than 60% of respondents think that BIM kiosk is appropriate to the type of project they work on (Figure 10).

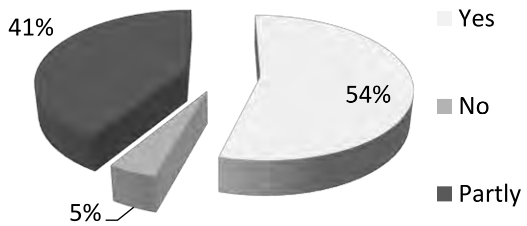

Figure 9: Applicability of BIM kiosk on Croatian construction site

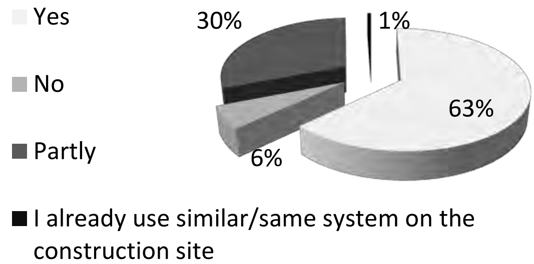

Figure 10: Applicability of BIM kiosk on respondents projects

Regarding site workers and their usage of ICT technologies, 42,39% of respondents think that BIM kiosk could be useful for them, 43,48% think it could be partly useful and only 14,13% think this kind of technology is not particularly helpful for the site workers. Actually, respondents think that BIM kiosk is most useful for contractors (46,20% of respondents), project managers (21,20%) and supervising engineers (14,13%). (Figure 11)

From the list with possible choices, respondents think that the most important benefits of BIM kiosk are: possibility to access to the updated drawings and project information; easier understanding and visualization of project assignment; better project control, monitoring and project information - planned vs. actual; and possibility of better communication, i.e. quicker decision making. (Figure 12).

Most of respondents (82,60%) agree that BIM kiosk should be constructed from the big flat screen that allows for more people to simultaneously view the project and associated documents, and enhanced with BIM software for detailed model review (73,37% of respondents). Also, around 62% of respondents think that BIM kiosk should contain Mobile Internet access, access to the cloud application where specific part of project documentation are stored and should have possibility of sending and receiving electronic mail (54,35% of respondents) (Figure 13).

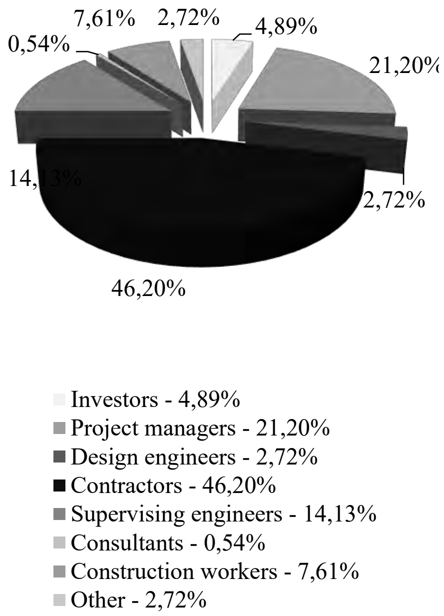

Figure 11: Benefits of BIM kiosk usage per project stakeholder

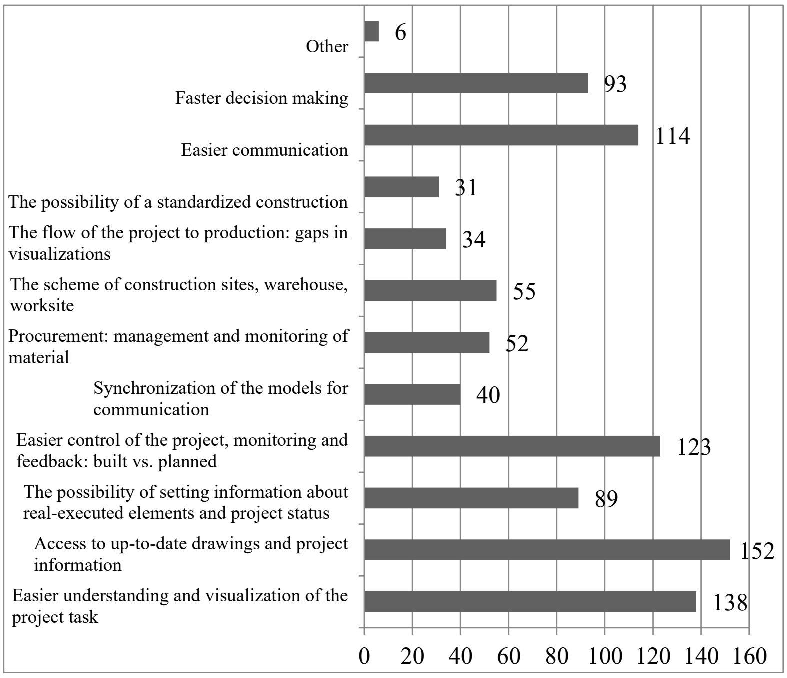

Figure 12: Top benefits of BIM kiosk

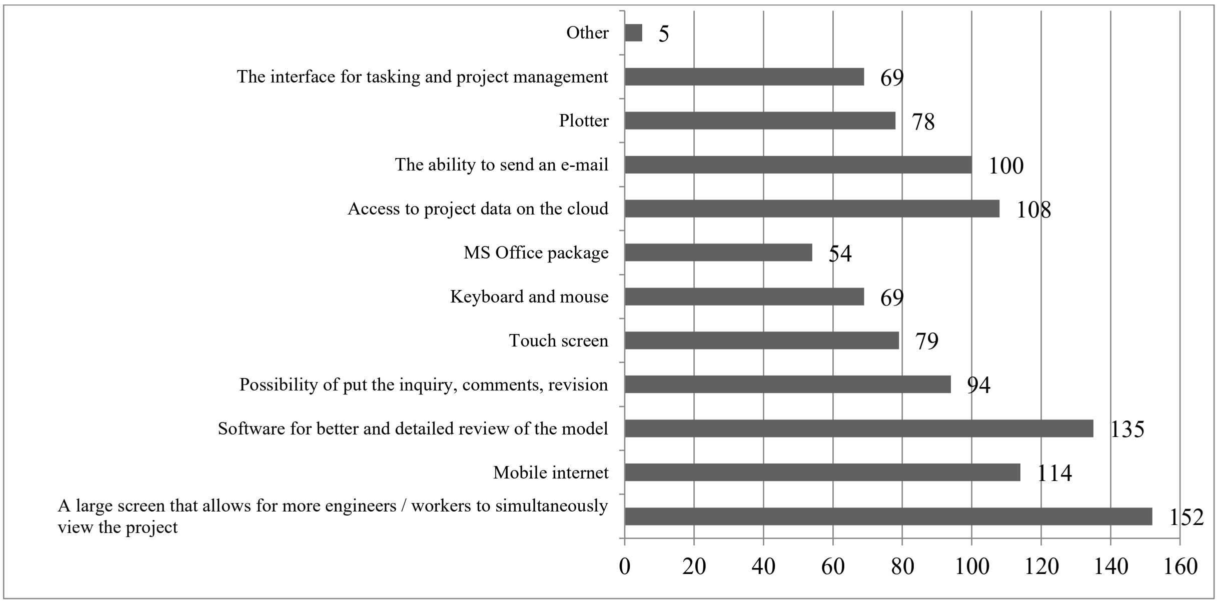

Figure 13: Main parts and features of BIM kiosk

For the point of accessibility to specific types of information, most of respondents agree that BIM kiosk should contain: 3D models, 2D drawings, instructions for assembly, bill of quantities, schedule and quantities for cost estimation, directory of project participants and reports from the coordination meetings on construction site (Figure 14).

Regarding BIM software for construction, according to the most mentioned software in literature and implemented in Croatian construction industry, the list of software for reviewing, planning, monitoring and control has been provided. Respondents were asked to choose software solutions from the list they are familiar with or, if not mentioned in the questionnaire, to write down the list of additional solutions they use or are familiar with. Listed software were:

Autodesk Navisworks, Solibri Model Checker, Bentley Interface, Gala Construction Software. According to the respondents, around 29% have heard or used Autodesk Navisworks and around 22% Gala Construction Software. Around 28% respondents have never heard from any of the listed software (Figure 15).

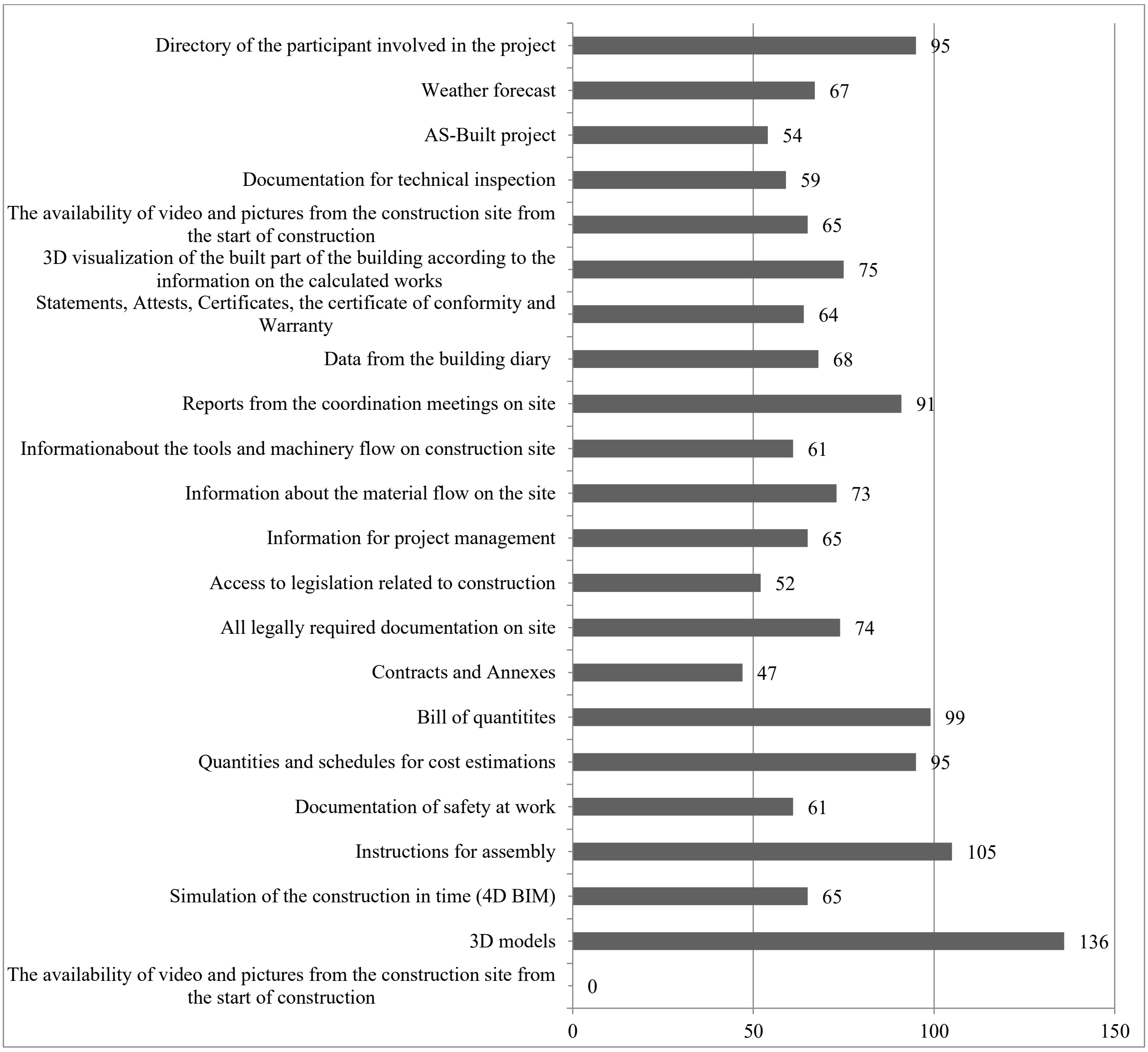

Figure 14: The key information BIM kiosk should contain

30,52% of respondents are not familiar with BIM software for reviewing, planning, controlling and monitoring of construction projects, 27,70% are not sure which software would be suitable for BIM kiosk and 23,00% agree that Navisworks Manage should be part of the BIM kiosk (Figure 16)

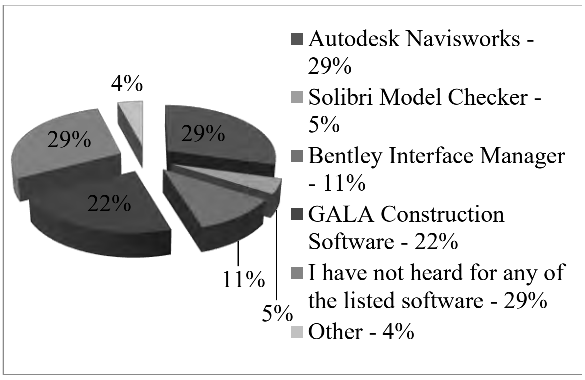

Figure 15: Awareness and knowledge of BIM software for reviewing, planning, controlling and monitoring construction projects

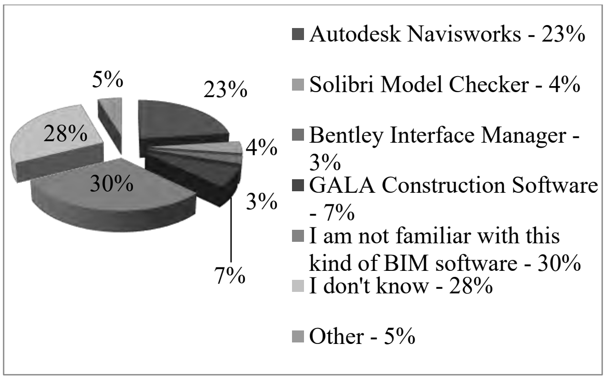

Figure 16: Suitable BIM software for BIM kiosk

Respondents were asked to think about the steps and barriers of BIM kiosk implementation on the construction site. Almost 90% of them agree that the education of participant on the construction site is necessary and that for implementation of BIM kiosk, the complete technological infrastructure is required (67,39%) (Figure 17). On the other hand, they are aware that this kind of implementation is very expensive in terms of education and that changes in traditional work system with new technology, could sample the resistance of employees on the site. The insufficient level of competence of site employees could also be one of the barriers in implementation (Figure 18).

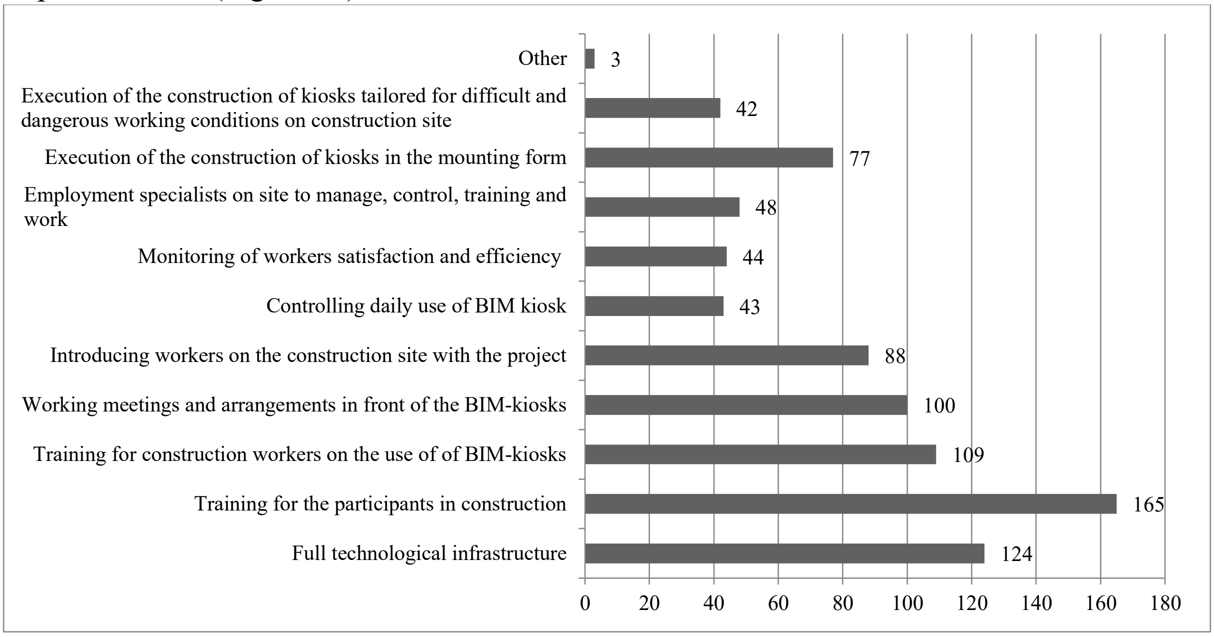

Figure 17: Main steps in implementation of BIM kiosk on the construction site

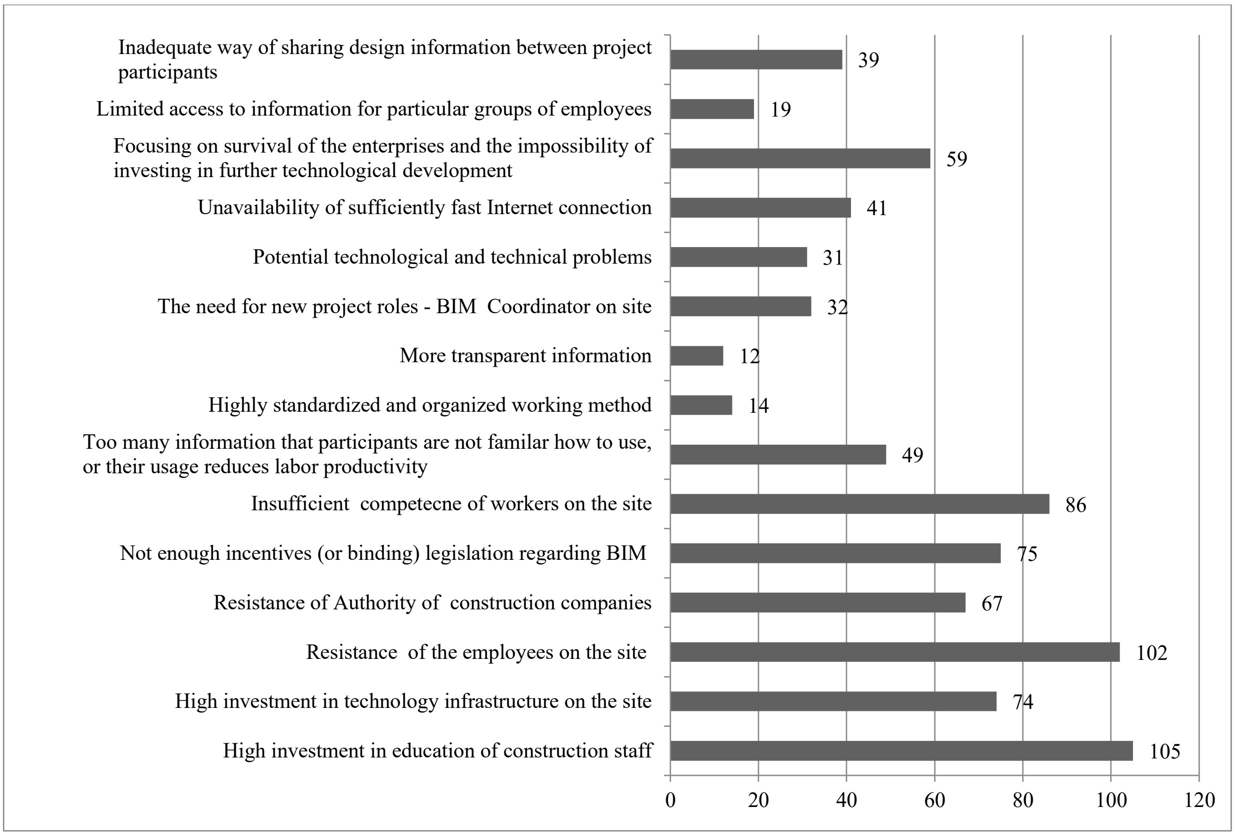

Figure 18: Barriers in implementation of BIM kiosk on the construction site

5. Discussion

Participants in the construction phase are aware of the importance of digital equipment and availability of Mobile Internet on the construction site. The idea to be constantly up-to-date with the project and project information today is the need and demand. Around 22% of respondents work with BIM, which confirms research results by Kolarić et al. (2016). Main focus of BIM technology and processes is to bring information to all project participants and project phases, therefore, BIM is one of the main answers to today's requirements project. BIM kiosk as a tool-source of information, in countries worldwide is being implemented on the sites (eg. Scandinavian countries, USA…). Survey has shown that around 86% of people heard about BIM, but more than 80% have never heard about BIM kiosk. Perception of the BIM is still more focused on a software tools for designing and less for the construction phase. As a part of the survey, the short description and image of BIM kiosk was given to the respondents. According to their prior knowledge and short introduction in to BIM kiosk, more than 50% of respondents agree that the BIM kiosk is applicable on Croatian projects and more than 60% of respondents think that BIM kiosk is appropriate to the type of project they work on. This results shows initial believe and awareness of participants that BIM kiosk could provide some benefits to the construction projects and construction participants. Results of the survey have shown that contractors could have the most benefits from the BIM kiosk. Although some case studies (e.g. Merschbrock and Nordalh-Rolfsen, 2016) shown benefits of BIM kiosk for site workers, results of this survey shown how BIM kiosk could be helpful for the site workers but as they do not derive the most benefit from kiosk. According to the literature review and results from the survey, BIM kiosk for sure should be constructed from the big flat screen that allows for more people to simultaneously view the project and associated documents, and enhanced with BIM software for detailed model review. Access to specific cloud system, possibility to send and receive and e-mail, i.e. Mobile Internet Access are also key parts of the BIM kiosk.

From the point of information type, BIM kiosk should contain 3D models (architectural, structural. MEP, coordination model etc.), 2D drawings, contract documents, plans and schedules, tutorials and education materials, videos for installations and many other information that provide continuous and quality construction of buildings, and could ensure time and cost reduction. Main barrier of BIM kiosk implementation on the site is the cost of technology and education. Time spent on education and transformation of the current (traditional) method of working is huge investment, but valuable. At the end, this tool provides projects with less errors, conflicts and interruptions in work that impacts on the cost reduction.

6. Conclusion

BIM technology and processes follow all phases of project life cycle. With development of technology, each project phase is being upgraded with new tools, detailed analysis, better collaboration processes etc. This progress on the project phases tends to reduce project costs and allows continuous transition from one project phase to the next one. With an idea to increase effectiveness in the construction phase, BIM kiosk is being developed and implemented on the construction sites. In countries worldwide BIM kiosk become standardized tool on the construction sites. It enables better communication between construction staff, easier project visualization, quality decision making, on-site planning etc. According to the literature research and case studies, BIM kiosk has shown positive impact on the participants on site and the end results of construction process. For further research, it would be interesting to take a pilot project on the several construction sites (with different types of construction projects) and monitor the implementation of BIM kiosk from the beginning till the end of construction project phase. Monitoring should include processes of education of construction staff about purpose and way of using BIM kiosk, then usage of BIM kiosk and measuring the efficiency of using BIM kiosks, analysis of ROI and cost benefits, and constantly tracking reaction of construction staff (during coordination meetings in front of kiosk, individual approach to kiosk, installation of equipment by using information from BIM kiosk, etc.). It would be interesting to measure impact and benefits of kiosk on a different type of project and to develop strategy for its implementation and usage on different project categories (e.g. for residential buildings, or for infrastructure projects). At the end of the construction, the feedback of the construction employees on the BIM kiosk should be taken.

References

1. Bråthen, K., Moum, A. (2016), “Bridging the gap: bringing BIM to construction workers“, Engineering, Construction and Architectural Management; Vol. 23 No. 6, pp. 751-764
2. Davies, R.,Harty, C. (2013), “Implementing ‘Site BIM’: a case study of ICT innovation on a large hospital project”, Automation in Construction, Vol. 30, pp. 15-24.
3. Eriksen Hellum, M. (2015),“Increasing Utility Value of BIM in All Project Phases“, Master Thesis, NORWEGIAN UNIVERSITY OF SCIENCE AND TECHNOLOGY, DEPARTMENT OF CIVIL AND TRANSPORT ENGINEERING
4. Hewage, K.N., Ruwanpura, J.Y. (2009), “A novel solution for construction onsite communication - the information booth”, Canadian Journal of Civil Engineering, Vol. 36, No. 4, pp. 659-671.
5. Kim, C., Park, T., Lim, H.,Kim, H. (2013), “On-site construction management using mobile computing technology”, Automation in Construction, Vol. 35, pp. 415-423.

6. Kimoto, K., Endo, K., Iwashita, S., Fujiwara, M. (2005), "The application of PDA as mobile computing system on construction management", Automation in Construction, Vol. 14, No. 4, pp. 500-511.
7. Kolarić, S., Vukomanović, M., Radujković, M., Pavlović, D. (2016), "Perception of building information modeling within Croatian construction industry"; International Scientific Conference People, Buildings and Environment 2016 (PBE2016); 29 September – 1 October, 2016, Luhacovice, Czech Republic, www.fce.vutbr.cz/ekr/PBE
8. McGraw Hill Construction. (2013), "The Business Value of BIM for Construction in Major Global Markets", Smart Market Report.
9. Merschbrock, C.,Nordahl-Rolfsen, C. (2016), "BIM technology acceptance among reinforcement workers - the case of Oslo airport's terminal 2", Journal of Information Technology in Construction, Vol. 21, pp. 1-12.
10. Sacks, R., Radosavljevic, M.,Barak, R. (2010), "Requirements for building information modeling based lean production management systems for construction", Automation in Construction, Vol. 19 No. 5, pp. 641-655
11. van Berlo, L.A.H.M., Natrop, M. (2015), "BIM on the construction site: providing hidden information on task specific drawings", Journal of Information Technology in Construction, Vol. 20, Special Issue, pp. 97-106
12. Wang, X and Love., P.E.D (2012), "BIM+ AR: Onsite information sharing and communication via advanced visualization", Proceedings of the 2012 IEEE 16th International Conference on Computer Supported Cooperative Work in Design, IEEE, pp. 850-855
13. Yeh, K.-C., Tsai, M.-H., Kang, S.-C. (2012), "The iHelmet: an AR-enhanced wearable display for BIM information", in Anumba, C.J. and Wang, X. (Eds), Mobile and Pervasive Computing in Construction, Oxford, Wiley-Blackwell, pp. 149-168.
14. Mobile field station; United States Design Patent D701363; San Clemente; Link: http://www.freepatentsonline.com/D701363.pdf

The Vico Office Software for the 4D and 5D Information Modelling for Building External Walls of the Residential Block in Ljutomer

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Abstract:

The paper addresses 4D and 5D information modelling in the Vico Office software (Trimble, 2017) for building external walls of the residential block in Ljutomer. Our practical example shows cost and time comparison of building, different kinds of bearing walls, and comparison of different compositions of external walls in the Vico Office software. In addition, the energetic calculation of building of relevant compositions of external walls is provided in PHPP software (Passive House Institute, 1998-2012), while taking into account three different factors of thermal conductivity »U«, U1=0,11 W/m^{2}K, U2=0,21 W/m^{2}K in U3=0,28 W/m^{2}K. We analysed Porotherm 30 PROFI, Porotherm 30 W.i.Plan, Porotherm 30 S and 20 cm reinforced concrete walls, according to the technology of conducting the bearing walls. Finally, the obtained results offer the decision which kind of bearing walls and the composition of external walls to choose for the optimal cost, time and energy consumption in the building.

Keywords: *cost estimating; time scheduling; building information modeling; BIM; 4D information modelling, 5D information modelling; Vico Office*

1. Introduction

In order to achieve effective work on a construction project with a team from various disciplines, we chose a modern BIM (Building Information Modelling) (Eastman et al., 2011) approach. The main intention at the beginning of using this approach was the formation of virtual 3D building models and thereby visualization of the entire construction work. In this way, the design of the building was more understandable for the user. The most known Software for a modelling object comprehends Allplan (Nemetschek group, 2017), ArchiCAD (Graphisoft, 2017), Bentley Architecture (Bentley, 2016), Revit (Autodesk, 2017), Tekla Structures (Tekla, 2017), etc. The increasingly massive use of BIM approach, the development of modellers and the tendency for additional information, important for the management of construction projects, resulted in the upgrade of the basic 3D model to 4D and 5D model. In addition to the geometric information, 4D model includes time information (3D + Schedule Plan); 5D model includes the cost information (3D + Cost Estimation) for the construction of the building (AIA and Rundall 2006); (Rundell and Stowe 2007); (Tulke and Hanff 2007); (Staub-French et al. 2007); (Muhič 2008); (König et al. 2012); (Bryde et al. 2013); (McCuen

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2014); (Pučko et al. 2014); (Boton et al. 2015). The main result of the 4D model is the project schedule, accompanying resource plans and the ability to display the animation of the erection of construction works in chronological order. Software to create 4D BIM models comprises Navisworks (Autodesk, 2017) and Synchro Software (Software, 2017). BIM models are upgraded in the 5th dimension, i.e. the 5D BIM model, which represents the cost aspect of constructing the building. Created 5D model is just as the 4D model associated with a 3D model of the object. Software for creating 5D models includes Exactal (Exactal, 2017), Rib software (Rib, 2017) and Vico Office (Trimble, 2017) etc. In this paper, we used Software with BIM approach, the so-called Vico Office (hereinafter referred to as VO) as well as the modules *Takeoff Manager*, *Cost Planner* and *Schedule Planner* (Trimble, 2017).

The basic aim of this paper is to present a constructed time (4D) and cost (5D) BIM model for the erection of various kinds of bearing walls and different compositions of external walls and their comparison. We analysed Porotherm 30 PROFI, Porotherm 30 W.i.Plan, Porotherm 30 S and 20 cm reinforced concrete wall, according to the selected technology of conducting the bearing walls. In this Porotherm 30 PROFI means the commercial code, namely 30 means the thickness of the block in cm. A thickness of 20 cm for a concrete wall was taken from the comparison of static calculation, wherein concrete wall of thickness 20 cm was equivalent to brick wall of thickness 30 cm. Compositions of external walls differ in thickness of added external wall insulation system Jubizol EPS (JUB, 2015); and relevant energetic calculation of thermal conductivity of each system of external walls was made by PHPP software (Passive House Institute, 1998-2012). In conclusion, the obtained results gave the basis for a decision to choose the most suitable variant of the bearing walls and external walls of the structure in terms of costs, time and energy consumption in the building.

2. Description of the building and selected variants

The focus of our consideration was the residential block in Ljutomer (Figure 1). The building has four floors, namely the ground floor, floor 1 and floor 2, each having a floor area of 565.24 m^2 and a penthouse floor size of 272.90 m^2 (Figure 1). There are four flats on each storey and two larger flats in the penthouse floor. The building has a total of 14 flats, i.e. 7 two-room and 7 three-room flats. The external walls are built with the bearing wall Porotherm 30 PROFI thickness of 30 cm, the inside is plastered with 2 cm thick lime gypsum plasters and painted with BIO paintwork. The outer side of external walls is thermally insulated by the heat insulating facade cladding JUBIZOL with plates type EPS F GRAPHITE - GO, a thickness of 16 cm with a final coat, in bright pastel colour (Domus project d. o. o., 2015).

Figure 1: Residential block Ljutomer. The image left during construction, image right after construction. The view from the south side (Source: Own source, 2015 and 2017)

The software VO was used to analyse the four systems bearing walls Porotherm 30 PROFI (Wienerberger, 2017), Porotherm 30 W.i.Plan (Wienergerger, 2017), Porotherm 30 S (Wienerberger, 2017) and the system of reinforced concrete bearing "20 AB wall" for our present building. Four systems of bearing walls will hereinafter be called a variant. The variant A (Figure 2, a set of yellow) represents the bearing wall with a brick Porotherm 30 PROFI; the variant B (Figure 2, a set of gray) shows a system of bearing wall with a brick Porotherm 30 WiPlan; the variant C (Figure 2, a set of red) is a system of bearing walls with a brick Porotherm 30 S; and the variant D (Figure 2, a set of blue color) displays a system of bearing reinforced concrete wall thickness of 20 cm. Figure 2 presents the model of considered building in VO, where the external walls are marked in yellow (Pavličič, 2016).

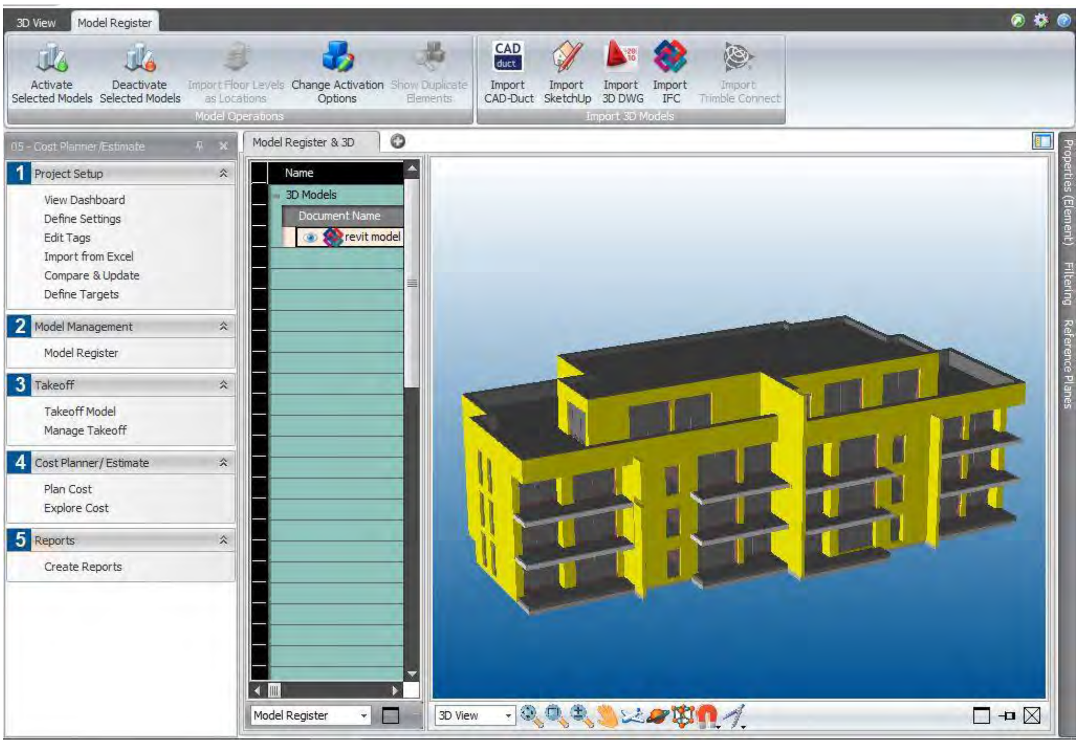
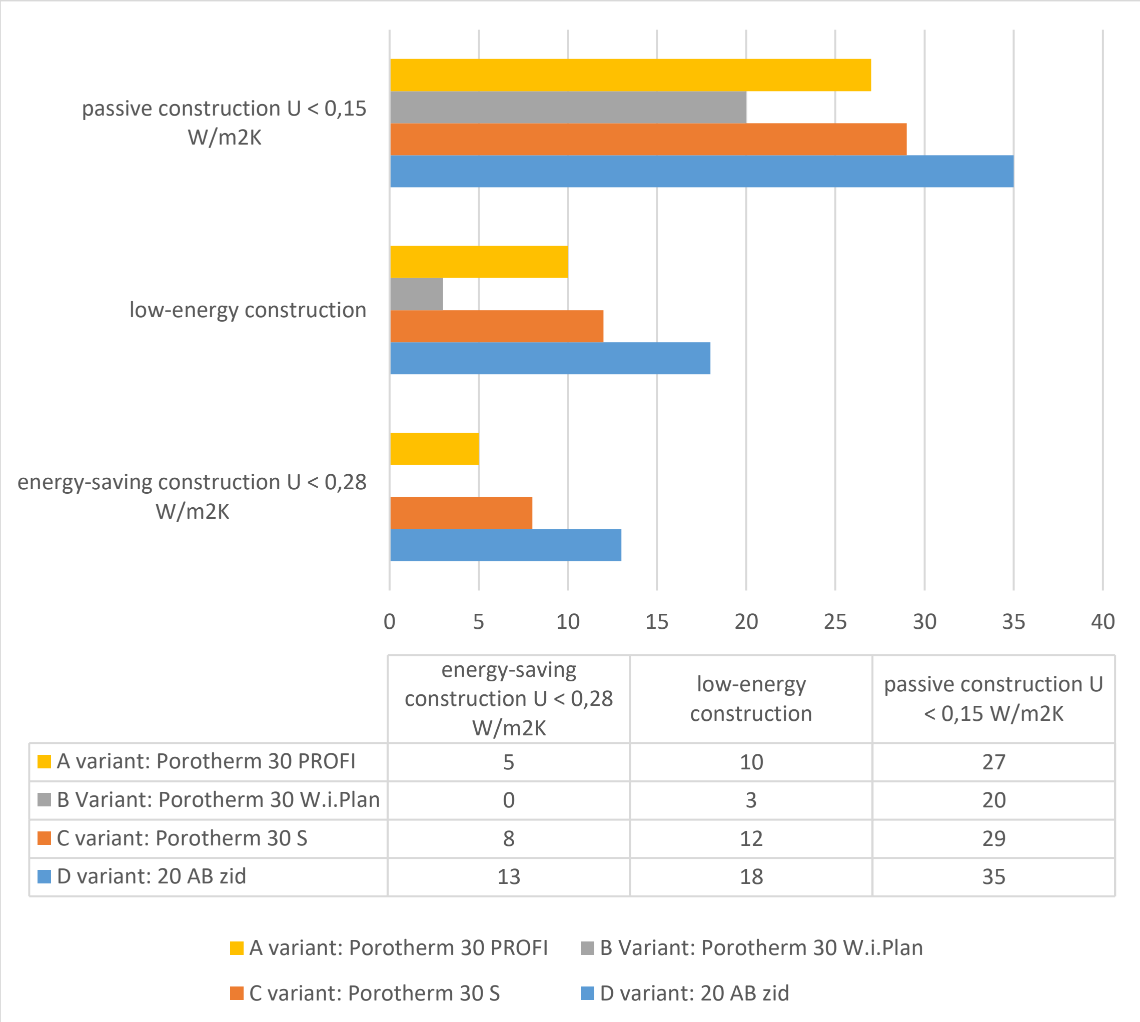


Figure 2: Model of residential block Ljutomer shown in VO

Variants from A to D have, depending on applied insulation, three different compositions of the external walls. Energetic calculation was carried out for each assembly of the external wall, taking into account three different factors of the heat transfer "U", namely U1 = 0,11 W/m^{2}K (passive construction-building) , U2 = 0,21 W/m^{2}K (low-energy building) and U3 =

0,28 W/m^{2}K (energy-saving building). This was achieved by adding a certain thickness of external wall insulation system Jubizol EPS (Figure 3). As a result, 12 different configurations of the external walls were included in the calculation of the cost and time for the erection of external walls.

From the technological viewpoint of the bearing wall construction, different technologies of Porotherm system (Wienerberger, 2017) are used. The construction with the Porotherm PROFI and W.i Plan is carried out by Dryfix adhesive, while the Porotherm S uses the application of the mortar. We considered the installation of lintels and corner elements in the calculation of the cost and time construction of bearing walls in all Porotherm systems. We did not take into account the erection of lintels and corner elements in a fourth variant but we included technological processes of panelling, installation of reinforcing steel, concreting, and care of fresh concrete in calculations.



	energy-saving construction U < 0,28 W/m2K	low-energy construction	passive construction U < 0,15 W/m2K
A variant: Porotherm 30 PROFI	5	10	27
B Variant: Porotherm 30 W.i.Plan	0	3	20
C variant: Porotherm 30 S	8	12	29
D variant: 20 AB zid	13	18	35

Figure 3: Adding insulation thickness [cm] according to U factor compositions of external walls

Moreover, for each composition of the external wall, we considered a working scaffold, wall cladding with Jubizol EPS insulation, plastering and surface treatment by a mesh in the calculation.

3. Analysis of price and construction time by using software VO

3.1 Use of software VO

First, the command "*Publish to Vico Office*" in the Software VO was used to import the 3D model of the building that was previously created with Revit modelling tool. In the module *Takeoff Model,* we obtained proper quantities of the structural elements, as they were generated from the geometry in the VO modelling tool. In the next step, we entered into the specified row in the *Cost Planner* module data such as: *Code, Description, Source Qty, Consumption, Waste, Qth, Unit Cost, UOM,* which displayed the following data: *Base Cost, Cost/Parent Assembly, %/Parent Assembly* (Trimble, 2017).

Code	Description	Sour..	Cons..	Cons..	Waste	Qty	Unit Cost	UOM	Base Cost	Cost/Par..	%/Parent..
000	F-B objekt Ljutomer	1,00	1,000	1,000	1,000	1,00	0,00		0,00	N/A	N/A
G	Gradbena dela	1,00	1,000	1,000	1,000	1,00	0,00	-	0,00	N/A	N/A
Z	Zidarska dela	1,00	1,000	1,000	1,000	1,00	0,00		0,00	N/A	N/A
1302	Zidanje	1,00	1,000	1,000	1,000	1,00	0,00	m3	0,00	N/A	N/A
130201	Nosilnih in nenosilnih	1,00	1,000	1,000	1,000	1,00	0,00	m3	0,00	N/A	N/A
13020101	V opečni izvedbi	1,00	1,000	1,000	1,000	1,00	0,00	m3	0,00	N/A	N/A
30 P	**Porotherm 30 PROFI**	**195,91**	**1,000**	**1,000**	**1,000**	**195,91**	**140,38**	**m3**	**27.501,06**	**N/A**	**N/A**
30 W.i	**Porotherm 30 W.i.**	**195,91**	**1,000**	**1,000**	**1,000**	**195,91**	**245,02**	**m3**	**48.001,35**	**N/A**	**N/A**
30 S	**Porotherm 30 S**	**195,90**	**1,000**	**1,000**	**1,000**	**195,90**	**144,17**	**m3**	**28.242,35**	**N/A**	**N/A**
130203	Stebrov/vogalnikov	1,00	1,000	1,000	1,000	1,00	0,00	-	0,00	N/A	N/A
130204	Preklad	1,00	1,000	1,000	1,000	1,00	0,00	m	0,00	N/A	N/A
B	Betonska in armirano	1,00	1,000	1,000	1,000	1,00	0,00	m3	0,00	N/A	N/A
T	Tesarska dela	1,00	1,000	1,000	1,000	1,00	0,00	m2	0,00	N/A	N/A
O	Obrtniška dela	1,00	1,000	1,000	1,000	1,00	0,00	-	0,00	N/A	N/A
F	Fasada	1,00	1,000	1,000	1,000	1,00	0,00	-	0,00	N/A	N/A

Figure 4: Meaning of rows in *Cost Planner*

Before entering data into the module *Cost Planner*, we analysed the price per unit of measure of individual items of the calculation, based on the input data. This analysis in the software allows MS Excel to serve as a basis; and the data in *Cost Planner* module can be compared. Price analyses based on pre-defined construction technology, the geometric characteristics of the element and corresponding norms for rate of works (OZS, 2005/2006), (Wienerberger, 2015), (Doka, 2015) and the current price lists of the time and materials per unit of measure (ZGIGM, 2015), (Wienerberger, 2017), (Doka, 2015), (Expo biro, 2015), (Merkur, 2015).

3.2 Analysis of prices in the module Cost Planner

After the certain numbers of individually estimated items obtained from the 3D model, we up*dated the basic model in module* Cost Planner with a cost component and got 5D BIM model. We included collected information of prices per unit with 5D-modelling, and demonstrated 12 calculations for 12 different compositions of external walls for all variants from A to D. The price of each construction services was analysed by the method of calculating the so-called internal prices that include only the direct material costs and direct labour costs. Direct costs were determined on the basis of norms and manufacturer (Porotherm d.o.o.), price list (http://wienerberger.si/) and other suppliers, and using the value of the average gross payroll. Figure 5 shows an example of price analysis for the construction of bearing walls with Porotherm 30 PROFI, which follows the norms of the manufacturer. Figure 5 shows an example of price analysis for the erection of bearing walls with Porotherm 30 PROFI, where provided material consumption is 53.3 pieces of brick and 500 l of glue for 1 m^3 according to the norms and the consumption of 1.12 hours of work for skilled worker and 0.48 hours of work for semiskilled worker.

Code	Description	Sour..	Cons..	Cons..	Waste	Qty	Unit Cost	UOM	Base Cost	Cost/Par..	%/Parent..
000	F-B objekt Ljutomer	1,00	1,000	1,000	1,000	1,00	0,00		0,00	N/A	N/A
G	Gradbena dela	1,00	1,000	1,000	1,000	1,00	0,00	-	0,00	N/A	N/A
Z	Zidarska dela	1,00	1,000	1,000	1,000	1,00	0,00		0,00	N/A	N/A
1302	**Zidanje**	**1,00**	**1,000**	**1,000**	**1,000**	**1,00**	**27.501,06**	**m3**	**27.501,06**	**N/A**	**N/A**
130201	**Nosilnih in**	**1,00**	**1,000**	**1,000**	**1,000**	**1,00**	**27.501,06**	**m3**	**27.501,06**	**27.501,06 /**	**100,00%**
13020101	**V opečni izvedbi**	**1,00**	**1,000**	**1,000**	**1,000**	**1,00**	**27.501,06**	**m3**	**27.501,06**	**27.501,06 /**	**100,00%**
30 P	**Porotherm 30 PROFI**	**195,91**	**1,000**	**1,000**	**1,000**	**195,91**	**140,38**	**m3**	**27.501,06**	**27.501,06 /**	**100,00%**
DE001	PK delavec	195,91	0,480	2,083	1,000	94,04	6,91	hr	649,79	3,32 / m3	2,36%
DE002	KV delavec	195,91	1,120	0,893	1,000	219,42	7,92	hr	1.737,80	8,87 / m3	6,32%
MA001	Zidanje z opeko	195,91	53,300	0,019	1,000	10.442,...	1,98	kos	20.675,17	105,53 / m3	75,18%
MA0011	Lepilo Dryfix	195,91	500,000	0,002	1,000	97.955,...	0,00	l	0,00	0,00 / m3	0,00%
TR001 (NK)	ROČNI Prenos opeke	195,91	2,080	0,481	1,000	407,49	5,97	hr	2.432,73	12,42 / m3	8,85%
TR002.2 (KV)	Dvigalo 20H+10V	195,91	0,285	3,509	1,000	55,83	35,92	hr	2.005,57	10,24 / m3	7,29%

Figure 5: Output of module *Cost Planner* showing the structure of the price for the total quantity of building with Porotherm 30 PROFI

3.3 Determination of the construction work in Schedule Planner module

BIM 3D model of the object was in the next step connected also with the time component depending on 4D BIM properties. For this, we used software module *Schedule Planner*. The module is treated as external BIM software for planning the duration of the project implementation and creating time schedule; and it provides a dynamic connection between the data in 3D, 4D and 5D information models.

Before we started to work in module *Schedule Planner,* we combined in module *Manage Tasks* estimated items that were specified in the *Cost Planner* and so project activities were determined to all 12 different configurations of the external wall. We had to determine for each project activity the work that defined duration of each activity in the program VO and the duration of the entire wall erection with a facade cladding in the final stage. Each project activity includes a team of three workers. Figure 6 illustrates printout of data in the module *Manage Task*, as it was carried out for each variant of bearing walls. Furthermore, the connection between *Cost Planner* and *Schedule Planner* was established in the *Manage Task* module.

Code	Name	Work	Dura...
0052	F-B objekt Ljutomer		1.200,40
0067	FASADA z delovnim odrom v B1	727,81	26,17
0056	Varianta B	919,68	47,00
0073	FASADA z delovnim odrom v. D1	1.087,89	52,85
0054	Varianta A	981,59	53,81

Code	Description	Qty	UOM	Hrs/...	UO...	Work
30 P	Porotherm 30 PROFI	195,91	m3			
DE001	PK delavec	94,04	hr	1,00	1,00	94,04
DE002	KV delavec	219,42	hr	1,00	1,00	219,42
MA001	Zidanje z opeko Por...	10.442,00	kos			
MA0011	Lepilo Dryfix	97.955,00	l			
TR001 (NK)	ROČNI Prenos opeke	407,49	hr	1,00	1,00	407,49
TR002.2 ...	Dvigalo 20H+10V	55,83	hr	1,00	1,00	55,83
30 Dryfix	Vogalnik 30 Dryfix	231,00	m			
PR1	Preklada 12 x 6,5	120,00	m			
PR2	Preklada 10 x 8,5	372,00	m			

Code	Name	Work	Dura...
0053	Varianta C	1.407,81	69,27
0058	Varianta D	1.972,35	85,98
0072	FASADA z delovnim odrom v. C3	1.157,78	86,43
0070	FASADA z delovnim odrom v. C1	1.135,63	86,43
0071	FASADA z delovnim odrom v. C2	1.139,91	86,43
0063	FASADA z delovnim odrom v. A1	1.132,50	86,43
0066	FASADA z delovnim odrom v. A3	1.155,64	86,43
0068	FASADA z delovnim odrom v. B2	1.130,39	86,43

Task Manager

Code	Description	Sour..	Cons..	Cons..	Waste	Qty	Unit Cost	UOM	Base Cost
G	**Gradbena dela**	**1,00**	**1,000**	**1,000**	**1,000**	**1,00**	**8.343,36**	-	**8.343,36**
B	Betonska in armirano	0,00	1,000	1,000	1,000	0,00	0,00	m3	0,00
T	Tesarska dela	1,00	1,000	1,000	1,000	1,00	8.343,36	m2	8.343,36
Z	Zidarska dela	1,00	1,000	1,000	1,000	1,00	0,00		0,00
Porotherm W.i.	New Component	1,00	1,000	1,000	1,000	1,00	0,00	-	0,00
Porotherm S	New Component	1,00	1,000	1,000	1,000	1,00	0,00	-	0,00
O	**Obrtniška dela**	**1,00**	**1,000**	**1,000**	**1,000**	**1,00**	**41.463,83**	-	**41.463,83**
F	**Fasada**	**1,00**	**1,000**	**1,000**	**1,000**	**1,00**	**41.463,83**	-	**41.463,83**
1304	**Oblaganje**	**1,00**	**1,000**	**1,000**	**1,000**	**1,00**	**41.463,83**	**m2**	**41.463,83**
1306	Ometavanje in	0,00	1,000	1,000	1,000	0,00	0,00	m2	0,00
1306 (5)	Ometavanje in	1,00	1,000	1,000	1,000	1,00	0,00	m2	0,00
1306 (10)	Ometavanje in	1,00	1,000	1,000	1,000	1,00	0,00	m2	0,00
1306 (9)	Ometavanje in	1,00	1,000	1,000	1,000	1,00	0,00	m2	0,00
1306	Ometavanje in	1,00	1,000	1,000	1,000	1,00	0,00	m2	0,00
1306 (1)	Ometavanje in	1,00	1,000	1,000	1,000	1,00	0,00	m2	0,00
1306 (2)	Ometavanje in	1,00	1,000	1,000	1,000	1,00	0,00	m2	0,00
1306 (8)	Ometavanje in	1,00	1,000	1,000	1,000	1,00	0,00	m2	0,00
1306 (7)	Ometavanje in	1,00	1,000	1,000	1,000	1,00	0,00	m2	0,00
1306 (6)	Ometavanje in	1,00	1,000	1,000	1,000	1,00	0,00	m2	0,00
1306 (3)	Ometavanje in	1,00	1,000	1,000	1,000	1,00	0,00	m2	0,00
1306 (4)	Ometavanje in	1,00	1,000	1,000	1,000	1,00	9.159,67	m2	9.159,67
130204	**Preklad**	**1,00**	**1,000**	**1,000**	**1,000**	**1,00**	**3.125,92**	-	**3.125,92**
130204 (1)	Preklad	1,00	1,000	1,000	1,000	1,00	0,00	-	0,00
130203	**Stebrov/vogalnikov**	**1,00**	**1,000**	**1,000**	**1,000**	**1,00**	**2.805,44**	-	**2.805,44**
130203 (1)	Stebrov/vogalnikov	1,00	1,000	1,000	1,000	1,00	0,00	-	0,00

Cost Planner

Figure 6: Output data from the module Manage Task

Work in the *Schedule Planner* module was conducted in a way that we first defined the links between the activities relating to the building technology and entered the appropriate resources (*Update resources from quantities*) that identified the duration of the construction works. In individual sections of working phases we defined a sequence of construction works and for all assumed we determined the option of the implementation of the so-called ASAP (as soon as possible). Technological interruptions such as weather, holidays, etc. and implementation of interim activities that followed the technology of building, which was the interim slabs and interim internal walls, were not considered in the time schedule. Thus, the duration of individual variants was the cumulative sum of the construction time of the flat due to the activities that were federally connected, i.e. without interruption. Properly configured parameters allowed the program to draw time schedule of construction work of bearing walls for each variant, and thus representing the 4D BIM model.

4. Analysis of results

4.1 Construction costs of bearing walls and assembling of external walls

In terms of achieving the quality of the building, we considered the level of energy efficiency of the element, taking into consideration three different factors of "U" and comparing them to the total cost of the construction of four variants of bearing walls. The results of the calculated total construction costs for four variants of bearing walls and 12 different assemblies of external wall is given in the chart in Figure 7. First four calculations include only the costs of the construction of bearing walls, while the remaining 12 variants include costs of construction of bearing walls, facades and working platforms, according to three levels of achieved quality factor "U". Mutual comparison of the results of total costs shows that the reduction of the factor "U" at all four variant's costs resulted in proportional increase, which obviously meant that better thermally insulated material showed a smaller leap of the curve of individual variants. The rapid upward trend cannot be seen at the variant of construction with the system of bearing walls Porotherm 30 W.i.Plan, since we achieved saving construction (factor "U2") with bearing walls without adding insulation. However, such a construction, in our case, represented the least cost-effective variant, due to the current high prices of building block on the market.

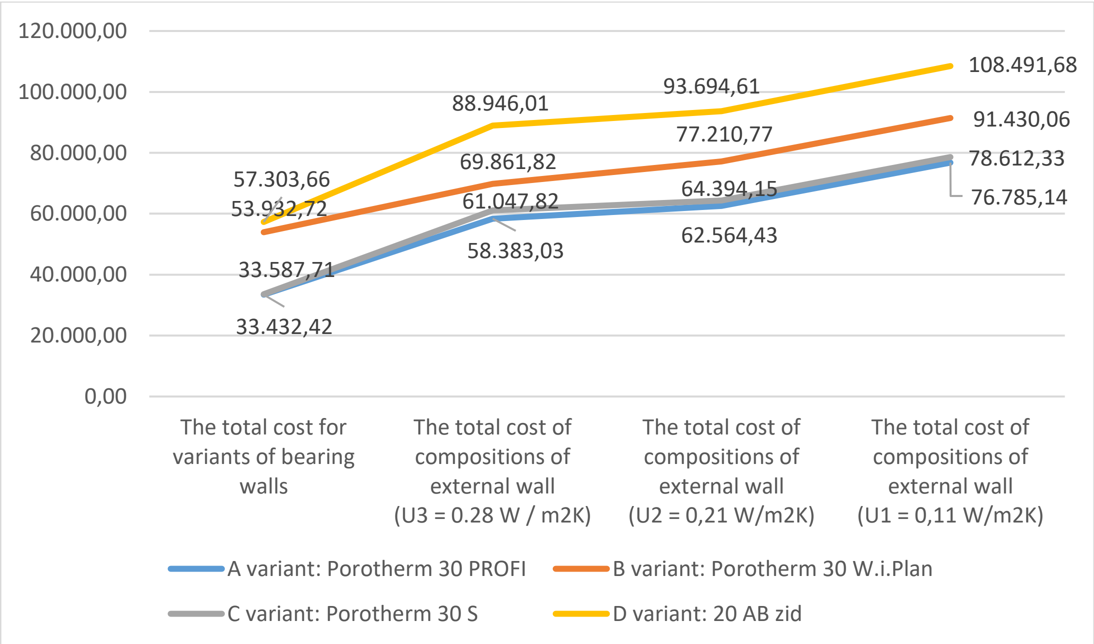


Figure 7: The direct costs of the compositions of external walls for 16 different variants

Due to the fact that the costs of all four variants proportionally increase by reducing the factor "U", we had hereafter focused only on the results of the total costs of four variants by the factor of thermal transmittance U3 = 0.28 W/m^{2}K. The results are shown in Figure 8 in percentage, wherein the best combination of the composition of the external wall represents 100%. We dealt with:

1. The composition of the external wall of variant A and added Jubizol EPS of 5 cm;
2. The composition of the external wall of variant B and added Jubizol EPS of 0 cm;
3. The composition of the external wall of variant C and added Jubizol EPS of 8 cm;
4. The composition of the external wall of variant D and added Jubizol EPS of 13 cm.

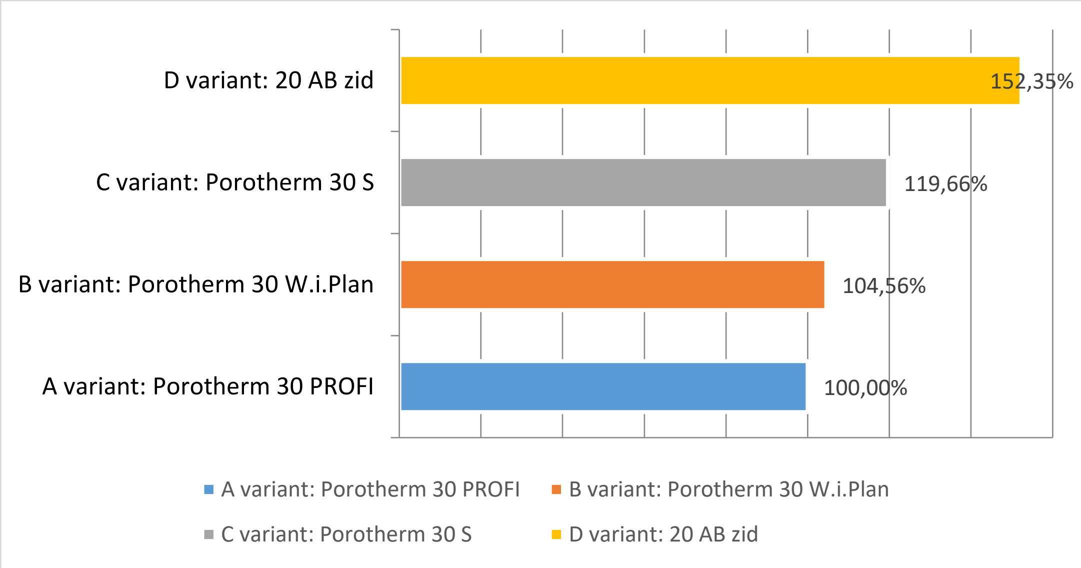


Figure 8: Comparison of direct cost of four compositions of external walls of the value U_3 = 0.28 W/m^{2}K

Figure 8 clearly shows that the most cost effective solution is to provide an assembly of external wall from the variant A (construction with the system of the bearing wall Porotherm 30 PROFI) and added Jubizol EPS isolation of 5 cm. It is followed by the composition of the external wall from the variant B (bearing wall Porotherm 30 W.i.Plan) and without added insulation Jubizol EPS, the cause is 4.56% more expensive than the composition of the outer wall from the variant A. The composition of variant C is 19.66 % more expensive than variant A. Less cost-effective solution represents the composition of the external wall from the variant D (monolithic construction from 20 cm reinforced concrete wall), which is 52.35% more expensive as variant A.

4.2 Time of construction of bearing walls and assemblies of external walls

Figure 9 provides a graphical representation of the time of construction for four variants of bearing walls and 12 different configurations of external wall, regarding the set quality. In terms of the quality of the building, we considered the level of energy efficiency of an element, taking into account three different factors of "U". We compared them with common times without erection of facade (four variants bearing wall) and with the total times with the erection of facades, including the time of installing the work platform (12 assembly of external wall). Figure 9 presents the latest by reducing the factor "U", the total time spent for the construction of the composition of the external wall steadily rising, since the addition of thermal insulation of greater thickness increases the time of construction. The maximum leap is noticed between the base wall and the wall, where the façade is taken into account in order to achieve efficient construction (factor "U3") in which we also considered the time of installing the work platform and the application of a certain thickness of the insulation. This bounce is in the variant B achieved at low-energy construction (factor "U2"), since adding isolation is not necessary to gain energy-saving construction (factor "U3").

Mutual comparison of the results of the total time consumption shows that the variant B represents the best solution, i.e. the construction with the system of bearing wall Porotherm 30 W.i.Plan. This is achieved because the building block is easier to manipulate and thus the cost of transfers of materials on construction site is lower than in the variant A. Furthermore, comparison of technologies of variants A and B with the building technology of variant C shows that we spent less time for the construction technology with Dryfix adhesive than for the technology of building with the application of the mortar used in variant C. However, monolithic construction with 20 cm of reinforced concrete wall gives us the longest time of building the walls, because we included the procedures of panelling, installation of reinforcing steel, concreting, formwork and concrete grooming in the course of activities.

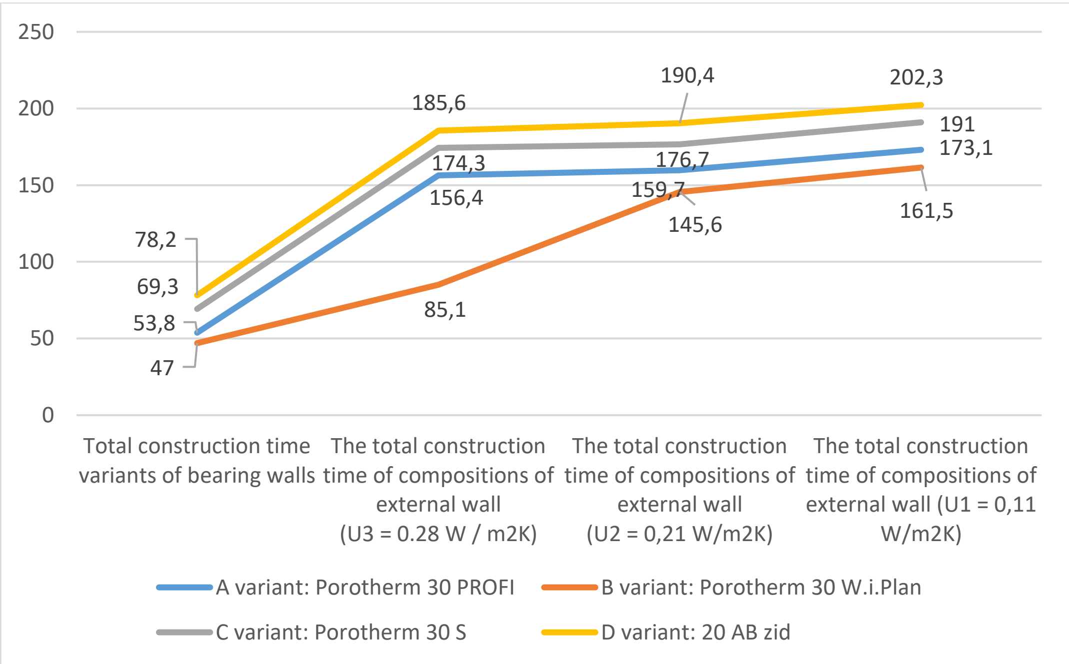


Figure 9: The total construction time of the compositions of external walls for 16 different variants, according to their quality factor "U"

Due to the fact that the construction time for all four variants proportionally increases with a reduction of factor "U", we hereinafter focused solely on the results of the construction time of four variants at factor thermal transmittance U3 = 0.28 W/m^{2}K in order to make the comparison easier. The results are shown in percentage, wherein the best combination of the composition of external wall represents 100 %. We considered the same composition of external walls as in the section 4.1.

Figure 10 shows that a most favourable solution delivers the assembly of external wall from the variant B (construction with the system of bearing wall Porotherm 30 W.i.Plan) and 0 cm of insulation of Jubizol EPS. It is followed by composition of the external wall from the variant A (bearing wall Porotherm 30 PROFI) and 5 cm of insulation JUBIZOL EPS, for which erection 84% more time is needed compared to variant B. The composition of the external wall from variant C (construction with the system of bearing wall Porotherm 30 S), and 8 cm of insulation Jubizol EPS requires 105% more time for the erection compared to variant B. Finally, most of the time for the erection demands the composition of the external wall from the variant D (monolithic construction with 20 cm of reinforced concrete wall), since it takes 118 % more time than for variant B.

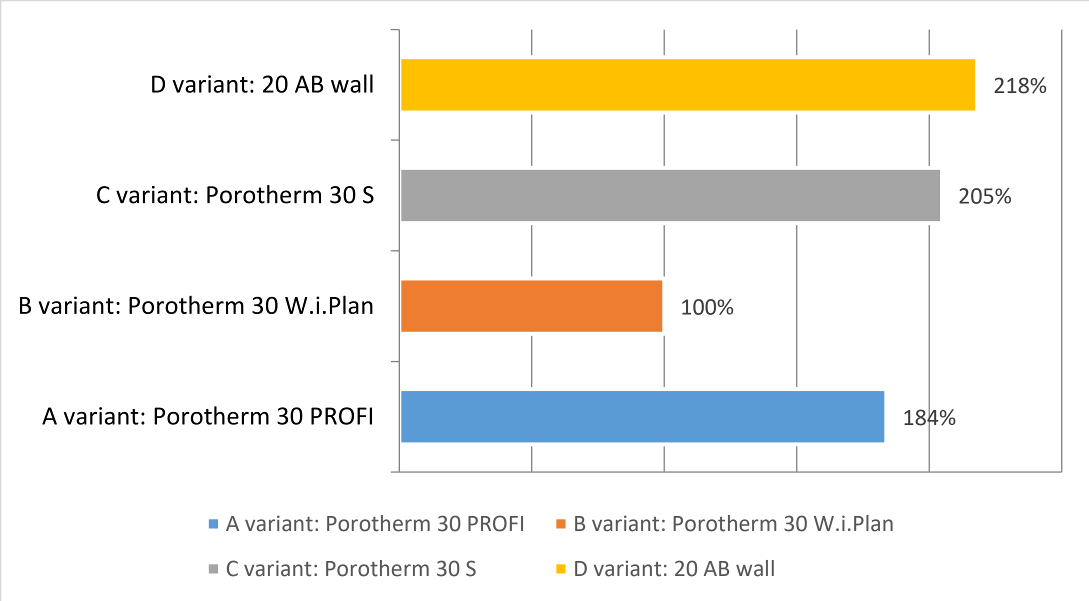


Figure 10: Comparison of total time of four compositions of external walls of the value U3 = 0,28 W/m2K

5. Conclusion

The modern BIM approach (Building Information Modelling) using the VO software enables a quicker and easier comparison of costs and construction time depending on the choice of different variants of bearing walls for the construction of residential block in Ljutomer. The results show that the total construction costs and time spent for the construction increase by reduction of factor "U" in all variants. In addition, the overall costs and time of building do not affect only the price of the underlying bearing wall, but also the quality in terms of thermal transmittance of bearing wall and building technology.

A comparison of the results about cost and time of the construction of all four variants at factor of thermal transmittance U3 = 0.28 W/m^2K shows that the most cost-effective construction for the residential object in Ljutomer is the assembly of external wall from the variant A (construction with the system of bearing wall Porotherm 30 PROFI) and 5 cm of insulation Jubizol EPS. It is followed by the composition of the external wall from the variant B (construction with the system of bearing wall Porotherm W.i.Plan) and 0 cm of insulation Jubizol ESP that is for 4.56 % more expensive than the composition of external wall from the variant A. The most favourable construction from the aspect of time is the variant B (construction with the system of bearing wall Porotherm 30 W.i.Plan) and 0 cm of insulation Jubizol EPS. This is followed by the composition of the outer wall from the variant A (a baring wall Porotherm 30 PROFI) and 5 cm of insulation Jubizol EPS which needs 84% more time for the erection compared to the external wall from the variant B. In the third place is in both cases the composition of external wall from the variant C (construction with the system of bearing wall Porotherm 30 S), and 8 cm of insulation Jubizol ESP, which is for 19.66 % more expensive than the composition of external wall from the variant A and it takes 105% more time for the erection compared to the composition of external wall from the variant B. From a cost and time perspective, the composition of the external wall from the variant D represents the worst solution (monolithic construction with 20 cm of reinforced concrete wall), which is 52.35% more expensive compared to the composition of external wall from the variant A and it takes 105% more time for the erection compared to the composition of external wall from the variant B.

Creating 4D and 5D BIM models is primarily important for the investor at the time of conception and design of the building to decide on the method of construction. Such decision obviously indirectly influences the evaluation of the eligibility of investment in construction. Results of information modelling are also useful for contractors, since using 4D and 5D BIM models allow them quick and easy comparisons of the costs and construction time. Further research of analysing the costs of construction of bearing walls should be directed towards assessing the eligibility of investments in an individual variant. Furthermore, research in energy consumption of the buildings (factor "U") could be expanded to consideration of all elements of the building envelope (including building joinery (windows and doors), roof and ground floor), heating and air-conditioning, location, sky direction of the building and the number of people in the building. In conclusion, these data allow analysis of costs and time of building the systems for entire building, and calculation of indictor return of investment (ROI).

Furthermore, information about costs of maintenance and rehabilitation of the building would be very important for the investor, and therefore created 4D and 5D information model could be expanded to 6D model. This would represent a comprehensive model of a constructed building by all attributes that serve planning and monitoring of maintenance and rehabilitation works in lifetime of the building.

References

AIA and Rundall, R. (2006), “1 – 2- 3 Revit : BIM and Cost Estimating, Part 1”, Cadalyst - Building Design, 7 August.

Autodesk. (2017), Navisworks, available at: http://www.autodesk.com/products/navisworks/overview (accessed: 12 January 2017).

Autodesk. (2017), Revit, available at: http://www.autodesk.com/products/revit-family/overview (accessed: 10 January 2017).

Bentley. (2016), Bentley, available at: https://www.bentley.com/en/about-us (accessed: 29 December 2016).

Boton, C., Kubicki, S. and Halin, G. (2015), “4D / BIM simulation for pre-construction and construction scheduling. Multiple levels of development within a single case study “, in Creative Construction Conference 2015 proceedings in Krakow, Poland, 2015, Diamond Congress Ltd., pp. 500–505.

Bryde, D., Broquetas, M. and Volm, J. M. (2013), “The project benefits of building information modelling (BIM)”, International Journal of Project Management, Vol. 31 No. 7, pp. 971–980.

Eastman, C., Teicholz, P., Sacks, R. and Liston, K. (2011), BIM handbook: A guide to building information modeling for owners, managers, designers, engineers, and contractors (2nd ed.), Hoboken, John Wiley & Sons, New York.

Exactal. (2017), Exactal Group, available at: https://www.exactal.com/en/ (accessed: 3 February 2017).

Expo. (2015), Expo biro, available at: http://www.expobiro.si/ (accessed: 6 December 2016).

Graphisoft. (2017), Archicad, available at: http://www.graphisoft.com/archicad/ (accessed: 12 January 2017).

JUB. (2015), available at: http://www.jub.si/fasadni-sistemi-energetske-resitve/fasadni-sistemi-jubizol/jubizol-eps (accessed: 6 December 2015).

König, M., Koch, C., Habenicht, I. and Spieckermann, S. (2012), "Intelligent BIM-based construction scheduling using discrete event simulation", in Winter Simulation Conference 2013 proceedings of the international conference in Washington, USA, 2013, WSC Foundation, New York, pp.662-673.

McCuen, T. (2009), "Cost Estimating in BIM : The Fifth Dimension", Construction Claims Advisor, 18 November, pp. 2–3.

Muhič, S. (2008), Proces brez lukenj, Dimensio, Vol 12 No 13, pp 33.

Nemetschek group. (2017), Allplan, available at: https://www.nemetschek.com/en/brands/allplan/ (accessed: 12 January 2017).

Pučko, Z., Natasa, S. and Uros, K. (2014), "Building Information Modeling Based Time And Cost Planning in Construction Projects", Organization, Technology and Management in construction. An International journal, Vol 6 No 1, pp. 958–971.

Rib. (2017). RIB Software, available at: http://www.rib-software.com/home.html (accessed: 3 February 2017).

Rundell, R. and Stowe, K. H. (2007), "BIM and Project Planning (1-2-3 Revit Tutorial)", Cadalyst - AEC, 1 March.

Software, S. (2017), Synchro Software, available at: https://synchroltd.com/ (accessed: 13 January 2017).

Staub-French, S., Khanzode, A., Analyst, B. and Candidate, P. (2007), "3D and 4D modeling for design and construction coordination: issues and lessons learned", ITcon, Vol 12, pp. 381-407.

Tekla. (2017), Tekla Structure, available at: https://www.tekla.com/ (accessed: 9 January 2017).

Tulke, J. and Hanff, J. (2007), "4D Construction Sequence Planning – New Process and Data Model", in CIB-W78 24th International Conference on Information Technology in Construction proceedings of the international conference in Maribor, Slovenia,2007, pp. 79–84.

Trimble. (2017), Vico Office, available at: http://www.vicosoftware.com/ (accessed: 9 January 2017).

Wienerberger. (2017), Navodila za gradnja, available at: http://wienerberger.si/sl/tehnicna-podpora/navodila-za-gradnjo (accessed: 22 October 2016).

Wienerberger. (2017), Porotherm 30 PROFI, available at: http://wienerberger.si/produkti/porotherm-30-profi (accessed: 22 October 2016).

Wienerberger. (2017), Porotherm 30 S, available at: http://wienerberger.si/produkti/porotherm-30-s- (accessed: 22 October 2016).

Wienergerger. (2017), Porotherm 30 W.i.Plan, available at: http://wienerberger.si/produkti/porotherm-30-w.i- (accessed: 22 October 2016).

Domus Project d. o. o. (2015), Residential block Ljutomer F-B, Detail Design.

Passive House Institute. (1998-2012), PHPP, Version 7.1.

Pavličič, A. (2016), Use of the Vico office software for the 4D and 5D information modeling for building external walls of the residential object in Ljutomer, Master thesis, University of Maribor; Faculty of Civil Engineering, Transportation Engineering and Architecture, Maribor.

ZGIGM. (2015), Indeksi za obračun razlike v ceni gradbenih storitev, Chamber of Commerce and Industry of Slovenia (CCIS), Ljubljana.

Doka Slovenia. (2015), Wooden formwork, available at: https://www.doka.com/si/index (accessed: 22 October 2016).

Norms for construction works, (2005/2006), Chamber of Craft and Small Business of Slovenia, Construction section, Ljubljana.

Merkur trgovina d.d. (2016), Price for construction, available at: http://www.merkur.si/gradnja (accessed: 22 October 2016).

Review of BIM's Implementation in some EU AEC Industries

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Abstract:

In recent years, BIM has been emphasized as the ultimate and unavoidable tool for the reengineering of the AEC industry. While BIM's theoretical concept is globally more or less equally accepted and interpreted, the level of practical implementation still has not. Generally, there are noted asymmetric expectations and feasible outcomes of BIM among stakeholders in projects which make considerable pressure on this concept. In this paper, authors analyze the gaps between theoretical and practical application of BIM, as well as the legislation regarding BIM implementation in the authors' countries (i.e. Croatia, Czech Republic, Germany and Slovenia). The paper presents a state of the art concept regarding BIM's practical application, general and theoretical feedbacks from realized construction projects with implemented BIM. In regard to the life cycle of a construction project, the current utilization and collaboration between individual contributors within the AEC industry is described. In view of the life cycle phases, possibilities of strategic and operational implementation are evaluated.

Keywords: *BIM, review, practical implementation, legislation, EU.*

1. Introduction

It is hard to remember, or trace back in time, when on the global level AEC industries have agreed on potentials and benefits of some concept, as they do in the case of BIM. Excitement underpinned by its potentials, as well as its sure practical implementation have been stressed by numerous authors in the last decade. However, it's been a while since Chuck Eastman (Eastman, 1975) presented a revolutionary idea of BIM and it is time to make a break through between expectations, potentials and feasible practical outcomes. Still there are asymmetric understandings and expectations among construction projects' stakeholders from BIM. Some authors define BIM as a 3D presentation of information gathered and compressed in one model by which the building should be build (Bazjanac, 2006, Eastman *et al.*, 2011), to some it is a platform for integration and visual presentation of project management (PM) tools (Azhar and Alex Behringer, 2013, Galić *et al.*, 2015). While to some authors BIM is changing the use of construction PM tools, stakeholders, contracting and concepts by acknowledging and merging project's life cycle phases (Succar, 2009, Bazjanac, 2006, Galic *et al.*, 2014) practically

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becoming a modern PM tool itself. Beside different stakeholders' and researchers' prospective of BIM, there are also differences of BIM's acceptance among well developed AEC industries (e.g. USA, EU, Australia, etc.).

Regardless to its global acceptance, BIM is developing on the local levels on which countries develop their own strategies based on the previous global experiences and their AEC industry circumstances. In 2014 EU commission issued a directive 2014/24/EU (European Parliament, 2014) by which it is recommended to member states the use of building information electronic modelling tools in case of public construction projects. This suggestion gives a clear tendency of making a unique construction market in EU enhanced by a BIM based unique methodology. However, in EU there are significant differences in levels of BIM acceptance, which is clear by the fact that BIM is mandatory in northern EU countries for almost a decade (e.g. Finland, Denmark, UK, etc.) while in the rest BIM's framework by national construction legislation is still matter of discussions and pilot projects.

Motivated by the trend of "learning on experiences" in terms of BIM gradual implementation, authors in this paper present a review of BIM's current level of implementation in their countries (i.e. in alphabetical order Croatia, Czech Republic, Germany and Slovenia). Each author gave a review of BIM acceptance in their country by listing the relevant BIM concerned initiatives, national projects groups, standardization initiatives, legislation framework, relevant scientific achievement and literature. In the discussion and conclusions chapter, authors gave a matrix form of the overall research findings.

2. BIM's implementation in some EU countries

2.1. BIM in Croatia

In Croatia BIM has certainly drawn attention. With its strongpoint in constructability, Croatian AEC oriented scientific, educational and professional circles are more or less aware of its potentials and probable unavoidability in the future (Galić *et al.*, 2013). However, as any new-coming concept, aforementioned circles are reluctant in its adoption and implementation, which was obvious with the CAD adoption in Croatia. Even though Croatia has well developed and organized AEC focused professional associations and chambers, which have started initiatives with the main goal to develop general guidelines for BIM's practical implementation, BIM was and still is mostly emphasized and developed by the scientific and educational circles. In Croatian construction legislation, there is still no sign of BIM. However, there are initiatives active in making the first steps in its standardization by the national standardization institute (i.e. Croatian Standards Institute).

First published articles in Croatia regarding BIM were on OTMC in 2011 conference (Pantouvakis, 2011, Kozlovská and Struková, 2011). The first journal published article in Croatia was presented in 2013 article concerning BIM's adoption prospective for housing refurbishment projects on the UK case (Kim and Park, 2013). In the following year, numerous BIM related papers were published in Croatian publications and/or by Croatian authors, which gives a clear signal that BIM became a relevant topic in Croatia. The relation of BIM and project management through stakeholders' prospective in EU was presented by authors (Travaglini *et al.*, 2014), (Galic *et al.*, 2014) presented a approach for BIM implementation in deconstruction projects, while authors (Salleh and Fung, 2014) presented an article with a quantitative proof that BIM's implementation costs are not the main obstacle in its practical implementation rather it seems to be the lack of previous computational skills and knowledge, as well as the lack of awareness of BIM's potentials. The same year (Skibniewski, 2014) presented a paper of BIM's application for project monitoring through gathering and filtering the photo data of the construction.

At the Croatian Civil Engineers' forum in 2014 was a presented paper (Stober *et al.*, 2015) about improvement potentials and achievements of education on Croatian civil engineering faculties, by embracing BIM and incorporating it in study programmes. In the conclusion of the aforementioned paper, authors underlined the necessity of multidisciplinary structured teams for structuring national frameworks and regulations, which will ease BIM's transition from educational level to practical, which was concluded in the article by the authors (Kovačić *et al.*, 2015) as well. Those thesis were partially confirmed in the research published in the article (Kolarić *et al.*, 2015) and revealed that Croatian practitioners in AEC are familiar with the BIM concept, but in most cases have not implemented it yet in their projects. Analysis of BIM's application and its reliability in construction elements load analysis was presented in a professional article by (Baroš, 2016) where the author presented a simple methodology for expansion of the concepts application. Along BIM's adoption in study programmes at some Croatian faculties, there have been organized seminars, programmes and workshops as a life-long learning for practitioners, as well as for students, given by private companies which are mainly tools oriented (e.g. Autodesk, Graphisoft, etc.).

Croatian Association of Civil Engineers and Croatian Chamber of Architects, along with the Croatian Standards Institute, in recent time are structuring multidisciplinary task groups (e.g. subcommittee TU B1) with the goal of making national guidelines for BIM which will serve as a path for its implementation in Croatian AEC industry.

2.2. BIM in Czech Republic

The implementation of BIM is rising in the Czech Republic, but with a sluggish character. The main trigger of discussions about the appropriateness of the BIM methodology was foundation of Czech BIM Council in 2011 (czBIM, 2016). It used to be the association of enthusiasts from the building design area. Civil association BIM-Forum was founded in the same year and focuses to Revit software using. Due to the above, it can be stated that the BIM implementation started "from the bottom" in the Czech Republic, i.e. not from the government decision.

The first annual conference called "Bim Day" was organized by Czech BIM Council (czBIM) in 2011 in Prague. At the conference, international experts from the Netherlands, Switzerland, United Kingdom, Norway etc. gave lectures in the field of BIM during the years 2011 to 2016. Since that time, the conference is a major annual event in the field of BIM in the country. Over time, other annual conferences appeared in the Czech Republic as a "BIM in the construction industry", "BIM Revit Forum" or newest one "BIM and cost estimation". All of these conferences bring together parties and experts interested in BIM, but it should be noted that they have very similar subject matter.

Several working groups for particular areas of BIM implementation have been established as part of czBIM. Working group PS #01 - Standards & legislation was established first. By this working group BIM handbook was published in 2013 (Černý et al., 2013) in cooperation with czBIM and scientific centre AdMaS of Brno University of Technology (the Working group

PS#01). BIM handbook focuses to explanation the main aspects of BIM methodology, terminology, advantages and disadvantages of its implementation. It also presents a possible connection to the Czech legislation and standards. Second published document was BIM continuity to European Parliament and Council Directive 2014/24/EU public procurement and repealing Directive 2004/18/EC published by czBIM in 2014 (Černý et. al., 2014). It focuses to the structuring transparency in public procurements and integration BIM as a tool to achieve this document. The group PS#01 also performs translations of European standards to Czech language. Creating a dialogue on education BIM across the educational system of the Czech Republic is the main objective of the working group PS#03 BIM & Teaching. This group gathers representatives of a various universities and high schools to make some national teaching frame. Working group PS#03 BIM & Realization aims to connect a construction companies to make common concept of BIM implementation into the construction practice. Members of this working group also prepare the standard properties of elements 3D/BIM model for the field of the building construction. Furthermore, working groups PS#04 engaged in Transportation Engineering and PS#05 focused to BIM & GIS connection were newly established in 2017.

The first scientific contributions about BIM in the Czech Republic (Venkrbec, 2013, Jašek et al., 2013, Fridrich et al., 2014) were published in 2013. Contributions about risk management of construction company (Tomek and Matějka, 2014, Matějka et. al., 2016) are a substantial part of BIM publications or preliminary research results about BIM implementation. The results concluded that 41% respondents already met or saw some project implemented by means of BIM method. BIM was currently used at work by 19% of respondents (Juszczyk et. al., 2015).

Implementation of BIM into Czech construction projects is presented in the table 1. The following table shows some examples, where BIM was used for more than design phase of the project.

Table 1. A BIM pilot projects in Czech Republic

name	utilization	Begin and end of project	BIM Aspects
State Opera and administrative building	Historical building	2012	Laser scanning; Creating BIM model from the point clouds; Collaboration in design phase; Modeling and visualization.
Subway - Line D, Prague	Pair of subway tunnels with 3 stations	2012	Creating a 3D model of the building; Creating a 3D model for continuous; Coordination of all the professes.
CSOB bank new headquarters	7 storey offices	2014	BIM execution plan for bank institution; Model implementation from the Study phase; BIM model of the construction part; BIM model of the HVAC part; Upgrade CAD & CAFM systems ; Use in facility management for planning the effective office spaces use; Monitoring of operational requirements and maintenance by QR codes, RFID chips.

Palmovka Park IV	7 storey office building; 111 parking places; Area: 18200 m^2	2016 - at the design stage	BIM project; HVAC technology, coordination, Quantities take off, Also will be used during the execution of the construction.

Some of the larger construction companies in the Czech Republic has introduced a new job position, namely of BIM manager i.e. Skanska company. BIM manager function can be defined as a hygienist of BIM model, because he/she implements actual and correct information into the model. It should be noted that the companies usually develop their own BIM Execution Plans (BEPs). Those plans are usually not centrally harmonized with standards and legislation.

The implementation of BIM was supported by Government Council for the construction industry. Government approval of this material confirmed the importance of BIM for Czech construction industry. Government determined Ministry of Industry as coordinator for the implementation of BIM. The aim of ministry is to deliver some frame of implementation until July 2017. The group czBIM PS#01 performs translations of European standards for BIM ČSN ISO 12006-2 and ČSN ISO 16757-1 to Czech language.

2.3. BIM in Germany

Study conducted by Fraunhofer Institute for Industrial Engineering IAO in 2015 analyzed applied planning tools and methodologies in Germany and came to the conclusion that the use of BIM has not yet become a standard. The majority of planners involved in the study are satisfied with 2D-files and traditional based plans (Braun *et al*., 2015). Being convinced about the advantages of using BIM, different initiatives are active in facilitating its use in Germany, as well as internationally, and making construction stakeholders familiar with BIM as a working method. Those intentions consist of several shapes, i.e. written recommended practices, guidelines on the basis of practical analysis or the policy of promoting nationwide entrepreneurial projects in view of the BIM-application. The common goal of all of the available programs seems to be the low-threshold access to this specific digital control of construction processes.

Among others, the BIM-Guideline has to singled-out. It was developed by an engineer brain trust and the Federal Ministry of Traffic, Construction and Urban Development to ensure a first approach to BIM for German building owners, architects and engineers, building companies, software enterprises and prefabricated component manufacturer concerning its practical use. The BIM-Guideline dissociates itself from general information about software functions and judicial and regulatory measures of construction and Fee Structure for Architects and Engineers. In contrast to others, the aforementioned guideline combines BIM definition as a model-based, collaborative working method, which involves all the life-cycle phases of construction projects. It gives an overview about the current situation in Germany of its application and theming in business venture, building authorities and academic and professional education. The report clarifies challenges, which are in connection with responsibilities of all actors in a model, necessary organizational structures and data integrity within BIM-based construction projects. It contains also a simple BIM-implementation plan on enterprise level (Egger *et al.,* 2013).

Different capabilities of using and needs in view of planning and executing stakeholders are mentioned and also the advantages for operating companies while the utilization phase.

Technical references and background edit functions for the conjointly work of different protagonists are commented. Thus, the reader receives practice support regarding the contents of BIM-settlement plans. According to necessity, the report incorporates references of data management within the model and recommended model access instructions. The review gives a summary of possibilities for software selection relating to their range of application and a set of regulations to minimize the collision risk in the model. Essential advantages and structures of a building information model are explained; with it user gets to know early about all types of professional models. Those contents give an overview about architectural, structural and HVACR exposition (heating, ventilation, air conditioning and refrigeration) as well as extended cost and time dimensions (Egger *et al.,* 2013).

Concluding the BIM-guideline recommends subjects for a prospective, general BIM-instruction, developed by the appropriate governmental institutions. It is recommended, that it should broach the issue of implementation of the BIM-method by government authorities and the further development for regulatory framework (Egger *et al.,* 2013).

In addition to public authorities, diverse associations are engaged in supporting a nationwide, standardized BIM application. Initially the VDI (The Association of German Engineers) as the major technical and scientific engineering registered society serves as national developer for generalities. In January 2017, VDI (row VDI 2552) published a policy row, which emphasizes the current activities of standardization concerning the BIM-practice. It is focused on the use of BIM models for the replication of activity quantity and controlling structures in the division of cost estimation, time scheduling, floating of tenders and awarding of contract, as well as the execution of construction work and accounting through all project phases. The target group consists of all participants of construction works, who are willing to design processes of common usable data. The policy represents the German national standard within the international standardization activities. Targeted is an overview of national and international BIM-committee to get universally valid engineer standards, which are consistent to all national and international boards. Based on the norm, calls for tenders, planning, construction work and the facility management shall be executed (VDI (Ed.), 2015).

The German Institute for Standardization as the national standards body is representing Germany in the official committees of the European (CEN) and international (ISO) standardization organizations. In these committees, BIM related standards are developed that facilitate the use of BIM by providing harmonized interfaces, data structures, terminology and processes. This supports the collaboration of different stakeholders of construction projects and is the prerequisite for an effective implementation of BIM in the AEC industry.

On the private sector, besides others, two initiatives are deeply involved in BIM implementation. The Building Smart e.V. is an association that goes back to 1995 when it was established as an initiative of leading German Design, Execution and Software companies to facilitate the use of model based planning tools in construction. The main focus of this initiative has been the exchange of data between the different parties in construction and the missing and insufficient software interfaces of existing tools (buildingSMART (Ed.), 2017a). The second initiative is the Planen Bauen 4.0 GmbH and can be regarded as the central initiative for the implementation of digital processes of all organizations among the life-cycle of design, build and operation in construction in Germany. Under the authority of the federal ministries for traffic and digital infrastructure (BMVI), there is a developed step-by-step plan for the implementation of BIM in all public infrastructure projects in Germany.

On governmental side, BMVI is an active player in the BIM implementation in Germany. The ministry is supporting the idea of building virtually first by different means including for example funding of research and pilot projects, legislation, networking and others. BMVI describes the role of the public sector as one of the largest clients in construction and derives from it the responsibility to go ahead and to support the cultural change BIM necessitates (Bramann/May, 2015).

The public BIM implementation strategy of the BMVI, which is transported by a plan by stages, has an influence to contractors as well as purchasers. Superficial this is a target for the infrastructural construction, but shall be useful equally for all AEC projects. The BIM introduction is planned until 2020 with the demand of a special proficiency level 1 for BIM application. The figure 1 shows the three stages plan of the implementation strategy. Stage one characterizes the preparation with practicing in pilot projects, standardization in education and advanced trainings, clarification of legal opinions and the development of BIM-guidelines for a precise utilization. The years 2017 – 2020 (stage two) are up to the beginning with level one. Stage three is responsible for the area-wide assertion of level one (Bramann/May, 2015).

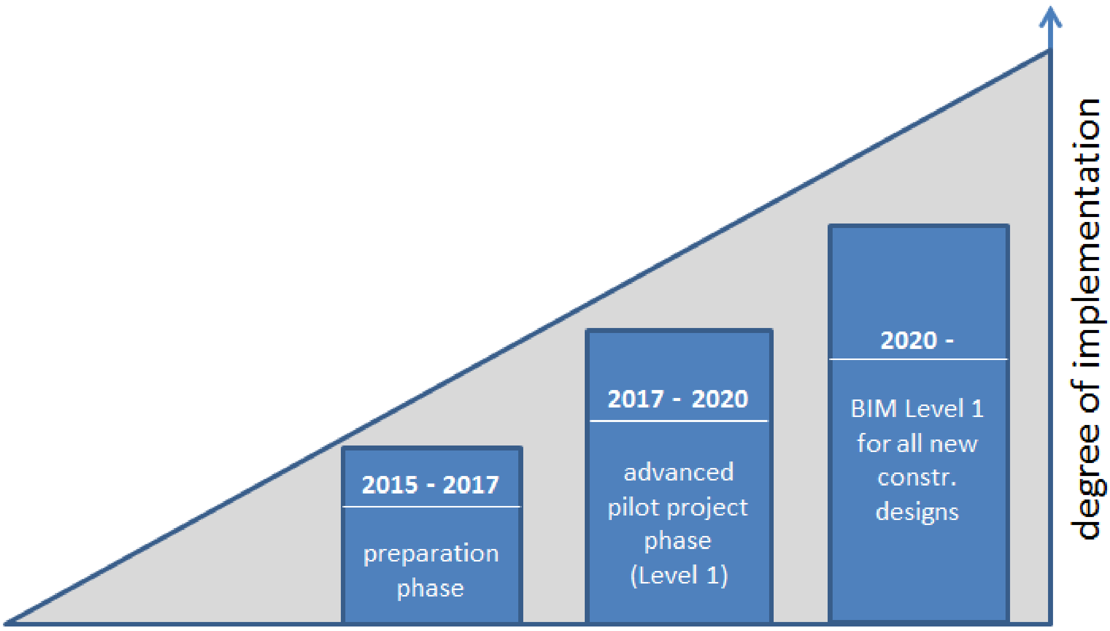

Figure 1: BIM implementation plan by federal ministry for traffic and digital infrastructure (Bramann/May, 2015)

Level 1 describes minimum requirements, which have to be fulfilled from 2020 within all public BIM projects. That is the responsibility of government authorities to dispose those demands in new floating of tenders. The requirements divide into three parts: data, processes and qualification. The contents are shown in the following table 2 (Bramann/May, 2015).

Table 2. Contents of level 1by the year 2020 (Bramann/May, 2015)

Requirements	Content
data	• necessary specifications about delivery time of data, file format and level of detail • model-based data of: geometry, building element attributes (building material, physical and thermic values

	• Purchasers can determine the following in addition: o digital description of the construction progress o classification of expenses as 5D-model • preservation of special fields: divided modeling of special field models and consolidation within one model of coordination
processes	• necessary roles, functions and interfaces have to be fixed in a BIM settlement plan: o amount and rhythm of project meetings, o consolidation of models, o time limits, o range of visualization, o quantity determination
qualification	• contractors have to have required competences for: o comply with level 1, o cooperative work, o BIM-competences • Purchasers have to be familiar with BIM-application to rate incoming offers

A series of BIM pilot projects also considered as BIM reference projects is carried out in Germany. The following table gives examples and outlines the BIM aspects of special interest in these projects.

Table 3. BIM pilot projects (PB40 (2016), buildingSMART (Ed.), 2017b; BMVI (Ed.) 2014; Hochmuth/Breining 2016, VDI (Ed.), 2015.)

Name	Utilization	Begin and end of project	BIM aspects
Office Center Pionierkaserne	4storeys; underground parking, offices and shops	October 2015 – Beginning of 2017	Collaboration between small-and medium sized companies.
Bürogebäude Haus H	5storeys office and seminar rooms seminar	August 2015 – End of 2016	Collaboration and as built model to be used in operation phase (life cycle approach).
Viaduct Auenbach	Total length 290 m Span lengths 20 – 35 m	Beginning of 2015 – End of 2016	Collaboration of special planners. One central model server. Quantity and cost estimation. Modeling and visualization. Model based scheduling.
Tunnel RASTATT	Total length 8.3 km Diameter: 10.6 m	5 years construction period	Transparency and visualization. Plausibility check of construction scheduling, and resource allocation.

The coordinated setting up of BIM pilot projects allows the accumulation of knowledge for various project types and thus facilitates the use of BIM in similar projects in future.

In Germany a growing number of innovative companies successfully execute construction projects by involving BIM-technologies. Whereas these projects in the past have mainly been located abroad there is a current tendency to involve BIM in national projects too. However, until today BIM is not used comprehensively in Germany (Eschenbruch *et al.,* 2014).

Challenges remain related to submission and accounting of BIM-based construction projects and the experiences of pilot projects will be used to provide the necessary guidance in these fields (BMVI, 2015). Furthermore, standardization of terminology, procedures and software interfaces is needed to allow an effective cooperation between the stakeholders in BIM-based projects as well as regulations related to the copyright of model and its data (VDI, 2015).

2.4. BIM in Slovenia

Awareness that BIM provides many benefits for construction project management spread among Slovenian expert and academic community years ago. In academia, most information was initially gained from published literature and participation on international conferences. Few years back, BIM topics were included into curricula of civil engineering study programmes at Slovenian universities and contents are now periodically updated in accordance with current developments.

Cooperation between academia and industry very quickly exposed the need for implementation of BIM approach in real-life construction projects. For example, some initial BIM-based projects, like DEGRIP (Tibaut et al., 2014) and jaBIM (Tibaut et al., 2015), were supported by Slovenian Human Resources Development and Scholarship Fund, which operates within the frame of European Social Fund. The results of DEGRIP project were 3D and 4D models for underpasses Grlava and Ljutomer while the execution of jaBIM project resulted in BIM models for Vinarium Tower in Lendava with the same informational dimensions, see Fig. 2.

Figure 2: a) Underpass Grlava (DEGRIP project) (Tibaut et al., 2014) and b) Vinaruim Tower (jaBIM project) (Tibaut et al., 2015).

There were also some more or less effective attempts to implement the BIM approach in Slovenian construction companies. However, successful BIM applications were often achieved notwithstanding the lack of the investor’s specific requirements or the state instructions and usually executed as individual projects without special guidelines for further use of developed models.

More serious movement in terms of systematic implementation of BIM approach in Slovenia represents the establishment of the BIM Association Slovenia (siBIM) in 2015 (BIM Association Slovenia, 2017). Association siBIM is an independent, voluntary and non-profit organization that links engineers who contribute to the field of BIM in construction industry. It was funded to provide networking, training, professional development, socializing and exchanging of experience. Today, the association has more than 135 members from the ranks of individuals, academics, government and companies. The association has successfully organized two conferences, i.e. in siBIM2015 (siBIM, 2015) and siBIM2016 (siBIM, 2016), as well as a BIMathlon event (BIMathlon, 2016).

An important event for BIM implementation in Slovenia represents the first BIM Forum organized at Bled in June 2016 (BIM Forum, 2016) where the main goal was to present good practices and ideas for preparation of national strategy for implementation of BIM approach in Slovenia. The main guest of the event was Mr. Adam Matthews, one of the most prominent representatives of BIM in EU and the chairman of EU BIM Task Group, which operates under the auspices of the European Commission. Attendees were from siBIM members, managers, directors and decision-makers from industry and public sector, including representatives from Ministry of Infrastructure, Ministry of the Environment and Spatial Planning, Ministry of Public Administration, Ministry of Health, Ministry of Defence and Slovenian Chamber of Engineers, see Fig. 3.

Figure 3: Attendees of BIM Forum 2016 (BIM Forum, 2016).

A milestone represents the inclusion of Slovenia into the EU BIM Task Group which currently includes 21 members within a frame of the European Commission (see Fig. 4) and whose primary purpose is to unite national efforts into a common and harmonized European approach to develop an excellent digital construction sector (EU BIM Task Group, 2017).

Figure 4: Members of EU BIM Task Group (EU BIM Task Group, 2017).

All successful past events encouraged siBIM association to set some challenging tasks for the future like execution of national research activities in field of BIM, formation of working groups for setting BIM guidelines in Slovenia, creation of register of successfully implemented projects where BIM approach was applied, membership in buildingSMART, etc.

3. Discussion and conclusions

The results have revealed, as expected, that in the analysed countries there are significant differences of BIM's acceptation and implementation. However, BIM is relevant topic in all analysed AEC industries. In table 4, authors gave a summary of research findings.

Table 4. Abstract of research findings

Country	Organisations/initiatives	Results	Contents and characteristics	Range and direction
Croatia	Croatian Standards Institute subcommittee TU B1; Croatian Association of Civil Engineers; Croatian Chamber Of Civil Engineers; Croatian Chamber of Architects; Faculty of Civil Engineering Osijek; Faculty of Civil Engineering Zagreb.	In progress: National guidelines for practical BIM implementation and platform for future legal framework. Sub-group for standardization of BIM implementation and requirements. Study programmes, workshops and life-long learning programmes.	Formal documents, which will be used as starting point for support for BIM's implementation in construction projects in Croatia.	Construction projects through their all life cycle phases, with an assumption that it will be an obligatory for public construction projects as it are in northern EU countries.
Czech Republic	Ministry of Industry and Trade,	The explanatory report No.167/16 Importance of BIM	Determining Ministry of Industry as	Coordinating the implementation of BIM in practice.

	The interdepartmental Expert Group for BIM Government Council for the construction industry; Czech BIM Council (czBIM); BIM group under Czech Chamber Authorized Engineers and Technicians in Construction (CKAIT).	for the Czech Government; BIM Handbook; BIM continuity to European Parliament and Council Directive 2014/24 / EU public procurement and repealing Directive 2004/18 / EC; BIM related standards translation.	coordinator for the implementation of BIM; BIM Handbook provides the basic framework and explanation of BIM.	Development of a national BIM standards and translation of EU standards. BIM issue lifelong learning. Use of BIM models from 3D to 5D; BIM manager role specifying.
Germany	Federal Ministry of Traffic, Construction and Urban Development Federal Ministry of traffic and digital infrastructure Association of German engineers (VDI) German Institute for Standardization (DIN) Building Smart e.V.	BIM-Guideline Implementation plan by stages Policy row VDI 2552 BIM-related standards Focus on model based planning tools	Current application of BIM, challenges, organizational structures in BIM-based projects Research funding and pilot projects Use of BIM-Models from 3D to 5D Use of BIM by harmonized interfaces and data structures Exchange of data	BIM as cooperative working methods, all life-cycle-phases Supporting cultural change Development of an International valid standard, consistent to all international boards Collaboration of different stakeholders of construction projects Insufficient software interfaces
Slovenia	BIM Association Slovenia; DRI Investment Management Ltd.; The Slovenian Chamber of Engineers; Ministry of Infrastructure; Ministry of the Environment and Spatial Planning; Ministry of Public Administration; Ministry of Defence; Faculty of Civil Engineering, Transportation Engineering and Architecture; Faculty of Civil and Geodetic Engineering.	Activity programme by BIM Association Slovenia; preparation of national guidelines for practical BIM implementation; BIM conferences; BIM Forum; BIM workshops; BIM integration in study programmes; membership in the EU BIM Task Group.	Forming working groups for preparation of partial templates for national BIM standards and guidelines; research cooperation agreements for BIM usage in construction projects.	BIM implementation in all life-cycle-phases of construction projects; practical examples; education; connections with international BIM associations.

Even though there is a clear trend of BIM expansion in Croatian AEC, there are obvious gaps and lack of feedbacks based on practical experiences of its implementation. The notion is that BIM in Croatia will from educational and science levels firstly go through legislation and standardization framework, and afterwards will be practically implemented in construction projects.

In the Czech Republic the construction industry has all the necessary preconditions to be fully BIM implemented. Architects and engineers have a good knowledge of the issue due to the frequency and availability of the information and the conferences. Unfortunately, the standards and some law framework that would speed up implementation in practice are still lacking. The first projects that were designed and processed in BIM appeared in the field of construction management. The first examples of implementation use the 3D model only; other dimensions are not meaningfully exploited. Other dimensions of model are not exploited (e.g. there is a large database of default price list items (around 170 000 items) which could be connected with 4D BIM). In addition, 5D BIM has the potential to be implemented using the extensive database of time standards (around 50 typical network diagrams). A great potential for development of BIM is hidden in these areas.

Different industry and governmentally driven organizations facilitate the BIM implementation in Germany. In the public sector, a step-by step-plan has been developed to ensure a BIM implementation in the design phase of all new public projects starting from 2020. In the private sector, companies started the implementation of BIM technologies on department level to increase efficiency in typical areas like quantity estimation, site layout planning, 3D and 4D representations of the project specifications.

The need for implementation of BIM approach in AEC industry was first detected by academic circles where early pilot projects were carried out mainly for the purpose of research. These projects soon attracted much attention among commercial and non-commercial companies. BIM Association of Slovenia was thereupon founded, which began with the integration and systematic regulation of BIM approach in a broader sense. A cornerstone was set for further development and use of BIM approach in Slovenia by successfully executed BIM conferences, BIMathlon and BIM Forum events as well as with inclusion into the EU BIM Task Group. The activity program, recently set by BIM Association of Slovenia, gives some directions for making standards of BIM approach, national guidelines for practical implementation of BIM, regulations for BIM approach, etc.

It can be concluded that in analysed countries BIM is a developing topic. There are initiatives active with the main goals of BIM’s educational and practical implementation. However, as a concept which changes current and adopted ways of business in AEC its adoption is formally supervised or entirely framed. As well, it can be concluded that tools and methodologies of BIM’s adoption are more or less similar in analysed countries. The path of recognizing and implementing BIM in EU member countries has a certain direction and goes from the northern to the southern EU countries. As far as BIM being a “bridge” of the unified construction market is just theoretical and it can be assumed that BIM will require standardization on the union level, similar those formed by Eurocodes.

References

Azhar, S. & Alex Behringer, B. (2013), "A BIM-based approach for communicating and implementing a construction site safety plan", (Ed.), pp.

Baroš, T. (2016), "Primjena BIM tehnologije i njezina pouzdanost u statičkoj analizi konstrukcija", *Tehnički vjesnik*, Vol. 23, No 4, pp. 1221-1226.

Bazjanac, V. (2006), "Virtual building environments (VBE)-applying information modeling to buildings", *August*, Vol. 29, No pp. 2009.

BIM Association Slovenia (2017), available at: http://sibim.si/ (accessed 20.03.2017).

BIMathlon (2016), "1. BIMathlon within the 2nd professional conference siBIM 2016 – BIM – The DNA of Built Environment", Maribor, available at: http://sibim.si/dogodki/siBIM2016_BIMathlon/ (accessed 20.03.2017).

BIM Forum (2016), available at: http://sibim.si/dogodki/BIMFORUM2016 (accessed 20.03.2017).

Bramann, H. & May, I. (2015), "Stufenplan digitales planen und bauen: Einführung moderner, IT gestützter Prozesse und Technologien bei Planung, Bau und Betrieb von Bauwerken", Bundesministerium für Verkehr und digitale Infrastruktur, Berlin, 2015.

Braun, S., Rieck, A. & Köhler-Hammer, C. (2015), „Ergebnisse der BIM-Studie für Planer und Ausführende: Digitale Planungs- und Fertigungsmethoden“, Fraunhofer Institut für Arbeitswissenschaft und Organisation, Stuttgart.

buildingSMART e.V. (Ed.) (2017a), “Information zum buildingSMART German Speaking Chapter”, available at: www.buildingsmart.de/buildingsmart-ev/verein (accessed 10 March 2017).

buildingSMART e.V. (Ed.) (2017b), „Pressemitteilung 19.09.2014: Präsentation BIM-Referenzobjekt“, available at: http://www.bimid.de/presse/presse-archiv/pressemitteilung-19092014-praesentation-bim-referenzobjekt (accessed 12 February 2017).

Bundesministerium für Verkehr und digitale Infrastruktur (BMVI) (Ed.) (2014), „BIM-Pilotprojekt Südverbund Chemnitz“, available at: http://www.bmvi.de/SharedDocs/DE/Anlage/Raumentwicklung/building-information-modeling-13-10-2014-02.pdf?__blob=publicationFile (accessed 12 Februrary 2017).

Bundesministerium für Verkehr und digitale Infrastruktur (BMVI) (Ed.) (2015), „Reformkommission Bau von Großprojekten: Komplexität beherrschen – kostengerecht, termingetreu und effizient: Endbericht“, available at: http://www.bmvi.de/SharedDocs/DE/Anlage/VerkehrUndMobilitaet/reformkommissionbau-grossprojekte-endbericht.pdf?__blob=publicationFile (accessed 11.08.2015).

czBIM (2016). Czech BIM Council. Available at: http://czbim.org/ (accessed March 20, 2017).

Černý, M. et al. (2013). BIM příručka 1st ed., Praha: *Odborná rada pro BIM o.s.*

Černý, M. et al. (2014). Návaznost informačního modelování budov (BIM) na směrnici Evropského parlamentu a rady 2014/24/EU o zadávání veřejných zakázek a o zrušení směrnice 2004/18/ES 1st ed., Praha: *Odborná rada pro BIM o.s.*

Eastman, C. (1975), "The use of computers instead of drawings in building design", *Journal of the American Institute of Architects*, Vol. 3, No pp. 46-50.

Eastman, C. M., Teicholz, P., Sacks, R. & Liston, K. (2011), BIM handbook: A guide to building information modeling for owners, managers, designers, engineers and contractors, John Wiley & Sons.

Egger, M., Hausknecht, K., Liebich, T. & Przbylo, J. (2013), „BIM-Leitfaden für Deutschland“, Endbericht, Bundesministerium für Verkehr, Bau und Stadtentwicklung, München, 01.12.2012 – 30.11.2013.

Eschenbruch, K., Gründer, J., Kar, C. K., Malkwitz, A. & Poloczek, A. (2014), Maßnahmenkatalog zur Nutzung von BIM in der öffentlichen Bauverwaltung unter Berücksichtigung der rechtlichen und ordnungspolitischen Rahmenbedingungen, Bundesministerium für Verkehr, Bau und Stadtentwicklung, 01. Februar 2013 – 30. April 2014.

EU BIM Task Group (2017), available at: http://www.eubim.eu/ (accessed 20.03.2017).

European Parliament (2014), "Directive 2014/24/EU of the European Parliament and of the Council of 26 February 2014 on public procurement and repealing Directive 2004/18/EC", EU: Official Journal of the European Union.

Fridrich, J. & Kubečka, K. (2014), "BIM - The Process of Modern Civil Engineering", *Advanced Materials Research,* Switzerland, Trans Tech Publications, pp. 579-582. Available at: http://www.scientific.net/AMR.899.579.

Galic, M., Dolacek-Alduk, Z., Cerovecki, A., Glick, D. & Abramovic, M. (2014), "BIM in planning deconstruction projects", in Mahdavi, A., Martens, B. & Scherer, R. (Ed.), CRC Press, pp. 81-85.

Galić, M., Dolaček-Alduk, Z. & Uremović, B. (2013), "Constructability-Buildability-Izgradivost", *e-GFOS*, Vol. 4, No 6, pp. 68-80.

Galić, M., Vu, L. N. & Feine, I. (2015), "Weather Forecast as an Additional Dimension to BIM", in Cerić, A., Korytarova, J., Radujković, M., Vukomanović, M. & Završki, I. (Ed.), Croatian Association for Construction Management ; University of Zagreb, Faculty of Civil Engineering, pp. 355-364.

Hochmuth, M. & Breinig, W. (2016), "BIM-Pilotprojekt Talbrücke Auenbach", in Ernst & Sohn Verlag für Architektur und technische Wissenschaften GmbH & Co. KG, Berlin. Bautechnik 93, Heft 7.

Jašek, M. et al. (2014). Application of BIM Process by the Evaluation of Building Energy Sustainability, *Advanced Materials Research*, Switzerland, Trans tech Publication, pp. 7-10. Available at: http://www.scientific.net/AMR.899.7.

Juszczyk, M., Výskala, M. & Zima, K. (2015). Prospects for the use of BIM in Poland and the Czech Republic – Preliminary Research Results, *Procedia Engineering*, 2015, Vol. 123, pp.250-259. Available at: http://linkinghub.elsevier.com/retrieve/pii/S1877705815031872.

Kim, K. P. & Park, K. S. (2013), "BIM feasibility study for housing refurbishment projects in the UK", *Organization, Technology & Management in Construction: An International Journal*, Vol. 5, No Special, pp. 765-774.

Kolarić, S., Pavlović, D. & Vukomanović, M. (2015), "Developing a methodology for preparation and execution phase of construction project", *Organization, Technology & Management in Construction: An International Journal*, Vol. 7, No 1, pp. 1197-1208.

Kovačić, I., Filzmoser, M., Kiesel, K., Oberwinter, L. & Mahdavi, A. (2015), "Izobrazba o primjeni BIM-a kao podrške integriranom projektiranju", *Građevinar*, Vol. 67, No 06., pp. 537-546.

Kozlovská, M. & Struková, Z. (2011), "Opportunities and possibilities for more effective construction site layout planning", in Cerić, A., Nahod, M.-M., Radujković, M. & Vukomanović, M. (Ed.), Faculty of Civil Engineering University of Zagreb & Croatian Association for Construction Management pp. 1-15.

Matějka, P. et al. (2016), "The Integration of BIM in Later Project Life Cycle Phases in Unprepared Environment from FM Perspective", *Procedia Engineering*, Vol. 164, pp.550-557. Available at: http://linkinghub.elsevier.com/retrieve/pii/S1877705816339984.

Pantouvakis, J.-P. (2011), "Building information modelling (BIM) - implications in construction management", in Cerić, A., Nahod, M.-M., Radujković, M. & Vukomanović, M. (Ed.), Faculty of Civil Engineering University of Zagreb & Croatian Association for Construction Management pp. 1-5.

PB40 (2016), Initiative Planen Bauen 4.0, available at: http://planen-bauen40.de/project/neubau-officecenter-pionierkaserne/.

Salleh, H. & Fung, W. P. (2014), "Primjena Building Information Modelinga: analiza na osnovi interesnih skupina", *Građevinar*, Vol. 66, No 08., pp. 705-714.

siBIM (2015), "The 1st. professional conference siBIM 2015 - BIM in Slovenia, 19.11.2015", Lendava, available at: http://sibim.si/dogodki/siBIM2015 (accessed 20.03.2017).

siBIM (2016), "The 2nd professional conference siBIM 2016 – 'BIM – The DNA of Built Environment', 25.11.2016", Maribor, available at: http://sibim.si/dogodki/siBIM2016/ (accessed 20.03.2017).

Skibniewski, M. J. (2014), "Construction Project Monitoring with Site Photographs and 4D Project Models", *Organization, Technology & Management in Construction: An International Journal*, Vol. 6, No 3, pp. 1106-1114.

Stober, D., Dolaček-Alduk, Z., Vukomanović, M., Radujković, M., Galić, M. & Kolarić, S. (2015), in Lakušić, S. (Ed.), *Improvement of civil engineering education in the field of building informatiom modeling*, Hrvatski savez građevisnkih nženjera (HSGI), Zagreb, Croatia, pp. 268-287.

Succar, B. (2009), "Building information modelling framework: A research and delivery foundation for industry stakeholders", *Automation in Construction*, Vol. 18, No 3, pp. 357-375 .

Tibaut, A., Kosednar, D., Pučko, Z., Čuš Babič, N., Časar, R., Žalig, V., Jakoša, D. and Hlastec, U. (2014), "DEGRIP - Povezava procesov in informacijskih modelov gradbenih objektov: končno poročilo o raziskovalnem projektu", Fakulteta za gradbeništvo, (in Slovene), available at: https://dk.um.si/IzpisGradiva.php?id=46566 (accessed 10 April 2017).

Tibaut, A., Kuhta, M., Pogačar, K., Jaušovec, A., Zih, M., Felkar, B., Kotnik, K., Jagrič, S., Škorjanec, M., Jakoša, D., Kramberger, T., Plut, P., Magyar, D., Recek, R., Roženičnik Korošec, M. and Mihalič, K. (2015), "jaBIM - Raziskava, razvoj in implementacija BIMa za digitalno gradnjo javnih objektov: končno poročilo o raziskovalnem projektu", Fakulteta za gradbeništvo, prometno inženirstvo in arhitekturo, (in Slovene), available at: https://dk.um.si/IzpisGradiva.php?id=57097 (accessed 10 April 2017).

Tomek, A. & Matějka, P. (2014), The Impact of BIM on Risk Management as an Argument for its Implementation in a Construction Company, *Procedia Engineering*, 2014, Vol. 85, pp.501-509. Available at: http://linkinghub.elsevier.com/retrieve/pii/S1877705814019432.

Travaglini, A., Radujković, M. & Mancini, M. (2014), "Building Information Modelling (BIM) and Project Management: a Stakeholders Perspective", *Organization, Technology & Management in Construction: An International Journal*, Vol. 6, No 2, pp. 1001-1008.

VDI (Ed.) (2015), "Erste VDI-Richtlinie zum BIM", available at: https://www.vdi.de/technik/artikel/vdi-2552-blatt-3-building-information-modeling-mengen und-controlling (accessed 20 March 2017).

Venkrbec, V. (2013), "Application process BIM in projects in Czech Republic", *Vývojové trendy v oblasti navrhovania, prípravy, realizácie a údržby stavieb*, Bratislava: Stavebná fakulta STU v Bratislave, Katedra technológie stavieb, Tribun EU s.r.o. Brno, pp. 228-233.

Recent Works and Activities on BIM Conducted at FCETEA in Maribor, Slovenia

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Abstract:

The aim of this article is to give an information about some recent works and activities on building information modeling (BIM) conducted on the Chair of Construction Management, Technology and Economics at the Faculty of Civil Engineering, Transportation Engineering and Architecture (FCETEA) in Maribor, Slovenia. The paper briefly presents the following BIM applications: i) 4D model for multi-storey underground parking garage in Maribor; ii) 4D model for prefabricated hall in Novo Mesto; iii) 4D and 5D models for external walls of the multi-residential building in Ljutomer; iv) 4D and 5D models for detached residential building in Braslovče; v) 4D and 5D models for Wienerberger wall systems; and vi) 6D model for business-storage building in Hoče. Additionally, the paper also gives a short report about BIMathlon event, an international team competition challenge in the frame of an international conference "BIM – the DNA of Build Environment" organized by BIM Association Slovenia (siBIM) and FCETEA in November 2016.

Keywords: *construction management; building information modeling; BIM; 4D model; 5D model; 6D model*

1. Introduction

Members of the Chair of Construction Management, technology and Economics at the FCETEA in Maribor are following the current trends and needs in Civil Engineering. According to our vision of development we are striving to include BIM approach in all fields of our activities. All curricula have been updated according to BIM approach principles. This move was met with a very positive response from students and a lot of them are willing to include BIM into their diploma and master works dealing with organization, construction technology and project management. Some of the latest student projects will be presented later in this paper. Members of our chair are active also in the field of research. Among such activities participation on BIM events like conferences and meetings are of great importance. A short report of such contribution is shown at the end of this paper. The paper is intended to share our BIM experience in the field of education as well as to open this topic to a wider international expert community for discussion and proposals for improvement.

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2. 4D model for multi-storey underground parking garage in Maribor

The first BIM application is related to construction monitoring of a parking garage Gabrijela, located at Prešernova Street in Maribor (Figure 1). Facility was designed to be built as a four-storey underground object made from monolithic reinforced concrete. Building comprised ground floor dimensions of 28.10 m × 35.00 m while the floor-to-ceiling height was set to be 3.00 m throughout the object. Each storey included the net area of 937.84 m^2.

Figure 1. Designed parking garage and construction site location

The 3D BIM model of parking garage was developed using Autodesk Revit modeling software. Work on the 3D model was conducted through several phases. In this case materials were also assigned to the modeled elements.

Prior to the development of the 4D model, each 3D element received a unique identification number which was subsequently matched with a group of activities in a project schedule. Afterwards, the 4D model was developed using Autodesk Navisworks Manage software with the support of 3D model imported from Revit and a project schedule obtained from MS Project. General project schedule was transformed into a detailed one by setting 262 activities. In this way, a time attribute was allocated to each defined 3D element by taking into account the selected production process. The 4D model was thereafter used to support both the construction monitoring and the time deviation analysis.

The construction process was monitored by responsible experts and by digital Ltl Acorn 6310 interval camera positioned at an appropriate height on a nearby existing building. The camera was set to take 6311 photos of construction site during the period between April 4 and July 15 2016. Outputs of BIM model and recorded photographic data were used for analytical comparison of planned and realized activities (Figure 2).

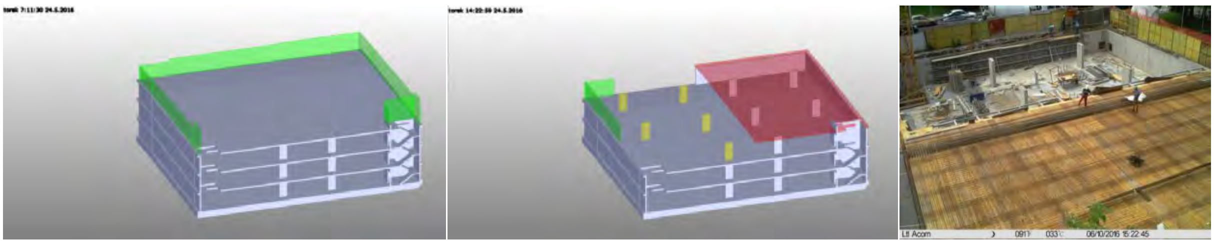


Figure 2. Comparison between planned and realized activities

3. 4D model for prefabricated hall in Novo Mesto

The scope of a second BIM application was the development of a 4D model for prefabricated hall in Novo Mesto. Building was conceived for commercial business purposes. It is rectangularly shaped with external dimensions of 47.80 m × 26.80 m × 6.70 m. Structural system was composed from symmetrical gable frames made of prefabricated reinforced and pre-stressed concrete elements based on pad foundations. The roof of a single floor building was built of »pi« slabs, mounted at the top of main frames and covered by high-polymer PVC strips. The secondary walls were made of concrete blocks and covered by a brick façade. Delivery flatbed, shielded above by a steel canopy, was positioned in front side of the facility.

ArchiCad 18 software was used for 3D modelling of the building. The individual elements of the building were modelled as geometrical bodies with attributes (such as dimensions, surface areas, volumes, etc.) necessary for subsequent application of building norms. After 3D model was developed, it was imported into BIM project management software Vico Office R5 for further processing.

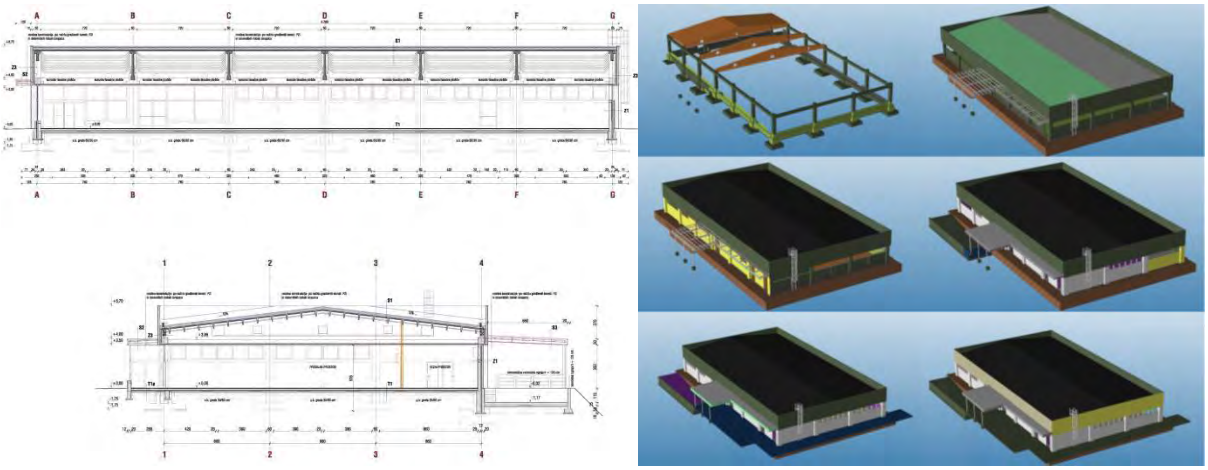


Figure 3. Designed prefabricated hall and construction simulation

The 4D modelling covered the definition of structural assemblies and their connections to norms (in the module *Cost Planner*), the determination of activities as well as the project scheduling in terms of Gantt charts, flowline charts, network diagrams, histograms, etc. The developed BIM model enabled the complete 4D simulation of construction process for addressed facility.

4. 4D and 5D models for external walls of the multi-residential building in Ljutomer

The third BIM application is related to development of a 4D and 5D BIM models for external walls of the multi-residential building, located in Ljutomer and designed as a four-storey building, see Figure 4. The first three floors are the dimensions of 36.35 m × 15.55 m and have four apartments. The last floor, named penthouse, has dimensions 24.15 m × 11.30 m and has two major apartments.

Figure 4. Designed multi-residential building and construction site location

With the aim of creating 4D and 5D BIM model, the composition of external walls and all possible technologies of their construction were presented (Porotherm 30 PROFI - variant A, Porotherm 30 W.i.Plan - variant B, Porotherm 30 S - variant C and 20 cm reinforced concrete walls - variant D). In addition, the energetic calculation of building for all relevant compositions of external walls was provided using PHPP software (Passive House Institute, 1998-2012), while taking into account three different factors of thermal conductivity: $U_1 = 0.11$ W/m^{2}K, $U_2 = 0.21$ W/m^{2}K and $U_3 = 0,28$ W/m^{2}K.

The 4D and 5D BIM models were created using BIM Construction Project Management Software the Vico Office software (VO) (Trimble, 2017). The 3D BIM model of the multi-residential building was previously developed with Autodesk Revit Modeler. Work on 4D and 5D BIM model was conducted in several steps by using VO modules *Takeoff Manager*, *Cost Planner* and *Schedule Planner* (Vico, 2017). First, in the *Takeoff Model* proper quantities of the structural elements were obtained, as they were generated from the geometry in the VO. In the next step, the basic 3D BIM was updated in module *Cost Planner* where direct cost calculations for 12 different compositions of external walls were demonstrated for all variants from A to D. Finally the 5D BIM model was created (Figure 5).

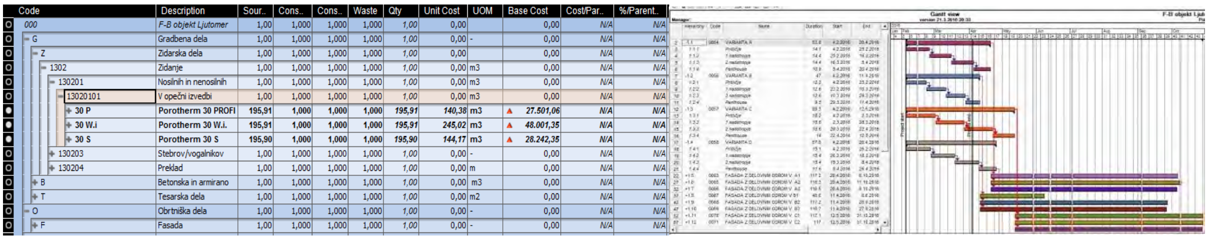


Figure 5: Display of cost calculation (left) and Gantt chart for all variants (right)

4D BIM model was developed using VO module *Schedule Planner*. The module is treated as external BIM software for planning the duration of the project implementation and creating time schedule. Therefore project activities and their duration were determined for all 12 configurations of the external wall (Figure 5). At the end the decision about the type of exernal walls was made on the basis of the optimal time and energy consumption and optimal construction costs as well.

5. 4D and 5D models for detached residential building in Braslovče

The forth BIM application discusses the creation of 4D and 5D BIM model for detached residential building in Braslovče. The building is designed as a compact two-floor building with external dimensions of 11.00 m × 9.00 m × 9.39 m. Next to the main building the garage and the additional parking space were also planned (Figure 6).

Figure 6: Designed detached residential building and 3D BIM model

Initially, the 3D BIM model of building was developed using Graphisoft ArchiCAD 18 software. From the model the quantities of activities which were later required for creation of 5D and 4D BIM model were summarized. Within next step the reference database that included the norms and unit prices of resources for the main construction works were created and linked to the corresponding individual building elements of 3D BIM model using VO software.

5D BIM model was developed by cost calculation for all construction works in module *Cost Planner*. The final result of the 5D BIM model was determination of biding price for construction works. 4D BIM model was created applying module *Schedule Planner*. It covered the definition of structural elements with connections to norms (in the module *Cost Planner*), and the determination of time duration of the planned activities. The end result of 4D BIM model is presented as project schedule in terms of numerical schedule, Gantt view, Flowline view, Network view, and Resource graph (Figure 7).

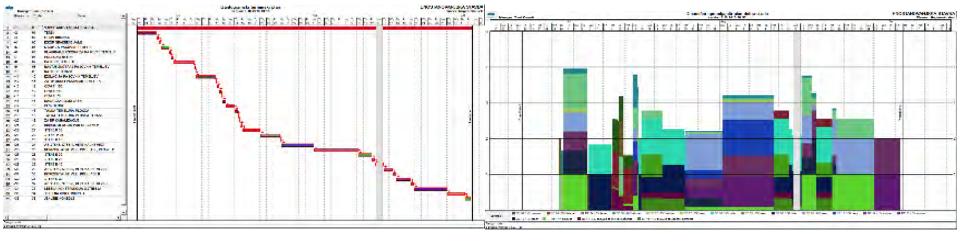


Figure 7: Gantt view (left) and Resource graph (right)

Time progress of detached residential building construction was also shown as 4D simulation, see Figure 8.

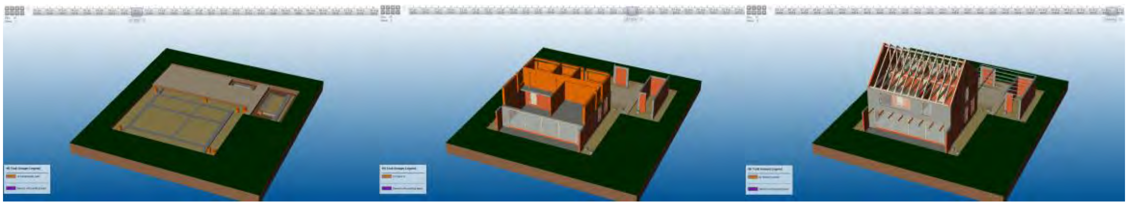


Figure 8: Sections of 4D simulation: construction of sewer shaft (left), construction of the wall on the first floor (middle), making of the roof structure (left)

6. 4D and 5D models for Wienerberger wall systems

The fifth BIM application addresses the development of a 4D and 5D BIM models for Wienerberger wall systems. Two wall systems Porotherm S and Porotherm PROFI were discussed, which have the different technologies of implementation and different included elements. The study was limited to masonry brick walls, lintels and the appropriate vertical bonds. First, two basic 3D BIM models of bearing walls were made, one with and one without openings (Figure 9 left). Second, for two wall systems and each basic models 12 variations were made in total. They differ in wall thickness (25 cm, 30 cm and 38 cm). In the right side of Figure 9 the model with the external surfaces needed for further cost and time analysis is shown.

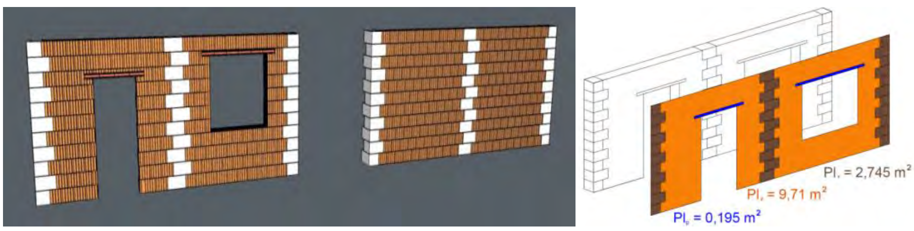
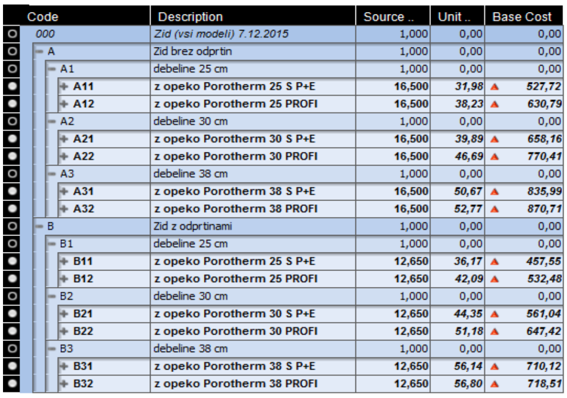


Figure 9: Basic 3D BIM models of bearing walls, one with and one without openings (left) and external surfaces necessary for further cost and time analysis (right)

5D BIM and then 4D BIM models were developed applying VO software, where previously the 3D BIM models are imported as IFC files previously created by SketchUP. In module *Cost Planner* calculations of direct costs for all 12 variants, and subsequently determination of time duration were made using *Schedule Planner*. Results of cost and time analysis are presented in Figure 10.



Code	Description	Source ..	Unit ..	Base Cost
000	Zid (vsi modeli) 7.12.2015	1,000	0,00	0,00
A	Zid brez odprtin	1,000	0,00	0,00
A1	debeline 25 cm	1,000	0,00	0,00
A11	z opeko Porotherm 25 S P+E	16,500	31,98	527,72
A12	z opeko Porotherm 25 PROFI	16,500	38,23	630,79
A2	debeline 30 cm	1,000	0,00	0,00
A21	z opeko Porotherm 30 S P+E	16,500	39,89	658,16
A22	z opeko Porotherm 30 PROFI	16,500	46,69	770,41
A3	debeline 38 cm	1,000	0,00	0,00
A31	z opeko Porotherm 38 S P+E	16,500	50,67	835,99
A32	z opeko Porotherm 38 PROFI	16,500	52,77	870,71
B	Zid z odprtinami	1,000	0,00	0,00
B1	debeline 25 cm	1,000	0,00	0,00
B11	z opeko Porotherm 25 S P+E	12,650	36,17	457,55
B12	z opeko Porotherm 25 PROFI	12,650	42,09	532,48
B2	debeline 30 cm	1,000	0,00	0,00
B21	z opeko Porotherm 30 S P+E	12,650	44,35	561,04
B22	z opeko Porotherm 30 PROFI	12,650	51,18	647,42
B3	debeline 38 cm	1,000	0,00	0,00
B31	z opeko Porotherm 38 S P+E	12,650	56,14	710,12
B32	z opeko Porotherm 38 PROFI	12,650	56,80	718,51

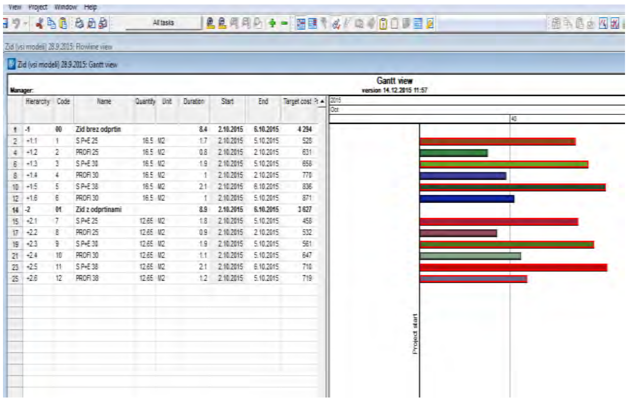


Figure 10: Calculation of direct costs in module *Cost Planner* (left); Determination of time duration in *Schedule Planner* (right)

All results obtained through 4D and 5D BIM modelling were collected in the summary table (Figure 11).

Zidni sistem	Zap. številka	Ime modela	Čas [ur]	Čas [%]	Strošek [€]	Strošek [%]	Čas + strošek [%]
Porotherm S	1.	S25	13,82	83,35	527,72 €	60,61	143,96
	2.	S25 O	14,03	84,62	457,55 €	52,55	137,17
	3.	S30	14,94	90,11	658,16 €	75,59	165,70
	4.	S30 O	15,44	93,12	561,04 €	64,43	157,56
	5.	S38	16,48	99,4	835,99 €	96,01	195,41
	6.	S38 O	16,58	100	710,12 €	81,56	181,56
Porotherm PROFI	7.	P25	6,02	36,31	630,79 €	72,45	108,75
	8.	P25 O	6,86	41,38	532,48 €	61,15	102,53
	9.	P30	7,67	46,26	770,41 €	88,48	134,74
	10.	P30 O	8,98	54,16	647,42 €	74,36	128,52
	11.	P38	8,4	50,66	870,71 €	100	150,66
	12.	P38 O	9,53	57,48	718,51 €	82,52	140,00

Figure 11: End results of time and cost analysis for all 12 variants

7. 6D model for business-storage building in Hoče

In this example the object of investigation was a business-storage building near Maribor, Slovenia (Figure 12). The rectangular solid shaped object with external dimensions 36.5 m x 16.5 m is divided into the office department and the store section with the corresponding warehouse. The business section (the store and the offices) has two floors, while the warehouse has only one floor but double height.

Figure 12: Western façade with the main entrance and east façade of the building

In the beginning the detailed 3D BIM model of the business-storage building was created using the ArchiCAD program package. Afterwards it was imported into the VO. 5D BIM model for all structural and non-structural elements was subsequently developed in module *Cost Planner*. The same module was later used to define the construction and finishing works, installations and external layout. An Element list created in VO is shown in Figure 13.

Code	Description	Source Q..	Consumpti..	Consump..	Waste	Qty	UOM	Unit Cost	Base Cost
01	Halder_18_4	1,00	1,000	1,000	1,000	1,00		403.255,15	403.255,15
1.0.0.0.	CONSTRUCTION AND FINISHING WORKS	1,00	1,000	1,000	1,000	1,00	kpl	267.680,51	267.680,51
1.10.0.0.	PAINTS AND COATINGS	1,00	1,000	1,000	1,000	1,00	m2	4.913,30	4.913,30
1.9.0.0.	LOCKSMITH WORKS	1,00	1,000	1,000	1,000	1,00	kos	1.600,00	1.600,00
1.8.0.0.	FLOORS – PAVEMENTS	1,00	1,000	1,000	1,000	1,00	m2	18.123,23	18.123,23
1.7.0.0	FINISHING OF WALLS AND CEILINGS	1,00	1,000	1,000	1,000	1,00	m2	34.545,37	34.545,37
1.6.0.0.	CARPENTRY	86,00	1,000	1,000	1,000	86,00	kos	846,28	72.780,50
1.5.0.0.	STAIRCASES	1,00	1,000	1,000	1,000	1,00	kpl	8.523,68	8.523,68
1.4.0.0.	FAÇADE	541,25	1,000	1,000	1,000	541,25	m2	51,47	27.859,18
1.3.0.0.	ROOF	534,37	1,000	1,000	1,000	534,37	m2	98,64	52.711,09
1.2.0.0.	CONSTRUCTION OF BUILDINGS	1,00	1,000	1,000	1,000	1,00	m3	41.123,50	41.123,50
1.1.0.0.	FOUNDATION	53,50	1,000	1,000	1,000	53,50	m3	102,82	5.500,66
2.0.0.0.	INSTALLATIONS	1,00	1,000	1,000	1,000	1,00	kpl	121.939,67	121.939,67

Figure 13: Elements list created in VO

Based on the data obtained in the cost and time analysis, the innovative approach was used to create the 6D BIM model specifying all costs for regular and investment maintenance of the building. The VO (with connection to 3D BIM model) and the Microsoft Excel (without connection to 3D BIM model) were used. The reason of using Excel was to obtain the more explicit visual overview of a large number of planned maintenance activities during proposed 60 years of facility exploitation (Figure 14).

			TIME AFTER CONSTRUCTION IN YEARS																								
Item/element number and description			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
HEATING AND COOLING	50	Heat pump air / water	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	●
	51	Heat pump air / air	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	●
	52	Air conditioning system	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	●
	53	Pipelines of steel																									●
	54	Pipelines of copper																									
	55	Gate valves on the pipeline															●										
	56	Floor heating																									
	57	Electric heater										●										●					
	58	Pump for hot water							●							●							●				

□ regular servicing 1x per year
● replacement

regular servicing, maintenance and a review by the expert
regular cleaning and maintenance
regular maintenance according to the manufacturer

Figure 14: Section of the schedule for execution of maintenance work (Vincek, 2015)

8. Short report about BIMathlon event

In November 2016 BIM Association Slovenia (siBIM) and FCETEA organized an international team competition challenge called BIMathlon. It has been carried out as a part of an international conference “BIM – the DNA of Build Environment” (siBIM, 2016). The aim of the competition was to create the most sophisticated BIM model for the selected construction object. In the competition participated several groups. Group that was formed under the initiative of the Chair of Construction Management, Technology and Economics, named “BIM TREK - AECO Industry” was the most numerous. It had ten members: five students, three representatives of the two companies and two representative of FCETEA. The slogan of group was “on BIM TREKs in the BIM universe”.

BIM TREK group discussed the multi-purpose sports hall for which a basic BIM model, was created as shown in Figure 15. The concept of modeling was implemented in the basic model A.0 and six sub-models: A.1 terrain, A.2 structural engineering, A.3 installation, A.4 cost estimating, A.5 4D and 5D BIM, and A.6 promotion.

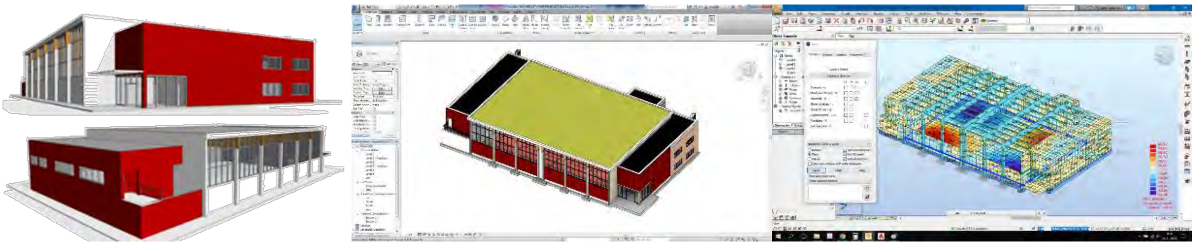


Figure 15: 3D visualisation of the Multi-purpose sports hall and 3D BIM model

For modeling a large number of different software was used, as presented in Figure 16. Open BIM approach was ensured by support of IFC (Industry Foundation Classes) format.

Figure 16: A set of different BIM-based software

Commitment and enthusiasm of all members of BIM TREK group led to the successful creation of a comprehensive and sophisticated BIM model of sports hall, which was finished in only one day. BIM model was created at the BIM Level 2 and partly BIM Level 3 and with the Level of Development (LOD) 300 and more.

Conclusion

This paper presented some works and activities on BIM recently conducted at FCETEA in Maribor. A brief overview about six project works with applications of 4D, 5D and 6D BIM models was presented. In addition, a short report about BIMathlon event was also given. It should be emphasized here that it will take some time, before BIM will be fully implemented in all phases of the building's life cycle. For now, most designers and contractors hardly recognize all practical potential of using BIM technology. Moreover, there is also an important issue that should be taken into account, i.e. the implementation of BIM currently represents a considerable expense for companies in AEC industry. Nevertheless, the incorporation of BIM into construction operations is promoted by European Directives and therefore the educational activities at faculties will need to support it.

References

Autodesk. (2017), Navisworks, available at: http://www.autodesk.com/products/navisworks/overview (accessed: 12 January 2017).

Autodesk. (2017), Revit, available at: http://www.autodesk.com/products/revit-family/overview (accessed: 10 January 2017).

BIMathlon. (2016), SiBIM 2016, available at: http://sibim.si/dogodki/siBIM2016_porocila (accessed: 9 March 2017).

Graphisoft. (2017), Archicad, available at: http://www.graphisoft.com/archicad/ (accessed: 12 January 2017).

Kresnik, T. (2016), Cost calculation and operational plans in the direct preparation for construction of one-dwelling building with BIM support, Master thesis, University of Maribor; Faculty of Civil Engineering, Transportation Engineering and Architecture, Maribor.

Lešnik, A. (2016), Time and cost analysis of building construction whit Wienerberger wall systems by the support of BIM, Diploma thesis, University of Maribor; Faculty of Civil Engineering, Transportation Engineering and Architecture, Maribor.

Pavič, U. (2017), Construction planning using 4D Building information model in Vico office R5 software, Master thesis, University of Maribor; Faculty of Civil Engineering, Transportation Engineering and Architecture, Maribor.

Pavličič, A. (2016), Use of the Vico office software for the 4D and 5D information modeling for building external walls of the residential object in Ljutomer, Master thesis, University of Maribor; Faculty of Civil Engineering, Transportation Engineering and Architecture, Maribor.

siBIM (2016), "The 2nd professional conference siBIM 2016 – 'BIM – The DNA of Built Environment', 25.11.2016", Maribor, available at: http://sibim.si/dogodki/siBIM2016/ (accessed 20.03.2017).

Tešić, D. (2016), Construction monitoring of parking garage with 4D building information model, Master thesis, University of Maribor; Faculty of Civil Engineering, Transportation Engineering and Architecture, Maribor.

Trimble. (2017), Vico Office, available at: http://www.vicosoftware.com/ (accessed: 9 January 2017).

Trimble. (2017), SketchUP, available at: https://www.sketchup.com/ (accessed: 19 April 2017).Vincek, D. (2016), 6D building information model of Halder d.o.o. enterprise in Hoče, Master thesis, University of Maribor; Faculty of Civil Engineering, Transportation Engineering and Architecture, Maribor.

BIM-based Material Passport

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Abstract:

Building stocks and infrastructures represent the largest material stock of industrial economies. These total material stocks on the global scale are about as large as primary resource stocks in nature. It is of long-term importance to maintain or frequently recycle these urban stocks, and in consequence to minimize the use of primary resources and thus the dependency on imports - a strategy labelled as "Urban Mining". For a successful implementation of the urban mining strategy knowledge on material composition of buildings and upcoming material flows is needed. A Material Passport (MP) is a qualitative and quantitative knowledge base of the material composition of, and the material distribution within, a building structure.

There are multiple purposes of a life-cycle oriented MP – as design-optimization tool regarding efficient use of material and resources; as material information for an efficient end-of-life demolition of structures and recycling of applied materials and finally, if applied extensively, as the informational basis for a secondary raw materials cadastre, which in return is the basis of sophisticated recycling plans.

Computational design and modelling tools such as Building Information Modelling (BIM) bear large potentials for automated compilation of MP. In this paper, a modelling method for creation of BIM-based MP simultaneously allowing resources-optimized design and life cycle analysis will be presented.

This paper presents ongoing research within funded project BIMaterial, as a central milestone towards standardized, BIM-generated building material passes, which again builds fundament for implementation of urban mining as part of circular economy strategy.

***Keywords:**; BIM; Urban Mining; Material Passport; LCA; Modelling; Circular Economy*

1. Introduction

Global material resources consumption is increasingly rising as well as the world's population; thereby the future challenge will be to provide sufficient land, material and natural resources; as well as to deal with upcoming waste.

Building stocks and infrastructures are the largest material stock of industrial economies. As research findings in Regional Substance Flow Analysis indicate, these total material stocks on the global scale are about as large as reserves of primary resources in nature. It is of long-term importance to maintain or frequently recycle these urban stocks, and in consequence to

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minimize the use of primary resources and thus the dependency on imports – a strategy labelled as "Urban Mining". The increased application of construction materials with some delay triggers the equivalent increase in solid waste generation. Considering the average lifetime for construction products to be 40 to 50 years, a significant increase in solid waste generation is to be expected within the next decades. The only response to the challenge of landfill shortages can be the consequent increase of recycling and re-use rates. For higher recycling rates, it is vital to have detailed knowledge about the composition of both building stocks and construction wastes. Recyclability changes over time, as it is a function of technological development and resource markets. Building design has also a strong impact on recyclability, which depends on constructive criteria defining accessibility and separability of building elements (or its parts).

Currently we lack knowledge on exact composition and construction of building stocks, representing a major obstacle for optimization of recyclability of build-in materials and thereby increase of recycling rates. New inventory methods and tools are needed for the creation of urban material cadasters, which would finally contribute to the development of a secondary raw materials cadaster, a necessary future completion to the Austrian Mineral Resource Plan.

The main research question is how to efficiently model, analyze and predict the material flows of urban systems, particularly with regard to the assessment of material masses and the reduction of landfill waste in order to increase re-use and recyclability thus limiting further extraction of natural resources?

Powerful computational technologies and tools such as BIM (Building Information Modeling) offer large potentials for modeling and analysis of both new construction and building stocks in terms of material composition, and thus development of so called Material Passport; which again is the first step towards implementation on larger, urban scale and creation of so called material cadaster.

In this paper we will present a proof of concept and modeling framework for the creation of an automated BIM-based Material Passport (MP); which is part of the ongoing funded research Project: BIMaterial - Process Design for BIM-based Material Passport conducted at TU Wien. The aim of this project is to increase the use of existing material resources incorporated in built environment in order to limit further exploitation of natural resources using coupled digital tools and technologies.

There are multiple purposes of a life-cycle oriented MP – as design-optimization tool for efficient use of material and resources; as material information for an efficient end-of-life demolition of structures and recycling of applied materials and finally, if applied extensively, as the informational basis for a secondary raw materials cadastre, which in return is the basis of sophisticated recycling plans.

2. Literature Review

1. Material Characterisation of Buildings

Throughout recent years various studies have been carried out regarding description of material inventory in buildings. Thereby the material reserves are approximated to app. 300-500 tons/capita. The greatest challenge for description of urban material inventories is generating knowledge and data on material composition of buildings on the one hand, and the upscaling for the specific urban systems on the other.

Kohler et al. (1999) have assessed the material flows and costs of the German building stock. Thereby the macroeconomic and statistical data (top-down) was analyzed and coupled with bottom-up analysis of buildings, building elements and materials as material inventory.

In Switzerland, the exploration of urban material storages was carried out by Lichtensteiger und Baccini (2008), using so called "ARK-Haus" Method. The method categorizes the buildings according to the age and typology; thereby assigning typical materials and respective volumes. This analysis considers only materials that contribute to 90% of the total mass (Dominant Materials).

In Austria six buildings in various areas were analyzed within the research project EnBa (Development of a strategy for sustainable use of construction waste). The impact of the contaminants on recyclability of materials was determined (Clement et al., 2011); as well as a concept for sustainable use of construction waste which builds a fundament for the implementation of EU Strategy for minimization of waste and recycling [KOM (2005) 666] was developed.

Tanikava et al. (2002) has determined material storage of roads and buildings using GIS-data in Kitakushu (Japan). In this study materials such as steel, wood, sand, gravel, cement and asphalt were estimated in regard to the art of construction.

"Christian Doppler Lab for Anthropogenic Resources" at TU Wien is assessing material characterization of building stocks for the city of Vienna, whereby buildings and chosen infrastructure is analyzed in terms of recyclability. A material inventory for the city of Vienna was assessed.

A MP, as documentation of material composition of a building, is a fundamental document for the description of material inventories of urban systems. Further on, it is an important tool for enabling circular economy in the building industry and for minimizing the carbon footprint. Enabling circular economy in order to persist the value of products and resources in an economy as long as possible (European Commission, 2017), is a part of the EU action plan "Closing the loop" (European Commission, 2015). Creating circular solutions in order to reduce waste and use less virgin resources is also the main goal of the research project BAMB (Buildings As Material Banks), where creating a MP is final aim of the project. BAMB uses electronic MPs in order to store material information, describe their characteristics and to assign value for recovery and reuse. BAMB also aims to create incentives for suppliers for producing healthy and sustainable building materials and to facilitate take back of products and materials (http://www.bamb2020.eu/).

2. *Life Cycle Assessment (LCA)*

Analysis and optimisation of resources and material-composition of buildings stands in close relationship with general assessment of environmental impacts of buildings along the life-cycle; whereby the environmental impacts of production process, transport, renewal, and finally recyclability or waste management of materials in terms of indicators such as global warming potential, primary energy consumption and further are being assessed. The oldest and most common life-cycle analysis method is the process analysis method, which evaluates the direct and indirect energy inputs in each product process, defined by the ISO International Organization for Standardization (ISO) Standard 14040:2006. The ISO Standard describes the principles, the framework and temporal and spatial system limits of the LCA. The main phases of LCA are also defined and imply the goal and scope definition, the inventory analysis, the impact assessment and the interpretation phase.

Currently, quantifying the environmental impact of human activities has increased in order to reduce climate change (Takano et al. 2014). The principle decision makers, planners and investors have recognized, that there is need for optimization of building performance, not only in terms of energy but also in terms of resources consumption (Srinivasan et al. 2014). In order to achieve sustainability, an assessment of the environmental performance of buildings and the sub-components based on evaluation and optimization of embodied and operational energy and emissions is required in the planning phase (Srinivisan et al. 2014). Therefore a Life Cycle Assessment (LCA) needs to be carried out, which aggregates and analyses the flows of resources and materials throughout the lifecycle of a building. For a successful implementation of LCA however reliable and accessible data is needed, such as Environmental Product Declarations, or databases and inventories on environmental performance of materials.

3. Use of BIM for LCA and MP

Due to lack of information about the materials existing in buildings and their production processes, accomplishing a LCA is a challenging task. A further obstacle is the manual input of life cycle inventory data for every material (Eastman et al. 2011), for what the integration of BIM and LCA software represents a solution, as material specifications and quantity take-offs are already included in BIM (Ajayi et al. 2015). Nevertheless there still exists lack of data interoperability between BIM and LCA-tools and the problematic of inaccessibility and complexity of LCA inventories and tools (Loh et al. 2007). In order to get a standardized implementation of LCA and improve data exchange, the LCA tools have to be built into BIM software (Fischer 2004) or LCA databases need to be coupled to the BIM-tools. Common LCA tools are available on the market, such as SimaPro and LEGEP as commercial software-tools. Eco2soft (https://www.baubook.info/eco2soft/) with corresponding database baubook is provided by IBO-Austrian Institute for Building Biology (IBO, 2013) and therefore freeware. Further on there exist calculation templates provided by building certificates such as DGNB, BREEAM or LEED, which are freely accessible to the public, but not in full extent. GaBi and SimaPro provide various assessment methodologies from energy to diverse impact category assessments. Building specific tools like Athena and BEES are frequently used, but they do not provide a range of impact assessment options (Anand et al., 2017). Other mentionable LCA tools are Umberto, EIO-LCA, TRACI and ECO-it (Anand et al., 2017, Bribian et al. 2009). Above mentioned LCA tools, do not provide a direct connection to BIM software and thus are time efficient, due to manual input of data. Wang et al. (2011) demonstrated the implementation of LCA in a use case, whereby the project was modelled in Revit Architecture. For the simulation of operational energy Autodesk Ecotect was used with an effortless file transfer between Revit and Ecotect.

BIM as information rich, 3D representation of a building offers large potentials for the automated generation not only of LCA, but also of MP. In a current research, Prins et al. described and evaluated several Circular Economy cases in the Netherlands. A resource passport for an educational building that had to be renovated, has been created in form of a digital BIM.

Construction and Demolition waste (C&D waste) is growing continuously and receives big attention from practitioners and researchers around the world (Lu and Yuan, 2011). As BIM has big potential for reducing design errors, rework, and unexpected changes, it has recently been identified as a tool for minimizing the amount of C&D waste (Won, 2016).

However, automated generation of MP as well as automated LCA from BIM are still facing numerous challenges, where LCA-data accessibility and automated coupling of BIM models (and object libraries) with LCA inventories is one of the major challenges. Further on, current LCA inventories are including eco-indicators regulated by ISO such as Global Warming Potential - GWP, Primary Energy Consumption - PEI, Acidification – AP etc., but are generally lacking information on recyclability or separability of materials within building elements or building elements themselves, information which is crucial for the generation of MP, in order to gain knowledge on re-usability potentials.

3. BIMaterial: Process Design for BIM-based Material Passport

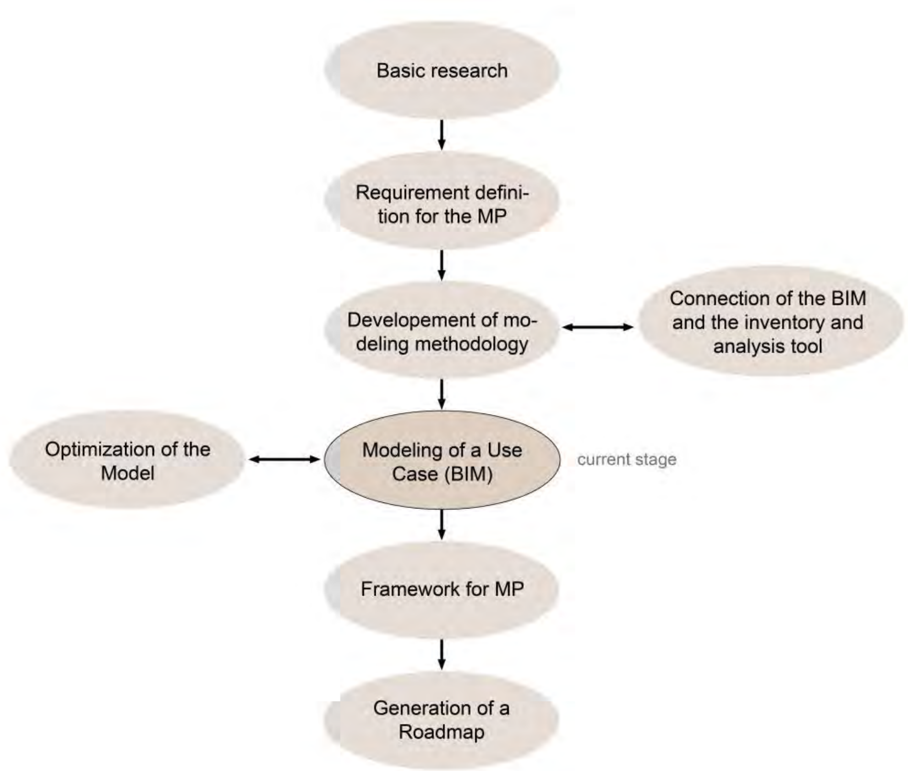
Currently a there is a lack of scientific method for the compilation of BIM-based material passport. Throughout the design process a large number of information regarding material information of building elements is generated, which would enable compilation of MP. However, currently this information is scattered throughout the planning stages or disciplines, a joint data repository is lacking. Implementation of computational design and simulation tools in automotive or electronic industry is already standard, thereby it can be expected that BIM use will become standard in AEC industry as well, thus enabling creation of a join knowledgebase for planning process participants.

The use of BIM for MP still represents a research gap. The main objective of the research project BIMaterial is to bridge this gap, through exploration of BIM-potentials for automated compilation of MP. The use of MP should be enabled across building's life cycle; in various stages. In the conceptual design stage MP is used for approximate analysis and design-optimization, supporting resources and material efficient design as well as and design for deconstruction. In the tendering stage, MP assesses exact material composition of the building through bill of quantities. Finally, in the operational phase, MP serves for due diligence, documenting material composition of the building and thus representing material inventory. In further step, through clustering of MPs and upscaling in e.g. GIS; MP should serve as a fundament for secondary raw material cadaster at urban level.

In this project a conceptual Framework for modeling and compilation of BIM supported MP across life cycle will be proposed, that should serve for optimization of resources and reduction raw material extraction, as well as for prevention of upcoming of waste. Finally, requirement specification for development of BIM-based MP App will be issued.

4. Methodology

MP will be compiled at the conceptual-structural level, and is regarding short-term as well as long-term benefits, where as raw material extraction and upcoming of waste should be minimized. In the first step, a modeling methodology will be developed, which builds upon national and international BIM-standards. The state-of-the art standards define Level of Development (LOD) of a BIM Model. Thereby the material matching and coupling with state-of-the art LCA-data inventories will be carried out according to the granulation of LOD. For the query and qualitative and quantitative assessment of the material composition of buildings Rule Sets will be defined. Finally the modeling methodology and Rule Sets will be verified in Use Cases, where specific, real time construction projects will be modeled in various BIM software and MPs compiled upon defined Rule Sets. This Framework builds the fundament for a requirement specification for software development of BIM_MP App, which will be used as



Plug-In for BIM Software such as Archicad or Revit in order to compile MP (Figure 1).

Figure 1: Methodology for development of BIM-based MP

1. Requirement definition for MP

In the first step the scope of necessary information was defined, which on the one hand included expert – interviews (demolition companies, material recycling union, material industry) and on the other was based on the knowledge generated in the project „Christian Doppler Lab". The MP should address resources and material efficiency along the life cycle of a building, and will thereby be developed for use along four various design stages (Figure 2):

MP 1 is addressing conceptual design phase (2 – Conceptual Design). This stage has the largest impact on life-cycle performance regarding re-usability of the building elements and materials as well as on upcoming waste. Thereby the optimization potential is the largest at this stage, as is the importance of MP 1 as design-optimization tool.

MP 2 is addressing the design phase (3 – Preliminary Design), as planning-optimization tool and support for design for deconstruction, as well as to compile a deconstruction concept.

MP 3 is completed in tendering stage (6 - Tendering) in order to assess exact material composition.

MP 4 is representing a final document on material inventory of a building and is delivered at the handover to the operation (9 – Documentation).

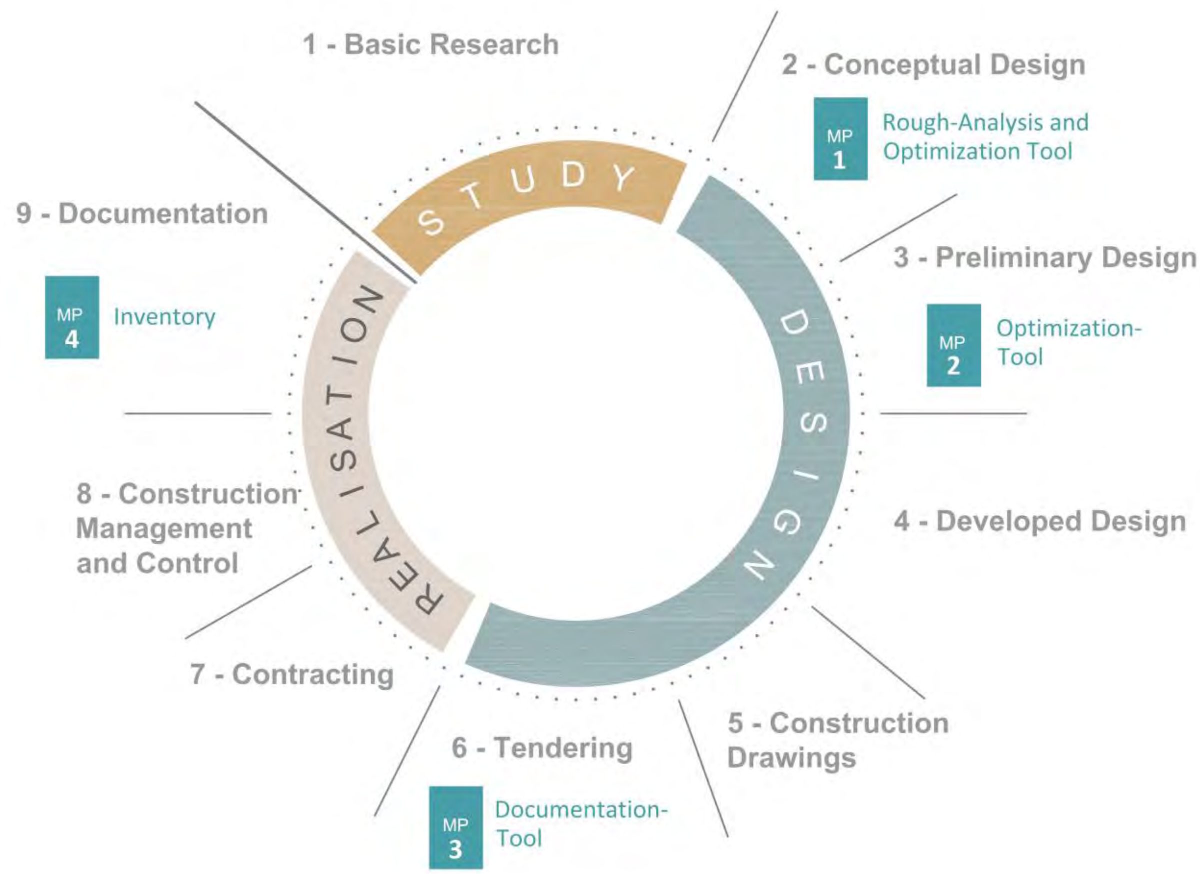


Figure 2: MP along various Planning Stages

2. Development of modeling methodology

A methodology for modeling is proposed considering Austrian BIM Standards ÖNORM 6241-1 and 6241-2. The framework defines the necessary Level of Development along various design stages.

Thereby five principles for resources efficient design are considered:

- Optimization of material input
- Waste minimization at the building site
- Reusability and Recyclability of building elements

- Prefabrication
- Design for deconstruction (Deconstruction concept) .

For the compilation of MP a LCA methodology is applied. LCA focuses on evaluating the total environmental impacts of buildings over their entire life cycles. The environmental impacts occur throughout several life cycle stages – production, transport, operation and end-of-life scenarios. The LCA assessment as proposed by building certificates or IBO assesses the three most important indicators as environmental impacts: Global Warming Potential (GWP) – CO_2 equivalent, Acidification Potential (AP) and Primary Energy Intensity (PEI), consisting of Non-Renewable and Renewable parts. For the compilation of MP additional indicators have to be assessed such as reusability, recyclability and separability; which are also proposed by IBO. In order to guarantee for consistency of data regarding eco-indicators as well as indicators of recyclability and separability, we use only data by IBO, from databases baubook or tools such as eco2soft.

In the first phase of the research, a data exchange between BIM-Software and as material inventory and assessment tool was tested. BuildingOne was chosen as powerful database and management tool, enabling bi-directional data exchange with BIM model, thus all of the geometry or material changes can be carried out either in the model or in the database; as a tool for material inventory and LCA assessment; and was tested for such use for the first time; as originally the software tool is developed for asset management. Further on BuildingOne enables the creation of Rule Sets for the assessment of quantities and LCA, thus supporting automated compilation of MP, once Rule Sets have been created and materials matched. Thereby the properties needed for LCA were generated in the tool. The results show that the data exchange between the BIM-Software and the tool works properly. Based on the insights of the study, requirements for generating a BIM-based MP and a proper workflow were developed. A workflow description will be presented in detail in Chapter 5.

3. Use Cases

In this stage specific projects will be modeled in various BIM tools, thus providing test platform for the developed framework. The usability of the tools for setting up of the LCA-data and export will be examined, as well as the usability of the BIM-modeling standards and conformity with MP structure.

4. Requirement Specification for MGP App

The requirement specification for the development of a BIM-based MP App will capture the modeling methodology, defining the modeling rules such as e.g. – all of the building elements must be modeled according to their function (walls as walls, slabs as slabs). The level of development of the BIM model should comply with ÖNORM 6241-2.

5. Modelling Methodology - Workflow Description

For the generation of MP, we propose coupling of BIM-Model with the material inventory and analysis tool (BuildingOne). BIM-Software is used for modeling and BuildingOne for matching of eco-indicators to materials and LCA/MP assessment. The workflow is tested with two BIM-Software Tools (ArchiCAD and Revit). The material inventory and assessment tool

BuildingOne offers a bi-directional data exchange to BIM-Software and an automated synchronization of data (Figure 3).

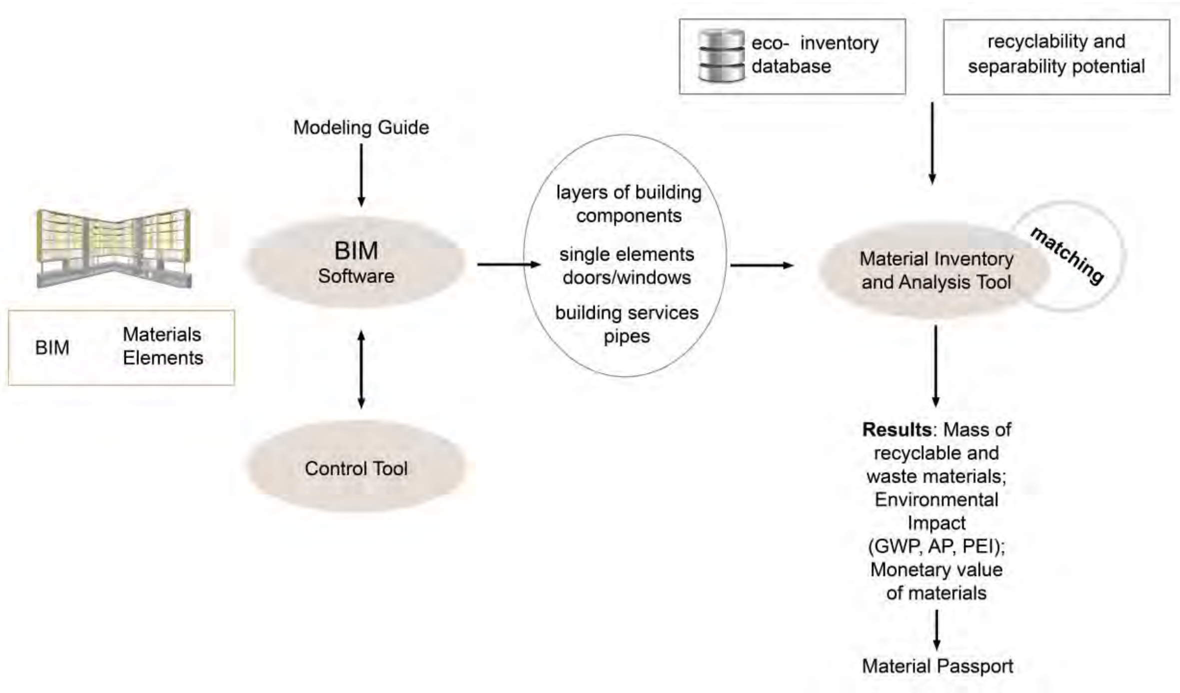


Figure 3: Workflow for assessment of BIM-based MP; using BuildingOne as Material Inventory and Analysis Tool

BIM-Software is used for generating a detailed model, whereby a modeling-guide is taken into consideration, which defines the requirements for a MP-Model, e.g. that all building elements should be multi-layered (in stage 3). A control tool (Solibri Model Checker) is used to ensure that the BIM-Model is error-free. In a further step all the required information about building components is exported to the assessment tool (BuildingOne), where the materials used in BIM-Software have to be matched with the materials existing in the eco inventory database in order to conduct the LCA and assess environmental life-cycle impact expressed through indicators such as e.g. the Global Warming Potential. Therefore, the eco-database needs to be linked with the tool. In the assessment-tool, the building components are also parametrized through values for the recyclability and separability in order to assess the total mass of recyclable and waste materials. Due to the direct connection with the BIM-Model, all model changes are synchronized automatically and queries are recalculated. As a result, a MP consisting of the information about all materials and their recycling potential existing in the building is obtained (Figure 4).

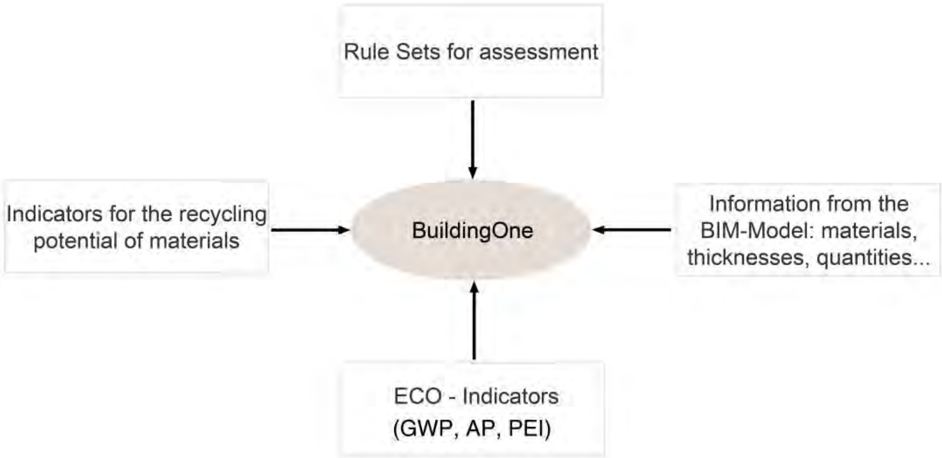
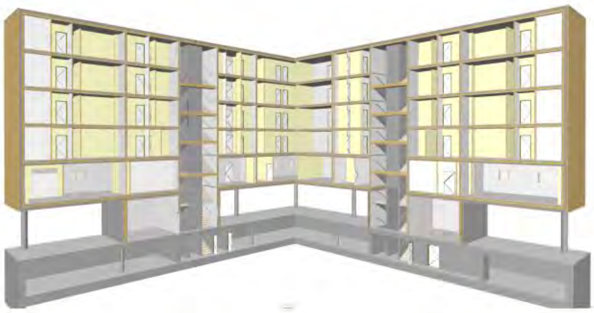


Figure 4: Data-Management System for MP in BuildingOne-Material Inventory and Analysis Tool

For the compilation of an automated MP a „component catalogue“, where elements are pre-defined has to be used. The „component catalogue“ is outlined in an Excel-file, whereby each layer of an element is attributed with properties like e.g. separability and recycling potential, data that originates from eco2soft database. In a further step, the developed elements are modeled in BIM-Software (Archicad or Revit), which are provided as a template. In BuildingOne these elements are enriched with further information (property/m²) and summed up in categories such as GWP, AP etc. On material-level, all materials have a characteristic value, which is also summed up on the element-level. Modeling in hybrid-modeling-methodology and monolayered-modeling-methodology (each layer as wall) is not permitted (assessment for elements would not be possible).

Figure 5 shows a proposal for Material Passport, displaying share of materials – organic or mineral, as well as quantities (masses) and shares of materials in a building.



Material	Share	Sum of Mass [t]
Cross Laminated Timber	35%	585,13
Synthetic substances	0%	5,77
Bitumen	0%	4,83
Sawn timber	1%	21,09
Wood fiberboard	1%	11,99
Wood fiberboard, insulation	5%	91,56
Massive parquet	2%	37,61
Plasterboard	5%	82,45
Plaster/mortar	6%	106,16
Rock wool	1%	24,18
Gravel	4%	64,57
Grit	19%	323,09
Screed concrete	14%	235,59
Glas	6%	100,30
		1694,32

	Share	Sum of Mass [t]
Organic	45%	757,98
Mineralic	55%	936,34
Metalic	0%	0
		1694,32

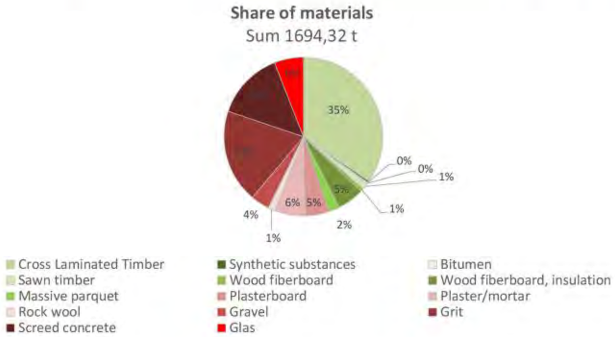
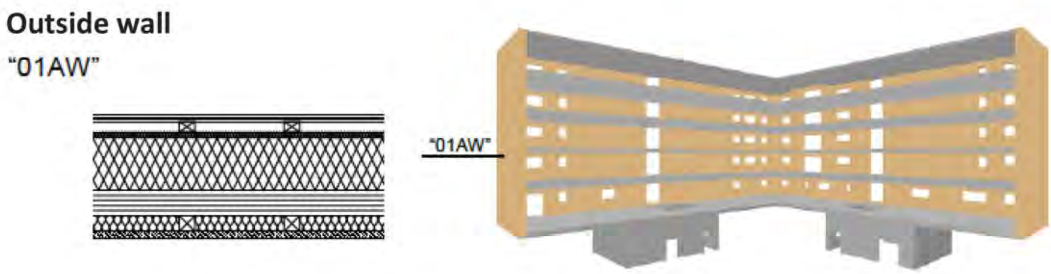


Figure 5: Proposal for MP

5.1 Encountered Problems

There are several encountered problems regarding the enabling of creation of automated MP. First, the inconsistent naming conventions of the materials in various databases can be identified. This leads to numerous problems with data exchange, and recognition and matching routines have to be conducted prior to assessment (Figure 6).



	Thickness [m]	Layers	Corresponding materials from IBO
1	0,024	Cladding	Plywood Planks
2	0,04	Spruce Furring (40/60) (10%)	Spruce Timber air dired
3	0,022	Wood fiberboard	Wood fiberboard, porose 250 kg/m3
4	0,2	Wood fiber insulation	Wood fiber insulation 160 kg/m3
5	0,1	Plywood Planks	Plywood Planks
6	0,06	Spruce Furring (40/60) (10%)	Spruce Timber air dired (10%)
7	0,06	Mineral Wool (90%)	Stone Wool (90%)
8	0,025	Rigips Fire Protection Gypsum Board	Fire Protection Gypsum Board
	0,471		

Figure 6: Matching of inconsistent naming conventions in material inventories

Further on, it was detected that there is a general problematic in BIM-Software regarding modeling and attributing of multi-layered elements, due to lacking possibility to define properties for each layer/material of a building component. For the "matching" of eco-indicators or material properties two concepts can be used:

- Direct adjoining of eco-indication as attribute in BIM Software; which currently in not possible with multi-layered elements
- Adjoining of eco-indicators in external data base.

In the current research we have opted for the second variant, as the adjoining of attributes to the multi-layered elements in not possible on the one hand, and to reduce data volumes and BIM model size on the other, as well as to proved more flexibility.

Next, a question arises whether to model with multi-layered elements or pre-defined building elements? If we consider multi-layered elements, which are defined by the planners, this would lead to linking each property (for example CO2) with the particular layer, and additional effort as well as required skills for the planners. If the model is created with pre-defined building elements, provided by a "component catalogue", architects are not flexible in the compilation of the model anymore. Despite the problematic with the flexibility, in this project the methodology of using pre-defined elements will be strived.

Last, a question of Level of Development and stage-dependent modeling arises; as various design stages employ BIM models of varying LOD; thereby in the earliest design stages – Conceptual design – material or building element information is hardly available (Figure 7).

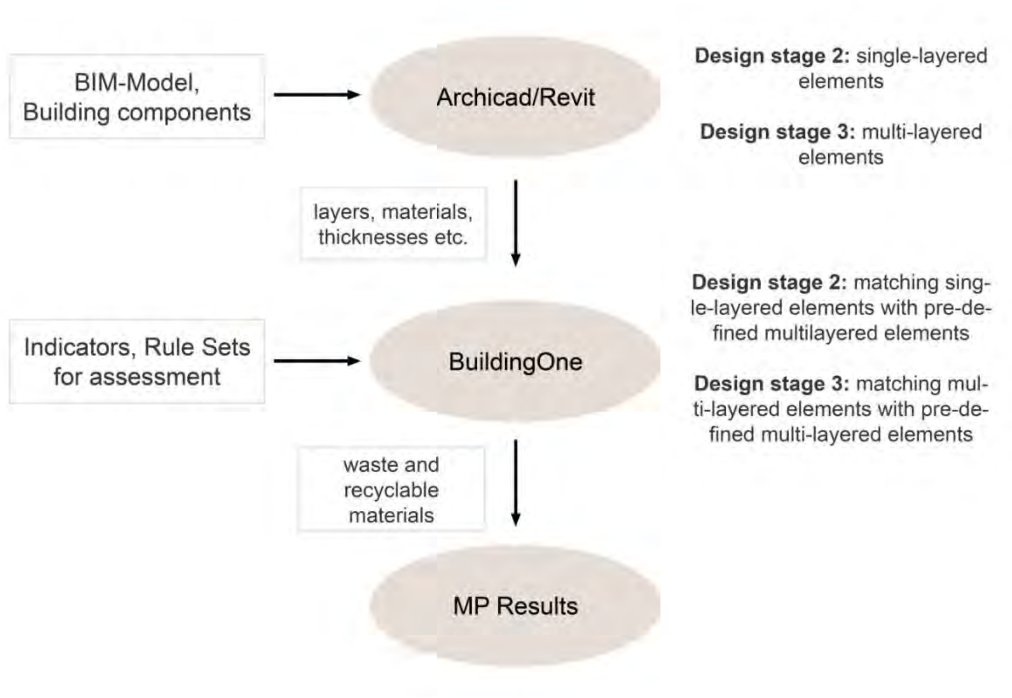


Figure 7: Design stage dependent modelling according to LOD

In design stage 2 (Conceptual Design) the designers work with mono-layered elements, as multi-layered elements are not defined yet, so that the architect creates a wall „AW01", which consists of only one undefined layer (e.g. "dummy" in Archicad). However, in order to carry out a variant-study, multi-layered elements are necessary. Therefore, we propose in this early design stage, the use of pre-defined multi-layered elements as created in BuildingOne, in order to link the components from the BIM with the components in BuildingOne (Figure 8).

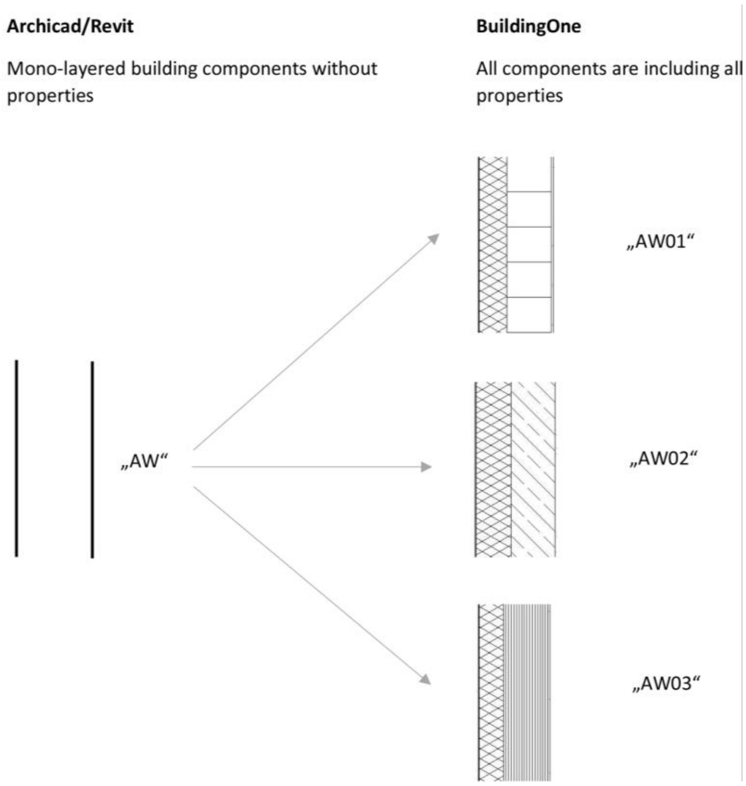


Figure 8: MP1 – Model LOD in Conceptual Design Stage

Starting with stage 3 (Preliminary Design), each building component has to be defined in BIM too, and only need to be matched in Building One. From this phase on the general multi-layered elements are defined, only individual layers can be changed (e.g. the thickness of a layer) (Figure 9).

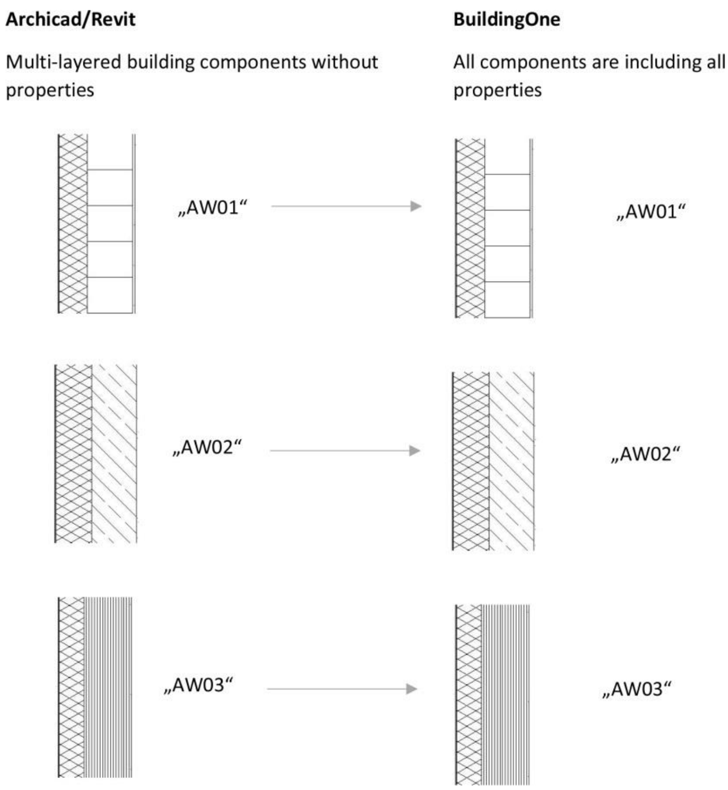


Figure 9: MP2 – Model LOD in Preliminary Design Stage

6. Conclusion and Discussion

In this paper we presented the aims of the research project BIMaterial and the framework for modeling a BIM-based Material Passport and the rule sets for a MP model-analysis. Application of MP allows resource- and material optimized design and LCA in the early planning stages, and documents the material composition of a building in later life-cycle stages, thus generating knowledge on material composition of building stocks.

For the generation of MP a tool-chain was created using BIM Software and coupling it to the material inventory and assessment tool BuildingOne. The proof of concept was realized as the data exchange between the BIM model and material matching and compilation of material building pass was carried out successfully.

However, there are some challenges that have to be overcome. There will be need for changes in BIM-Software in order to make the tool more applicable in practice, as there exist difficulties in the parameterization of materials. Further on the question arises on the procedural level, if the designers working with proposed framework in the earliest design stage will find it limiting; through advised use of “catalogue elements”; where as creation on own elements requires knowledge and experience with eco-inventories and LCA.

Currently, we only use data by IBO (baubook and eco2soft) however this might be limiting for design and choice of materials. In the next step coupling with further data bases should be considered, such with German database “ökobaudat”, as it offers wider-ranging data than IBO and is available as an open source database, which can be linked to BuildingOne. However mixing of the data from varying sources (databases) is not advisable due to the inconsistencies and large differences in the data structuring and LCA assessment methodology in the background. The inconsistency of the data can be seen as one of the major challenges for achievement of automated MP.

The research results are expected to have direct environmental impact and to produce new insights and approaches for research activities. On the urban level, the MP should serve as a basis for a secondary raw material cadaster, a necessary future completion to the Austrian Mineral Resource Plan and as an important support tool for circular economy. Besides, it is a determining tool for planers for the optimization of resource efficiency in early planning stages. Further on the MP acts as a crucial instrument for material manufacturers, construction companies, engineers and architects, recycling and waste companies and policy-makers.

This research is a central milestone towards standardized, BIM-generated material passports, which should become a standard procedure for certified structures and buildings.

References

Ajayi, S. O., Oyedele, L. O., Ceranic, B., Gallanagh, M. and Kadiri, K. O. (2015), "Life cycle environmental performance of material specification: a BIM-enhanced comparative assessment", International Journal of Sustainable Building Technology and Urban Development, Vol. 6 No. 1, pp. 14-24.

Anand, C. K. and Amor, B. (2017), "Recent developments, future challenges and new research directions in LCA of buildings: A critical review", Renewable and Sustainable Energy Reviews, Vol. 67, pp. 408-416.

Bribián, I. Z., Usón, A. A. and Scarpellini, S. (2009), "Life cycle assessment in buildings: State-of-the-art and simplified LCA methodology as a complement for building certification", Building and Environment, Vol. 44 No. 12, pp. 2510-2520.

Eastman, C. M., Teicholz, P., Sacks, R. and Liston, K. (2011), BIM handbook: A guide to building information modeling for owners, managers, designers, engineers and contractors, John Wiley & Sons, New Jersey.

European Commission (2017), "Report from the Commission to the European Parliament, the Council, the European economic and social Committee and the Committee of the Regions on the implementation of the Circular Economy Action Plan", available at: http://ec.europa.eu/environment/circular-economy/implementation_report.pdf / (accessed 09 April 2017).

European Commission (2015), "Communication from the Commission to the European Parliament, the Council, the European economic and social Committee and the Committee of the Regions, Closing the loop - An EU action plan for the Circular Economy", available at: http://eur-lex.europa.eu/resource.html?uri=cellar:8a8ef5e8-99a0-11e5-b3b7-01aa75ed71a1.0012.02/DOC_1&format=PDF / (accessed 09 April 2017).

IBO (2013), Austrian Institute for Building Biology, "OI3-Berechnungsleitfaden", available at: http://www.ibo.at/de/documents/20131016_OI3_Berechnungsleitfaden_V3.pdf/(accessed 09 April 2017).

ISO (2006), 14040:2006, International Organization for Standardization, "Environmental Management–Life Cycle Assessment–Principles and Framework".

Loh, E., Dawood, N. and Dean, J. (2007), "Integration of 3D tool with environmental impact assessment (3D EIA)", in Em'body'ing Virtual Architecture: The Third International Conference of the Arab Society for Computer Aided Architectural Design (ASCAAD 2007), 28-30 November 2007, Alexandria, Egypt, pp. 51-66.

Lu, W. and Yuan, H. (2011), "A framework for understanding waste management studies in construction", Waste Management, Vol. 31 No. 6, pp. 1252-1260.

Srinivasan R.S., Ingwersen W., Trucco C., Ries R., Campbell D. (2014), "Comparison of energy-based indicators used in life cycle assessment tools for buildings", Building and Environment, Vol. 79, pp. 138-151.

Takano, A., Winter, S., Hughes, M. and Linkosalmi, L. (2014). "Comparison of life cycle assessment databases: A case study on building assessment", Building and Environment, Vol. 79, pp. 20-30.

Wang, E., Shen, Z. and Barryman, C. (2011). "A building LCA case study using Autodesk Ecotect and BIM model", Papers in construction management 2011 proceedings of the 47th ASC Annual International Conference, paper 6, University of Nebraska, Lincoln.

Won, J., Cheng, J. C. and Lee, G. (2016), "Quantification of construction waste prevented by BIM-based design validation: Case studies in South Korea", Waste management, Vol. 49, pp. 170-180.

BIM Awareness and Education Preliminary Results among Students of Graduate Study Program in Construction Industry

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Abstract:

The continuous increase of the scope of investment construction projects and their goals in environment, which abounds with many constraints and stakeholders, asks for efficient project management with adequate software support. Building Information Modelling (BIM) emerges as one such integral tool. Although it is accepted by the scientific community, there are several subjective and objective barriers in its wide application such as lack of knowledge, qualification, and awareness of necessity for BIM implementation. Using a web-based questionnaire and personal questioning, the data of students of the graduate study programs in the architecture, engineering, and civil engineering fields at four universities in Croatia (Rijeka, Zagreb, Split, and Osijek) was collected, analyzed, and compared. Results of the performed statistical analysis show that students gain knowledge and skills (CAD modelling, n-D modelling, and multi-disciplinarity of projects environment), which is a good prerequisite for BIM implementation in the future. The conducted research gives a preliminary insight into possibilities of BIM implementation into lecturing plans and programs at technical universities to become basic knowledge of the construction industry and its improvement.

Keywords: *BIM; modelling in civil engineering; project management; BIM in teaching; graduate study program;*

1. Introduction

The application of Building Information Modelling (BIM) in the architecture, engineering and construction (AEC) industry should no longer be analyzed in a way to explore its advantages and disadvantages but rather to analyze how to implement it in education processes to become basic AEC knowledge in the future. Construction projects increase in size daily and so does the number of planning processes and disciplines where the multi-disciplinary collaboration is of critical importance for achieving project goals. For years the AEC industry was fragmented, and individuals who managed construction projects often overstepped project constraints regarding time and budget. As construction projects became more complex and their requirements greater, the need for systematic and solid project management arose in the form of project management methodologies. Basically, project management (PMI, 2013) is "… the application of knowledge, skills, tools, and techniques to project activities to meet project

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requirements." As such, the project's success is directly influenced by stakeholder involvement as they discover and describe their needs into requirements.

Various tools and techniques have been developed over the years, and the BIM became the tool of today as it refers to the development and use of computer-generated n-dimensional (n-D) models. It is not only considered a powerful modelling tool for design and construction but also a life-cycle optimization and management tool (Kovačić et al., 2015a) by which the present fragmentation of the AEC industry can be reduced. Today, BIM is not equally adopted in the AEC industry around the world. In 2010 (McGraw-Hill Construction Smart Market Report, 2010), a little over 36% of the Western European industry participants reported adopting BIM in comparison to 49% in North America in 2009, while in 2015 it ascended to 70% worldwide (Dodge Data & Analytics Smart Market Report, 2015).

The main goal of this paper is to identify the level of BIM awareness and education among students of graduate study programs in the architecture, engineering and civil engineering fields at four universities in Croatia (Rijeka, Zagreb, Split and Osijek). According to universities' public available data, the total number of students in the aforementioned study programs was 1212, while a total of 245 questionnaires were collected. Such preliminary results are of great importance to give insight to BIM implementation possibilities into lecturing plans and programs at technical universities to become basic AEC knowledge and improve AEC industry.

This paper is structured as following: In the next chapter, the theoretical background of BIM is given with an emphasis on implementing BIM in teaching. In the third chapter, the research design is given with the focus on a conducted survey followed by results and discussion. In the last chapter, conclusions are drawn for the practice purposes stating the prerequisites for BIM implementation in the future.

2. Theoretical background

At the beginning of 2014, the European parliament updated public works procurement regulation by recommending the use of an electronic tool like BIM in public works contracts and competitions, resulting in Directive 2014/24/EU. In Article 22(4) of Directive 2014/24/EU (2014) it is stated that "For public works contracts and design contests, Member States may require the use of specific electronic tools, such as of building information electronic modelling tools or similar." The adoption of the directive means all 28 European Member States may encourage, specify, or mandate the use of BIM for publicly funded construction projects in the European Union by 2016.

Unlike traditional CAD drawings, the data in BIM enhances the project to remain consistent, coordinated, and more accurate across all stakeholders, regardless of how many times the design changes or who changes it. The understanding of the managerial relationship gap between the BIM and project/project management is of crucial importance as construction projects become much more complex and difficult to manage (Travaglini et al., 2014). Therefore, they provided an insight of the stakeholders' perspectives on BIM and project management regarding the key stakeholders' adoption of BIM, and regarding public situations in the different European countries.

A good practice of BIM embraced by AEC industry can be found in UK, Netherlands, Denmark, Finland, and Norway as they already require the use of BIM for publicly funded building projects. Other states are trying to overcome all BIM disadvantages during its implementation processes as they cope with legislation as well as traditionalism. Such is evident in countries where the AEC industry is characterized by a strong engineering tradition such as Germany (Von Both, 2013), Austria (Kovačić et al., 2015a; Kovačić et al., 2015b), and Croatia (Kolarić et al., 2015), which are based on fragmented, sequential planning procedures.

It was widely expected that BIM would lead to changes in the performance of professionals in the AEC industry, but it turned out that there are a lot of obstacles. Two recent surveys give insight into BIM implementation in construction industry from the stakeholders' point of view. The survey (Cao et al., 2017) resulted with insight in project participants (designers and general contractors) motivations for BIM implementation in construction projects as their motivations and desires differ. Their results suggested that, although project participants have strong economic motivations to improve project performances as their BIM capability maters, the increase in economic motivation does not necessarily require a parallel decrease of desires to improve social image. Results also suggest that motivations for BIM implementation relate both to organizational ownership type and project characteristics. The results of a survey (Howard et al., 2017) conducted in UK among 84 industry stakeholders signifies that BIM is perceived as an unrewarded addition to existing work process. Authors concluded that their findings evince the need to redefine policies and strategies to advance the acceptance of BIM in construction industry. Therefore, a social influence has the greatest impact on the project participants and their affection towards BIM.

The literature has recorded several experiences regarding the use of BIM in teaching architecture and civil engineering in countries where BIM is most employed and widespread as well as the challenges of introducing BIM in the university curricula (Kymmell, 2008) and BIM teaching strategies (Barison and Santos, 2010; Macdonald, 2012). Experimental studies on BIM teaching conducted at the Vienna University of Technology (Kovačić et al., 2015a; Kovačić et al., 2015b) showed the sole adoption of BIM tools is not sufficient for the realization of integrated planning. They confirmed that BIM software is useful for planning, simulation, and optimization of students' projects during their education, but such processes require a more intense communication and team coordination regarding traditional CAD tools and traditional teaching. Kovačić et al. (2015a) stated that "…BIM implementation requires changes along the lines of technology as BIM is not new CAD." The study (Salleh and Fung, 2014) focuses on the study of the barriers and strategies of BIM application through qualitative approach via focus-group discussions, thus resulting in three key aspects (people, processes, and technology) which will eventually lead to a quicker adoption of BIM.

Peterson et al. (2011) did a comparative study of two classes at different universities to address the necessity for further research in multi-disciplinary projects as they used BIM to facilitate construction project management. Kolarić et al. (2015) developed a methodology for preparation and execution phase of a construction project to achieve a better communication and cooperation between the project stakeholders when they discovered that Croatian construction companies are familiar with BIM, but it is rarely applied in construction practice. An interesting study was done by Tsai et al. (2010) as they measured students' time-effort needed to model a structure based on 2D drawings and the efficiency of data transfer from a BIM model to scheduling software to gain insight into resource planning while using BIM tools.

3. Research design

This research examines the level of BIM awareness and education among students of graduate study programs in the architecture, engineering, and civil engineering fields at four universities in Croatia. For such purpose, the research procedure was developed (shown in Figure 1) in a form of process flowchart. The research began with gathering a research team and identifying the research problem, closely followed by setting up the research goals. The next step was identifying the experts and conducting the literature review. The purpose was to assemble the appropriate list of questions and the research questionnaire. Firstly, the performed literature review served the research team as a starting point for creating an appropriate list of questions to which the requirements on BIM awareness and education among students of graduate study program in AEC industry will be evaluated. Afterwards, particular questions were discussed with the panel of experts (experts from University of Rijeka and from local small and medium business firms within the construction industry) in order to:

- Confirm the relevant ones,
- Remove those assessed as inappropriate or superfluous, and
- Consider others that might be included in the survey.

In such synergy, the final list of questions emerged and is given in the form of a questionnaire. The survey is done by a structured questionnaire to gain insight into students' knowledge of CAD tools, their awareness of n-D modelling, and their awareness of multi-disciplinarily knowledge in the AEC project environment.

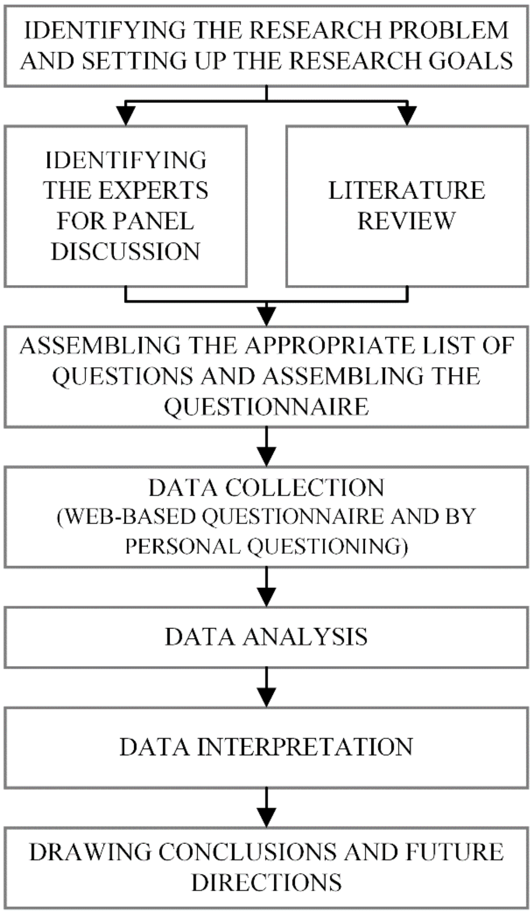

Figure 1. Research process flowchart

The target examinees were students of the university graduate study programs in architecture, engineering (both electrical and mechanical), and civil engineering from four universities in Republic of Croatia (Rijeka, Zagreb, Split, and Osijek). They were asked to make estimations on a questionnaire by the Likert scale (1 – very bad, 2 – bad, 3 – average, 4 – good, 5 – very good) in which they could specify their level of agreement or disagreement for a series of statements. Once collected, data was analyzed and interpreted regarding affiliation of examinees and their graduate study program, allowing the authors to draw conclusions and set future research directions.

3.1 Survey and data

Firstly, the performed literature review and panel discussion served the authors as a starting point for creating an appropriate list of questions. The survey was structured of two parts: general information (university location and study program) and a five-question poll (Table 1).

Table 1. Questionnaire

No.	Question	Grade
1	How familiar are you with the concept of BIM?	1-5
2	Self-evaluate your knowledge in using 2D CAD tools.	1-5
3	Self-evaluate your knowledge in using 3D CAD tools.	1-5
4	Self-evaluate your ability to work in a team.	1-5
5	How important do you think that cooperation and mutual recognition of professional knowledge and skills of all AEC participants is for the project's success?	1-5

According to universities' public available data, the total number of students in the graduate study programs (architecture, engineering, and civil engineering) was 1212. The data was collected by personal questioning and using a web-based questionnaire (available at https://docs.google.com/forms/d/1tsbrC3aOdXFjqqDWs5E5iPEHI4y6C9PuEnjk_d0M7PI/viewform#responses). The survey was conducted from December 2015 to April 2016, and at the end, a total of 245 questionnaires were collected.

4. Results and discussion

As previously stated, the survey resulted in 245 examinees i.e. 20,21% of the total student population dispersed over nine faculties in four universities. All students in the graduate study program are aged 20 and older. The distribution among potential examinees and their affiliation is shown in Table 2 as they are grouped into three categories regarding the AEC field.

Table 2. Number of students on graduate study program and their affiliation

University	Graduate study program		
	Architecture	Engineering	Civil Engineering
University of Rijeka (UNIRI)	-*	94	122
University of Zagreb (UNIZG)	118	120	374
University of Split (UNIST)	46	85	105
University of Osijek (UNIOS)	-**	45	103

* Architecture study program is not performed at the university

** Architecture study program wasn't available at the university at the time of the survey

From a potential of 164 students of architecture, 65 answered the questionnaire (i.e. 39,63%), while only 33 of the potential engineering students answered the questionnaire (i.e. 9,59%). Of the potential 704 students, 147 civil engineering students answered the questionnaire (i.e. 20,88%). Most of the 245 examinees were form UNIZG (85 students i.e. 34,69%), followed by UNIRI (71 students i.e. 28,98%) and UNIST (59 students i.e. 24,08%), while the least examinees were form UNIOS (30 students i.e. 12,25%).

Observing the curricula of nine faculties reveals some differences, but one should have in mind that despite of their affiliation, the students of civil engineering acquire on completion of graduate study program the same degree–master in civil engineering. Although some competencies vary considering modules of the specific branches of civil engineering–as not all modules are performed at all affiliations–students gain similar general knowledge and competences with completion of the graduate study program (achieving 300 ECTS credits). Likewise, the students of architecture (master in architecture) and engineering students (master of engineering).

The results of the examinees' questionnaires regarding their affiliation are given in Figure 2. Examinees' answers from all four universities are very similar with the exception regarding familiarity with the concept of BIM.

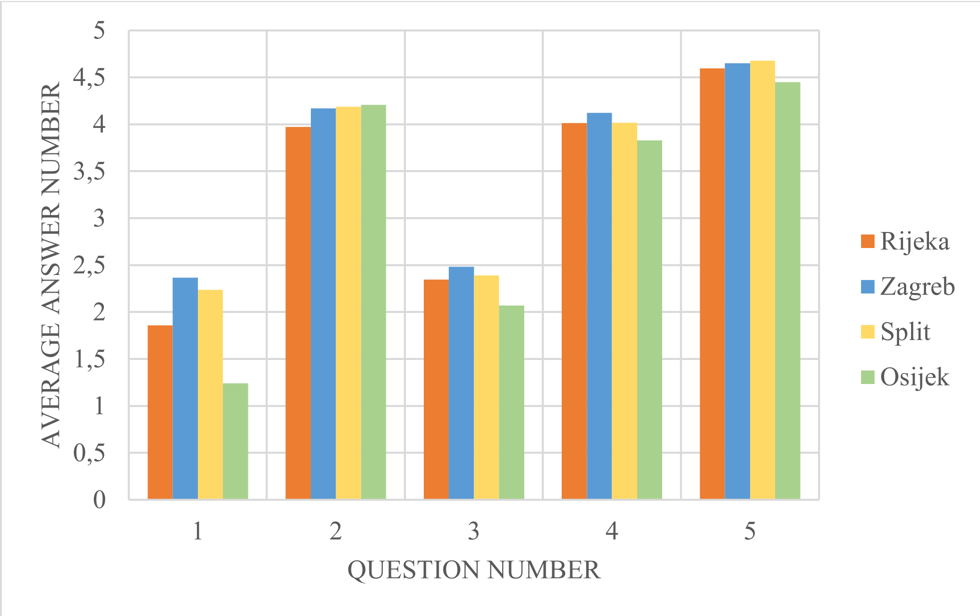

Figure 2. Results of examinees' questionnaires regarding their affiliation

Due to students' similar answers, it can be concluded they gain similar sets of knowledge and competencies regardless of the university environment. They self-evaluate themselves highly regarding gained knowledge in using 2D CAD tools and their ability to work in a team. Even as students, they develop a comprehension that cooperation and mutual recognition of professional knowledge and skills of all AEC participants is important for project success. Unfortunately, they are not formally oriented for developing such knowledge and competencies. Such is supported by their poor familiarity with the BIM concept. All previously stated reasons (see Theoretical background) are certainly the practical ones for the current state of the universities' AEC curricula.

If the examinees' questionnaires are grouped according to the different graduate study programs of the AEC field (Figure 3), additional conclusions could be drawn. Although the students of architecture, engineering, and civil engineering highly value the importance of cooperation and mutual recognition of professional knowledge and skills of all AEC participants for the project success, and their ability to work in a team, they lack the necessary tools (questions 1 and 3).

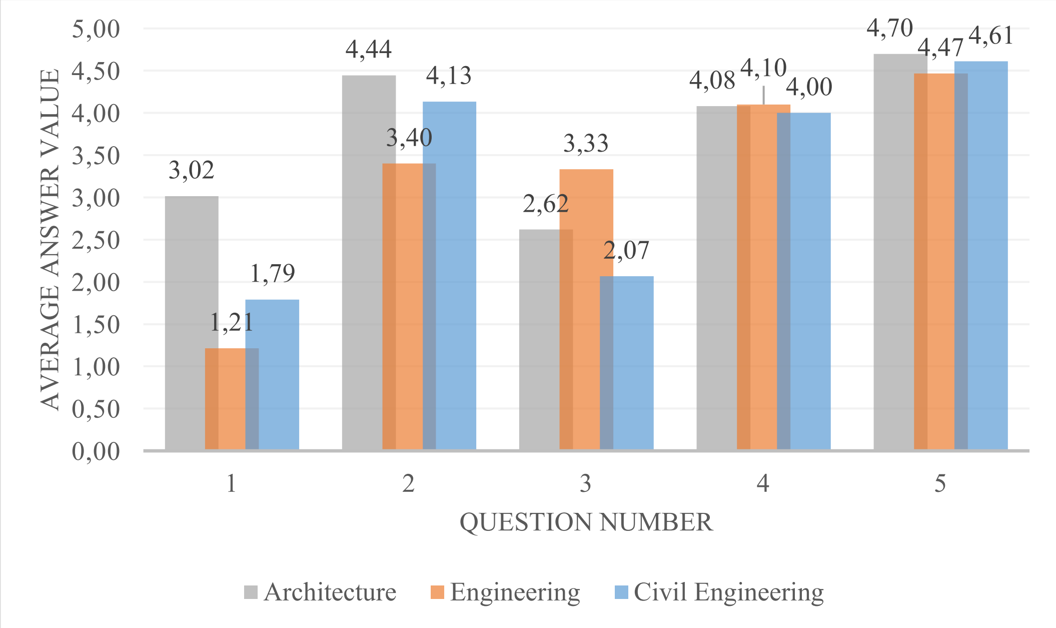

Figure 3. Results of examinees' questionnaires regarding their graduate study program

Although students of both architecture and civil engineering are very good with 2D CAD tools, they significantly showed lack of knowledge in 3D CAD tools. Simultaneously, engineering students showed an average knowledge in using both 2D and 3D CAD tools. One should be aware that the results are based on students' self-evaluation, which can be further discussed, but it certainly provides insight into students' body-of-knowledge and their openness to emerging tools on a global market.

As knowledge in using CAD tools is not the most important prerequisite in working in BIM environment, as its models give an opportunity to simulate planning, design, construction, and operation of a facility i.e. to manage the whole life-cycle of construction project, the insight in student answers 4 and 5 shows they are aware of the multi-diciplinarity of projects. Such gives hope, because this goes in hand with BIM implementation prerequisites.

Student answers and comments from AEC industry experts give insight into BIM awareness and education in BIM, suggesting possibilities for BIM implementation into lecturing plans and programs. Alternatively, whether universities can implement BIM in their study program remains the big question. Such could be a future research direction resulting with implementation possibilities that would ultimately lead to the upgrade of basic AEC knowledge with computer-generated n-dimensional models, consequently improving AEC industry.

5. Conclusions

The main goal of this paper was to identify the level of BIM awareness and education among students of graduate study programs in the architecture, engineering, and civil engineering fields at four universities in Croatia (Rijeka, Zagreb, Split, and Osijek). Using a web-based questionnaire as well as personal questioning, a total number of 245 questionnaires were collected, analyzed, and compared among universities.

This preliminary research reveals that students of graduate study programs gain similar sets of knowledge and competencies in AEC field regardless of the university environment. Also, they developed a comprehension that cooperation and mutual recognition of professional knowledge and skills of all AEC participants is important for project success. Such shows a good prerequisite for BIM implementation in the future. These results are good indicators and can serve as the starting point for BIM implementation in the future as it is formally required by EU Directive.

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References

Barison, M.B.; Santos, E.T. (2010), "BIM teaching strategies: an overview of the current approaches", Proceedings of the International Conference on Computing in Civil and Building Engineering, 30 June – 2 July 2010, Nottingham, UK, pp. i1-i7.

Cao, D.; Li, H.; Wang, G.; Huang, T. (2017), "Identifying and contextualizing the motivations for BIM implementation in construction projects", International Journal of Project Management, Vol. 35 No. 4, pp. 658-669.

Directive 2014/24/EU of the European Parliament and of the Council of 26 Feb 2014 on public procurement and repealing Directive 2004/18/EU, Official Journal of the European Union, L94(57), pp. 65-242, Luxembourg.

Dodge Data & Analytics Smart Market Report (2015), Measuring the impact of BIM on Complex Buildings, Dodge Data & Analytics, Bedford.

Howard, R.; Restrepo, L.; Chang, C-Y. (2017), "Addressing individual perceptions: An application of the unified theory of acceptance and use of technology to building information modelling", International Journal of Project Management, Vol. 35 No. 2, pp. 107-120.

Kolarić, S.; Pavlović, D.; Vukomanović, M. (2015), "Developing a methodology for preparation and execution phase of construction project", Organization, Technology and Management in Construction: An International Journal, Vol. 7 No. 1, pp. 1197-1208.

Kovačić, I.; Filzmoser, M.; Kiesel, K.; Oberwinter, L.; Mahdavi, A. (2015a), "BIM teaching as support to integrated design practice", Građevinar, Vol. 67 No. 6, pp. 537-546.

Kovačić, I.; Vasilescu, D.; Filzmoser, M.; Suppin, R.; Oberwinter, L. (2015b), "BIM in teaching – lessons learned from exploratory study", Organization, Technology and Management in Construction: An International Journal, Vol. 7 No. 3, pp. 1358-1366.

Kymmell, W. (2008), Building Information Modeling: planning and managing construction projects with 4D CAD and simulations, McGraw Hill, New York.

Macdonald, J.A. (2012), "A framework for collaborative BIM education across the AEC disciplines", 37th Annual Conference of Australasian University Building Educators Association (AUBEA), 4-6 July 2012, Sydney, Australia, pp. 223-230.

McGraw-Hill Construction Smart Market Report (2010), The business value of BIM in Europe, McGraw-Hill Construction, Bedford.

Peterson, F.; Hartmann, T.; Fruchter, R.; Fischer, M. (2011), “Teaching construction project management with BIM support: Experiences and lessons learned”, Automation in Construction, Vol. 20, pp. 115-125.

PMI (2013), A guide to the project management body of knowledge (PMBOK guide), 5th edition, Project Management Institute Inc., Newtown Square.

Salleh, H.; Fung, W.P. (2014), “Building Information Modelling application: focus-group discussion”, Građevinar, Vol. 66 No. 8, pp. 705-714.

Travaglini, A.; Radujković, M.; Mancini, M. (2014), “Building information modelling (BIM) and project management: a stakeholdres perspective”, Organization, Technology & Management in Construction: An International Journal, Vol. 6 No. 2, pp. 1058-1065.

Tsai, M.H.; Wu, C.H.; Md, A.M.; Fan, S.L.; Kang, S.C.; Hsieh, S.H. (2010), “Experiences using building information modelling for a construction project”, Proceedings of the International Conference on Computing in Civil and Building Engineering, 30 June – 2 July 2010, Nottingham, UK, pp. 183-189.

Von Both, P. (2013), “Implementing BIM in the German Architecture, Engineering and Construction Market – A Survey about the Potentials and Barriers”, Journal of Civil Engineering and Architecture, Vol. 7 No. 7, pp. 812-820.

Academic Teaching of BIM in Germany

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Abstract:

Building Information Modeling (BIM) becomes increasingly established in the construction industry. Accordingly higher education institutions (providing architecture, civil engineering and related degree programs) have to adapt adequate BIM modules to their curriculum so that future young professionals learn not only how to use but also how to implement, shape and control BIM processes in professional life.

In the first part of the paper "Academic teaching of BIM in Germany" the **state of BIM** in 2017 and the **development of BIM** in academic teaching in Germany within the last two years is presented. In 2015 only 28 out of 69 investigated institutions (about 40 %) provided BIM modules, since then the number has risen up to 41 institutions (about 60 %). In addition to that further topics for instance the distinctions between universities and universities of applied sciences as well as architecture and civil engineering degree programs are examined.

In the second part of the paper a **target state** of BIM learning contents at higher education institutions is defined. An examination reveals the **current state** at German higher education institutions so that the gap between the target and current state is unveiled. One of the main results is, even if multiple involved parties require practicing of new work and communication processes while working on BIM projects in interdisciplinary teams, it is still underrepresented in academic teaching of BIM.

Keywords: *BIM; Academic teaching; Curriculum; Learning contents; Universities in Germany*

1. Introduction

"Even though BIM is becoming widely adopted in the construction industry, the lack of individuals with BIM skills and knowledge is a key issue in effectively utilizing BIM" (Lee and Hollar, 2013). The implementation of BIM changes not only the requirements on technical skills but also the whole work and communication processes as well as the understanding of job profiles (Liebchen, 2014). As a connector between students and the construction industry, higher education institutions need to implement BIM in their curriculum to support their students to meet the new requirements (Khorrami and Heins, 2015; Lee and Hollar, 2013).

The aim of the research is to present the state of the quantitative spread of academic teaching of BIM in Germany. Furthermore disparities between the current and target state of BIM

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learning contents and consequently the action required at higher education institutions are shown.

2. Research process and methods

The research process is divided into two work packages. In **Work package I** general information and figures about the quantitative spread of BIM in academic teaching in Germany are examined. Therefor figures of 2015 to 2017 are compared concerning the number of institutions offering BIM, the differences between universities and universities of applied sciences, the number of compulsory and elective modules and the differences between architecture and civil engineering degree programs.

In **Work package II** the actual learning contents of BIM are shown. The goal is to examine the focus of offered BIM modules and point out, in what extend German higher education institutions meet the requirements. First the target state of BIM learning contents in academic teaching needs to be defined. Afterwards an examination of the current state of existing learning contents in different higher education institutions needs to be accomplished. On this basis the gap between the target and current state can be shown, to highlight the fields where action is required. Finally recommendations for higher education institutions are given (see figure 1).

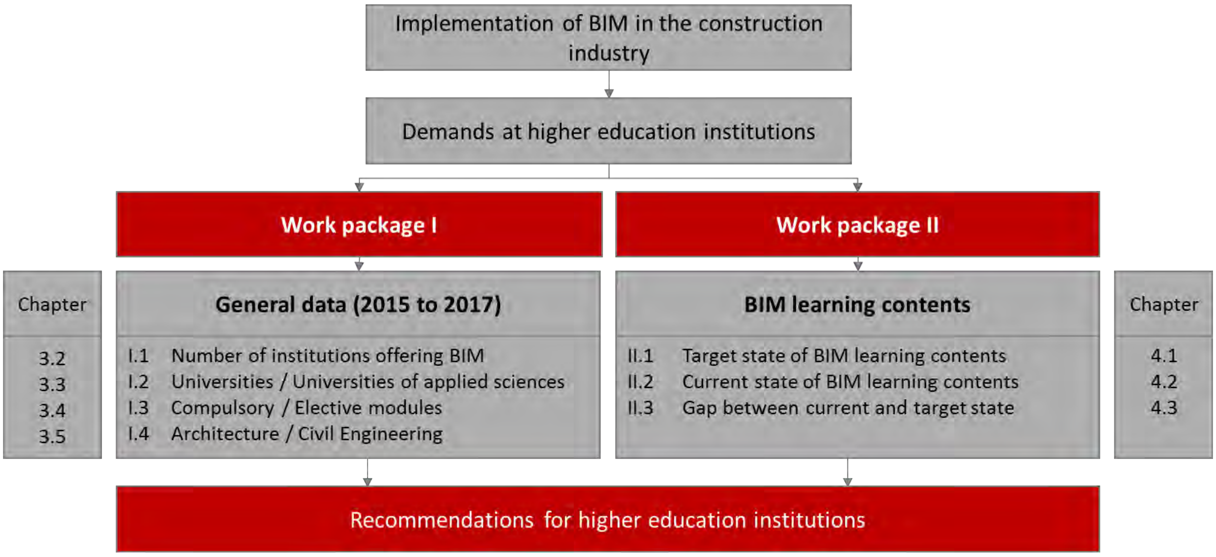

Figure 1. Research process

Following the research method of both work packages is presented. To depict not only the state of academic teaching of BIM but also the development, a **longitudinal research design** is chosen. This permits to study the changes and progress in academic teaching of BIM (Baur and Blasins, 2014). Therefor the first research was accomplished in 2015 while the second research was finished in 2017. The selected research method is a **nonreactive quantitative method**, which implies no interference with those being studied. The nonreactive quantitative method for this research is a **content analysis of process-produced data**. This involves all data which are produced by public and private organizations within the scope of their duties and not only for academic usage (Diaz-Bone and Weischer, 2015).

The process-produced data which are examined for this paper include the websites of the 69 higher education institutions in Germany which offer architecture and civil engineering degree programs. Especially the curriculums, module descriptions of offered degree programs and additional information about the modules, provided by the higher education institutions on their websites, are investigated

To accomplish a systematic and replicable content analysis a **coding scheme** (Diaz-Bone and Weischer, 2015), on the basis of the research questions, needs to be developed for each work package. The coding scheme (keywords) for work package I is based on the subdivision of universities and universities of applied sciences, compulsory or elective modules as well as architecture and civil engineering degree programs.

The coding scheme (keywords) for work package II is based on the target state of BIM learning contents (developed in chapter 4.1, figure 7). For each subdivision a list of keywords is created to scan the process-produced data. Afterwards the data are collected and analyzed.

3. Work package I – General data of BIM in academic teaching (2015 to 2017)

3.1 The higher education system in Germany

In Germany exist 427 state accredited higher education institutions which can be divided into three types: universities, universities of applied sciences and colleges of art, film and music (Deutscher Akademischer Austauschdienst e. V.). In this paper only the first two types of institutions are considered. While “universities offer strong theoretical and academically-oriented degree programs” (Deutscher Akademischer Austauschdienst e. V.), universities of applied sciences are practice-oriented and impart the skills for “real-world requirements of professional life” (Deutscher Akademischer Austauschdienst e. V.).

Out of the 427 higher education institutions in Germany, 69 provide architecture and/or civil engineering degree programs. Among these 69 institutions 21 are defined as universities and 48 as universities of applied sciences.

3.2 BIM at higher education institutions

In 2015 BIM is implemented in the curriculum of 28 higher education institutions (about 40 %). The learning contents of the offered modules is fluctuating (see chapter 4). Out of these 28 higher education institutions 11 are defined as universities and 17 as universities of applied sciences (cf. Khorrami, 2015, University of Wuppertal, comparable results). The development over the last two years shows that BIM becomes more and more implemented in academic teaching. In 2017 already 41 higher education institutions (about 60 %) provide one or more BIM modules for their students, whereby 15 are defined as universities and 26 as universities of applied sciences (see figure 2).

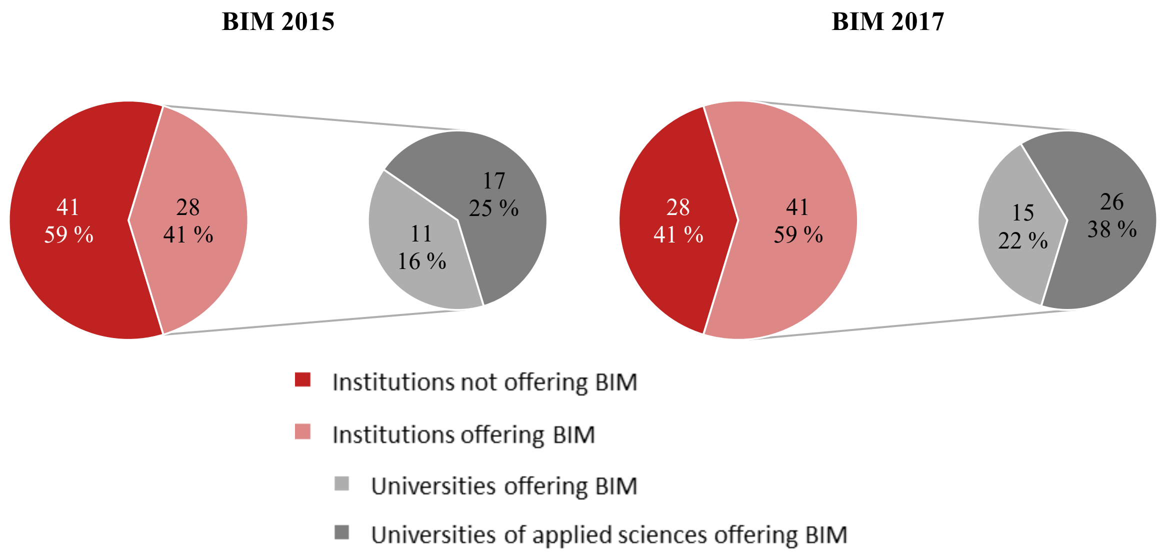

Figure 2. Development of BIM at higher education institutions (2015 to 2017)

The total number of offered BIM modules depends on the respective institution. While most institutions just offer one to two BIM modules, some provide several modules with different focuses (Khorrami, 2015). While the number of institutions offering BIM has risen from 28 to 41 from 2015 to 2017, the number of offered BIM modules has almost doubled (36 to 67). On average the intensity (BIM modules per institution) increased from 1.3 (36/28) to 1.6 (67/41) modules per institution (see figure 3).

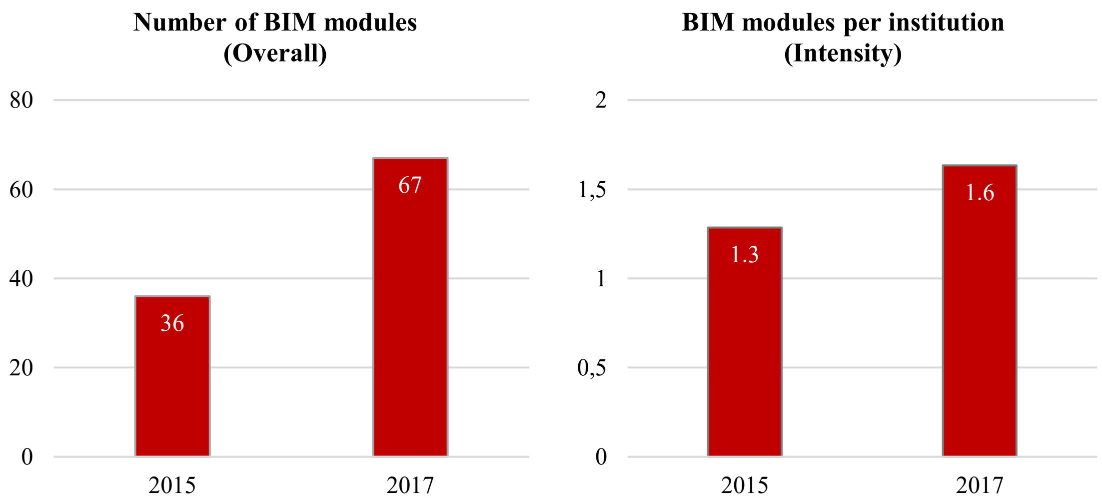

Figure 3. Number of BIM modules overall and number of BIM modules per institution (2015 to 2017)

3.3 *Universities and universities of applied sciences*

While in 2015 only 11 out of 21 (52 %) universities offer BIM to their students, in 2017 already 15 out of 21 (71 %) universities provide BIM modules. At universities of applied sciences the spread is significantly lower. While in 2015 only 17 out of 48 (35 %) universities of applied sciences offer BIM modules, in 2017 at least 26 out of 48 (54 %) provide BIM in different intensities (see figure 4).

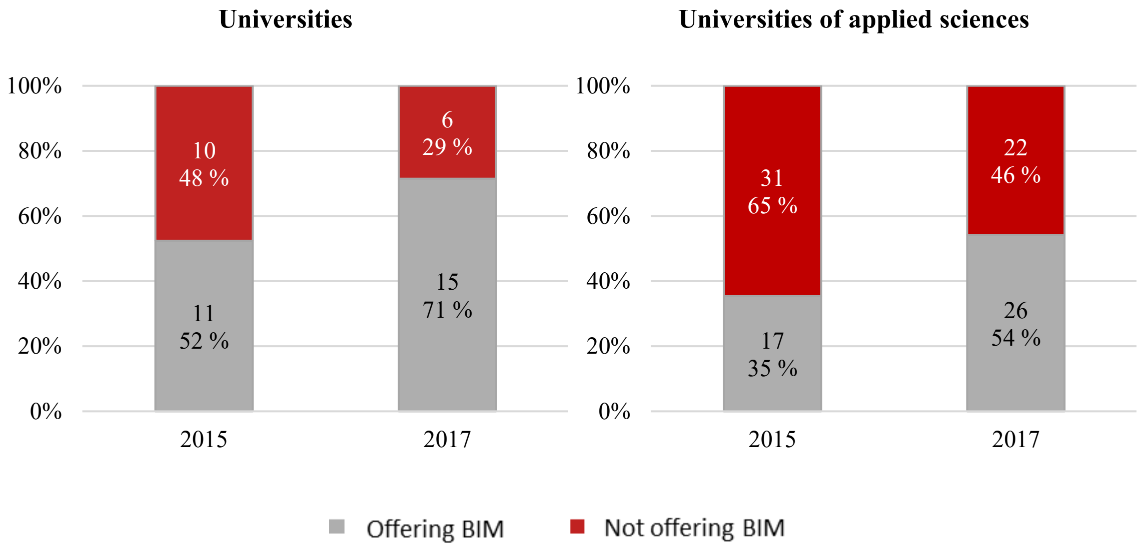

Figure 4. Development of BIM at universities and universities of applied sciences (2015 to 2017)

3.4 *Compulsory and elective modules*

The required information for the following analysis is not offered by all institutions so that only 33 out of 67 BIM modules are evaluated. Out of these modules only 27 % are compulsory modules while 73 % are elective modules, which students can choose on their own interests (see figure 5).

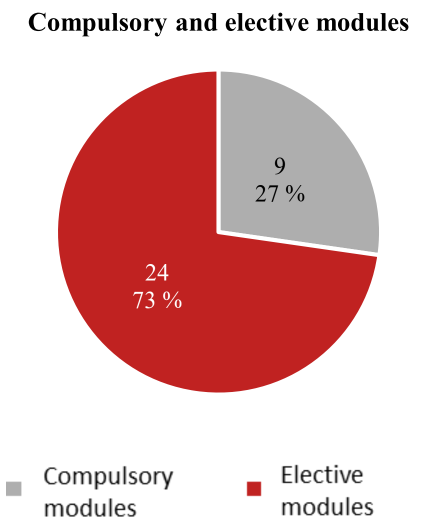

Figure 5. Compulsory and elective BIM modules (2017)

One of the reasons that higher education institutions mostly just offer elective modules might be the effort it takes to introduce a new compulsory module in an existing degree program. Depending on the higher education institution and their respective regulations the establishment of a new module may lead to a change of the examination regulations, which may be fairly time consuming. Because of that it is often easier to introduce an elective module, even if this means that not all students obtain necessary BIM learning contents.

3.5 Architecture and civil engineering degree programs

Furthermore the discrepancy between architecture and civil engineering degree programs is remarkable. In 2017 only one third (22 out of 67) of the offered BIM modules is for architects and about two thirds (45 out of 67) are offered within the scope of civil engineering degree programs (see figure 6). This reflects the situation in the construction industry. Although architects have a large impact on implementing BIM, they are skeptical, partly even refusing towards BIM. One of the reasons, which is frequently stated by architects is that BIM threatens the process of creative planning (Pilling, 2015). In addition to that questions as authorship, liability and insurance are discussed critically and hamper the development of BIM (Ettinger-Brinckmann, 2016).

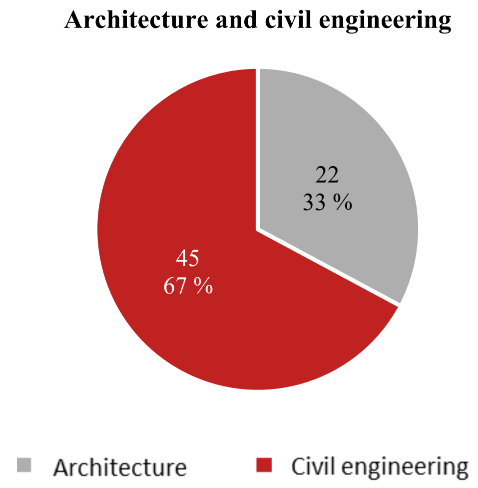

Figure 6. BIM in architecture and civil engineering degree programs (2017)

3.6 Results – work package I

As BIM is becoming increasingly important to the construction industry, over the last two years (2015 to 2017) a huge development regarding academic teaching of BIM took place at higher education institutions (figure 1).

Nevertheless, in figure 2 it is shown that universities of applied sciences need to increase the number of BIM offers to justify their reputation as practice-oriented institutions. But also universities may have to enhance the number of BIM offering institutions to enable future young professionals to implement BIM in the construction industry.

For this it also is decisive that all students get the BIM training they need for their future career. It is most likely that “students with relevant BIM knowledge and skills will have a competitive edge in the current job market” (Lee and Hollar, 2013). To ensure that all students have the best chances on the job market it could be reasonable to offer at least one compulsory BIM module at each higher education institution (figure 3).

In figure 4 it is depicted that especially architecture degree programs need to increase their number of adequate BIM lectures for their students, particularly as they have a key role in BIM processes.

4. Work package II – BIM learning contents

4.1 Target state of BIM learning contents

To analyze in what extend German higher education institutions meet the set requirements, regarding BIM learning contents, the target state needs to be defined. Therefor three sources are considered:

- BIM organizations,
- literature and
- the construction industry.

In Germany multiple organizations, like *BuildingSMART e.V.*, *Planen-Bauen 4.0* and the *5D Initiative*, are working on the implementation of BIM in the construction industry. In addition to that especially the *German Association of Computing in Civil Engineering (GACCE)* defined recommendations on which learning contents should be provided at higher education institutions (GACCE, 2015).

In the literature the most discussed problem concerning BIM learning contents is that BIM modules, provided so far, mainly focus on using BIM capable software. In contrast the imparting of new work and communication processes, which are vital for working as a part of a BIM project, is being neglected (Khorrami, 2015; Khorrami and Heins, 2015; Maaß, 2016; Pilling, 2016).

This allegation is being supported by requirements set by the construction industry. A study of the Karlsruhe Institute of Technology (KIT) encompasses how the construction industry rates the BIM qualification of young professionals. Surveyed were the following parties of the construction process: public and private clients, planning teams (e.g. architects, engineers), construction teams (e.g. building contractors) and facility managers. In the results it is shown that the work and communication process skills of young professionals are rated poor compared to their IT-skills (Both et al., 2013).

The gathered learning contents can be divided into theoretical and practical lectures. The **theoretical lectures** contain basics, e.g. fundamental knowledge about the topic as well as the introduction of job profiles which emerge out of using BIM. In addition to that technological knowledge needs to be imparted. This includes object-based parametric modeling, data exchange and management and the scope of various BIM tools. The third part are processes which change while working on a BIM project. This encompasses changing work and communication processes and modified responsibilities of the involved project parties. Moreover it includes difficulties regarding the construction law and contractual characteristics. At last the fields of application, which can be improved by using BIM, need to be demonstrated e.g. calculation, tendering or scheduling.

The **practical lectures** can be divided in two parts. First the technological part where the application of BIM capable software is taught. The second part includes participation in an interdisciplinary team were students can experience the changed work and communication processes during their own project. An overview of these learning contents is given in figure 7.

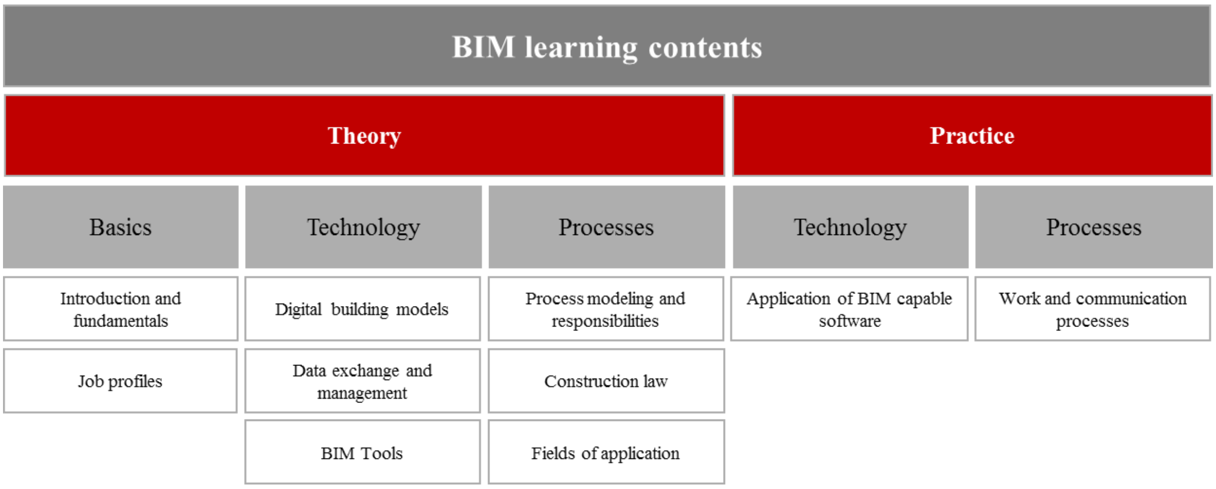

Figure 7. Target state of BIM learning contents

4.2 Current state of BIM learning contents

Based on the learning contents the coding scheme of the content analysis for work package II is developed. For each subdivision a list of keywords is gathered. On the basis of this coding scheme the process-produced data (websites of higher education institutions) are scanned. The examination reveals the current state where higher education institutions focus on while teaching BIM. The percent values refer to the number of BIM offering institutions and not to the total number of offered BIM modules (figure 8).

It has to be taken into account that on the one hand the chosen coding scheme and on the other hand the provided information by the higher education institutions (process-produced data) have an essential impact on the results of the examination. It can be expected that the learning contents, which are presented on the websites, may differ from the actual teaching contents. This may lead to a slight variation of the results. Nevertheless, it can be assumed that the overall trend is depicted by the results.

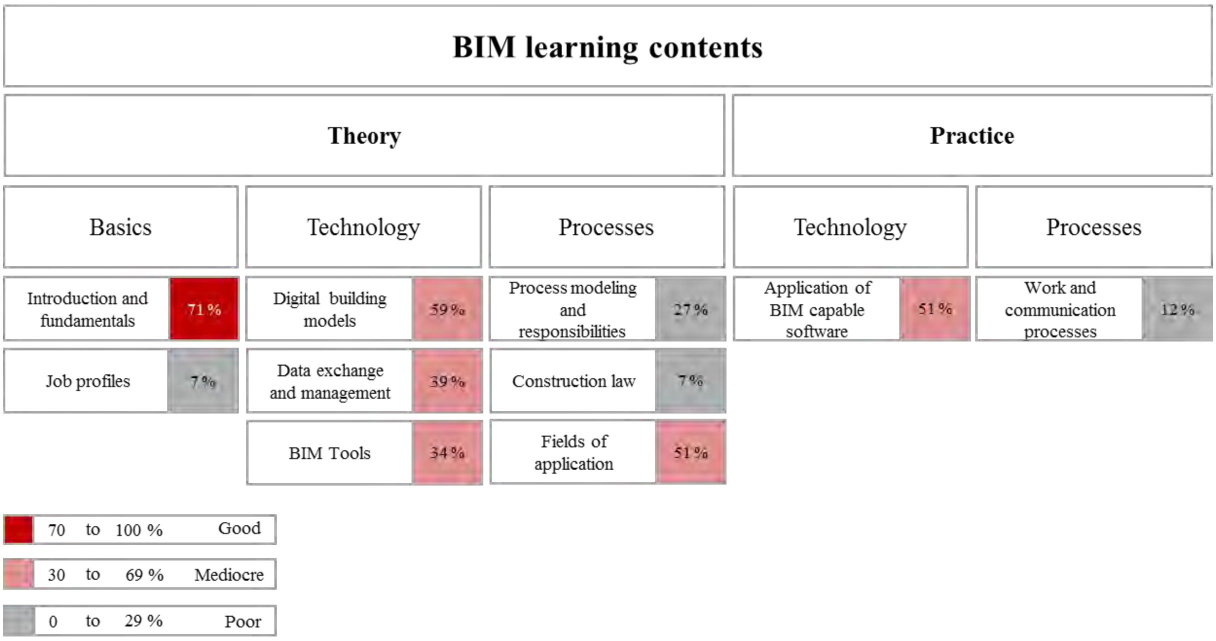

Figure 8. Current state of BIM learning contents in Germany (2017)

The topics, which higher education institution focus on, are divided into three groups depending on how many higher education institutions offer the respective content. Topics are rated as good if at least 70 % of the examined higher education institutions offer the particular topic, with 30 to 69 % the topics are rated mediocre, with less than 30 % they are rated as poor.

4.3 Gap between current and target state

In this paper only the results for BIM learning contents in 2017 are shown. Additional results for 2015 point out that the focus of the higher education institutions did not change considerably during the last two years.

While only one topic, introduction and fundamentals, is rated as good, five topics are classified as mediocre:

- Digital building models,
- Application of BIM capable software,
- Fields of application,
- Data exchange and management and
- BIM Tools.

Topics which are treated poor at higher education institutions are:

- Process modeling and responsibilities,
- Work and communication processes,
- Job profiles and
- Construction law.

Remarkable is that especially modules, where the work and communication processes are taught in interdisciplinary working groups, are not very common at German higher education institutions.

Since BIM has been longer practiced and taught in other countries, it is highly recommended to consider international education concepts as well (Pilling, 2016). In the USA higher education institutions started to implement BIM concepts in 2002. Now there can be found three teaching concepts: single-course concepts where they provide modules for just one discipline, interdisciplinary concepts where they offer modules for two or more disciplines, and distance collaboration where they cooperate with distance schools to offer modules for two or more disciplines (Barison and Santos, 2010).

A possible reason, why German higher education institutions usually just offer single-course concepts, is the high competitive pressure between higher education institutions or departments of one institution which may prevent interdisciplinary concepts and distance collaboration (Khorrami and Heins, 2015).

4.4 Results – work package II

The gap between the target and current state regarding BIM learning contents at higher education institutions reveals that there is a demand for action. Not only topics which are treated poor, for instance process modeling and responsibilities as well as work and communication processes but also topics which are classified as mediocre, e.g. BIM tools as well as data exchange and management, need to be adapted into the curriculum of more institutions.

Especially the academic teaching of work and communication processes in interdisciplinary groups, which is not only discussed in literature but also required by the construction industry, should be provided by higher education institution. As the competitive pressure between higher education institutions seems to prevent distance collaboration, particularly higher education institutions, which already have corporate academic training of architects and civil engineers and related degree programs, should take advantage of this benefit and provide interdisciplinary modules (Liebchen, 2014).

5. Summary

In the first part of the paper it is depicted that academic teaching of BIM in Germany had a remarkable development between 2015 and 2017. The number of higher education institutions offering BIM modules has risen from about 40 % up to almost 60 %. The intensity at this period has risen from 1.3 to 1.6 offered modules per institution. The distinction between universities and universities of applied sciences shows that in 2017 already 71 % of the universities and only 54 % of the universities of applied sciences provide BIM modules to their students. In addition to that it is noticeable that two thirds of the offered BIM modules are embedded in civil engineering degree programs and only one third are offered to architects.

The examination shows that the total number of BIM offering institutions, especially with reference to universities of applied sciences, needs to be increased. In addition to that each institution should offer at least one compulsory module instead of offering elective modules to prepare all students for changing processes in the construction industry. Further the higher education institutions need to ensure that future young professional are able to implement, shape and control BIM processes and as a consequence can contribute to the development of the construction industry. Moreover particularly architects who hold a key role in BIM processes need to increase offered BIM modules to their students.

In the second part of the paper the gap between the target and current state regarding the learning contents of provided BIM modules is presented. The focus differs from institution to institution and also from module to module. Most of the time the modules focus on fundamental knowledge, digital building models, fields of BIM application and the use of BIM capable software.

Nevertheless, working within a BIM project involves interdisciplinary team work and new working and communication processes. These changes in the construction industry are preferably taught in interdisciplinary groups were students experience the new processes during their own project. This learning concept is frequently discussed but still relatively rare spread at German higher education institutions. Only 12 % of the higher education institutions offer this kind of module to their students. This shows that there is still a high potential of development in academic teaching of BIM at higher education institutions in Germany.

References

Barison, M. B., Santos, E. T. (2010), "BIM teaching strategies: an overview of the current approaches", paper presented at the International Conference on Computing in Civil and Building Engineering, Nottingham University, United Kingdom, available at: http://www.engineering.nottingham.ac.uk/icccbe/proceedings/pdf/ pf289.pdf (accessed 1 February 2017).

Baur, N., Blasins, J. (2014), Handbuch Methoden der empirischen Sozialforschung, Wiesbaden, Springer Fachmedien.

Both, P., Koch, V., Kindsvater, A. (2013), "BIM - Potentiale, Hemmnisse und Handlungsplan - Analyse der Potentiale und Hemmnisse bei der Umsetzung der integrierten Planungsmethodik", Frauenhofer-IRB-Verlag, Stuttgart, available at: http://www.mittelstand-digital.de/MD/Redaktion/DE/PDF/bim-potentiale-hemnisse -und-handlungsplan,property=pdf,bereich=md,sprache=de,rwb=true.pdf (accessed 1 February 2017).

Deutscher Akademischer Austauschdienst e. V., "Types of Universities", available at: https://www.study-in.de/en/plan-your-studies/types-of-universities_26607.php (accessed 23 March 2017).

Diaz-Bone, R., Weischer, C. (2015), Methoden-Lexikon für die Sozialwissenschaften, Wiesbaden, Springer Fachmedien.

Ettinger-Brinckmann, B. (2016), "BIM: Architekten an zentraler Stelle", Deutsches Architektenblatt, available at: http://dabonline.de/2016/02/01/bim-architekten-an-zentraler-stelle-standpunktsynchronisierung/ (accessed 6 April 2017).

GACCE (2015), "Arbeitskreis Bauinformatik – Building Information Modeling (BIM)", available at: http://gacce.de/bim.php (accessed 19 January 2017).

Khorrami, N. (2015), "Implementierung der Methode BIM in der Aus- und Weiterbildung in Deutschland", in 26. BBB-Assistententreffen - Fachkongress der wissenschaftlichen Mitarbeiter der Bereiche Baubetrieb, Bauwirtschaft und Bauverfahrenstechnik ; 17.–19. June 2015 proceedings of the BBB-Assistententreffen in Stuttgart, Germany, pp. 95–104.

Khorrami, N., Heins, C. (2015), "Generation BIM - Von BIM in der Ausbildung, Arbeitspaketen und gemeinsamen Nennern" BIM - Building Information Modeling, November 2015, pp. 33–35.

Lee, N., Hollar, D. A. (2013), “Probin BIM Education in Construction Engineering and Management Programs Using Industry Perceptions” paper presented at the 49th ASC Annual International Conference, 2013, San Luis Obispo, USA, available at: http://ascpro.ascweb.org/chair/paper/ CEUE44002013.pdf (accessed 1 February 2017).

Liebchen, J. H. (2014), “Building Information Modeling (BIM) - Eine Herausforderung an die zeitgemäße Ausbildung von im Bauwesen tätigen Ingenieurinnen und Ingenieuren“, available at: https://opus4.kobv .de/ opus4-htw/files/266/Liebchen+-+BIM+Ausbildung+HTW.pdf (accessed 1 February 2017).

Maaß, C. (2016), “BIM - Qualitätsverbesserung durch integrative Planung - Von der Qualität in Planung an sich und Planung in BIM sowie von der Offenheit der Projektbeteiligten“, BIM - Building Information Modeling, November 2016, pp. 59–62.

Pilling, A. (2015), “BIM in der Ausbildung - Ungewohnte Nähe zum Fachingenieur - Von interdisziplinärem Lernen, fachübergreifender Ausbildung und von Vorbehalten“, BIM - Building Information Modeling, November 2015, pp. 36–38.

Pilling, A. (2016), “Best Practices in der BIM Ausbildung - Von einem besseren BIM-Verständnis und zukunftsorientierte BIM-Ausbildung“, BIM - Building Information Modeling, November 2016, pp. 63–65.

Use of the BIM Platform in Teaching Contents of Environmental Comfort

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Abstract:

With the unfolding worldwide trend of BIM implementation, there is a natural linkage between the adequacy of professionals and the new methodology of work, which necessitates the training of specialised labour. Since universities have the role of forming the new generation of the AEC industry (Architecture, Engineering and Construction), it becomes inevitable to include BIM implementation on the course curriculum. The purpose of this article is to identify the relationship between BIM software and the subjects taught in the area of environmental comfort, to subsequently draw up proposals for the incorporation of the use of BIM technology in the syllabus for environmental comfort. This study is part of a Masters research with partial results, and uses a documentary, library review, and case study as a basis. The results show that almost all of the BIM work elements of building performance energy analysis and simulation approach are taught in the syllabus of environmental comfort. As a proposal to incorporate BIM into teaching, it is argued that the BIM platform can be the means by which students learn the concepts of environmental comfort, contributing to facilitate the practical exemplification of the theme, being the conciliation of theory and practice as the best way to increase student learning. It is believed that the proposal within this research can be applied to any degree in Architecture, since the proposal is to encourage teachers to incorporate new construction technologies in the discipline, and not change the composition of the curriculum.

Keywords: *BIM; teaching; enrivonmental comfort; Architecture*

1. Introduction

The construction industry is undergoing transformations in the design and construction process and the implementation of Information and Communication Technologies applied to construction (TICs) has been contributing to overcome obstacles faced by it (Kassem and Amorim, 2015). Among the building technologies, BIM (Building Information Modeling) is one of the most discussed themes in Architecture and Civil Engineering both in academic publications and in professional practice (Santos and Barison, 2011; Castro *et al*., 2011; Kassem and Amorim, 2015).

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The BIM methodology, which emerges as an alternative to the CAD (Computer Aided Design) methodology, deals with a new approach to the design, construction and management of facilities. According to Eastman *et al.* (2014), is one of the most promising developments in the AEC-related industry, and does not refer to a type of software, but a human activity that involves extensive changes in the construction process. The same author adds that the BIM methodology is not the conversion of 2D to 3D, but a new design process based on a parameterized 3D model that contains specifications of the components of all the projects involved in the building. BIM manages and produces construction data throughout its entire life cycle, allowing for better building performance (Eastman *et al.*, 2014).

In an international context, according to Kassem and Amorim (2015), in the United Kingdom, France, the Netherlands, Finland and Norway there is a great state incentive to invest in strategies for implementing the BIM platform, since the results are more consistent and there is a positive economic impact Construction. Likewise in Brazil, Castro *et al*. (2011) states that "in recent years, the number of companies and professionals who have invested in the knowledge and implementation of this new technology has been growing, especially among architectural offices and builders."

With the unfolding of the worldwide trend of BIM implementation, the Brazilian construction industry goes through a transition phase from the traditional CAD model to this platform. With this, there is a natural linkage of the adequacy of the professionals to the new working methodology, who have an understanding in all the processes of design, construction and operation, to the success of a BIM model implementation (RUSCHEL *et al.*, 2013). In order to conduct successful implementation, it is necessary to train skilled labour so that a business can benefit from the potential of BIM.

The authors Ruschel, Andrade and Morais (2013), Santos and Barison (2011), Delatorre (2014), Godoy *et al.* (2013), Eastman *et al*. (2014) and Menezes (2011) agree that universities have the responsibility of forming the new generation capable of implementing BIM in the AEC industry, since a new type of professional is emerging in the market. Eastman *et al*. (2014) states that universities have a fundamental role in contributing to the formulation of positions that value new design processes and building construction, which are essential aspects for the implementation of BIM in undergraduate studies.

Building Information Modelling is a technology to be explored that is being adopted by the AEC industry and offers such interesting potential that it would be important for the Architecture and Urbanism course to have this potential investigated in the syllabus of different undergraduate courses. There are initiatives and publications about teaching BIM, but little is said about BIM in teaching. In other words, there are few publications on how teachers can incorporate the potentialities and possibilities of the platform in teaching course content and this article begins a research on this subject. Among the several areas of architecture and urbanism curriculum to be explored, for this article the area of environmental comfort was chosen. In future work, research will be carried out on other areas of the curriculum.

In this context, this research discusses the BIM platform in the teaching of contents treated in the area of environmental comfort of the undergraduate Architecture and Urbanism course. The intention of this study was to investigate how the BIM platform can support the teaching of environmental comfort in the context of Architecture and Urbanism degrees in Brazil. The main objectives were: (a) to identify the relationship between BIM software and the subjects taught in the area of environmental comfort; (b) to draw up proposals for the incorporation of the use of BIM technology in the syllabus for environmental comfort.

2. Methodological Procedures

The methodological procedure of this research is qualitative in its approach to the problem, and exploratory in respect of the related objectives. Considering the theoretical procedures, three approaches were adopted: documentary research, case study and bibliographic research.

As a starting point, documentary research was undertaken analyzing the legislation establishing guidelines and rules for Brazilian Universities, also denominated “Higher Education” in Brazil (IES), to identify the areas of study that constitute the degree in Architecture and Urbanism. Among the areas mentioned, environmental comfort was highlighted as one of the main subjects.

Next, a Brazilian university was chosen as a case study and the disciplines of environmental comfort were highlighted in the curriculum of that university. The syllabus of the subjects of environmental comfort were analyzed and keywords were highlighted with the purpose of identifying the contents to be taught in these disciplines. These keywords were posteriorly used to identify the relationships between BIM software and environmental comfort contents.

After, the research is based on bibliographic research on BIM software to relate the possibilities of the BIM platform to the contents of the disciplines of environmental comfort.

Finally, proposals were made to incorporate the BIM platform into the environmental comfort field of the Architecture and Urbanism course, in order to verify if BIM can support lecturers in teaching the related content.

The chosen case study was the Architecture and Urbanism course of the Federal University of Rio de Janeiro (FAU-UFRJ). The criteria used for selection were that it was "the oldest university course in architecture in Brazil" (FAU-UFRJ, 2016a) and is the third ranked Architecture and Urbanism course in the Folha University Ranking (RUF) 2016. This ranking classifies institutions and courses according to market evaluation, lecturers and teaching methodology, numbers of lecturers with doctorate and master's degrees, an evaluation based on the MEC criteria, position of each student in the National Student Performance Exam (ENADE) and teachers’dedicated capacity (Folha of São Paulo, 2017).

In this context, the sample was considered as representative of degrees in Architecture and Urbanism offered by Brazilian educational institutions since the disciplines offered are representative of other Brazilian universities. It is worth mentioning this case study is a theoretical study that took as basis the information about the curriculum of a renowned course in Brazil to investigate how it would be possible for the lecturers to incorporate BIM into the teaching of environmental comfort contents.

3. Brazilian legislation for Architecture and Urbanism courses

To begin this study, the Brazilian legislation for Architecture and Urbanism courses was researched to understand the aspects of the area of environmental comfort required of Brazilian universities.

The Brazilian Ministry of Education (MEC) is the federal body responsible for matters related to teaching. The 2010 National Curriculum Guidelines establish MEC's requirements for Architecture and Urbanism degree curricula.

The curricular extension guidelines, specified in article 6 (MEC, 2010) of National Curriculum Guidelines, are classified in three interdependent areas: academic foundational knowledge, professional knowledge and course work. Paragraph 2 (MEC, 2010, Art. 6) specifies that professional knowledge area will be structured around study of

> Theory and history of architecture, urbanism and landscaping; architecture, urbanism and landscaping; urban and regional planning; construction technology; structural systems; **environmental comfort**; restoration techniques; informatics applied to architecture and urbanism; topography.

The area of environmental comfort is determined by the guidelines (MEC, 2010, Art. 5) as: "IX - understanding of climatic, acoustic, lighting and energy conditions and mastery of the appropriate techniques associated therewith." For the purposes of this article, the above definition was used to identify the disciplines of the Architecture and Urbanism course that fit this area of knowledge for later analysis.

4. Evaluation of Environmental Comfort in Modules of the FAU-UFRJ Course

Considering environmental comfort as a parameter, analysis was undertaken in the syllabus of all disciplines of the curriculum of FAU-UFRJ to identify the subjects that fall within the definition of environmental comfort. The modules Environmental Comfort I (3^{rd} semester), and Environmental Comfort II (5^{th} semester), were found to present the characteristics of the area considered within this article (FAU-UFRJ, 2016b). Table 1 sets out the content of these modules.

Table 1. Content of the modules Environmental Comfort I & II of FAU-UFRJ (source: FAU-UFRJ, 2016b)

Module	Content	Required	Required in parallel
Environmental Comfort I	Environment, energy and architecture; Notions of thermal comfort and natural ventilation; Heat exchanges; Direct, diffuse and global solar radiation; Notions of natural and artificial lighting; Notions of acoustics; The propagation of sound (mechanical waves) in the air	Topography	Architecture Project I
Environmental Comfort II		Environmental Comfort I	Architecture Project III

Students of the module Architectural Project I, in which students study the basis of the project process, must take Environmental Comfort I simultaneously. The same is true for Architectural Project III and Environmental Comfort II. Students will thus use the knowledge acquired in Environmental Comfort I and II in their projects modules.

Although they fall in different semesters, the purpose of Environmental Comfort I and II are alike. Their contents were used to identify relationships between their associated objectives and the BIM platform. The keywords used in the search for this relationship were: (1) thermal comfort; (2) natural ventilation; (3) solar radiation; (4) natural lighting; (5) artificial lighting; and (6) acoustic.

The next section does a bibliographic research of the BIM software linked to the environmental comfort area.

5. Possibilities of BIM software

Eastman *et al.* (2014) state that linking of Building Information Modeling (BIM) and computational simulation tools allows evaluation of buildings' efficiency and environmental quality performance during initial project phases, not previously possible with traditional 2D tools, permitting the development of buildings with improved efficiency and environmental quality. The traditional method (2D tools) requires separate analysis at the end of the design process, reducing opportunities for modification and, consequently, efficiency of the building. Furthermore, the same author (2014, p.18) adds that "the ability to link the construction model to various types of analysis tools provides several opportunities to improve the quality of construction itself."

In this sense, the BIM concept, which "presupposes the existence of a set of integrated and complementary tools, capable of performing different types of operation on the single model of the building ..." (Freire *et al.*, 2012), becomes limited by additional processes during transfer: reworking is needed to transfer model data from one design software to another for computational analysis and vice versa leading to information loss. Considering the scenario above, interoperability is necessary to allow exchange of information between project designers. Eastman et al. (2014, p.65) state that interoperability "is traditionally based on the exchange of file formats".

In the BIM platform, interoperability between design software and environmental analysis of different manufacturers can be done through ifc, dxf, gbXML, among others (EASTMAN, 2014). Interoperability between files from the same manufacturer can be done by the proprietary extension. According to Cho, Bode & Alaskar (2009), the gbXML format was identified as the most accurate file format for interoperability between BIM and energy simulation programs.

There are computer simulation programs that address several areas of knowledge, however, there are few programs considered BIM, that is which allow interoperability. As such, the applications certified by BuildingSMART were analyzed, since they allow better workflow in the AEC industry. Founded in 1995, BuildingSMART is the worldwide authority for the creation and adoption of open international standards and is a neutral, open, and nonprofit international organization designed to support the adoption of BIM and meet the demands of the built environment in the digital world (BuildingSMART, 2016a).

In this research were analyzed the BIM applications classified by BuildingSMART (2016b) that approach the area of environmental comfort taught in the courses of Architecture and Urbanism. According to the BuildingSMART classification, these applications are called software of building performance energy analysis and simulation. With this, the article analyzes these certified softwares until 2016 that are IDA ICE, RIUSKA, Simergy, OpenStudio and IES-VE (BUIDINGSMART, 2016b).

It is worth mentioning that these softwares are parametric simulation tools and they use the geometric (shape, position, dimensions, etc.) and non-geometric information (material, volume, cost, etc.) contained in the BIM model to perform analyzes. In other words, these tools use BIM as information source and the information, the "I" of BIM, is very important for the platform because it is used to make decisions throughout the life cycle of the building. And in the environmental analysis stage, the information constantly migrates from the BIM model to the analysis and simulation software until the project meets the established aspects.

3.1 IDA ICE

IDA Indoor Climate and Energy (IDA ICE), belongs to the Swedish company EQUA Simulation AB. It is a simulation application for whole building and thermal indoor climate energy consumption studies seeking to optimize occupant comfort. This software provides carbon emission analysis; energy analysis; heating load and dynamic cooling calculation; thermal comfort analysis; solar penetration and shadow animation; simulation and airflow modeling for natural and mixed ventilation; thermal equilibrium and daylight factor light calculations (EQUA, 2016).

In addition, it allows daylight calculation by interfacing the Radiance™ lighting simulation tool, calculation of daylight factor and illuminance with presentation of the results in color gradation, including the possibility of showing percentage of area in relation to a limit value (EQUA, 2016).

The software provides climate information from 6,443 worldwide locations including extreme days of heat and cold per month, with values automatically adjusted to compensate for any longitudinal differences between the building and the weather station (EQUA, 2016). Analysis results are visualized through real-time 3D models and animations, as well as charts, and tables, with automatic updates for every design change. The program has extensions for ASHRAE 90.1 (beta), BIM import, boreholes (beta), ice rinks and pools (beta), and daylight (EQUA, 2016).

3.2 RIUSKA

RIUSKA was developed by the Finnish company Granlund in collaboration with Lawrence Berkeley National Laboratory, part of the US Department of Energy. RIUSKA is a thermal comfort and energy efficiency simulation software that uses BIM to calculate the thermal conditions of buildings and their spaces in different conditions of load and time (Granlund, 2016).

RIUSKA covers all thermal performance simulation requirements in the preliminary design (Granlund, 2003) and can be used to set premises' temperatures for both summer and winter. The software can also: compare internal climate quality levels, compare architectural solutions (windows, window protection, building facade solutions); compare and specify systems; analyze problematic spaces; calculate the energy consumption of buildings and building systems; and, calculate projected consumption for maintenance. In addition, it considers the structure, strength, local climate, thermal loads, hours of use, annual energy consumption, temperature variations, as well as heating and cooling needs (Granlund, 2016).

RIUSKA's simulation data can also be used for the building's life cycle data management. It is possible to import and export in IFC format, and analysis results are provided in 3D visualizations, tables and graphs (Granlund, 2003).

3.3 Simergy

Developed in a public-private partnership led by a Lawrence Berkeley National Laboratory team, Simergy is a free EnergyPlus software that addresses energy modeling needs to enable energy-efficient building design (Energy- Models, 2016).

The software creates energy models, does heating, ventilation and air conditioning system (HVAC) analysis; performance analysis; controls for natural light and ventilation; verifies local consumption; temperature and local humidity profiles; and, climate, lighting, daylight and water analysis (Simergy, 2016).

Data can be imported in several formats such as IFC, gbXML or DXF and offers the possibility of creating a model in the tool itself. Up to five alternatives can be included for the same file, thus enabling comparative analysis in early project design stages. Analysis results are provided through 3D visualizations, graphs and tables (Simergy, 2016).

3.4 OpenStudio

OpenStudio is a free open source software released in 2008 by the National Renewable Energy Laboratory (NREL), part of the US Department of Energy. This tool is a SketchUp plug-in and features a graphical interface for EnergyPlus, which offers thermo-energetic simulation, and Radiance, which performs lighting analysis (Openstudio, 2016).

This tool provides a platform for developing life cycle analysis; simulation of natural light input; and, daylight analysis (NREL, 2016); as well as envelope analysis, loads, schedules and HVAC (Openstudio, 2016). For geometry creation, the software supports the import of gbXML and IFC. Results visualization is done by browsing, plotting and comparing simulation output data (Openstudio, 2016).

3.5 IES-VE

Integrated Environmental Solutions - Virtual Environment (IES-VE), performs analysis at every stage of the project lifecycle. At conception, the software covers climate, bioclimatic and daylight analysis; solar studies; project optimization; feasibility studies and environmental impact assessment (IES, 2016).

During the project detailing process, it can perform energy modeling with comfort studies; HVAC simulation; risk and feasibility studies; computational fluid dynamics (CFD); pollutant studies; crowd movement analysis for fire evacuation and pedestrian traffic around the building; energy, carbon and cost calculation; window analysis; impact of materials and LCC / ACL; and accounts for availability of natural resources and renewable energies (IES, 2016).

In the operation phase, it is possible to perform post-occupation evaluation, monitor and verify building performance, identify operational data analysis problems, and improve operational models for retrofit information and contracting performance (IES, 2016). With a view to improving bidirectional workflow between tools, IES-VE offers free plug-ins for Revit, imports gbXML, DXF or IFC, and exports to gbXML, as well as connecting with SketchUp and Vectorworks. In addition, it allows certification verification for BREEAM, LEED, Green Star, Green Mark, QSAS / GSAS, Estidama and GRIHA (IES, 2016).

The next section lists the keywords identified from the modules Environmental Comfort I and II against the BIM software for energy performance analysis and simulation.

6. Analysis of the BIM Software and the Contents of Environmental Comfort I & II

With the information obtained on the BIM software, a comparison was made between these tools and the keywords from the Environmental Comfort modules. See Table 2. The software that offered functionality corresponding to the keywords were classified with "Yes", and where absent received "-".

Table 2. Connection between Environmental Comfort I & II content and BIM software (source: Author)

Environmental Comfort Keywords		BIM software				
		IDA ICE	RIUSKA	Simergy	OpenStudio	IES-VE
Thermal comfort		Yes	Yes	Yes	Yes	Yes
Natural ventilation		Yes	-	Yes	-	Yes
Solar radiation		Yes	-	Yes	Yes	Yes
Lighting	natural	Yes	-	Yes	Yes	Yes
	artificial	Yes	-	-	Yes	-
Acoustic		-	-	-	-	-

From the information above it can be seen that thermal comfort is considered by all five softwares, while acoustics is analyzed by none of them. In fact, there appears to be a shortage of acoustics software that work in BIM, demonstrating an area requiring development. The IDA ICE software offers the most comprehensive coverage of environmental comfort functionality using the Radiance interface, followed by IES-VE and Simergy, which do not perform artificial light analysis, and OpenStudio, which does not simulate natural ventilation. The RIUSKA software has a specific use in simulation of comfort and energy efficiency resulting in it only being classified in thermal comfort among the considered themes.

The availability of software with free and / or educational versions is an important consideration when applying the BIM platform in educational institutions. Thus, Table 3 presents the different procurement models available for the BIM softwares analyzed.

Table 3. Acquisition types and BIM software (source: Author)

Procurement Model	BIM software				
	IDA ICE	RIUSKA	Simergy	OpenStudio	IES-VE
Paid	x	x			
Free			x	x	x
Educational Version	x				

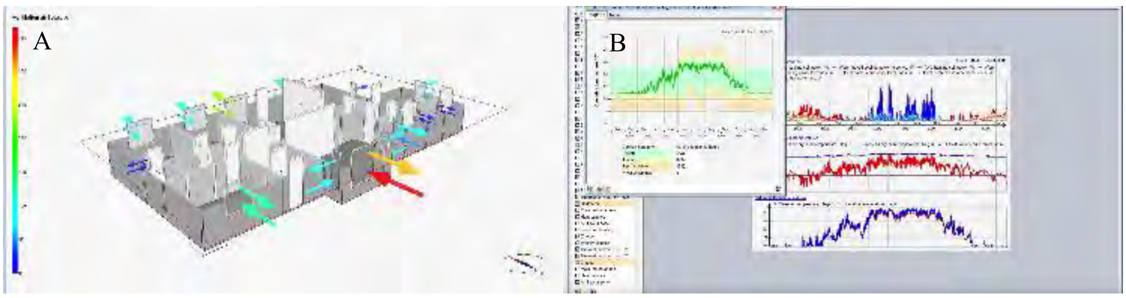
The comparison in Table 3 demonstrates that all the programs, except RIUSKA, have educational or free license versions. The absence of an educational version of RIUSKA and its offering only a specific analysis in thermal comfort make its use by lecturers difficult. Below, an explanation is provided of how BIM can be used by environmental comfort lecturers in teaching the contents of the modules mentioned.

7. Proposal for Incorporation of BIM in Environmental Comfort Modules

Information and communication technologies (ICTs), according to Paula (2015, p.11), "are present in the daily lives of people, changing the way they relate to each other and to the world." "The new space-time perspective defined by ICTs also influences the way people share, learn, and appropriate knowledge," he adds. In this context, WEF (2016) states that technology is seen as a tool that can be used as a complement to, and extension of learning, in addition to providing a more interactive experience. Therefore, taking technology to the classroom is a way to stimulate learning and facilitate content's memorability.

The research proposal seeks to change the approach to inclusion of BIM technology within environmental comfort modules, providing new experiences for lecturers and students. The BIM platform becomes the means by which students understand the concepts of environmental comfort, while maintaining the latter as the modules' focus. The potential of BIM, represented in this article by computer simulation software, can be utilized by environmental comfort lecturers through graphics, tables and three-dimensional visualizations generated by the programs. The simulation does not exclude theoretical explanations, on the contrary, the latter is fundamental for students' conceptual understanding. Thus, first the theoretical grounding is given and subsequently, analysis of the simulations is undertaken as a practical activity demonstrating what was taught through the theoretical conversations.

This way, it would be easier for students to understand the taught contents and to show different results for different project proposals, being able to exercise practical application of the theoretical contents. Through this new didactic resource, it would be possible to present images generated in the programs or manipulate the tool in the classroom in order to show results such as those pictured in Figure 1.



C

D

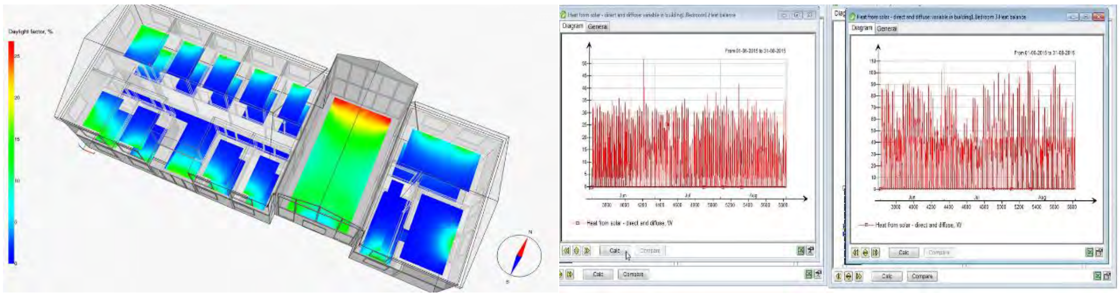


Figure 1. (A) Simulation of natural ventilation, (B) Thermal comfort chart, (C) Natural light chart; (D) Solar energy heat chart (source: EQUA, 2016)

The figure above shows some environmental comfort simulations. The same analyses can also be expressed in table form. The BIM softwares mentioned in the previous section perform thermal comfort analysis, natural ventilation, solar radiation, natural and artificial lighting, among other simulations, so that this knowledge can be used in the environmental comfort modules, though the acoustics theme still requires development on the BIM platform tools.

In addition, the use of computational simulations contributes to students developing the capacity to work with BIM. For the purposes of this study, among the skills described by Checcucci (2014, p.102), the following are of particular relevance: "the collection, processing, analysis and interpretation of data and information"; "The ability to work with [...] multimodal information"; "The ability to work in complexity, with its many variables, high degree of uncertainty and subjectivity [...]"; "The development of strategies to solve problems"; "The development of projects"; "The development of creative and innovative solutions"; "The development of critical and well-articulated thinking"; "The use of different means of expression and representation"; "The ability to develop effective communication, whether graphic, written or verbal."

In order to incorporate this technology, lecturers need to acquire skills such as understanding of BIM concepts, software training, choice of tools that best adapt to their design and teaching, as well as greater involvement with these technologies, in order to contribute to classroom learning and develop in the students the knowledge prescribed in the course outline.

As most specialized BIM programs with building performance energy analysis and simulation have free versions or educational licenses, their adoption in the academic arena is viable. Considering also that utilization of BIM provides a more dynamic model of teaching, it can be concluded that it is possible to integrate modeling and communication tools into the teaching process while also maintaining students' motivation.

8. Conclusions

Through investigation of BIM building performance energy analysis and simulation., the link has been demonstrated between environmental comfort course content and the potential offered by the BIM platform, identifying that almost all contents can be demonstrated in computational simulations. The absence of software that addresses acoustics content is however notable, this being a more complex topic than the others due to the difficulty of relating to students the often abstract concepts. The development of BIM acoustics tools will bring benefits to the academic context from the moment the theoretical and abstract contents are reconciled with design practice; it will also facilitate students' understanding, through virtual visualization of sound propagation and reverberation, and its impact on the projected environment.

The incorporation of BIM in environmental comfort contents contributes to facilitating the practical demonstration of the subject, as reconciliation of theory and practice is the best way to increase students' learning. Furthermore, this approximation of technology with the academic environment does not demand alteration of the existing curriculum, which is a significant consideration in Brazilian public institutions.

It is important to note that use of computer simulation software in environmental comfort classes is not intended to teach students to use the programs, but rather to use the outputs that these tools provide to aid classroom learning and encourage those with interest to further study these softwares.

The recommendation of this research can be applied to any degree course in Architecture and Urbanism, whether new or existing, as the proposal is to encourage teachers to incorporate new construction technologies into the discipline, not to change the institutions' curricular composition. In addition, BIM can be inserted both in the environmental comfort modules seen in this article, and in other curriculum areas, thus stimulating more dynamic teaching.

Finally, it can be noted that there is a long way to go in implementation of BIM in the teaching of graduate courses related to the civil construction sector. However, we believe that the significant steps made by the AEC industry in implementing this technology will stimulate higher education institutions to incorporate BIM in graduate teaching and, as such, the proposals of this research contribute in this respect.

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References

BUILDINGSMART. (2016a). *About buildingSMART***.** Available online: http://buildingsmart.org/about/about-buildingsmart/, Last accessed: June 2016.

BUILDINGSMART. (2016b). *All applications by category*. Available online: http://www.buildingsmart-tech.org/implementation/implementations, Last accessed: June 2016.

CASTRO, M. da F. et al. (2011). O Brasil – universidade, projetistas, arquitetos, engenheiros – está preparado para o BIM? *aU*. e. 208. Available online: http://au.pini.com.br/arquitetura-urbanismo/208/o-brasil-universidades-projetistas-arquitetos-engenheiros-esta-preparado-224289-1.aspx, Last accessed: June 2015.

CHECCUCCI, Érica de S. (2014). *Ensino-aprendizagem de BIM nos cursos de graduação em Engenharia Civil e o papel da expressão gráfica neste contexto.* Ph.D. thesis, Education University, Federal University of Bahia.

CHO, Y., BODE, T., & ALASKAR, S. (2009*). BIM-Driven Energy Analysis for Zero Net Energy Test Home (ZNETH).* The 3rd international conference on construction engineering and management, and the 6th international conference on construction project management.54-3,156

DELATORRE, V. (2014). *Potencialidades e limites do BIM no ensino de Arquitetura: uma proposta de implementação.* Master. thesis – Technological Center, Federal University of Santa Catarina.

EASTMAN, C. *et al*. (2014). *Manual de BIM: um guia de modelagem da informação da construção para arquitetos, engenheiros, gerentes, construtores e incorporadores*. Porto Alegre: Bookman, 483 p.

ENERGY-MODELS. (2016). *Simergy.* Available online: http://energy-models.com/software/simergy, Last accessed: June 2016.

EQUA. *IDA ICE*. (2016). Available online: http://www.equa.se/en/ida-ice, Last accessed: June 2016.

FAU-UFRJ - FACULDADE DE ARQUITETURA E URBANISMO DA UNIVERSIDADE FEDERAL DO RIO DE JANEIRO. (2016a). *Institucional*. Available online: http://www.fau.ufrj.br/, Last accessed: May 2016.

____. (2016b). *O curso*. Available online: http://nova.fau.ufrj.br/index.asp?n1=2&n2=ocurso, Last accessed: May 2016.

FOLHA OF SÃO PAULO. (2017). *RUF 2016.* Available online: http://ruf.folha.uol.com.br/2016/ranking-de-cursos/arquitetura-e-urbanismo/, Last accessed: January 2017.

FREIRE, M. R. *et al.* (2012). Investigação sobre ferramentas computacionais de avaliação do desempenho térmico apropriadas ao contexto BIM para aplicação em projetos de HIS. *In: XIV Encontro Nacional de Tecnologia do Ambiente Construído - ENTAC.* Juiz de Fora: pp. 3413-3418.

GODOY, V. H. *et al*. (2013). BIM: Desafios para um conceito em construção no ensino de arquitetura e engenharia. *In: XLI Congresso Brasileiro de Educação em Engenharia – COBENGE.* Gramado: pp. 1- 10.

GRANLUND. (2003). *RIUSKA***.** Available online: http://no.dds-cad.com/files/no.dds-cad.com/downloads/PDF-Datein/RIUSKA_english.pdf, Last accessed: June 2016.

GRANLUND. (2016). *RIUSKA*. Available online: http://www.granlund.fi/en/software/riuska/>. Last accessed: June 2016.

IES. (2016). *IES Consulting***.** Available online: http://www.iesve.com/consulting, Last accessed: June 2016.

KASSEM, M. and AMORIM, S.R.L. de. (2015). *BIM Building Information Modeling no Brasil e na União Europeia.* Brasília: Ministério do Planejamento, Orçamento e Gestão. Available online: http://sectordialogues.org/sites/default/files/acoes/documentos/bim.pdf, Last accessed: January 2016.

MEC - MINISTÉRIO DA EDUCAÇÃO. (2010). *Resolução nº 2, de 17 de junho de 2010*. Available online: http://portal.mec.gov.br/index.php?option=com_docman&view=download&alias=5651-rces002-10&category_slug=junho-2010-pdf&Itemid=30192, Last accessed: May 2016.

____. (2007). *Resolução nº 2, de 18 de junho de 2007***.** Available online: http://portal.mec.gov.br/cne/arquivos/pdf/2007/rces002_07.pdf, Last accessed: May 2016.

MENEZES, G. L. B. B. (2011). Breve histórico de implantação da plataforma BIM. *Caderno de Arquitetura e Urbanismo*, 18(22), pp. 153-171.

NREL. (2016). *OpenStudio User Docs*. Available online: http://nrel.github.io/OpenStudio-user-documentation/, Last accessed: June 2016.

OPENSTUDIO. (2016). Available online: https://www.openstudio.net/, Last accessed: June 2016.

PAULA, Kênia A. de. (2015). *Integração do conforto ambiental ao processo de ensino-aprendizagem de projeto arquitetônico com o uso de aplicativos em dispositivos móveis***.** Master. thesis, Federal University of Viçosa.

RUSCHEL, R. C. *et al.* (2013). O ensino de BIM no Brasil: onde estamos? *Revista Ambiente Construído***,** 13(2), pp. 151-165.

SANTOS, Eduardo T. and BARISON, Maria B. BIM e as universidades. (2011). *Construção Mercado*, e. 115. Available online: http://construcaomercado.pini.com.br/negocios-incorporacao-construcao/115/o-desafio-para-as-universidades-formacao-de-recursos-humanos-282479-1.aspx., Last accessed: June 2015.

SIMERGY. (2016). *10 Things to know about Simergy*. Available online: http://simergy.d-alchemy.com/things-to-know.html#top, Last accessed: June 2016.

WEF - WORLD ECONOMIC FORUM. (2016). *New vision for education*: fostering social and emotional learning through technology. Available online: https://www.weforum.org/reports/new-vision-for-education-fostering-social-and-emotional-learning-through-technology/, Last accessed: June 2016.

Employment Of BIM In Italy.
Lights And Shadows On New Design Approach

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Abstract:

The purpose of the paper is to show the positive aspects and to highlight the negatives ones of a new design method (BIM), in light of its introduction in the New Code of Public Procurement, in Italy. Building Information Modeling, as a wise relationship between drawing and database, systematizes geometrical data, material performances and quantity. These data are associated with Architecture, Engineering & Construction components (AEC) to virtually simulate the construction (or restoration) phase of the building.

Through the example of a case study, the research investigates on the interaction between the various disciplines, sometimes far apart, involved in the complex project of architecture and the ability to reduce the number of errors and discrepancies among different knowledges, making a virtuous path in contrast with the traditional parceled approach.

Moreover, while this method involves a qualitative improvement in the workflow, starting from the phase of meta-project for the customer, to the design, construction and implementation, maintenance and restoring, there is the potential introduction of critical issues due to the lack of required skills and the high number of stakeholders involved throughout the entire process. Can all these competences turning around the BIM coexist with each other?

The thoughts that arise on the sidelines of a growing number of design interventions, especially aimed at existing building heritage, push the researchers in the field to suggest new ways of working able to overcome the discrepancy for the inevitable distortions that a new design approach carries with it.

Keywords: *BIM Design; Existing Building Heritage; Transdisciplinary; Interoperability; Integrated Planning; Built Environment; IFC.*

1. Introduction

In recent years, the systemic approach to a new way of conceiving the building process is rapidly spreading both in the scientific community and in professional practice, thanks to the recent international guidelines that promote the BIM adoption as the proper methodology to be used, with legal consequences related to the reliability degree of the model (Lo Turco *et al.*, 2016).

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For some years, BIM is becoming the main tool in designing and restoring building heritage. Among the novelties of the New Code of Public Procurement in Italy (Public Procurement Code, 2016) there is the use of the BIM which is a tool for reformulating the relationship between administration and enterprises, mainly to reduce the variants and consequently the costs of production. As with many advantages, BIM could also lead to negative risks and consequences, especially in the design phase, mainly due to the contribution of the various actors it contains (Maggio, 2016).

The limitation of the model of representation and elaboration of the recent past, both of the project and of the production cycle, through limited and unconnected fragments - aimed at confining in the enclosure of a plurality of closed systems of products and services -, has generated the need of cooperation between the holders of skills involved in the design of an architecture and engineering project, which instead claims the need to be integrated from the beginning of its phases.

So a framework of requirements that can no longer be circumscribed in the knowledge of traditional disciplines of design, based on both specialization and mutual separation: a 'wonderful isolation'.

The work of the designer is nowadays characterized by the management of a quantity of information that should be easily accessible and should support him in the decisions to be taken. The designer's ability is right in his ability to know, correlate, resolve some conflicts of interfering decision-making factors.

The architectural project consists of a set of propositional ideas aimed at achieving a goal, ideas to organize and manage at all stages of development of design activity from the idea to the turnkey delivery of the product.

The project, coming out of the nebula of disorganized ideas, finds a representation in the recognition and organisation of a collection of entities with distinctive features.

The process of specifying the characteristics of the project components through the transformation of disordered and fragmented ideas into rational entities, as well as the general criteria that identify the guidelines and support the goals, must be coherent in the management processes and in an appropriate communication code.

The actors participating in the development process of the project must have communication tools that can facilitate an efficient management of the induced information's flow. In fact, a non-secondary aspect to be addressed in designing actions is the need to minimize the uncertainty that arises from the error generated in the transfer of content from one actor to another, from one design document to another, from the inefficiency in the representation of choices, the lack of correlation between design documents, their weak articulation and specialization.

Hence the need to set up an efficient communication code to ensure a proper management of design. The design choices, solutions adopted, and document content require coordination of information flowing inside the project's information system to ensure efficiency, effectiveness, and minimization of risks. Whenever in the life of the project, information must therefore support the choices and solutions adopted. In order to govern the correct flow of information, it will be necessary, through systematic and coherent actions, to acquire the basic data on which the process will be developed in all its phases (feasibility, preliminary, final, executive, contractor choice, assembly plans, yard, control actions). Appropriately developing such data to ensure coherent development of the project, make available and communicate the results of the elaboration through the production of appropriate documents of various kinds: technical, economic, organizational.

1.1 Complex System Theory

The painting ‘Anatomy Lesson of Dr. Nicolaes Tulp’, by Rembrandt in 1632, was commissioned to the painter from the Amsterdam Guild of Doctors. It represents Professor Nicolaes Tulp, who holds the local anatomy chair, while performing the dissection of the body of an executed, infamous criminal hanged in Amsterdam in January 1632. Dr. Tulp is portrayed while showing the attendees the functioning of the tendons of the left arm: he grabs them with big pliers, while with the left hand, mimics the movement of the fingers made possible by the tendons themselves.

It is likely that the corpse will still be torn apart to study other parts and organs. The scene will be repeated in the years and in the following centuries, and not just on the legal medicine tables, for autopsy and dissection. The human body will be subdivided into different apparatus and functions, which will be studied separately and will become the aim of the study of different branches of medicine and biology departments.

This division and dispersion of humanity in so many disciplines, which has come to our days, did not happen accidentally (Morin, 2016), but followed the fundamental principles of the dominant paradigm that, right from the century of the modern scientific revolution , guided the knowledge and governed thought, that is, the constitution of theories and the production of speeches. It is the paradigm of reduction, exclusion and disjunction, which has prescribed to reduce the complex to the simple, the global to the element, everything to the parties, organization to order, quality to quantity, multidimensional to formal. And it has cut the phenomena into decontextualized objects and separated by the same knowledgeable subject.

But the imperialism of this paradigm begins to get bogged down. In fact, according to Morin, “we are in an era that needs a change of paradigm, and that is very rare in history”. It is necessary to make science with conscience, aware of the permanent exposure to the error and to the illusion of our knowledge, which depends on a theoretical organization of not only cognitive factors, but also meta-cognitive factors (paradigms) and infra-cognitive factors (needs, aspirations), inseparable from the historical, social, and cultural context.

Today there is an increasing resistance to what can be called reductionist thinking, that is, the thought that reduces the knowledge of everything to the knowledge of the elements that compose it, as well as to the 'fragmented knowledge', in which the reality that in Nature is continuous becomes divided into sub disciplines and disciplines. Some have argued that it is necessary to oppose this reductionist or parcelling thought to a thought that they have called holistic, from ‘holos’, ‘the whole’.

But the defect of holistic thought was to be a reductionist theory, in the sense that instead of reducing the knowledge of a whole to the knowledge of its elements, it reduced knowledge to only the knowledge of a whole.

The knowledge of a whole requires not only the knowledge of the elements that makes up this but also the knowledge of the actions and the feedback that are continually between the parts and the whole when this is all active when it is alive when it is a Social whole, a human whole.

1.2 The project as a complex system

The architectural project is a complex decision-making process involving several related, often unprogrammed, variables, and continuing needs and strategies that change its purpose. Its complexity stems from the high number of variables that are integral to it and the ways in which these variables relate to one another and interact with each other (Truppi, 1999).

Among the factors that generate the complexity of the design and construction process are the heterogeneity of domains of knowledge and technical skills, the rules of building standards, the activity of an increasing number of involved actors in the process and, finally, the interferences in decisions related to the various disciplinary fields.

Architectural design is a deliberate planning activity where both the rules governing the process and the required properties of the final solution are subject to permanent refinement, replacement and revision. A decision taken in a disciplinary field will inevitably have an impact on the complexity of the process.

Developing a project means addressing and managing a complex set of specific issues related to identify the goal to be achieved, defining the qualitative and quantitative characteristics, the entities and attributes of the project, and finally defining and coordinating the benefits that are useful in achieving the fixed results.

In this path of configurations, which develop as a result of troubleshooting contingent problems, the project develops and integrates itself with other levels and application fields. The resulting increasing complexity of the process needs to be continually verified and validated by evaluation tools to ensure its quality and compliance with the initial goals.

Some authors agree on a definition of the design process as "global activity occurring in a contemporary and non-linear evolution of needs and design status through continuous mutual adaptation" (Smithers, 1991)

This affirmation sets the architectural design as a progressive model, which, based on the human and economic resources available to the designer, generates a synthesis, corresponding to the final solution, able to combine the needs of the specialized concerned disciplines.

Then, the architectural design appears as a complex process that follows a path from an initial configuration to achieve a desired final situation through a path marked by variations for both objectives, constraints, and therefore the evaluation and verification results also change. A project that is constantly revisable and changeable respect to the primordial idea with ever more detailed specifications.

Planning means deciding how to turn a certain initial situation by modifying one or more of its features that define it, so that it makes it more responsive to expectations both in terms of aesthetics and in terms of costs / benefits.

A distinction must therefore be drawn between what, as a matter of principle, a designer thinks of getting and what he actually decides, precisely because he can not foresee all the details and all the consequences that are in progress compared with the preliminary planning. Due to the crisis of both human and economic resources, continual variations in such a dynamic world lead to a waste of time in going back on the decisions taken and in modifying all the inputs of the involved people.

So a project can be seen as a complex network of knowledge and decisions each of which has, or may have, an influence on the others. Defining a project completely means developing all the nodes towards the desired level of detail. In this process, every level of knowledge and intentions can reverberate their effects on others. Starting from scratch and analysis of initial goals and constraints, the designer’s job is to transform an initial situation into a more appropriate and responsive customer’s needs, while critically modifying the dynamic characteristics of the preliminary design.

If the requirements of the client must be able to express the information that is able to orient the design process in an accomplished way, the requirements must characterize the specific object or context to which they relate. The demanding analysis of a project and its subtypes that characterize it will lead to different solutions in relation to the reference actor. So it’s possible to have the needs of the user, the buyer, the designer, but also the contractor.

Indeed, for its provisional and partial definition, the validation of a design work in progress may indicate a new more satisfactory direction than another, which can make saving time and energy, which requires a small and acceptable sacrifice by abandoning the solution not yet accomplished for the most convincing one.

The design process has three levels:

• The first level includes all potentially acceptable solutions. This level is about mapping of goals and constraints. These allow the initial description or configuration of the model, which is necessarily incomplete and indefinite, but already has the specific character of creative design activity: it produces a hybrid between the nature of abstract intentions and final processing;

• The intermediate level includes the scope of all decision-making knots, explored along the process, which constitute the path from “potential” solutions to the final solution, “target”.

• The last level includes the set of decisions and / or objects actually adopted that, once taken together, constitute the real solution (Arlati *et al*., 1995).

1.3 The project as a system of information

The Architectural works are characterized by products that stand out for the uniqueness of the result accompanied by aspects of considerable complexity, in many cases with reduced adaptability once made.

The prefiguration of the result through the drawing of the architectural design, alone, does not allow to efficiently overcome the moments of criticality present in the life of the project. In fact, the planning of all stages of a project’s development is loaded with complex problems that need to find congruent solutions but which are very difficult to govern in order to the large number of involved variables.

The complexity of the project requires that for the achievement of the predefined results an information system should be adopted that can provide the actors involved with the effective tools and manage all the activities, in the context of constant monitoring of the quality of the result, progress of the project and its implementation.

The project, as a method of compiling information aimed at rendering a virtual reality, presents a level of complexity that requires a procedural model that allows efficient recognition and the good integration of all design activities.

The problem that arises is to set up a schematic figure of the project that best suits the needs of representation of its information framework. Obviously, in order to provide an information framework able to correctly represent the results of project choices and relationships and interactions, the problem must be solved by adopting a single model that has substantial validity in every situation. This in order to avoid conceptualizations and abstractions of project content through different images and schematizations for each phase of its life cycle, for each design document or for each disciplinary field involved. A successful project management claims that different organizational schemes for every document are avoided (Utica, 2011).

1.4 Interoperability

The assumption is to affirm the possibility that the network of motivations, requirements and objectives be made explicit, described, operable and controllable by a community of co-interested actors that shares the whole, or at least significant sub-sets, of aims and interests. So, this community progressively can lose its current features of exclusivity and separation, enabling it to observe and co-operate its development up to the articulation of detail.

Interoperability is the ability to interact between specific systems to allow the sharing of data and the context of operation among the different protagonists of the building process.

IT can work concretely to foster interaction and integration among the protagonists of the design phase to better structure the final product, the ‘project’, which must be clear and without any interpretative ambiguity to ensure proper execution of the works. However, software applications are often unable to exchange information, since each one is optimized for the purpose for which it was conceived and has its own data representation format, usually not directly interpretable by other softwares. Each software deals with a particular aspect of the design, and therefore requires specific data.

In order that prospects offered by IT for the project quality can be realistic, software tools need to share and exchange data in a simple and secure way, according to the concept of software interoperability (Ciribini *et al.*, 2015). Sharing and exchanging data automatically, without the need for manual intervention to re-enter already defined information or to integrate any data loss that may be the result of incorrect exchange transactions.

1.5 Industry Foundation Classes (IFC)

The aim of the International Alliance for Interoperability (IAI) is to ensure the interoperability of software for the construction industry in order to facilitate the exchange of information through the use of a single Object-Oriented Project model, shared by Operators (contractors, designers, manufacturers, performers ...), based on a standard IFC (Industry Foundation Classes) (Caffi, 2001).

The IFC standard allows to have a shared language from all disciplinary domains of the project, able to describe the data needed to represent a building in its complexity and build an integrated project archive - defined as an Integrated Project Database, IPDB - shared between the operators.

The IPDB allows to avoid errors related to repeated data insertion, ensures consistency of project data throughout the process, enhances efficiency of communication and facilitates the exchange of data and information between designers, each for its own disciplinary field. For example, the structural engineer can access the data provided by the architect in a simple and direct way, and vice versa can provide the architect with up-to-date data based on his own simulations and verifications so that the architectural design can be modified correctly and quickly, without loss of information or time.

In this way it is possible to build a real project document shared between building operators, useful throughout the building's lifecycle.

The obvious advantage of this way of working is the coherency of information. The existence of a single IPDB, from which operators deduce their information and in which changes are noticed according to the evolution of a building, allows to have certain and unique data available, as opposed to what is normally the case with documents on paper, but often also with computer-based documentation, when not sufficiently and properly structured. Separate documents are not always able to ensure the homogeneity and coherence of the data contained in them, as they do not always are mutually updated.

On the contrary, a single archive does not cause any such problems, since the data are recorded once and possibly changed if necessary. Each operator is required to update the project archive with any changes made to the building.

2. Building Information Modeling (BIM)

The directive voted in January 2014 by the European Parliament called the European Union Public Procurement Directive (EUPPD) stipulates that the 28 European Member States may encourage, specify or impose the use of BIM for building projects funded by public funds in the European Union, starting from 2016 (Directive, 2014/23/EU).

In Italy, from April 2016, the new public procurement decree, transposing the European directive, was issued. Procurement stations may require the use of BIM for new works and services above the Community threshold. The platforms to be used must be open, in order to not restrict market competition.

Subsequently, by a new decree, the Ministry of Infrastructure and Transport should identify the practices and monitoring systems to make the instrument compulsory, with a gradual timing, evaluated also in relation to the amounts and type of works and services to be entrusted to.

Building Information Modeling is the information system of the project that materializes the dynamics of its development throughout all phases, to cover the entire lifecycle of building intervention. It is a true 'model' that constitutes a unitary information' system in which all members are explicitly known by their nature and their geometrical, topological correlations and attributes. This knowledge can be accessed in a mode of agreement with each of the subjects of competence and decision-making role, according to the tasks and responsibilities assigned to them, with the possibility to see the whole set of transactions going on the model, although they have the ability to operate only on those in charge. So, integrating decisions can take advantage of contemporaneous control over unwanted interferences or conflicts, enabling the solution to be in a non-distant or unharmed time sequence from their production (Deutsch, 2011).

Building Information Modeling (BIM) is one of the most promising implementations that have been made in the field of architecture, engineering and manufacturing. With BIM technology, a building is digitally constructed with an accurate and complete virtual model. Once the model is completed, it contains a very precise geometry and a number of extremely important information needed for the construction, manufacture and operation of the building process. The Building Information Model also contains a number of features that allow of monitoring the lifecycle of the building, providing the basis for the workability, role management and interrelationships of a project team. When this model is implemented in the right way, its benefits are a more integrated design and construction process that results in better quality at lower cost and with reduced construction times (Eastman *et al*., 2008).

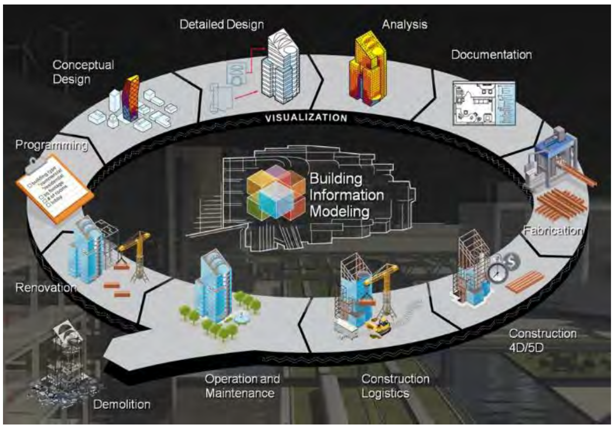

Figure 1. BIM Scheme. Source: https://www.buildipedia.com

The use of BIM technology is divided into three phases. The project, the data extraction and the life of the building.

- Selection of compositional components; the Calculation; Coordination between the parties; Checks through the model checking
- Details; Production tables; Cost estimating
- Site Management and SAL Calendar; scheduled Maintenance; Energy sustainability; Management costs.

In summary, the steps are characterized by a LOD (Level of development) and a numeric sequence ranging from 100 to 600.

Lod 100 – Concept design

Lod 200 – Schematic design

Lod 300 – Design model

Lod 400 – Construction

Lod 500 – Cost estimating

Lod 600 – Facilities management

A BIM model in particular is characterized by:

- Building components that are digitally represented 'smart' having awareness of what they are and which can be correlated by computational graphics, information contained in the data inside it, and parametric rules entered.
- Components that include information describing how they behave, both for analysis and for the job process.
- Coherent and non-redundant data, every change within a component is immediately displayed in all views of the component itself.
- Coordinated data so in all the views of the template are displayed in a coordinated manner.

Today, the architect is still the leader of the design team, but while there are some buyers who are still focused on this figure, one perceives that the actors of all the other disciplines involved in design are becoming increasingly important.

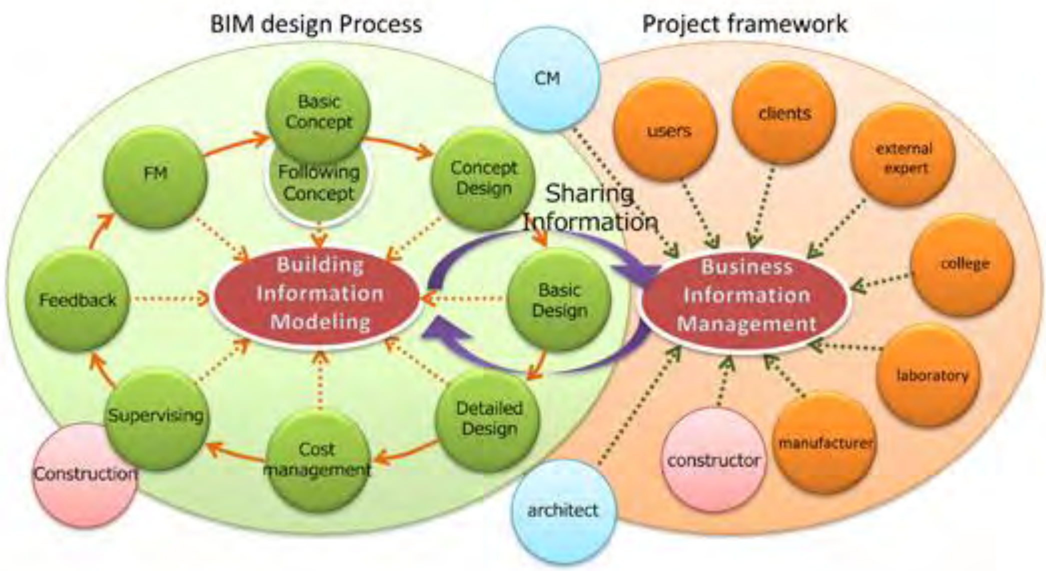

Figure 2. BIM Design Process and Project framework. Source: http://www.yasui-archi.co.jp

Beyond the architect, there are more figures participating in the project team; they are interior designers, green designers, civil, structural, mechanical, electrical, and plumbing engineers. In the twenty-first century other new specialized figures such as cost estimators, light designers, acoustic, security, fire-fighting, telecommunications, renewable energy consultants, real estate agents, building sustainable designers, etc.

It’s need to be able of integrating all these specializations into the design process in the right times and ways. Each specialist branch will see the same project in completely different aspects and will often collide. Each will develop its own methodology to solve the problem and propose solutions. It's need to be able to pick the best idea from everyone and apply it. Today, new communication technologies enable team members to interact even at a certain distance from the construction site, but to do this, everyone needs to talk in a unique way so that this can be a benefit and not a source of new problems.

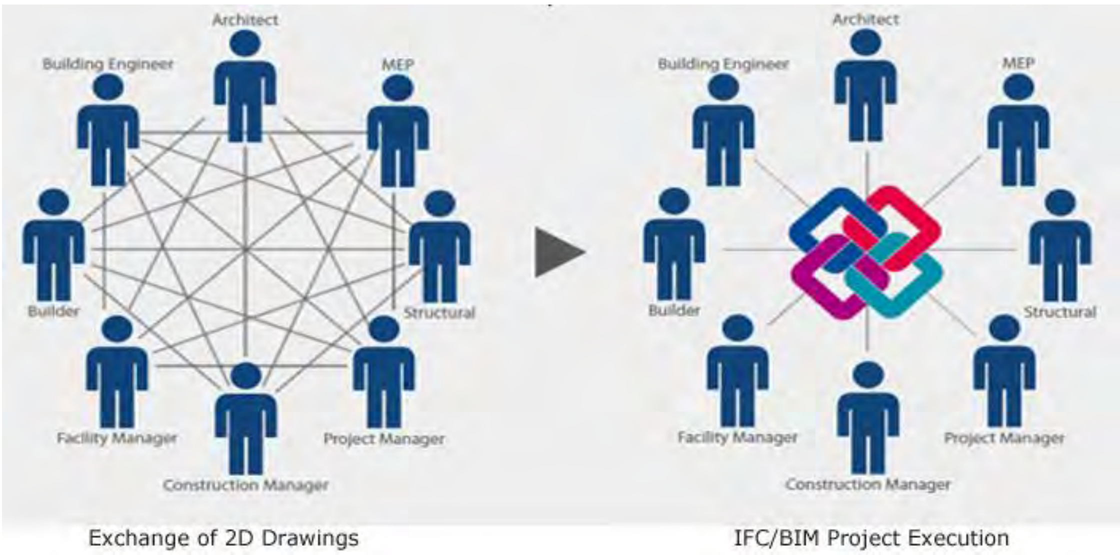

Figure 3. Interoperability. Source: (http://www.sperastudio.it).

In order to be able to communicate in a correct and continuous way so that it is possible to reach the individual goals at a time, to solve problems and to develop a sustainable project, it is necessary to have a communication, project, visualization, and effective estimation tool. A BIM model always connected and accessible to all figures, which displays, updates, modifies in real time every single aspect of the project is ideal (Krygiel *et al*., 2008).

The parametric format is essential in using the BIM model. In the parametric drawing, instead of drawing building elements such as a wall or a door, the designer defines the model's family or the element class that it wants to introduce into the project. This is equivalent to a set of relationships that govern the values of many parameters of each inserted element and forces them to be coherent with the context in which they are inserted.

These relationships allow each instance of each element class to adjust according to its own parameters and relationships given by the context in which it is placed.

While with the traditional 3D design each aspect of the drawn geometric element has to be manually modified by the user, the shape and the aggregation of the geometries in a parametric 'conscious' modeler automatically adjusts to the changes that are made to the context and allows the user a high level of control over what is modeled.

The BIM tool allows to carry out analyses regarding the orientation of the building, its volume, the impact of climate (wind, irradiation and lighting in particular), understand the resources needed to evaluate the reduction of it, know the thermal dispersions of the building as well as the presence of thermal bridges.

From these data, it is possible to define and modify the volume of the building by trying to give optimum illumination, aeration and irradiation to every environment, depending also on the activity that will be done, thus optimizing thermal efficiency and comfort (Krygiel *et al.*, 2008).

Using a BIM process allows to reduce the time needed for construction by implementing the design itself, collaborating between the different figures of the building process and the detail level of this.

As the design continues and the template upgrades, various spatial details and quantity of materials used directly from the template can be quickly extract. All BIM tools have the ability to extract counts from their components, areas and volume of spaces, quantity of materials, and return these data to different types of tables. These quantities thus obtained are eligible for a preliminary cost estimate.

3. Case History – Grand Egyptian Museum (Cairo)

The purity of the architectural design and the perfection in the execution of the Egyptian pyramids have become iconic of the fascinating Age of the Pharaohs and, over 4,500 years after their construction, have lost nothing of their magical appeal.

The open architectural competition received a total of 1,557 entries from 82 countries in 2002, making it one of the biggest architectural competitions to date worldwide. After one year, the competition jury chose the elaborated design from architects Heneghan Peng in Ireland as the winning design. Similarly plain and ingenious as the nearby and visible pyramids, this design stands out with its use of the triangle as its primary design element. Building on this, the design succeeds in converting the 800 m long main façade into a delicate, translucent and openable exterior membrane by using the Sierpinski triangle. As a result, an interior outer space is created within the building that skillfully links the forecourt with the building interior, subjecting the concept of the foyer to a new interpretation.

The search for a location with historic ties has been found in the immediate vicinity of the Giza pyramids and not far from the Nil. The museum will contain about 93,000 m² of exhibition space. Up to 16,000 visitors are expected to flock through the exhibitions each day. But it is not only the size and design that stand out, for the project's cost is also setting records. The building will house not only the exhibition space proper, but also storage rooms and archives, a conference center and a children's museum. The restoration workshops alone will account for about 7,000 m² of space. Also included are restaurants, cafés and ancillary buildings such as the museum's own power generator and fire department. Not to be overlooked is the extensive landscaping of the roughly 50 ha of park-like grounds. The construction costs are currently put at around 1 billion US dollars.

The façade is certainly one of the biggest challenges. It consists of MSH sections that frame the light-permeable, large-area stone panels. The façade's ornamental character stems from the subdivision of the 30 m high triangles on the Sierpinski principle. For this, the overall area of the equilateral triangle is divided equally into four smaller triangles. The central triangle remains undivided, while the system of division is applied again to the corner triangles. The triangles thus become progressively smaller, and the large initial pattern is reiterated in the smallest triangles. The development of a lasting structure and the façade’s construction with the delicate stone panels, transport to the construction site, plus assembly locally certainly rank among the most exacting and difficult processes of the entire project. On completion, spectacular light effects will be achieved both inside and outside due to natural light and artificial illumination.

The realization of this mega-project has been divided into three stages. The initial preparation of the site got underway in 2006. The first buildings and infrastructure measures were completed by 2008. Work on the museum itself has been in progress since 2013. A so-called ‘soft opening’ is scheduled for 2018.

Responsibility for the design of the 800 m long and up to 30 m high exterior membrane lies with Arup, the internationally renowned firm of engineers with 92 offices in 37 countries. Steel fabrication work is handled by National Steel Fabrication (NSF) based in Cairo, to which Salzgitter Mannesmann Line Pipe, through Vallourec and ThyssenKrupp Mannex, has supplied round and square MSH sections between 114.3 and 406.4 mm in diameter and with wall thicknesses of 3.6 to 20 mm.

The assignment of the associated Buzzi’s studio, in Italy, was to participate in the design of the envelope, of the cover and the vertical facade. The size of the property is approximately 231 m x 388 m for 46 m high.

The liner is made of stretch mesh panels. 50,000 panels for an area of 127,000 square meters. The structure with rail, tubular structure and nodes was also engineered, and it had to interact with Arup’s supporting structure.

The General Contractor, a joint venture between an Egyptian and a Belgian company, had the task of coordinating all contractors involved in the design. Each contractor, responsible for a part of the project, realizes his own model and uploads it to a dedicated and shared server between the various contractors and managed by the general contractor. He had the task of communicating the various models between them and concerned with the verification of the model checking, that is to verify the interference between the models through an exchange of encoded information with the sheets, which are part of the BIM method statement. This consists of an official document that dictates the rules to the various contractors involved in the project.

The stages that preceded BIM modeling relate to the collection of basic material in the form of a 3D CAD architectural grid line on Revit, provided by the General Contractor. It consists of a 3D model that defines the architectural wires within which the various working parties must adhere to. It is a common element to all subjects in the field, so crucial for the starting of the process.

Subsequently, the study prepared the development of 3D work plans with Archicad within the provided grid. From there, the design of the single panel began with the realization of the parametric object capable of adapting to the different solutions and shapes. Associated with each parametric element there are information that changes according to formal variations.

Parallel to the development of the parametric model there is the study of the single element for which calculations are made on the sizing, structural loads, flexures or cuts that architectural choices have determined.

Another aspect concerns the structural elements being analysed with another software and therefore all that concerns structural calculation, including pillars and nodes and the engagement systems. This part of the project is studied in Tekla, another software free from the architectural component managed with a software that defines the spatial conformation.

Within the dedicated server, to which all contractors admit, each model is loaded and deals with a part of the whole project and is visible to all contractors. In this way, for example, Arup uploads its own graphic material so that it shares its progress with the other subjects in the field. In this case, the Buzzi's studio downloads the format generated by Arup on which they tried to insert their three-dimensional IFC model of the building envelope to verify compatibility and effectiveness. Ultimately, the architectural layer created by a subject is overlapped on the structural layer designed by another subject so that it has a unique image with more complex information than the two separate models. Verified the compatibility with models generated by other subjects, the study performs an IFC file of the only designed component and is loaded on the server of the General Contractor to share it with others. The General Contractor in turn has the task of inserting it into his database, making the checks and notifying the final approval.

Final approval, which involves overcoming the next stage of the LOD 400 with the generation of the construction files and then the production tables.

Interoperability is present not only between a contractor and the other, so between different companies and professional studies dealing with different disciplines, but also within the same study, where hundreds of files are present. Moreover, on the same file different operators can see the work done by colleagues with greater interaction between them for a better communication skill of information and design advices.

The output of the project in BIM allows to overcome the problem of the difficulty of communicating figurative results to the customer. Nowadays, when interacting with the customer, they communicate visually the most obvious figurative results from the point of view of the final yield, so in 3 dimensions, no longer using hundreds of files or two-dimensional drawings that do not make justice to the conceived project. Three-dimensional images that showcase constructional details through axonometric splits or perspective sections that can directly communicate the final compositional outcome, dimensions, and relationship between the parties, having the entire template result of the assembly of all parts in game. From the whole model, on request, they were able to extrapolate all those configurations useful to express in an effective and probable manner what was designed in the various disciplines.

The goal was also to get integrated work management team that would allow multiple users to work simultaneously on the same project on a local area network and on the internet, in fact clearing the times and errors of coordination between the various professionals (Buzzi Studio, 2016).

4. Lights & shadows

For some time BIM is at the centre of the research and experimentation of technologists, designers, structuralists, planters, restorers, maintainers and all those who have, to some extent, some expertise in building.

Can all these competences turning around the BIM coexist with each other? The answer can only be positive with a clarification, that is, the designer is the central figure and reference of all the many actors in the design process. This consideration stems from the fact that in a mechanism as complex as the BIM, though apparently open, there is a danger that everyone can feel full-fledged designer losing the sense of their role.

The conceptual problem of BIM is precisely in identifying roles and in coordinating the actors. Many consider it to be just a very powerful software as, once, CAD has replaced pencil without ever taking it off.

An indiscriminate use of BIM could, for example, involve some of the misrepresentations that the computer revolution has previously determined, including the most dangerous of sense loss. In fact, the ability to make high-impact visual rendering was in contrast with a poor, if not absent, architectural quality.

This consideration can be understood as a possible rejection of BIM by sceptics opposed to an innovative form of the design process, but it is not at all so, indeed it is absolutely the opposite because BIM, as an instrument, is certainly part of a process of creative processing. Instead, it is important to evaluate what are the values to be preferred, if the project is to aim at controlling technological evolution or to rely solely on supporting it, utilizing it in a predominantly instrumental dimension.

The positive aspect of BIM is that it is both the one and the other. And it is precisely for this reason its multi-valued character that it is legitimate to say that preventing means of becoming goals does not mean suppressing means, it means suppressing their claim to become goals (Severino, 1980).

Another aspect that may be worrying in the BIM is to find, in the new architectural process of design, the melodramatic scene where one can not identify the characters and their roles within the show. Authors without author. If all this can hinder the design of architecture, its contribution to the building's maintenance is different. BIM is not only necessary but becomes indispensable.

BIM systems, in fact, allow for easy monitoring of the life cycle of a building by planning a management plan especially in relation to maintenance costs. Its contribution is similar to that of a TAC in the human body. Building management thus becomes dynamic and its changes are recorded in real time.

Refurbishing the existing heritage through new IT technologies that help to plan costs, means moving with small but steady steps avoiding unnecessary waste. This could really produce a change, a real change in the state of things and at least in our country. Just think of a possible restoration of those commonly called cathedrals in the desert and of all those historic buildings that have been in disuse for many years that are part of the constellation of our territory.

A restoration based on a BIM design allows to halve planned restoration costs. It is in the phase of construction that the greatest initial commitment and good design give the greatest benefits.

If the benefits of the BIM are evident in the field of building recovery, the questions on the project remain open. In fact, states that the categories of professional figures that have peripheral commitment with architecture have greatly multiplied: commercial technicians, customer service technicians, quality system engineers, control and testing technicians, production technicians, industrial computer technicians, lab technicians, and then technicians for the 'layout' of the tertiary, technicians for performance, cost, timing, yard, etc (Maggio, 2016).

5. Conclusions

The reality of the project as “turbulent complexity” (Maldonado, 1992) having, as intrinsic elements for architectural design, specificity and variation, should abandon sectoral approaches and be based on the application of a methodology that can incorporate as many as possible of aspects from the first stage of the creative process corresponding to the heuristic sketch (Nardi, 1991), as to define a preliminary scheme.

The potential of the BIM oscillates between lights and shadows, then. That is absolutely natural whenever some new system must have the time to be tested in its multiple aspects and then settled to make the appropriate corrections (Galimberti, 1999).

Ultimately in a direct comparison between traditional design and design in BIM advantages and disadvantages can be synthesized.

In the traditional design, the CAD tool was used as an electronic drafting machine for bidimensional design.

The advantages were great versatility, wide dissemination in the territory, low technical skills of management systems of the project.

The disadvantages were due to the very long time of designing the project, project updates, changes of difficult control and verification. Coordination between different parts (structures, installations ...) according to overlapping of two-dimensional layouts. No three-dimensional and total control. Drafting of hundreds of two-dimensional project plans for the global coordination.

In BIM’s design, there is the use of the CAD tool as a dynamic platform capable of absorbing the three-dimensional complexity of an architectural project.

The advantages: interoperability between the disciplines and sharing of choices and programs; Tight drafting times; Simplified management of the contract; Updates and changes to the project in real time; Possibilities of developments and implementations beyond the drafting phase of the project. Clash detection; Verification of project design compliance to specific standards; Metric calculation of the elements entered; Cloud working.

Disadvantages: diffusion on Italian territory still low; High technical requirements for management systems of the project.

References

Arlati E., Bottelli V., Fogh C., Tirassa M. (1995), “Modelling process knowledge in architectural design: a case-based approach” In Proc. 8th International Conference on Systems Research, Informatics and Cybernetics. Baden-Baden, August 16-20.

Buzzi, Architectural Studio (2016), Report Design Intervention.

Caffi V. (2001), Information Technologies e processo edilizio – Applicazioni e prospettive per il progetto,

tesi di dottorato in Ingegneria Ergotecnica Edile, Politecnico of Milano.

Ciribini, Mastrolembo, Ventura & Paneroni. (2015), "BIM methodology as an integrated approach to heritage conservation management", in WIT Transactions on The Built Environment, WIT Press, Vol 149, pp.265-276.

Deutsch R. (2011), BIM and integrated design: strategies for architectural practice, Wiley, New York, NY.

Directive 2014/23/EU of the European Parliament and of the Council of 26 February 2014 on the award of concession contracts.

Eastman C., Teicholz P., Sacks R., Liston K. (2008), BIM Handbook, John Wiley & Sons Inc, New Jersey.

Galimberti, U. (1999), Psiche e techné. L'uomo nell'età della tecnica, Feltrinelli, Milano, p.13.

Kensek K., Noble D. (2014), Building Information Modeling: BIM in Current and Future Practice, Wiley, Hoboken.

Krygiel E, & Nies B. (2008), Green BIM, Wiley Publishing, Indianapolis.

Lo Turco M., Edoardo B, (2016), "Historic Building Information Modeling: from historical database platform to fully suitable and multidisciplinary design instruments", in: XIV Forum Internazionale di Studi Le vie dei Mercanti, Napoli - Capri, 16/18 Giugno 2016. pp. 233-242.

Maggio F. (2016), "Architecture is not a Martini. Reflections about BIM", in Disegnare con, Vol 9 No 16, June 2016.

Maldonado, T. (1992), Reale e Virtuale, Feltrinelli, Milano.

Morin E. (2016), Sette lezioni sul pensiero globale, Cortina Ed., Milano.

Nardi G. (1991), "Il progetto euristico in architettura", in Bertoldini M. (a cura di), L'atto progettuale. Struttura e percorsi, Città Studi, Milano, pp.131-140.

New Public Procurement Code (2016), D.Lgs 50/2016, Italy.

Severino, E. (1980), Destino della necessità: katà tò chreòn, Adelphi, Milano.

Smithers, T., et al., Design is intelligent behaviour, but what's the formalism?, in: AI-EDAM 4(2), 89-98.

Truppi C. (1999), La città del progetto. Trasferimento di tecnologie e convergenze multidisciplinari, Liguori, Napoli.

Utica G. (2011), Tecniche avanzate di analisi e gestione dei progetti, The McGraw-Hill Companies, Milano.

Teicholz P. (2013), BIM for facility managers, IFMA Foundation, Wiley, Hoboken, New Jersey.

Sustainability in the Built Environment

Comparison of Sustainability Reporting in Construction Industries of Slovenia and Croatia

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Abstract:

The paper aims to compare the state of the sustainability reporting in two neighboring countries, Slovenia and Croatia. The method used is desktop research based on analysis of annual reports and web pages of the judgmental sample of construction companies in both countries. The research of the current state of the sustainability reporting in the construction industry needed to be revised and updated based on previous studies (Glass, 2012). Developing sustainability requires investment and many construction companies in both countries, especially local ones did not pick up since the economic crisis from 2009 and are still lacking financial resources to invest further in sustainability programs. The companies are aware that sustainability is an important topic, however we are questioning whether the demand for environmentally oriented solutions is strong enough to drive the companies to invest and develop sustainable solutions. Our study provides up to date comparison of sustainability activities and critically evaluates the quality of sustainability reporting in Croat and Slovene construction companies. We show that the structure of Slovene and Croat industry is different, since the environmental impact does not entirely depend on the production value of an industry or GDP growth. Based on the comparison we recommend developing sustainable policies of the companies with determining companies' focus areas and companies' materiality aspects, establishing partnerships with other companies for the development of sustainable practices possibly with the support of European funds, discovering business niches by offering solutions for environmental buildings and civil engineering structures.

Keywords: *sustainability; reporting; construction, Slovenia, Croatia*

1. Introduction

The paper aims to compare the state of the sustainability reporting in two neighboring countries, Slovenia and Croatia. The method used is desktop research based on analysis of annual reports and web pages of the judgmental sample of construction companies in both countries. The research of the current state of the sustainability reporting in the construction industry needs to be revised and updated based on previous studies (Glass, 2012).

Sustainability is nowadays an important trend in the construction industry. Since 1990 the sustainability has been gaining the importance in the academic literature (Hahn and Kühnen, 2013). The construction companies, encouraged by their stakeholders, customers, government

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bodies, laws and international institutions such as UN [1][2] and EU (EUROSTAT, 2016, 2015), have been developing their own sustainable practices. The sustainability (UN, 2014) encompasses ten principles in the areas of human rights, labor, environment and anti-corruption. In our view 13 out of 17 sustainability goals by UN are more relevant for construction industry and their customers. These goals are goal (3) good health and well-being, (4) quality education, (5) gender equality, (6) clean water and sanitation, (7) affordable and clean energy, (8) decent work and economic growth, (9) industry innovation and infrastructure, (11) sustainable cities and communities, (12) responsible consumption and production, (13) climate action, (15) life on land and (17) partnership for the goals.

The sustainability in construction sectors involves at least two aspects, one is from the viewpoint of the final product and the other is from the viewpoint of the management systems construction companies are adopting to support their sustainability endeavors. The literature mostly focuses on the sustainability of buildings (Berardi, 2012, Buyle et al., 2013, Ortiz et al., 2009), to some extend on the sustainability of civil engineering structures (Bocchini et al., 2013, Sahely, 2005) and to a much lesser extend on the management systems (Robinson et al., 2006, Darnall et al., 2008) of the construction projects (Robichaud and Anantatmula 2010, Edum-Fotwe and Price, 2009, Srdić and Šelih, 2011), construction companies and construction sector (Uttam, 2014).

Most of the big international companies, such as Vinci, ACS, Hochtief, Skanska, Saipem and Strabag that we looked at, have determined their own pillars of their sustainability policies and most of them have based their reporting system on GRI (2011) standards. Besides, these companies publish cases of sustainability practices that they applied within their projects, on their web pages. Buildings that have been awarded with one of the certificates and prizes are good examples of environmentally friendly and in other aspects advanced sustainable solutions. Buildings can be certified based on BREEAM [2][3] (UK and international), CEEQUAL [3][4] (UK), LEED [4][5] (USA), Green Star [5][6] (Australia), MINERGIE [6][7] (Swiss), DGNB [7][8] certificate. While road constructions can be certified by Greenroads [8][9] certificate and can benefit from German federal highway research institute that provides research advices, tests and standards for sustainable road construction (BAST, 2010).

Although approaches such as the quality management systems (ISO14001, ISO 9001, OHSAS 18001), compliance policies, codes of ethics and of conduct for employees and for business partners, approaches to health and safety, environmental policy, employee satisfaction,

[2] UN Global Compact Goals, available at: https://www.unglobalcompact.org/sdgs/17-global-goals (accessed on March, 15th, 2017).

[3] BREEAM, Building Research establishment environmental assessment method, available at: http://www.breeam.com/ (accessed on March, 17th, 2017).

[4] CEEQUAL, available at: http://www.ceequal.com/ (accessed on March 17th, 2017).

[5] LEED, Leadership in energy and environmental design, available at: http://www.usgbc.org/leed (accessed on March, 17th, 2017).

[6] Green Star, Green building council of Australia, available at: http://new.gbca.org.au/green-star/ (accessed on March, 17th, 2017).

[7] MINERGIE, available at: https://www.minergie.ch/minergie_fr.html (accessed on March 17th, 2017).

[8] DGNB, Germany Sustainable building council, available at: http://www.dgnb.de/en/ (accessed on March 17th, 2017).

[9] Greenroads, available at: https://www.greenroads.org/certification (accessed on March 17th, 2017).

development of environmental friendly solutions for buildings and construction of environmentally responsible buildings were to some degree practiced in the nineties and before, nowadays companies in construction sector have been developing these and related approaches within the companies' sustainability policies. Before the year 2000 these approaches were less developed in the construction sector and were mostly managed directly under umbrella of company's strategy and corporate governance. Nowadays, the focus is on sustainability, which has developed into an umbrella approach and one of the main if not the major strategic orientation as well as organizational policy of most construction companies. Further, we claim, that in the last decade, the construction industry has been developing more advanced sustainable practices much faster than other industries have.

Construction companies share many common focus areas, whereby they differentiate themselves from other industries where other focus areas might come more to the foreground. Since construction companies are often operating not only locally but internationally, we are highly aware that it is fairly difficult to define a national or a local construction industry. Moreover, any generalizations to local markets undermine the achievements of the star performer within local community. Nevertheless, we claim that due to obvious discrepancies, such comparison is meaningful.

The table 1 presents basic information of the selected Slovene and Croat companies. The rough estimate shows that the companies represent 29% of Croat and 12,87% of Slovene construction market. The share is calculated based on the overall production value of Slovene and Croat construction market and the net sales income of the companies, respectively on operating income or total revenue if net sales income is not given. The production value of Slovene construction market amounts 4.298 million EUR in 2015 and of Croat construction market 5614 million EUR [9][10]

[10] Eurostat, available at: http://ec.europa.eu/eurostat/web/structural-business-statistics/data/database# (accessed on March, 25th, 2017).

Table 1. Data for analyzed Slovene and Croat companies

	Main business activity	Number of employees	Net sales income or operating income or total revenue operating	Rough share estimate
Croat companies				
GP Krk [10] [11]	Low and high construction	793 (2015)	Revenue: 92,48 mio EUR (2015)	1,65%
Kamgrad Inženjering	Construction of buildings	520 (2015)	Net sales income: 115,558 mio EUR Operating income: 120,056 mio EUR	2,06%
S.E.G. Inženjering Osijek	Solar energy products, renewable energy	-	-	-
Tehnika Zagreb	Civil engineering and construction	775 (2015)	Total revenue: 1.343 mio EUR	23,93%
Tomin Inženjering Osijek [11] [12]	Design and supervision of construction projects	3 (2016)	_	-
Strabag Croatia and international	Building construction & civil engineering	705 (2016)	Output volume: 78 mio EUR (2016)	1,39%
Slovene companies				
CGP Novo mesto	Civil engineering	554 (2015)	Net sales income:89.187.466 EUR (2015)	2,08%
CPG Primorska	Civil engineering	422 (2015)	Net sales income:84.585.028 EUR (2015)	1,97%
Kolektor Koling	Building construction	101 (2015)	Net sales income:68.494.242 EUR (2015)	1,59%
Gradis skupina G	Building construction & civil engineering	66 (2014)	Net sales income: 3.640.238 EUR (2014)	0,08%
SGP Pomgrad	Civil engineering	618 (2017)	Net sales income:124.807.745EUR (2015)	2,90%
Riko	Building construction, design, civil engineering	128 (2015)	Net sales income: 97.009EUR (2015)	2,26%
Trimo	Building construction	763 (2016)	Net sales income: 85.277.726 EUR (2015)	1,98%

Sources: Annual reports and webpages of companies.

[11] Bisnode, Poslovna.hr, available at: http://www.poslovna.hr/Login.aspx?ReturnUrl=%2f (accessed on June, 28th, 2017).

[12]Moja djetalnost, available at: http://www.moja-djelatnost.hr/projektiranje-i-nadzor-strojarskih-instalacija-na-podrucju-osjecko-baranjske-zupanije/tomin-inzenjering-doo/MMx2Fsdg (accessed on June, 28th, 2017).

2. Sustainability reporting in Croat construction companies

The Croat companies included in our research are GP Krk, Kamgrad Inženjering, S.E.G. Inženjering Osijek, Tehnika Zagreb, Tomin inženjering Osijek. Although the Austrian company Strabag has an important presence in the local Croat construction market, the description of Strabag is provided at the group level.

Although these companies might apply more sustainable approaches than they actually report for on the internet pages, the difference between the maturity of sustainability practices in multinational versus local Croat companies is evident.

Tehnika Zagreb [12][13] includes care for environment and community in their mission statement: "significantly contribute to the construction industry with the care of the environment and the community at large". Although Tehnika Zagreb operates with net profit it accumulated loss from operations, which makes the company less economically sustainable. The company **GP Krk** [13][14]**, s**imilarly as Tehnika Zagreb provides 1 page of environmental and 1 page of quality policy and is ISO 9001 and ISO 14001 certified company.

Kamgrad (Kamgrad, 2017) establishes itself as a financially sustainable company, which is evident from the AAA credit rating awarded by Bisonde [14][15]. Kamgrad's [15][16] corporate social responsibility is based on the donations and sponsorships, care for younger generations and health and environment. Their three organizational units dealing with sustainability issues within their management system are 1) The quality management system 2.) The occupational health and safety system and 3.) The environmental protection system with the General objectives of "achieving greater care for the environment, prevention of harmful effects on the environment and raising awareness among employees about the need for environmental protection".

Kamgrad [16][17] indirectly supports sustainability in its mission and vision. The vision entails the aspect of quality, while the mission, which is based on innovation and creativity, focus on the user, integrity, teamwork and sharing knowledge and success includes care for the quality of life, of working spaces and environmental awareness within the integrity aspect.

The main activities of **S.E.G. Inženjering Osijek** [17][18] include renewable energy, electrical and computer engineering and automation in the industry. Their offerings include solar energy sources for which they provide education and information. Apart from the case studies of their projects they do not provide much information on how they foster sustainability within their company.

[13] Tehnika Zagreb, available at: http://www.tehnika.hr/ (accessed on March, 17th, 2017).
[14] GP Krk, available at: http://gp-krk.hr/index.php (accessed on March, 17th, 2017).
[15] Kamgrad, available at: http://www.kamgrad.hr/en/certificates/ (accessed on March, 21st, 2017).
[16] Kamgrad, available at: http://www.kamgrad.hr/en/about-us/management-systems/ (accessed on March, 21st, 2017).
[17] Kamgrad, available at: http://www.kamgrad.hr/en/about-us/mission-and-vision/ (accessed on March, 21st, 2017).
[18] SEG, available at: http://www.seginzenjering.hr/ (accessed on March, 21st, 2017).

Similarly, the company **Tomin Inženjering** [18][19] offering design and supervision of construction projects have not went much further from emphasizing the aspect of service quality in their mission and vision statements.

Strabag is present on the Croat market through their daughter company. Nevertheless, the sustainability is presented at the group level. **Strabag**'s [19][20] main focus areas of sustainability policy include the economic responsibility (seizing opportunities and recognizing risks at an early stage, innovation), people and workplace, ecological responsibility, corporate governance, business compliance and corporate citizenship. **Strabag** (2016) identified the following materiality areas: anti-discrimination, business compliance, child labor, client satisfaction, corporate governance, dialogue with the stakeholders, digitalization, employment conditions, energy management, environmental management, equal treatment of women and men, material use, promotion of environmentally friendly technologies and products, risk and opportunity management, societal engagement, sustainability in the supply chain, sustainable building, waste management and recycling, water, work safety and health.

Within the economic sustainability Strabag [20][21] identified five strategic priorities, staying diversified, maintaining financial strength, strengthening the risk and opportunity management, showing flexibility, offering sustainability. Within the people focus area they focus on occupational safety and health, qualification and training, diversity and equal opportunity, internal communication, knowledge management, employment and social fund. Within the environmental focus area, the main goals of the Strabag group [21][22] include reduction of energy use and CO_2 emissions through energy and fuel management, reduction of the direct and indirect negative environmental impact during construction and continued development of processes and technologies for resource- and energy-efficient buildings. Besides, Strabag focuses on establishing good corporate governance and compliance with external and internal regulations based on code of conduct for employees and stakeholder and business compliance guidelines for employees and partners, whereby they considered the rules of the Austrian Code of Corporate Governance (ÖCGK).

[19] Tomin Inženjering, available at: http://www.tomin-inzenjering.hr/ (accessed on March, 21st, 2017).

[20] Strabag, available at: http://www.strabag.com/databases/internet/_public/content.nsf/web/EN-STRABAG.COM-strategischeransatz.html#?men1=5&men2=2&sid=520&l=EN (accessed on April, 2nd, 2017).

[21] Strabag, available at: http://www.strabag.com/databases/internet/_public/content.nsf/web/EN-STRABAG.COM-strategie_strabag.html#?men1=5&sid=510 (accessed on April, 3rd, 2017).

[22] Strabag, available at: http://www.strabag.com/databases/internet/_public/content.nsf/web/EN-STRABAG.COM-oekologischeverantwortung.html#?men1=5&men2=2&sid=523&l=EN (accessed on April, 3rd, 2017).

Table 2. Overview of sustainability approaches in Croat companies

	GP Krk	Kamgrad Inženjering	Tehnika Zagreb	S.E.G. Inženjering Osijek	Tomin Inženjering Osijek	Strabag
Several pillars of sustainability		X				X
Mission and /or vision statement	X	X	X	X	X	X
Basic environmental policy	X	X	X			X
Basic quality policy	X	X	X			X
ISO 9001 and ISO 14001	X	X	X			X
OHSAS 18001	X	X				X
Donations and sponsorships		X				X
Extended environmental policy		X				X
Economic responsibility (seizing opportunities, recognizing risks at an early stage)	X	X				X
People and workplace, health and safety	X	X	X	X	X	X
Business compliance and corporate citizenship						X
Memberships in organizations supporting sustainability		X				X
Sustainability case studies				X		X
Innovation for improving product sustainability		X				X
Sustainability Goals	3,9	3,8, 9,11,12	3	3	3,9	3,8, 9,11, 12, 13

Sources: Annual reports and webpages of companies.

3. Sustainability reporting in Slovene construction companies

Company CGP Novo mesto has publicly available sustainability statement in its values [22][23]: high quality, care for the environment, social responsibility, development of employees, and safety at work. It is developing and advancing the technology of producing construction materials (CGP, 2016, p. 9).

Quality control is performed in 2 laboratories. Within the CGP Group, quality control is performed by the Quality and Development Division. The Division includes the Technical Control and two laboratories [23][24].

In cooperation with external laboratories, both laboratories also perform production control of their products and internal control of the performed work on construction sites. Internal control of the performed work on site is performed by the Technical Control. Product quality control is performed in accordance with the Slovene Construction Products Act (ZGPro), Rules on Conformity Compliance and on Marking Construction Products, and applicable technical specifications. Based on the existing production control system, they received production control certificates for all manufacturing facilities in the CGP Group. In 2015 CGP Group

[23] CGP Novo mesto, available at: http://www.cgp.si/en (accessed on March 8th, 2017)
[24] CGP Novo mesto, Certificates, available at: http://www.cgp.si/en/ABOUT-US/Certificates, (accessed on March 8th, 2017)

continued with research and development activities with the purpose to meet the demands of the market and reduce production costs by using recycled materials in producing construction materials (CGP Group, 2016, p. 15).

Sustainability report is incorporated as one chapter within the annual report and is dedicated to environmental protection. Regular control and education raised environmental awareness among employees. They have an established system of measuring environmental impacts, which includes air, water waste, emissions, dust omissions, noise and waste. In 2015 they collected and recycled 5000 tons of construction waste for the purpose of reusing it (CGP Group, 2016, p. 16).

Education is perceived in the company as the enabler of the constructive ideas for improving the working process (CGP Group, 2016, p. 18). In 2015 CGP Group had 76 different educational events and trainings and participated at the 43rd Winter sports games for road workers in Slovenia and participated at the Workers' sports games. Average age of employees is 48, 05, percentage of women is 11,2 % and percentage of employees with higher education is 13,4 % (CGP Group, 2016, p. 18).

Company CPG Primorska was established in 1962 with the purpose of building and renovating roads in northern Primorska region in Slovenia. Dedication to sustainable development is highlighted in their strategical goals (CPG, 2016, p. 7): "With responsible management of natural resources we take care of higher life standard of local community in which we perform our activities." In 2015 despite the large number of construction providers in the industry and small demand in the market, CPG, d. d., enlarged the value of their conducted large objects.

They are modernising their technology with the aim of decreasing the usage of energy, encouraging entrepreneurship and innovation of their employees. The gained environmental permission for recycling construction waste in 2013 (CPG, 2016, p. 14). Research and development activities are focused on modernisation of the existing equipment, buying of new equipment and introducing new technology.

Sustainability report is part of the annual report and is divided into four main parts: 1) employment of workers; 2) education and training; 3) local community support and 4) environmental protection.

CPG is in the stage of employing new and younger workers (December 31st, 2015: 422 workers) and average age of employees is 45 years (CPG, 2016, p. 39). Due to the retirement reason half of the employees will change in the next 10 years and that represents a challenge in transferring tacit knowledge from older generation to youth. On average, each worker was part of education activities for 4,17 hours and 116,07 EUR was spent for education on average for an employee (CPG, 2016, p. 42). Care for employees, buyers and collaboration with local community is part of their community engagement. Economic sustainability for them means retaining economic performance, competitive advantage, reputation, image, trust of the people in the community and is built on implementing employment policy, environmental policy, marketing policy and community policy. They are dedicated to employing local people, sponsoring local societies and solving problems together with the local community that protect the environment and quality of life.

Environmental protection is being aligned with the EU legislation. CPG, d. d., is expecting more demands on a state level for energy efficiency and usage of renewable sources of energy through new taxes, difficulty in gaining operation permissions and larger role of public in decision making. Environmental projects that reduce the negative impacts of the environment are (CPG, 2016, p. 44):

- Raising environmental awareness of employees and subcontractors;
- Reducing the usage of electricity and strengthening energy efficiency;
- Reducing the usage of drinking water by introducing recycling technology and reusage of water;
- Renovation of technology and reducing CO_2 emissions;
- Reducing dust intake;
- Improving handling with dangerous chemicals, improving storage and reducing uncontrolled dumping into soil and water;
- Better construction waste management.

CPG, d. d., perceives sustainable development as a long-term investment that will resolve in less complaints from the public as public can stop certain construction works (CPG, d. d., 2016, p. 44).

Company Kolektor Koling, d.o.o. was established in 2004 and has daughter companies in Bosnia and Hercegovina (in 2011), in Serbia (in 2014) and Croatia (in 2015). Annual report is constructed of strategical statements, description of products and services, risk management, business analysis, key products description, human resources analysis, investment, plans for next year, statement of top management team and accounting report. Mission is providing holistic solutions to the customers from the idea to implementation and construction by paying attention to the well-being and healthy environment.

Company **Gradis skupina G, d. d.,** was established in 2004. Its developmental goals are own projects, environmental protection and own research and development department in order to foster innovations (organizational and technological) and searching for new solutions in materials, appliances, products, processes, systems and services that enable constant development of employees.

Annual report of Gradis skupina G, d. d., is structured in two parts, business and accounting report. Chapters dedicated to sustainability reporting are risk management; investment; research and development; employees; responsibility towards the local community; and environmental protection. Environmental protection is embedded in the company's strategical development plan and in all management levels and company's working fields. In the company, they recycle waste. On construction sights, they comply with demands and regulations according to environmental protection, health legislation, cultural heritage and space regulation. They committed subcontractors through contracts to respect the principle of environmental responsibility (Gradis skupina G, 2015, p. 24). Company is dedicated to improving the environmental aspects of business and reducing the usage of energy and natural resources. When buying materials, they choose energy efficient solutions and ecological materials and equipment. In 2008 the company joined the project of energy efficiency that is led by ESCO-SI, d.o.o., and includes modernization, reconstruction and renovation of equipment (Gradis skupina G, 2015, p. 24).

Market stagnation and lower number of gained projects forced the company in 2014 to reduce the number of employees and reduce costs also by lowering the salaries of employees.

Company did not invest in 2014 due to the state on the market. The company is aware of social responsibility, however due to financial limitations did not invest in the local environment in 2014 and did not sponsor or donate. Gradis skupina G, d. d. conducts construction of parking houses according to the latest technological solutions of top-down construction. That kind of technological approach is designed for constructing objects on unsolid grounds, where it is not possible to use any other technology. A lot of engineering knowledge in concrete mixture is needed for technological preparation of this kind of construction and company prepared all the needed materials with the help of external partners (Gradis skupina G, 2015, p. 18). The company plans to invest in research and development of new technology in order to offer products and services with added value in the future. The average age of workers in 2014 was 52,4 years (59 men and 7 women; December, 31st 2014 (Gradis skupina G, 2015). Company Gradis skupina G, d. d., is struggling with employing workers as there is not enough suitable qualified workers in Slovenia due to the low salaries. Company spent only 500 euros for education and training of employees in 2014. Company employs a lot of older workers that are occasionally on a sick leave (Gradis skupina G, 2015, p. 17). Due to 4 accidents at work and 71 lost days of work due to accidents, the company is dedicating attention also to safety measures at work.

Company **SGP Pomgrad, d.d**. has a special section of the annual report dedicated to social responsibility that is divided into three subchapters: 1) responsibility towards employees; 2) environmental protection; and 3) responsibility towards the wider social community. Their values are quality, expertise, openness, environmental protection and partnership. In 2015 the company started working in the Croat market. In the company, they focus on the quality of the relationships, in the processes and relations with business partners. Department for the safety at work is responsible for healthy work environment, health assessment, levels of risk and establishing control over construction process. They sponsor and donate within local and wider environment.

Human resources policy is based on (SGP Pomgrad, 2016, p. 74) keeping key workforce, encouraging research and development, innovation, investment in the development of human abilities, enabling good organizational climate, education of employees and management and safety of work. In SGP Pomgrad, d.d., the majority of employees is in the age group of 51-60 years. Environmental engagement can be divided into two groups: 1) reducing and limit the influence on the environment due to their activity and 2) environmental protection projects. They renovate appliances and production line and introduce modern ways of work of the highest ecological standards. According to the National program of environmental protection and Law on environmental protection they introduced modern approaches of construction waste management (SGP Pomgrad, 2016, p. 75).

Group Riko directed activities into projects that are connected with ecology, such as cleaning devices in Russia. In Slovenia income from ecological projects was relatively smaller. Environmental projects are carried out based on two approaches: FIDIC yellow and red book (Riko, 2016, p. 6).

Riko provides complete technological solutions in the fields of industry, energy, environmental protection, logistics systems and construction. They support arts, culture, and sports and are committed to the core values that make life better in all of the environments in which Riko is active. In Riko they have head of the environmental protection. They offer integral solutions in the area of drinking water preparation and purification of waste water, waste management and the use of renewable energy sources. Together with their partners, they offer state-of-the-art solutions and equipment in the area of municipal purification plants with low operating costs and high reliability. Waste management includes: mechanical and biological treatment of municipal waste; sorting separately collected waste fractions or remaining mixed municipal waste; thermal waste treatment; industrial waste treatment; and construction of disposal sites. Water treatment includes: purification of municipal waste water (mechanical, chemical, biological, SBR, MBR, aerobic, anaerobic); preparation and purification of industrial waste water; purification of leachate from disposal sites and preparation of drinking water. Renewable energy sources include biogas energy; waste to energy (WTE) and Biomass power plants [24][25]

Sustainability reporting in **Trimo** is encompassed in chapters on development strategy, managing risks, research and development, investments, products, quality management and sustainable development (responsibility towards employees, investors, buyers, suppliers, social environment and natural environment). In December 2015 Trimo got a new Polish owner Innova Capital (Trimo, 2016, p. 1). Trimo has 50 years of tradition, its brands are present in over 60 countries and are based on strategical direction of sustainable development, differentiation, innovation and partnership. Trimo offers sustainable solutions Qbiss. Their risk management system includes 44 key risks (Trimo, 2016, p. 16). Added value per employee rose for 19 % from the previous year (Trimo, 2016, p. 29). Trimo offers simple, fast, multifunctional, sustainable and esthetic solutions and they also measure life-cycle assessment, fire safety of their products (also member of Fire Safe Europe association). Trimo develops partnerships with over 100 domestic and foreign partners. They endeavor to create lean organization (Trimo, 2016, p. 38) with educating employees, teamwork, creating learning organization environment, quality of the processes, strengthening key operational areas, customer satisfaction (in-time delivery, quality, responsiveness), owner satisfaction, lowering costs and providing high quality, optimization of all processes at all the levels, reducing waste, zero accidents and mistakes and best practice implementation.

Trimo Group reduced the number of employees in 2015 for 7 % due to smaller workload and optimization process. Average age of Trimo employees is 44 years. In 2015 48 % of employees had VI or higher education level. In 2015 first competence assessment connected with new reward system took place. In 2015 6,6 % of employees were included into the training and education activities with 13,5 training hours per employees on average (Trimo, 2016, p. 45). Trimo has well developed tracking of its impact on social and natural environment. Trimo spent 78,272,00 EUR in 2015 for sponsorships and donations; the largest amount went to handball club Trimo Trebnje (Trimo, 2016, p. 51).

With the strategical partners, Trimo is improving technical, functional, esthetic characteristics of products. Long-term collaboration with key-suppliers is directed into development of new materials, technologies, processes; development of one integral marketing approach in order to strengthen the position on the market; strategical activities with suppliers in order to shorten

[25] Riko, available at: http://www.riko.si/en/activities/environmental-engineering (accessed on March, 31st, 2017)

the supply period and constant improvement of product functionality in order to enable better solution for the buyer.

Dedication to sustainable development is one of the pillars of Trimo organizational culture and mission. Model of green business, such as the development of environmental and human friendly products and technologies, principle cradle to cradle (C2C) and energy efficient buildings. They understand sustainable development as balancing economic, social and ecological interests on a long-term basis that is developed together with values, key competences and clear vision (Trimo, 2016, p. 52).

Key Trimo products are at least 98 % recyclable. They carry out periodical activities, such as monitoring of emissions, control of active fire protection and education of employees. Waste management is an important part of Trimo, they inform and educate employees for constant improvement of their systems. They measure the usage of energy sources and water.

Table 3. Overview of sustainability approaches in Slovene companies

	CGP Novo mesto	CPG Primorska	Kolektor Koling	Gradis skupina G	SPG Pomgrad	Riko	Trimo
Several pillars of sustainability						X	X
Mission and /or vision statement	X	X	X	X	X	X	X
Basic environmental policy	X	X	X	X	X	X	X
Basic quality policy	X	X	X	X	X	X	X
ISO 9001 and ISO 14001	X	X	X	X	X	X	X
OHSAS 18001			X				X
Donations and sponsorships						X	X
Extended environmental policy	X	X		X		X	X
Economic responsibility (seizing opportunities, recognizing risks at an early stage)		X		X		X	X
People and workplace, health and safety	X	X	X	X	X	X	X
Business compliance and corporate citizenship						X	X
Memberships in organizations supporting sustainability						X	X
Sustainability case studies						X	X
Innovation for improving product sustainability		X		X	X		X
Sustainability Goals	3,7,8	3,7,8	3,7,8	3,7,8	3,7,8	3,7,8, 9,11, 12	3,7,8,9, 11, 12

Sources: Annual reports and webpages of companies.

4. Impact on the environment by Slovene and Croat construction industry

Construction industry in Slovenia and Croatia are still experiencing challenging times, especially the civil engineering sector within the construction industry is still shrinking although the overall European construction market is recovering from the recent economic crisis. The number of construction companies in Croatia has been falling from 27.043 construction companies in 2009 to 17.575 companies in 2015. Similarly, the number of construction enterprises in Slovenia was falling from 19.499 companies in 2009 to 18.066 in 2013 and has risen slightly in 2014 and 2015 when it reached 18.254 companies [25][26]. Although there are some differences between the sectors of the construction, industry the growth rate of employment in the entire construction industry of Slovenia and Croatia has been falling from year to year from 2009 to 2014.

Although EEA (European environmental agency) [26][27] publishes the industrial pollution reports by countries, these reports do not include construction sector data (EEA, 2016a, EEA, 2016b). Therefore, the contribution of construction industry to the overall industrial pollution in Slovenia and Croatia is not sufficiently measured. Nevertheless, Eurostat [27][28] reports the data for hazardous and non-hazardous waste produced as well as the energy consumed by the construction sector in different European countries [28][29]. On the other hand, only couple of countries report in Eurostat data base for the water supply provided to construction industry or for any kind of water pollution by construction sector, for this indicators data for Slovene and Croat construction industry are not available.

ARSO [29][30], Slovene environmental agency highlights that the urbanisation, new residential areas, construction of transport infrastructure contributes to changes in country's climate, land, waste, water and biodiversity. It is worrying that Slovene construction industry has a large share of raw materials obtained in Slovenia. In Slovenia, the environmental impact assessment and environmental protection is regulated under the Environmental Protection Act and Environmental Protection. The construction companies perform their work under the Construction act, Act on Urban Planning and Other Forms of Land Use and Residence Registration Act.

AZO, the Croat environment agency, acknowledges that the industry impacts environment and support that with the list of environmental indicators for all sectors of economy (AZO, 2015). The regulations under which the companies operate include Environmental Protection Act (OG 110/07), Ordinance on EPR (OG 35/08), Regulation on the prevention of major accidents involving dangerous substances (OG 114/08), Ordinance on the registry of installations in which dangerous substances are present and the register of reported major accidents (OG 113/08), Regulation on the procedure for determining integrated environmental protection requirements (OG 114/08), Ordinance on the register of use permits establishing

[26] Eurostat, available at: http://ec.europa.eu/eurostat/web/structural-business-statistics/data/database# (accessed on March, 23rd, 2017).

[27] EEA, European environmental agency, available at: http://www.eea.europa.eu/themes/industry/industrial-pollution (accessed on March, 25th, 2017).

[28] Eurostat, available at: http://appsso.eurostat.ec.europa.eu/nui/submitViewTableAction.do (accessed on March, 25th, 2017).

[29] Eurostat, available at: http://appsso.eurostat.ec.europa.eu/nui/show.do (accessed on March, 25th , 2017).

[30] ARSO. Slovene environmental agency. Republic of Slovenia. Ministry of the environment and spatial planning, available at: http://www.arso.gov.si/en/ (accessed on April, 6th, 2017).

integrated environmental protection requirements and decisions on integrated environmental protection requirements for existing installations (OG 113/08) [30][31].

Although the EEA, ARSO and AZO agencies report for indicators on the industry level in which they include construction industry with other industries, they lack providing data for construction sector separately. Therefore, we present the data for construction industry below based on Eurostat database.

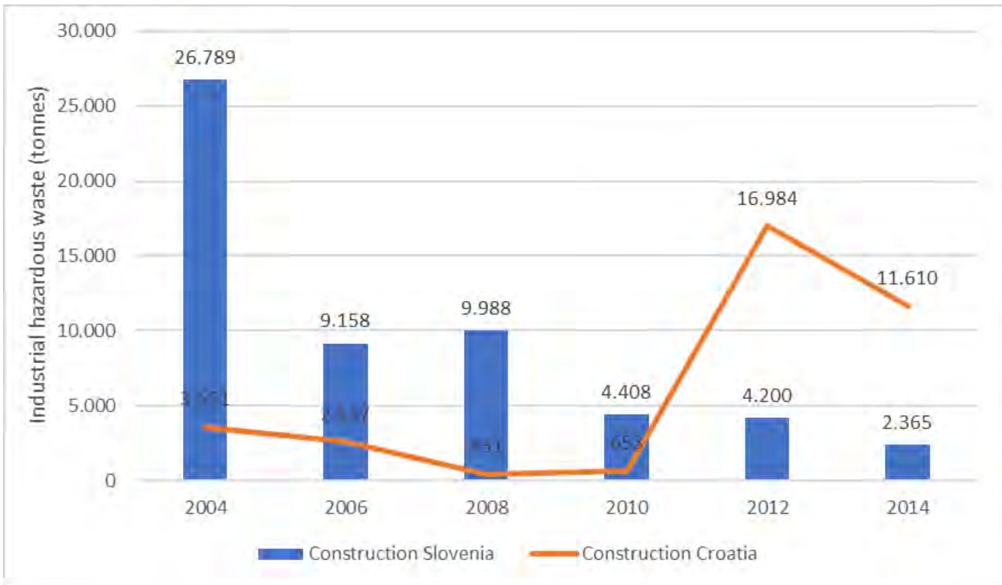

Figure 1: Industrial hazardous waste (tonnes) (Source: Own presentation based on data from Eurostat, available at: http://appsso.eurostat.ec.europa.eu/nui/submitViewTableAction.do, accessed on March, 25th, 2017.)

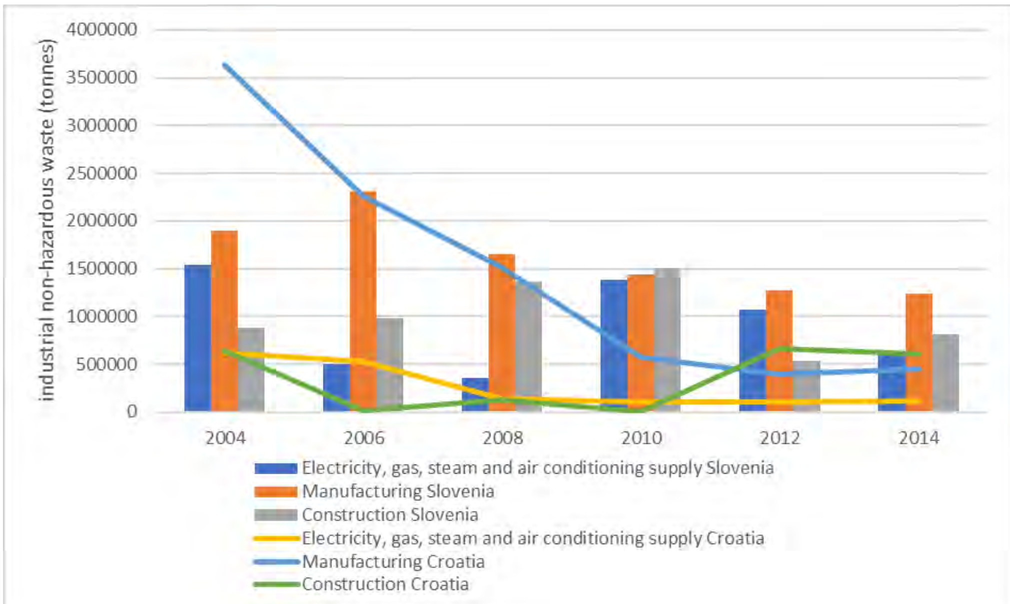

Figure 2: Industrial non-hazardous waste (tonnes) (Source: Own presentation based on data from EEA, 2016a, EEA, 2016b and Eurostat, available at: http://appsso.eurostat.ec.europa.eu/nui/submitViewTableAction.do, accessed on March, 25th 2017.)

[31] AZO. Croat environment agency. Industry, available at: http://www.azo.hr/Industry (accessed on April, 6th, 2017).

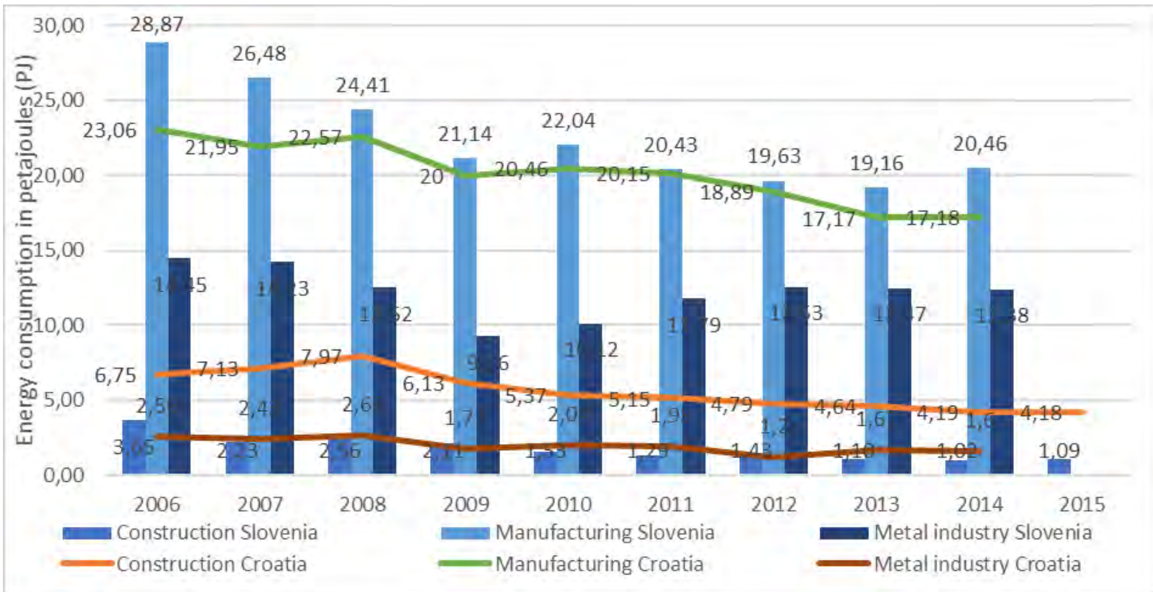

Figure 3: Energy consumption in petajoules (PJ) (Source: Own presentation based on data from EEA, 2016a, EEA, 2016b and Eurostat, available at: http://appsso.eurostat.ec.europa.eu/nui/show.do , accessed on March, 25th, 2017.)

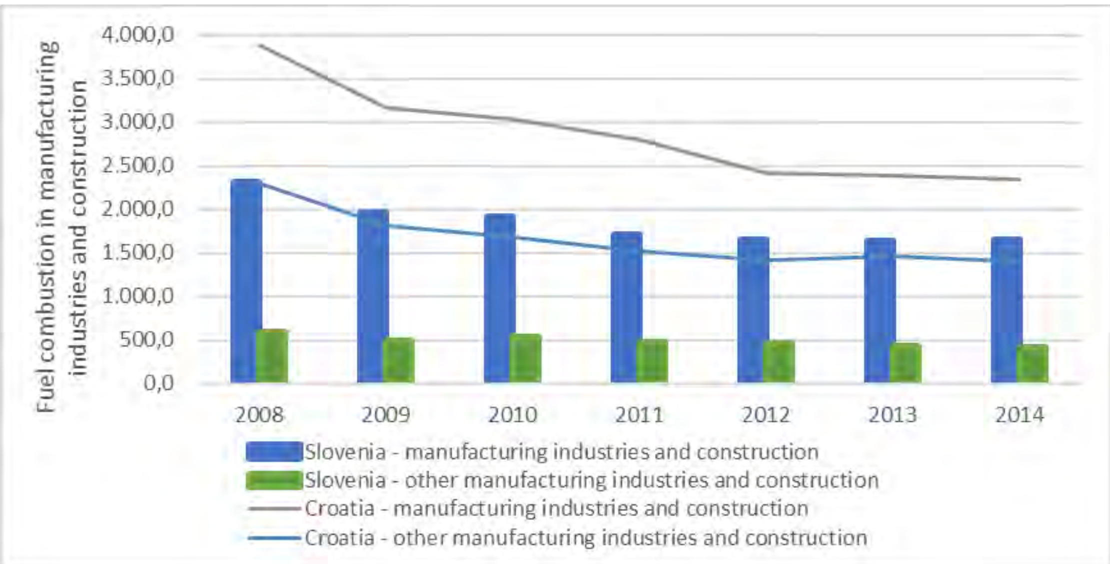

Figure 4: Fuel combustion in manufacturing industries and construction (Source: Own presentation based on data from Eurostat, available at: http://appsso.eurostat.ec.europa.eu/nui/submitViewTableAction.do , accessed on March, 23rd 2017.)

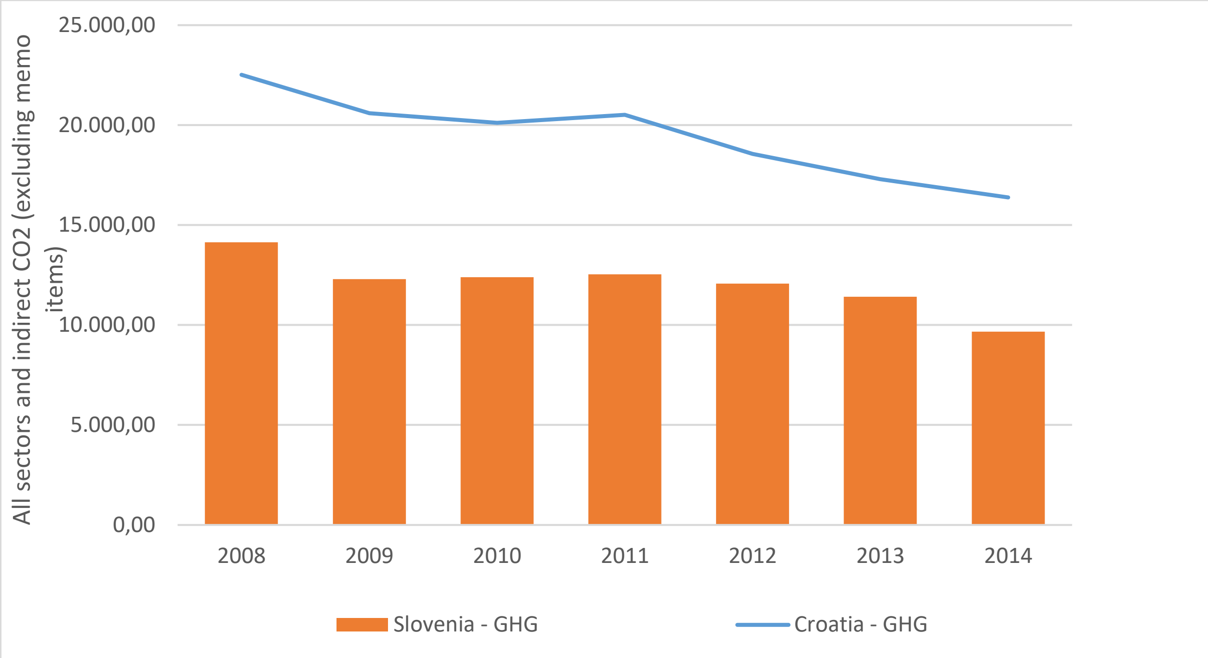

Figure 5: All sectors and indirect CO2 (excluding memo items) (Source: Own presentation based on data from Eurostat, available at: http://appsso.eurostat.ec.europa.eu/nui/submitViewTableAction.do , accessed on March, 23rd, 2017.)

5. Discussion and conclusion

The article shows that the sustainability reporting for construction industry and within construction companies in Slovenia and Croatia has a lot of room for improvement. Besides, we show that the structure of Slovene construction industry is different from Croat industry regarding their environmental impact.

Namely, when the structure of the Slovene and Croat industry was similar, we could assume that the impact on the environment would be correlated to the value of production in construction industry. In Slovenia, the production value of construction reached between 4,1 and 4,5 billion EUR from 2012 to 2015, while in Croatia the production value reached between 5,1and 5,65 billion EUR in the same period. Although the production value of construction industry in Croatia was higher than in Slovenia the amount of hazardous waste was bigger in Slovenia until 2010. In the year 2012 and 2014, the amount of hazardous waste in Croatia rose significantly above the Slovene level, although the overall production of Croat construction industry was declining. It is evident that in this period an existing or a new company introduced hazardous materials in the production processes, which substantially worsened the environmental impact. Moreover, the amount of industrial non-hazardous waste was in 2012 higher in Croatia, which is in line with its bigger production value. However, the amount of Slovene non-hazardous waste reported was above Croat non-hazardous waste, although their production values was higher. The waste production is obviously not in line with production value of the countries, which tells that the structure of Slovene and Croat industry differ.

However, the energy consumption reported is much higher in Croatia than in Slovenia and therefore in line with the differences in the production values. The data also shows that fuel combustion in manufacturing industries and construction was much higher in Croatia than in Slovenia. The data for all business sectors show that direct and indirect CO2 emissions were much higher in Croatia than in Slovenia although the GDP growth was higher in Slovenia. The within country comparison shows that the CO2 emissions in Croatia were falling together with the GDP decline from 2011 to 2014, while in Slovenia the CO2 emissions from 2013 to 2014 were declining despite the higher economic growth. We can therefore confirm that the environmental impact depends not only on the production value of an industry or GDP growth but mostly on the structure of the industry. Thus, companies experiencing growth should endeavor to develop new technologies, processes and products that would on the long term decrease the use of natural resources. In future, the new technologies, structures and processes with lower impact on the environment should replace those which more excessively use the natural resources.

We observe huge discrepancies between the maturity of sustainability practices of European construction companies being recognized for sustainability and the companies devoting more attention to sustainability such as Vinci, ACS, Hochtief, Skanska, Saipem, Strabag, Kamgrad and Trimo and other, especially only locally present construction companies. Even if the sustainability practices in the construction industry are better developed than in other industries, we claim that the gap between the construction companies recognized for sustainability and other construction companies represents the challenge that the construction industry should overcome in future. More effort is needed to deploy well developed sustainability practices in all construction companies, especially among small local construction companies.

Companies in Slovene construction sector base their sustainability reporting on quality management, safety regulations, employee age and education. Similarly, in Croatia, although some companies did not go beyond ensuring quality of their products and ISO certification. It is evident from their reporting that they perceive sustainability as important, however do not have the resources to manage and measure sustainability systematically. Star performer in Slovenia in terms of most elaborated sustainability reporting among the chosen Slovene construction firms proved out to be Trimo group with a clear structure of sustainability reporting in terms of economic, social and environmental dimensions. Among the Croat companies the Kamgrad and Strabag group (at the group level) stand out as examples of companies oriented towards sustainable development.

Based on our research we realized that many construction companies, especially local ones did not pick up since the economic crisis from 2009 and are still lacking financial resources to invest further in sustainability programs. The companies are aware that sustainability is an important topic, however we are questioning whether the demand for environmentally oriented solutions is strong enough to drive the companies to invest and develop sustainable solutions.

Based on the comparison we recommend developing sustainable policies of the companies with determining companies' focus areas and companies' materiality aspects, establishing partnerships with other companies for the development of sustainable practices possibly with the support of European funds, discovering business niches by offering solutions for environmental buildings and civil engineering structures. An important finding of our study is that large construction companies have more developed sustainability practices while small local construction producers are lagging behind. Construction companies are aware that dissemination of construction companies within their supply chain to local construction companies and to other partners is quite a challenge.

References

ARSO. Slovene environmental agency. Republic of Slovenia. Ministry of the environment and spatial planning, available at: http://www.arso.gov.si/en/ (accessed on April, 6th, 2017).

AZO. Hrvatska agencija za okoliš i prirodu. (2015). *Nacionalna lista pokazatelja. Broj dokumenta 25-17-15-1888/31. Revizija 3.* Zagreb, Hrvatska: 2015. 892 str.

AZO. Croat environment agency. Industry, available at: http://www.azo.hr/Industry (accessed on April, 6th, 2017).

BAST (2010), Federal highway research institute. Research advices, tests and standards. Bergisch Gladbach, Germany: BAST. 28p. available at: http://www.bast.de/EN/Publications/Media/bro-englisch.pdf?__blob=publicationFile , http://www.bast.de/EN/Home/home_node.html (accessed on April, 6th, 2017).

Berardi, U. (2012), Sustainability assessment in the construction sector: rating systems and rated buildings. *Sustainable Development*, 20(6), 411-424.

Bisnode, Poslovna.hr, available at: http://www.poslovna.hr/Login.aspx?ReturnUrl=%2f (accessed on June, 28th, 2017).

Bocchini, P., Frangopol, D. M., Ummenhofer, T., & Zinke, T. (2013), Resilience and sustainability of civil infrastructure: Toward a unified approach. *Journal of Infrastructure Systems*, 20(2), 1-16p.

BREEAM, Building Research establishment environmental assessment method, available at: http://www.breeam.com/ (accessed on March 17th, 2017).

Buyle, M., Braet, J., & Audenaert, A. (2013), Life cycle assessment in the construction sector: A review. Renewable and Sustainable Energy Reviews, 26, 379-388.

CEEQUAL, available at: http://www.ceequal.com/ (accessed on March 17th, 2017).

CGP Group, družba za gradbeništvo, inženiring, proizvodnjo in vzdrževanje cest, d. d. (2016), Prihodnost tradicije. Letno poročilo 2015 Skupine CGP, CGP, d.d., Novo mesto.

CGP Novo mesto, Certificates, available at: http://www.cgp.si/en/ABOUT-US/Certificates (accessed on March, 8th, 2017).

CGP Novo mesto, available at: http://www.cgp.si/en (accessed on March, 8th, 2017).

CGP Novo mesto, ISO 9001:2008, available at: http://www.cgp.si/Portals/CGP_EN/pdf/CGP%20certifikat_ISO%209001_en.pdf?ver=2016-08-22-140531-127 (accessed on March, 8th, 2017).

CPG, Cestno podjetje Nova Gorica, družba za vzdrževanje in gradnjo cest, d. d. 2016. Letno poročilo za leto 2015, CPG, d.d.: Nova Gorica.

Darnall, N., Jolley, G. J., & Handfield, R. (2008), Environmental management systems and green supply chain management: complements for sustainability? *Business Strategy and the Environment*, 17(1), 30-45.

DGNB, Germany Sustainable building council, available at: http://www.dgnb.de/en/ (accessed on March, 17th, 2017).

Edum-Fotwe, F. T., & Price, A. D. (2009), A social ontology for appraising sustainability of construction projects and developments. *International Journal of Project Management*, 27(4), 313-322.

EEA, European environmental agency (2016a), *Industrial pollution.* Slovenia. EEA: Europe.

EEA, European environmental agency (2016b), *Industrial pollution.* Croatia. EEA: Europe.

EEA, European environmental agency, available at: http://www.eea.europa.eu/themes/industry/industrial-pollution (accessed on March 25th, 2017).

EUROSTAT (2015), *Sustainable development in the European Union. 2015 monitoring report of the EU sustainable development strategy.* Luxemburg: European Union. 354p.

EUROSTAT (2016), *Sustainable development in the European Union. A statistical glance from the viewpoint of the UN sustainable development goals.* Luxemburg: European Union. 168p.

EUROSTAT. Production value in construction industry, available at: http://ec.europa.eu/eurostat/web/structural-business-statistics/data/database# (accessed on March, 23rd, 2017).

EUROSTAT. Growth rate of employment (%), available at: http://ec.europa.eu/eurostat/web/structural-business-statistics/data/database# (accessed on March, 23rd, 2017).

EUROSTAT. Industrial hazardous and non-hazardous waste (tonnes), available at: http://appsso.eurostat.ec.europa.eu/nui/submitViewTableAction.do (accessed on March, 23rd, 2017).

EUROSTAT. Energy consumption in petajoules (PJ), available at: http://appsso.eurostat.ec.europa.eu/nui/show.do (accessed on March, 23rd, 2017).

EUROSTAT. Fuel combustion in manufacturing industries and construction, CO2 all sectors and indirect (excluding memo items) available at: http://appsso.eurostat.ec.europa.eu/nui/submitViewTableAction.do (accessed on March, 23rd, 2017).

Glass, J. (2012). The state of sustainability reporting in the construction sector. *Smart and Sustainable Built Environment*, *1*(1), 87-104.

GP Krk, available at: http://gp-krk.hr/index.php (accessed on March, 17th, 2017).

Gradis skupina G, d. d. (2015), Letno poročilo družbe Gradis skupina G, d.d. za leto 2014, Gradis skupina G, d.d., Ljubljana.

Green Star, Green building council of Australia, available at: http://new.gbca.org.au/green-star/ (accessed on March, 17th, 2017).

Greenroads, available at: https://www.greenroads.org/certification (accessed on March, 17th, 2017).

GRI. Global Reporting initiative. (2011), RG 2000-2011. Sustainability reporting guidelines. The Netherlands: GRI. 195 p.

Hahn, R., & Kühnen, M. (2013). Determinants of sustainability reporting: a review of results, trends, theory, and opportunities in an expanding field of research. *Journal of Cleaner Production*, *59*, 5-21.

Kamgrad (2017), Annual financial statements registry. Balance sheet and profit and loss account for the year 2015. Zagreb, Croatia: 2017.

Kamgrad, available at: http://www.kamgrad.hr/en/certificates/ (accessed on March, 21st, 2017).

Kamgrad, available at: http://www.kamgrad.hr/en/about-us/management-systems/ (accessed on March, 21st, 2017).

Kamgrad, available at: http://www.kamgrad.hr/en/about-us/mission-and-vision/ (accessed on March, 21st, 2017).

Kolektor Koling, d.o.o. (2016), Letno poročilo Kolektor Koling, d.o.o, Kolektor Koling, d.o.o., Logatec.

LEED, Leadership in energy and environmental design, available at: http://www.usgbc.org/leed (accessed on March, 17th, 2017).

MINERGIE, available at: https://www.minergie.ch/minergie_fr.html (accessed on March, 17th, 2017).

Moja djetalnost, available at: http://www.moja-djelatnost.hr/projektiranje-i-nadzor-strojarskih-instalacija-na-podrucju-osjecko-baranjske-zupanije/tomin-inzenjering-doo/MMx2Fsdg (accessed on June, 28th, 2017).

Ortiz, O., Castells, F., & Sonnemann, G. (2009). Sustainability in the construction industry: A review of recent developments based on LCA. Construction and Building Materials, 23(1), 28-39.

Riko, d.o.o. (2016) Konsolidirano letno poročilo za poslovno leto 2015. Ljubljana: Riko, industrijski in gradbeni inženiring, d.o.o.

Riko, available at http://www.riko.si/en/674 , (accessed on March, 25th, 2017)

Robichaud, L. B., & Anantatmula, V. S. (2010), Greening project management practices for sustainable construction. Journal of Management in Engineering, 27(1), 48-57.

Robinson, H. S., Anumba, C. J., Carrillo, P. M., & Al-Ghassani, A. M. (2006), STEPS: a knowledge management maturity roadmap for corporate sustainability. Business Process Management Journal, 12(6), 793-808.

Sahely, H. R., Kennedy, C. A., & Adams, B. J. (2005), Developing sustainability criteria for urban infrastructure systems. Canadian Journal of Civil Engineering, 32(1), 72-85.

SEG, available at: http://www.seginzenjering.hr/ (accessed on March, 21st, 2017).

SGP Pomgrad, d.d. (2016), Letno poročilo družbe SGP Pomgrad, d.d. in skupine Pomgrad za poslovno leto 2015, SGP Pomgrad, d.d., Murska Sobota.

Srdić, A., & Šelih, J. (2011), Integrated quality and sustainability assessment in construction: a conceptual model. Technological and economic development of economy, (4), 611-626.

Strabag (2016), Annual Report 2015. Austria: Strabag. 220p.

Strabag, available at: http://www.strabag.com/databases/internet/_public/content.nsf/web/EN-STRABAG.COM-strategischeransatz.html#?men1=5&men2=2&sid=520&l=EN (accessed on April, 2nd, 2017).

Strabag, available at: http://www.strabag.com/databases/internet/_public/content.nsf/web/EN-STRABAG.COM-strategie_strabag.html#?men1=5&sid=510 (accessed on April, 3rd, 2017).

Strabag, available at: http://www.strabag.com/databases/internet/_public/content.nsf/web/EN-STRABAG.COM-oekologischeverantwortung.html#?men1=5&men2=2&sid=523&l=EN (accessed on April, 3nd, 2017).

Tehnika Zagreb, available at: http://www.tehnika.hr/ (accessed on March, 17th 2017).

Tomin Inženjering, available at: http://www.tomin-inzenjering.hr/ (accessed on March, 21st, 2017).

Trimo, d.d. (2016). Letno poročilo družbe in skupine Trimo 2015. Trimo, d.d.: Trebnje.

UN Global Compact (2014), Guide to Corporate Sustainability. Shaping a sustainable future. UN: New York, USA. 48p.

UN. Sustainability Goals, available at: https://www.unglobalcompact.org/sdgs/17-global-goals (accessed on March, 15th, 2017).

Uttam, K. (2014). *Seeking sustainability in the construction sector: opportunities within impact assessment and sustainable public procurement.* Doctoral dissertation.

Vinci (2017), Annual report 2016. France: Vinci. 348 p.

Historical Town Centres - Challenges and Opportunities for Renewal

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Abstract

International guidelines concerning cultural heritage emphasise the importance of preservation and regular maintenance to protect historical buildings. The aim of this paper is to propose a framework for the renewal of historical town centres (rHTC), using the HTC zone of Trogir on the Adriatic coast of Croatia as a case study. The town of Trogir is included on the UNESCO's World Heritage List. Based on the collected data, the framework for the rHTC of Trogir is proposed, and a multicriteria analysis, as well as strengths, weaknesses, opportunities and threats matrix (SWOT) analysis are used. The framework includes important activities that must be conducted in order to preserve integrity of this cultural heritage. The proposed framework can be applied to other historical town centres throughout Croatia and around the world.

Keywords: *historical town centre; Trogir; renovation challenges*

1. Introduction

Town renovation is a continuous process of improvement. It is not simply a process of rehabilitation, but much more: improving and increasing the value of the built space (Pegan and Jukić, 2003). Reservation and protection of historical town centres (HTCs) are of great social interest. The processes of rehabilitating many historic towns and cities have lasted for decades, although there is no general agreement on the meaning of this term. Therefore, the approaches range from the preservation and protection of cultural and historically important buildings to revitalisation of a larger area of historical cities (Poljičak, 2014).

The renewal of HTCs (rHTCs) is affected by many concerns, including theoretical, methodological, practical, organisational, financial and political. Each of these concerns has a range of implications, and they are interconnected in many ways. Balancing the impacts of certain aspects of concrete renewals is essential. The fundamental principle of rHTCs is to prevent the devastation and deterioration of individual buildings, including inhabitants and guests' requirements for tourist offerings as well as the preservation of original, urbanistic-architectural, historical, artistic, and aesthetic features. Historical landscapes cannot be seen only as a complex of historical buildings and monuments; they must be accessed as 'living environments' that change their inhabitants and change for their inhabitants.

Croatia has concluded a few agreements and joined several important international organisations, promising and being committed to maintaining high-quality care for the preservation of cultural heritage. One of the famous is UNESCO's Convention for the

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Safeguarding of the Intangible Cultural Heritage; with the main duty of each member country to ensure the maximum protection, conservation, and presentation of the cultural and natural heritage for future generations (Duraj et al., 2016).

Croatia joined the Council of Europe in 1996 (COE, 2016). Obligations as a member state include, above all: preventing the destruction protected goods and ensuring the financial funds for this effort, promoting a private initiative for protection and preservation of culture heritage, adopting an integral policy to protect the country's architectural heritage, promoting and making proper use of restoration and heritage conservation programs, encouraging cooperation on heritage conservation, setting up a decision-making information system, encouraging sponsorship development and non-profit organisations, and providing education on the needs of occupations and trades.

The International Council on Monuments and Sites (ICOMOS) is an international professional association that deals with the preservation, protection, and promotion of cultural heritage. It was founded in 1965, and today is headquartered in Paris. Croatia is one of ICOMOS' 110 national committees around the world (ICOMOS Croatia, n.d.). It has released a full range of orders, decisions, guidelines, and recommendations. Some of them are relatively old, but remain very important and useful (see Table 1).

Table 1. Excerpts of important ICOMOS acts (ICOMOS Croatia, n.d.)

Act	Year
Conserving Smaller Historical Towns	1975
Charter on Cultural Tourism	1976
Recommendation on the Preservation and Contemporary Role of Historic Areas	1976
Guidelines for Education in Conservation of Monuments, Ensembles, and Entities	1993
Charter on Sustainable Tourism	1995
Principles of Marking Monuments, Groups of Buildings, and Entities	1996
The Burra Charter	1999
Charter on International Cultural Tourism	1999
Principles of Analysis, Conservation, and Structural Renovation of Architectural Heritage	2003

On the national level, there are numerous associations and societies whose mission is to preserve immovable cultural heritage. Some of them are: Society of Cultural Heritage Friends of Split, Citizens Association for the City Centre Protection, Maintenance, and Development of Life Therein and its GENIUS LOCI, Department for Reconstruction of Dubrovnik, Society of Friends of Dubrovnik Old Testament. The above examples work locally. In Trogir, there is the Society for the Protection of Radovan's Cultural Heritage, but it engages in few, if any, activities. The Croatian Association of Historical Cities (CAHC) was launched in Dubrovnik, based on the model of European Association of Historical Cities and Regions (EAHTR). The EAHTR is a multinational network of historic cities founded in 1999 in Strasbourg, with the aim of promoting the interests of cities with rich cultural and historical heritage. It was recently renamed 'Heritage Europe'.

The CAHC highlights the advantages and disadvantages of cultural tourism in the historic towns of Croatia, as well as the impact of contemporary cultural tourism on the sustainable management, protection, and reconstruction of towns. Historic towns are looking at cultural tourism as the main driver of regeneration and heritage prosperity. In parallel, problems arising from the specific needs of historical towns have multiplied, as well as the challenges of preserving cultural and natural heritage, traditional culture, satisfying citizens' needs, and citizens' relationships with their cultural heritage. Not least, recognizing the importance and value of Croatia's cultural heritage and its management and use are also of concern. The long-term goal of the HUPG is to jointly and systematically address and solve relevant challenges through the exchange of views and experiences between cultural heritage experts, representatives of local governments, researchers, and tourism workers (CAHC, 2016).

Global frameworks suggest the establishment of indicators to monitor the state of conservation of cultural heritage properties and identification of threats resulting from possible developments (UNESCO World Heritage Centre, 2015). In the world heritage context, development is mainly monitored as a threat. Reports from advisory bodies, the World Heritage List in Danger, and Monument Watch have raised concerns about the negative impacts of urban development (Guzman et al., 2017). These issues are not solely local; even nowadays we have witnessed many monuments deteriorating due to insufficient protection or neglected maintenance on the part of their owners. For example, due to the circumvention of the law, the state has lost valuable buildings throughout the Czech Republic, demonstrating that each effort to reverse this course is important for the general protection of heritage sites (Duraj et al., 2016).

Unfortunately, many monuments are damaged or destroyed primarily because of military and religious conflicts. Cultural heritage sites and protection is an issue discussed in many works—see, for example, Anania et al. (2012), Armaly, Blasi, and Hannah (2004), Armesto et al. (2008), Harris (2006), Monteiro (2011), Palau-Saumell et al. (2013), Papageorgiou (2015), and Vlcko (2004). In order to verify the results of previous studies worldwide, and to develop practical guidelines for considering rHTC projects, the case study of Trogir is analysed and reviewed below. By integrating existing knowledge and facts from this particular case, the overall guidelines are given as well, which could be applied to similar HTCs around the world.

2. About Trogir

Trogir is located at the western end of the vast bay of Kaštela in Croatia. It is the part of the urbanised area, including its HTC. It is part of the long, narrow urban agglomeration, together with Kaštela, Solin, Split, and Omiš. It is protected from continental impacts by the Dinarides (Mt. Kozjak and Mt. Mosor), which contributed to the development of the region's Mediterranean climate. Trogir is one of the oldest Mediterranean towns (Travirk, 2008). It is a unique cultural and urban area, and protected at the national and international levels. According to renowned world historian Bernard Berenson, Trogir is a 'treasury of art', or 'city museum'. From the nineteenth century to this day, it has had an attractive environment and an extraordinary heritage, and tourist interest in the city centre and the surrounding area is intensifying (Trogir City Council, n.d.a).

At the national level, the most relevant protections are implemented and monitored by the Ministry of Culture. For any intervention in the cultural or historical sites, the prior consent of the Conservation Office is required. Special conditions for renovations are stipulated to ensure that these sites are protected. These efforts are designed to achieve full protection on the one hand and maintain the utmost respect for functions and the contents of these spaces on the other. Internationally, Trogir has been under the protection of United Nations Educational, Scientific, and Cultural Organization (UNESCO) since 1997. Its acceptance in the list of such sites was based on two criteria: (1) it proves a significant exchange of cultural values and achievements in architecture, technique, art, urbanism, or landscape designing between periods or cultures and (2) it is an outstanding example of a building that represents an important stage of human history (Repository of Croatian Studies, 2016; HSTU, 2016). Including Trogir on UNESCO's

World Heritage List is a great marketing benefit for the area, especially in terms of tourism, and is the reason for investing in extra care for cultural monuments (Radić, 2005).

Trogir's rich heritage encompasses many historical, economic, social, and cultural events. The HTC covers about 112,000 m^2. Most of the buildings in the area date back to the Middle Age, and their mediaeval features are extremely well preserved (Radić, 1995). Most were built as residences, although a small number were designed for educational, religious, or commercial purposes. Their functions have changed over time. Formerly residential buildings have been partially converted to include shops, business facilities, and restaurants. Tourism exploitation develops the city centre, but it also conflicts with the needs of cultural heritage preservation. Entrepreneurs' initiatives are often focused on tourism, and the needs of local indigenous people are often neglected or ignored.

The area of 64,000 m^2 is protected at the national level as a zero-category monument (highlighted with a in Figure 1), with a buffer zone of 48,000 ha (highlighted with a in Figure 1). The area under UNESCO protection (UNESCO, 2016), the border of which is highlighted with a dark dotted line in Figure 1, is not harmonised with national protection: This mismatch causes problems in monitoring, planning, and coordinating renovation activities, and it disturbs managing procedures on an international level.

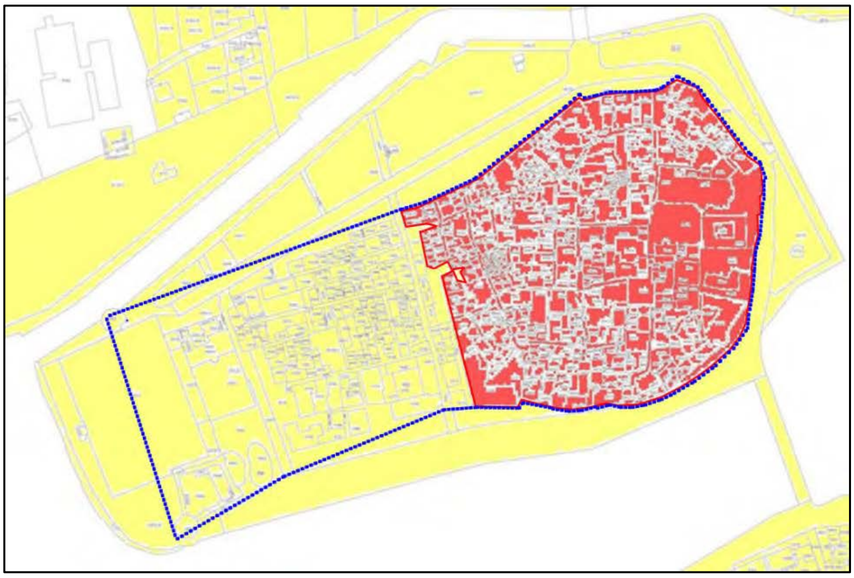

Figure 1. The protected area of rHTC of Trogir (Adjusted from UNESCO, 2016)

The condition of Trogir is a direct consequence of the existing system of care, investment planning, and realisation, as well as constraints that come from administrative and legislative rules regarding protection and spatial management. Certainly, there is an unquestionable need for more systematic recording and managing of remedies and interventions. To identify the investments in rehabilitation and preservation projects made up to the present, it was necessary to integrate more data sources. This included several days of collecting and looking for data in archives and conservation offices before summing up to make such identifications as clear and transparent as possible.

Most of the buildings are made from stone. Some of their facades are adorned with perforations and decorations (such as coats of arms), especially on more representative buildings (e.g. the Palača Andreis in Mornarska Street or Berislavićeva House). Streets are mostly paved with stone. On average, the forms of buildings are simple, interlocked, and in usable condition. Most of the individually protected buildings are in the protected area, although a few of the religious buildings are in the buffer zone.

3. Earlier investments in preservation and renovation in the rHTC of Trogir

Restoration of the HTC should not cover only the individual protected facilities, but the complete reconstruction of the area. There is a lack of interdisciplinary understanding of urban dynamics interacting with cultural heritage in general (Guzman et al., 2016), as in the particular case of Trogir.

Priority has been given to the renovation of the buildings in the heart of the town centre, which is not surprising; this is the area with the most important religious and residential buildings. The reason for setting up representative buildings in the circle around the main town square and St Lovre Cathedral, together with City Hall and the Lodge, is that these sites are certainly included in historical-sociological analyses of the urban development of Trogir's town centre.

Restorations of buildings in Trogir have taken place for centuries. Investments are divided here into historical investments (up to 2006) and recent investments over the past 10 years. Data have also been gathered from the official site of the Ministry of Culture (n.d.). For insight into the historical investments, here is the chronological review from the thirteenth century, based on the authors' research (see Table 2). St Lovro Cathedral is excluded from the table because work on it lasted continuously from the thirteenth century to today. The conservation work was carried out in the nineteenth century under the leadership of the Imperial Royal Central Commission in Vienna. Thereafter, there are records of repairs to the roofs, vaults, windows, organ, gate, and inventory from the beginning of the twentieth century (Piplica and Mamut, 2014).

Table 2. Overview of the rHTC of Trogir (adjusted from Piplica and Mamut, 2014; Šverko, 2008; Piplović, 1999)

Period	Buildings	A brief description of the works
1200s	Town walls (*Gradski bedemi*)	The whole rebuilding
1400s	Town walls and lodge (*Gradske zidine i loža*), Kneževa Palace (*Kneževa palača*); Fortification towers and bridges; Communal House (*Komunalna kuća*)	Renovation of the buildings damaged in the attacks of the Mlećani; applying of the obligation of renovation of the buildings by inhabitants
1700s	Town gate and streets	Repairing
1800s	Church and monastery, St Dominik	Interior and exterior decoration
	Town Lodge (*Gradska loža*)	The renovation according to the conservator Alois Hauser
1900s	Church and monastery, St Dominik	Reconstruction of the roof, foundation reconstruction, and refurbishing; reconstruction of the cloister (345 m^2)
	Church of St Barbara	Restoration of the basilica and removal of the subsequent reconstruction parts
	Church of St Ivan Krstitelj	Reconstruction of the roof and facade
	Bell tower, St Mihovil	Reconstruction of the belfry that was slanted for more than a meter and damaged by air bombardment in February 1944; it was taken off due to the danger of falling in April 1952 and was later reinstalled

At the beginning of the twenty-first century, the Chapel of St Ivan in St Lovro Cathedral as well as one of the bell towers was restored. The atrium of the cathedral, including Radovan's portal, the baptistery, and the sacristy was also restored. The Church of the Carmel and the St Ivan Krstitelj were also restored at the same time.

Religious sites were continually restored between 2006 and 2016. This includes construction, conservation renovations, and maintenance works. In the past 10 years, the investment into such work has included technical documentations and investment studies, including projects on Cega House, Ranoromanička House, Big Palace Ćipiko, and Garagnin-Fanfogna Palace (Museum). The total amount of remediation works in the last 10 years came to somewhat less than 1,73 million euros, of which 75 per cent was invested in religious buildings and 25 per cent in residential and private buildings for public use (the Town Museum, Public Association offices, Conservation Department offices, etc.). More investment in renovations of public buildings (e.g. Mala i Velika Loža, City Hall, and Kula Kamerlengo) would produce more effective results and make a positive contribution to cultural heritage development and preservation. Some building conditions are so bad that they require emergency repairs; these renovations are not carried out according to technical criteria, but according to the individual purposes of the building or structure in question.

A further analysis compared planned and realised investment in renovation and reconstruction works. The renovation costs were monitored by applications for protection programs, which must be archived in the Conservation Department of Trogir, along with a list of approved and rejected programs from the official site of the Ministry of Culture (n.d.). The reason for this is that Trogir's Conservation Office is obliged to give its consent to the interventions in the each of historical and cultural part of the town. The collected data is considered to be a reliable source for analysis. The Conservation Office does not initiate works, but the incentive for renewal programs comes from the program proponent. The proponent of the renewal program may be a person, public institution, society, association, organisation, religious community, trading company, etc. In Trogir proponents are usually religious communities and sometimes persons.

The planned proposal for financing includes funds from the Ministry of Culture, funds from the renovation program applicant, and funds from other sources (e.g. the town). The Ministry of Culture approved or co-financed only 13,28 per cent, or about 850.000 euros, through the Program of Prevention and Cultural Goods Conservation.

Results obtained after collecting and processing the data are shown in Figure 2. The totals of the amounts of planned funds were collected from data drawn from contracted bills of quantities and finished calculations, where such data were available.

Year	*Planned/realised*
2010	12,58 %
2011	6,46 %
2012	25,26 %
2013	13,76 %
2014	6,57 %
2015	52,71 %
2016	24,02 %
Total	*13,28 %*

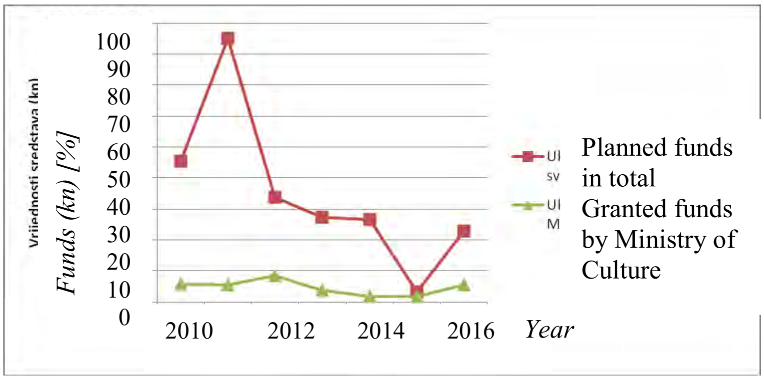

Figure 2. Renewal review, 2010–2016

Obviously, there is a disparity between those works planned for Trogir and those actually carried out. Planned funds derive from individual analyses of the existing state, while the realisation refers to less than 15 percent of planned interventions. There is a general impression that the existing state is neglected and disappointed. Walking around the town, one can occasionally see cracks in the outer walls. Façades are uneven, and only some have been restored. The interventions and actions undertaken by the rHTC as a spatial entity with its functional, ecological, demographic, and similar challenges need appropriate solutions involving the cooperation experts from a variety of backgrounds, in coordination with various associations and civil society (Babić, 2012).

Given the existing special conditions and defined protection scale, it is obvious that those actions are, in general, well defined. Theoretical guidelines are sufficiently detailed so that each operation can be successfully planned and realised, but the final solution for each site requires more detailed supervision and work control in order to eliminate irregularities.

4. The current state of HTC evaluations of Trogir

There was no current plan for restoration or development of the HTC as a whole during the writing of this paper. At present there are no urban projects that would follow spatial plans and protection requirements and offer a concept to rehabilitate the HTC. The town centre has been deteriorating for many years due to the impacts of weather, neglect, and vandalization. Ownership—private, public, and religious—has also impacted the efficiency of planning and investment. There is a disagreement over certain administrative cadastral data produced by the actual state, and so further property analysis is currently disabled. By reviewing the state of the public registry, it has been found that the buildings in question have partially mixed public-private ownership, with partly incomplete location data (address, cadastral plot, etc.).

There is an obvious disparity between the economic exploitation of the hereditary monument heritage and investment in rHTC. Cultural tourism is developing very rapidly, but the organisational models for planning and managing the cultural heritage protection is not. Despite Trogir being a world-renowned historical location, insufficient effort has gone into maintaining and restoring buildings. Some of the major problems stem from the contradictory state of preservation and the renewal of certain cultural goods: For example, St Lovre Cathedral is fully functional and open to visitors, while the Kula Kamerlengo is in extremely poor condition and within the sight of the tourists. According to the available data, the revenue from monument rents (*spomenička renta*) in Trogir in 2015 was about 42.000 euros (Trogir City Council, n.d. b). Compared to 2014, the revenue increased by 0,5 percent, and compared to 2013, there was an insignificant loss of rent revenue from these monuments. Data for 2012 are unavailable, but considering the ratio for 2011, about 12.000 euros more in revenue was realised in 2015 (ICOMOS Croatia, n.d.). It is interesting to compare the planned and realised investments in 2004 and 2015, as in 2004 the system for monument rent annuities had only just been implemented. In 2004, about 88.000 euros was earmarked for planning and less than 2.000 euros were invested.

A rough estimate of usability was formulated to assess the condition of facilities in Trogir's HTC. Each individual structure in the Cultural Heritage Registry was assigned to one of the following four categories: *good condition*—buildings whose state is sufficient to continue to be sustained; *acceptable condition*—buildings that require partial renovation and should receive regular maintenance afterward; *poor condition*—buildings which require rebuilding or reconstruction; and *derelict*—sites where only the remains of former buildings still stand (see Figure 3 below).

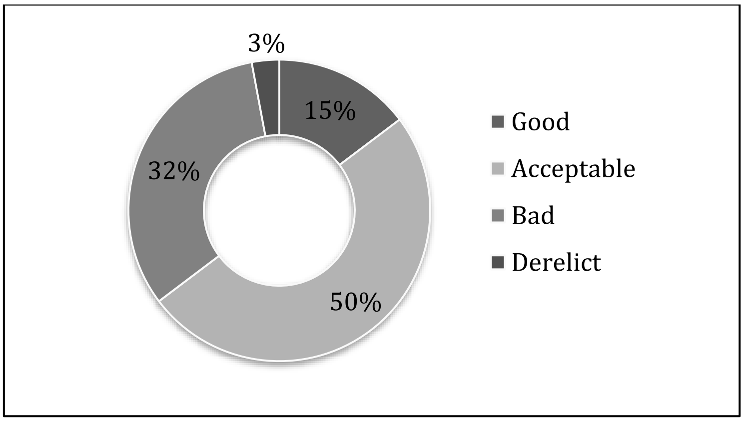

Figure 3. Individual building evaluations in Trogir's HTC

The assessment was done on the basis of an Urban Plan of *Karlovačke zvijezde* (Hadrian 2015) and the expert assessment of the author (Milat, 2016). Individual buildings protected by the Cultural Heritage Registry of Croatia have been analysed; although these assessments do not apply to all of the facilities of the HTC of Trogir, they do provide an overview framework of the current state.

Table 3 below lists the conditions (good, acceptable, bad, or ruinous) and purpose categories of a number of buildings. If we link the purpose of the buildings with their condition, it is evident that residential buildings (dwellings) are in the worst condition—50 per cent are in poor or ruinous condition. The likely reasons for this are proprietorships, funding problems, or failures to reach an agreement on the joint financing of renovations (by EU funds, financing by local state level, etc.). Residential buildings are not of primary interest for the renewal process, and are left to their individual owners. In contrast, 80 per cent of religious buildings are in acceptable condition, due to owner financing and support from other funding resources.

Table 3. Assessment of buildings' condition by purpose and number

Purpose	Condition				**Total number**
	Good	Acceptable	Bad	Ruinous	
Religious	2	6	2	-	**10**
Residential	2	6	7	1	**16**
Public	1	2	-	-	**3**
Fortification	-	1	2	-	**3**
Other	-	2	-	-	**2**
Total	***5***	***17***	***11***	***1***	***34***

The Ministry of Culture of Croatia should recognise the value and potential of UNESCO protection and significantly increase its funding for renovations. Town government support is currently inadequate; the renewed efforts are evident, but funding remains the greatest challenge. As a result, there are lots of buildings standing empty and being sold as many owners try get their problems off their hands.

5. Strengths, Weaknesses, Opportunities and Threats (SWOT) analyses

Strengths, Weaknesses, Opportunities and Threats (SWOT) analysis are one of the most widely used types of analysis, and is useful in a variety of contexts: It allows an analysis of a unit's development in the present and future (Mrak, 2014). Its goal is to identify internal strengths and weaknesses, as well as external opportunities and threats that come from the unit's environment (Grad Split, n.d.). SWOT analysis is an excellent tool for clarifying the criteria for multicriteria analysis to make decisions about renovations in the future, as well as strategic decisions.

So far, SWOT analyses have been developed for certain other destinations, such as the HTCs of Split, Varaždin, Karlovac, etc. These previously conducted SWOT analysis served as examples and a starting point for the SWOT analysis of Trogir's HTC (see Table 4 below).

Table 4. SWOT analysis of Trogir's HTC

Strengths	**Weaknesses**
- UNESCO protection - Rich cultural and historical heritage - Geoclimate, locational and natural features - Traffic availability - Unique attractive heritage for further cultural tourism development - Marketing potential of the historical town centre - Continuity of living in the historical town centre	- Absence of a conservation base for the space in the whole - Insufficient public information about the HTC's condition - Insufficient utilisation of space - Lack of regular maintenance activities - Insufficient elaboration of tickets sales procedures regarding the issues related to improving conditions - Unregulated integral management - Documentation collecting is unorganised - Absence of a strategy to develop and improve the condition of buildings in the heart of the town centre - Absence of a management plan - Inconsistent protection zones ('A' and 'B', compared with UNESCO protection) - Lack of financial resources - Large seasonal variation of capacity and utilisation
Opportunities	**Threats**
- Foreign funding investments in cultural heritage - Integral solutions for communal infrastructure and archaeological works - New job openings during the renewal process - Existence of national and international support programs - Growth of demand in the cultural tourism development	- Road traffic destruction of valuable monuments (road vehicles, aircraft) - Spatial overload due to the uncontrolled increase of visitors during the peak of the tourist season - Problematic space management processes - Dysfunctionality of the relevant institutions - Global trends in the real estate market - Insufficient funding resources - Inadequate relationships and communication with government - Lack of investment in projects involving historical and heritage protection - Realisation of incorrect or unsuitable aims in the revitalisation process - Degradation of the value of cultural heritage

6. Guidelines for Trogir's renewal of historical town centres

The first step in developing appropriate plans for renovations suited to specific conditions such as those of Trogir is to synthesise and create categories for the *status quo*, followed by investment categorisation. These plans must be based on known facts, collected data. and methods used for planning renovations in such an environment.

It is proposed that the activities for the town renovation be divided into three main categories:

- Complete reconstruction of the HTC;

- Revitalisation of individual historical buildings; and
- Soft infrastructure development.

A description of each category is given below.

The complete reconstruction of the HTC includes planning and restoration work to revitalise the communal infrastructure of Trogir's HTC. It refers to projects in the HTC and covers more buildings. It creates structures with added value and strengthens the visual identity of the HTC, as well as supporting the realisation of further reconstruction processes.

Based on the collected data, the confirmed proposals for Trogir's rHTC consist of:

- Making an architectural project of the current state;
- Restoring street pavements and town squares;
- Constructing a drainage system and waste water purifier; and
- Renovating roofs.

The revitalisation of individual historical buildings includes restoration works on religious and residential buildings, which are listed on the Croatian Cultural Heritage Registry maintained by the Ministry of Culture of Croatia. The proposed restoration activities will be implemented in the following buildings: Kula Kamerlengo, Kula St Marko, Palača Lucić, Palača Ćipiko, Palača Berislavić, the Churches of St Dominik and St Svih Svetih, House Cega, a house with gothic *bifore* windows on Obrova, the Rožić, Stafileo, Tomaš, and Obrov buildings, and the reconstruction of Palača Andreis.

Soft infrastructure development includes facilitating the implementation of activities that impact the further raising of awareness of the importance of the HTC and implementing the renewal processes. That means proposals for education, partnerships, presentations, etc. It does not require significant funding in relation to other renewal activities, and their realisation contributes significantly to the overall improvement of the renovation of the HTC. The proposed projects and activities are as follows:

- Tourist signalisation;
- Urban renovation;
- Establishing a cultural event marketing company;
- Restoration of advertising contents;
- Heritage impact assessment;
- Educating the inhabitants of the HTC;
- Designing a transparent support system for heritage monument renewal activities; and
- Strengthening the cooperation between institutions and local governments.

An analytical hierarchical process (AHP) was conducted to determine the possible priorities of reconstruction activities. This method was selected because of its ability to support complex decisions, taking into account different aspects (economic, construction, functional, historical) while avoiding the risk of making a subjective decision on renewals. Due to resource constraints (number of relevant experts, money, time constraints) and the need for optimal implementation of renewal activities, an AHP was conducted to support ranking activities by priority. Such ranked activities can serve as a basis for further decision-making on priorities in the process of cultural heritage renovations. The AHP was used to rank activities as possible alternatives due to certain weights of proposed criteria. It was conducted using Expert Choice software (see Figure 4 below).

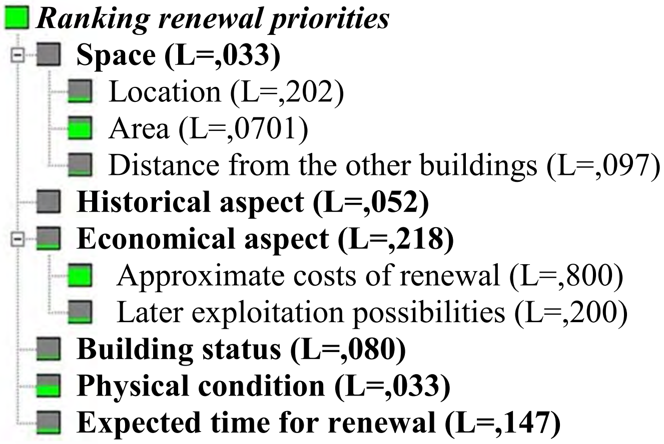

Figure 4. AHP model for proposed renovation priorities

Although the AHP is the most popular method of solving complex decision-making problems, it has advantages and disadvantages that need to be considered before use. Many advantages are reflected in the structured approach to decision-making factors: the successful simulation and integration of quantitative and qualitative factors in the decision-making process, consistency checks, low cost, and the very applicable and customisable results. Its disadvantages include the significant impact of the human factor in selecting a criterion’s weight, the large number of necessary comparisons, the difficulty of achieving an acceptable consistency ratio, and the insufficient scale for comparing the criteria or alternatives for certain specific problems (Begičević, 2008).

The criteria used in the AHP were also evaluated using Saaty’s scale of relative importance (Saaty, 2005). For the criterion ‘*time for project completion*’, the shorter the time, the greater its relevant prioritisation weight. This criterion included three categories: short-term (one to three years), middle-term (three to five years), and long-term (more than five years). With regard to ‘*Physical state*’, the degree of damage is in question, and priority is given to buildings that represent the exceptional importance of an architectural style and uniqueness (unique buildings are given higher priority).

‘*The later exploitation possibilities*’ are considering sales revenue for sightseeing, renting, and the like. The greater the possibilities for economic exploitation, the higher a site’s rank in AHP. Conversely, the lower ‘*the approximate renewal costs*’, the greater a site’s importance in ranking renewal priorities. ‘*Historical criteria*’ is a greater priorities if the building is older. ‘*Distance of neighbouring structures*’ imparts a higher priority rank if there are other listed buildings nearby; buildings that are isolated have a lower priority. Buildings with a smaller area are ranked higher than larger buildings because less time is required for the reconstruction process. ‘*Location*’ is used to evaluate whether a site is in zone ‘A’ or ‘B’. The closer to the centre a site is, the higher its priority.

Figure 5 below shows the results of the AHP analyses. It is evident that Kula Kamerlengo, Palača Andreis, and the Church of St Dominik have the highest priority.

Ranking renewal priorities

Space

Historical aspect

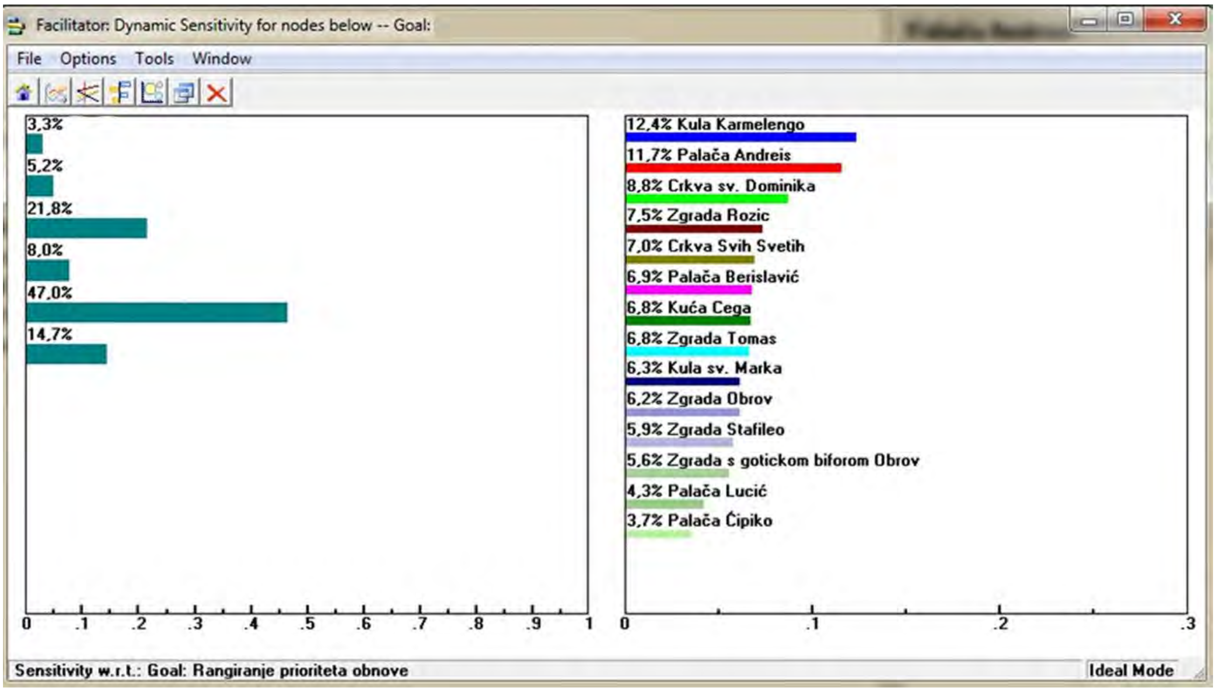

Figure 5. Summarised results of AHP analysis in software: Expert Choice

Sensitivity analyses and criteria weighted by importance were used to organize the priority list and enable the comparison of items from the criteria's importance list. Changing the relative weight of '*historical criteria*' from its initial 5,2 per cent to 12,1 per cent and proportionally changing the relative weights of other criteria alters the ranking of renewal priorities considerably (see Figure 6). This proves the importance of well-set goals and priorities, which must be based on objectively established relationships between criteria.

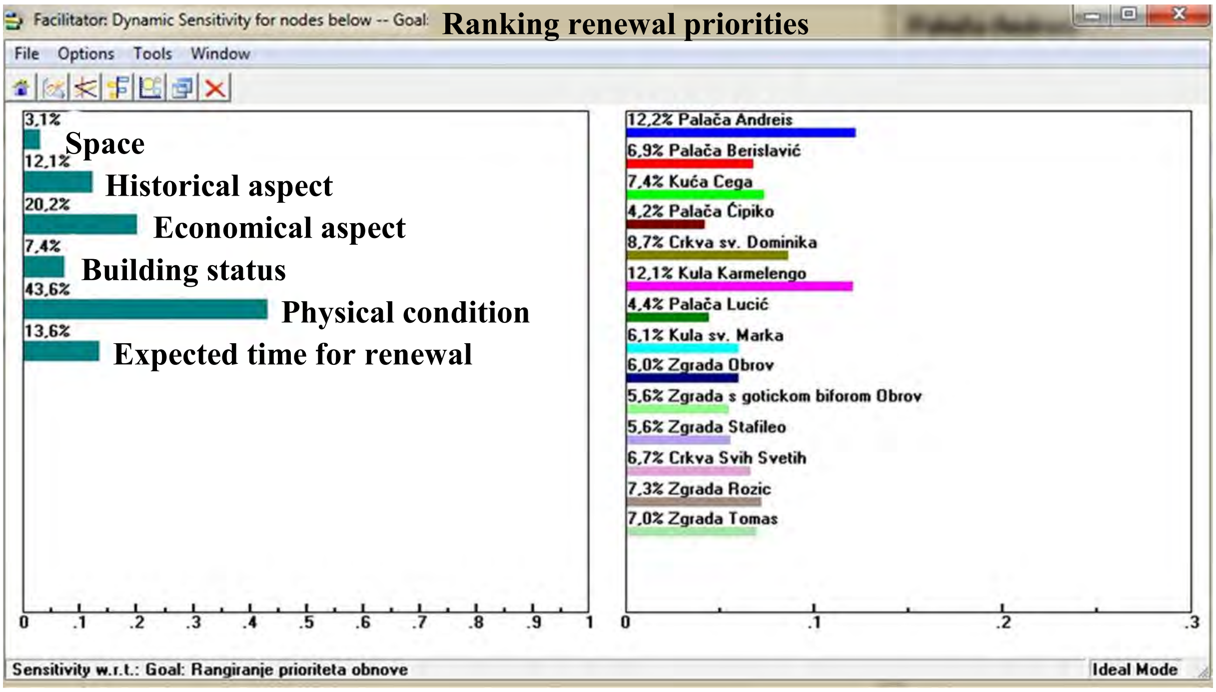

Figure 6. Sensitivity analysis results in Expert Choice software

7. A proposed framework for similar renewals

Interventions are needed if balanced and sustainable cultural heritage protection is the ultimate goal. Such a structured approach requires the preparation and adaptation of management plans aligned with European, regional, and local strategies. There are several different models and methods of heritage preservation, and recognizing the optimal process for each HTC is not only key to maintaining immobile cultural heritage but also a precondition for living in such an area (Magdić, 2014).

Precondition activities include the following:

- Step 1: Previous detailed research on archive documentation, old maps, cadastres, photographic documentation, and other materials;
- Step 2: Implementation of conservation and restoration research by assessing buildings to determine the most complete or most valuable historical layer that should be restored and presented;
- Step 3: Creating or modifying existing situation plans in detail, in parallel with research activities; and
- Step 4: Developing detailed reconstruction projects based on which construction and restoration works have already been carried out (Croatian Conservation Institute, 2013).

Furthermore, the use of strategic tools such as SWOT analysis, stakeholder analysis, and AHP to prioritise activities and decisions at each process level (from strategic to operational) is also welcome. RHTCs are organised, well-supported, and focused interests that lead to revitalisation and finding innovative ways of life for old towns in modern conditions.

The proposed activities could, in general, be divided into three main categories: parts for *complete rHTC*, *revitalisation of individual cultural goods*, and *soft infrastructure development*. Detailed analyses of these areas greatly depend on their specific economic, historical, and social environments, and must be conducted in an appropriate way. However, methods for determining status and the necessary support for planning future action may be different. AHP was used in this particular case study for the purposes of this paper, but there are many other possibilities:

- *Leopold's Matrix Model*: First described in 1971, this is probably the most important of assessment models, and it has become the basis for most of the models developed since. It uses multi-criteria matrices involving planned interventions and environmental components. These matrices introduce environmental aspects and include significant impacts, positive and negative signs, grades, and weights (Mrak, 2014).
- *Mathematical methods* of determining the hierarchical priorities In terms of project management, large companies use them particularly often. Such methods—e.g. Satty's AHP, Analytic Network Process (ANP), Zeleny's theory, the regulatory analysis of Nijkampa and Hinloopen, approximate cluster analysis, Evamix, and the Vimda method—are useful in determining the scale of priorities. The use of these methods is often facilitated by software tools (Mrak, 2014).
- *Kalman's method* is based on a generated table, where the indicators are given and assigned values according to an existing scale. The indicators are style, construction, age, architect, project, interior, history of events, context and people,

environment, services and costs, and integrity. The same indicators could be applied for analysing the current state, evaluating the project, and for observation.
- *Campeol's Pyramid model* was developed during a UNESCO project. It is based on a multicriteria analysis where data is grouped according to the quality and damage to space within the matrix model, and the type of intervention is then defined: conservation, valorisation, preservation, renewal, regular use, or change of purpose. This model allows a synthetic approach to heritage considerations (Mrak, 2014).

8. Conclusion and further research

RHTC is a complex task and must be managed as a programme—solving these issues requires reliance on a variety of research disciplines, while the process as a whole is always long-lasting. The renovation goals are ultimately the end at which the renewal activities are directed, and thus, they should be measurable and realistic. The main goal of rHTC is to preserve exceptional value, which is globally recognised.

The overall aim of the renovation of Trogir is to preserve the individual buildings of the whole HTC (a bottom-up approach), as well as to revitalise the development of the town's cultural and historical heritage. Specific objectives include highlighting and presenting the values of the area's cultural and historical heritage through renewal processes and creating preconditions for space transformations by enhancing the development of different business activities. When these goals are realised, Trogir's HTC will be a more comfortable place to live.

The goals for this project derive from international and national goals using current strategies, and include the fact that a large number of residential and/or business premises in the HTC are neglected, unused, or inadequately used, while the general condition of the building fund is worrying.

The suggestions presented for the rHTC of Trogir could be applied to other HTCs as well. Such a proposal is only a starting point for the long-term and continuous process of renewal, and further elaboration of the solution to this issue could give rise to ideas for other works that will be proposed in the future.

There were several obstacles and challenges during the process of collecting data and analyses for this research. Challenges include the inconsistent implementation of statutory provisions for collecting monument rents; unsettled and unstructured databases maintained by competent bodies for mapping the long-standing problems to date (which seem to be the same for most HTCs at the national level). These issues raise the question as to why, to date, there is no standardised methodology for gathering information on renewal processes and why those methodologies that are used are not applied in more effective ways. Creating common, consistent, and available databases is imperative as the starting point for further work. Room for further progress exists, but time is running out and inaction is exacerbating the mistakes of our forerunners and contemporaries. Next steps should aim at allowing the preservation of value as we know it and opening the door to possibilities for further progress.

References

Anania, L., Badalà, A., Barone, G., Belfiore, C.M., Calabrò, C., La Russa, M.F., Mazzoleni, P., and Pezzino, A. (2012), 'The stones in monumental masonry buildings of the "Val di Noto" area: new data on the relationships between petrographic characters and physical–mechanical properties', *Construction and Building Materials*, vol. 33, pp. 122–132.

Armaly, M., Blasi, C., and Hannah, L. (2004), 'Stari Most: rebuilding more than a historic bridge in Mostar', *Museum International*, vo. 56, no. 4, pp. 6–17.

Armesto, J., Arias, P., Roca, J., and Lorenzo, H. (2008), 'Monitoring and assessing structural damage in historic buildings', *The Photogrammetric Record*, vol. 23, no. 121, pp. 36–50.

Babić, I. (2012), Povijesne jezgre dalmatinskih gradova i njihova sudbina, Građanska inicijativa Split, available at: http://www.gist.hr/?p=71 (accessed 31 October 2016).

Begičević, D. (2008), 'Višekriterijalni modeli odlučivanja u strateškom planiranju uvođenja e-učenja', PhD dissertation, University of Zagreb.

Council of Europe (COE) (2016), Home page, available at: http://www.coe.int/en/web/portal/home (accessed 26 October 2016).

Croatian Conservation Institute (2013), 'Graditeljsko naslijeđe', available at: http://www.h-r-z.hr/index.php/djelatnosti/konzerviranje-restauriranje/graditeljsko-naslijee (accessed 16 January 2017).

Duraj, M., Marschalko, M., Niemiec, D., and Yilmaz, I. (2016), 'Monuments of the Czech Republic on the UNESCO World Heritage Site List and their significance for geotourism', *Procedia Engineering* vol. 161, pp. 2265–2270.

Grad Split (n.d.), 'Plan upravljanja povijesnim kompleksom Splita (PKS)', available at: http://www.split.hr/Default.aspx?art=7774 (30 March 2016).

Guzman, P.C., Pereira Roders, A.R., and Colenbrander, B.J.F. (2017), 'Measuring links between cultural heritage management and sustainable urban development: an overview of global monitoring tools', *Cities* vol. 60, pp. 192–201.

Hadrian (2015), 'Posebna stručna podloga za UPU karlovačke Zvijezde—ekonomsko vrednovanje', Hadrian, Zagreb, available at: http://www.karlovac.hr/UserDocsImages/2016/dokumenti/ZVIJEZDA%20-%20EKONOMSKO%20VREDNOVANJE%20FINAL.pdf [2 November 2016].

Harris, L. (2006), 'UNESCO reconstruction plan for Kosovo', *The Art Newspaper*, vol. 15 no. 165, p. 23.

Hrvatska udruga povijesnih gradova (HUPG) (2016), 'O nama', available at: http://www.hupg-povijesnigradovi.com/hr/o-nama/ (accessed 31 October 2016).

International Council on Monuments and Sites (ICOMOS) Croatia (n.d.), Official web site home page, available at: http://www.icomos-hrvatska.hr/ (accessed 28 November 2016).

Magdić, D. (2014, November 30), 'Prema demokratskoj paradigmi zašite baštine', *Stav!*, available at: http://stav.cenzura.hr/prema-demokratskoj-paradigmi-zastite-bastine/ (accessed 30 October 2016).

Milat, M. (2016), 'Prijedlog obnove povijesne jezgre grada Trogira', Graduate thesis, University of Zagreb, 2016.

Ministry of Culture of the Republic of Croatia (n.d.), Official web site home page, available at: http://www.min-kulture.hr/ (4 November 2016).

Monteiro, L.D. (2011), 'The Mezquita of Córdoba is made of more than bricks: towards a broader definition of the "heritage" protected at UNESCO world heritage sites', *Archaeologies*, vol. 7 no. 2, pp. 312–328.

Mrak, I. (2014), 'Metode procjene u funkciji očuvanja graditeljske baštine', *Građevinar*, vol. 66, no. 2/2014, available at: http://hrcak.srce.hr/117041 (27 November 2016).

Palau-Saumell, R., Forgas-Coll, S., Sánchez-García, J., and Prats-Planagumà, L. (2013), Tourist behavior intentions and the moderator effect of knowledge of UNESCO world heritage sites: the case of *La Sagrada Família*', *Journal of Travel Research*, vol. 52, no. 3, pp. 364–376.

Papageorgiou, M. (2015), 'Planning practices for the protection of cultural heritage: lessons learnt from the Greek UNESCO sites', *European Spatial Research and Policy*, vol. 22 no. 2, pp. 111–125.

Pegan, S., and Jukić, T. (2003), 'Polazišta i pristupi organizaciji provedbe obnove grada', *Prostor: znanstveni časopis za arhitekturu i urbanizam*, vol. 9, no. 2, p. 22, available at: http://hrcak.srce.hr/10797 (accessed 18 December 2016).

Piplica, P., and Mamut, M. (2014), *Bogatstvo sakralne baštine, Župni ured sv. Lovre*, Trogir.

Piplović, S. (1999), Dominikanski samostan u Trogiru u XIX. stoljeću, Rad. Zavoda povij. znan. HAZU Zadru. sv. 41/1999.

Poljičak, I. (2014), 'Utjecaj suvremenog kulturnog turizma na promjene načina života u starim gradskim jezgrama na hrvatskoj obali', *Zbornik radova Veleučilišta u Šibeniku*, vol. 1-2, available at: http://hrcak.srce.hr/124905 (accessed 27 November 2016).

Radić, D. (1995), 'Stanje trogirske baštine', *Vartal, časopis za kulturu*, vol. 1-2

Radić, D. (2005), Gradska jezgra Trogira—Svjetska baština (UNESCO), Radovan, časopis društva za zaštitu kulturnih dobara Trogira (Journal), br.3/2005.

Repository of Croatian Studies. (2016), 'Hrvatska zaštićena prirodna i kulturna baština, povijesni grad Trogir', available at: https://www.hrstud.unizg.hr/_download/repository/Povijesni_grad_Trogir.pdf (23 October 2016).

Saaty, T.L. (2005), 'Theory and Applications of the Analytic Network Process', Pittsburgh, PA: RWS Publications.

Šverko, A. (2008), 'Prilozi trogirskoj klasicističkoj arhitekturi', *Prilozi povijesti umjetnosti u Dalmaciji*, vol. 41, no. 1, p. 431, available at: http://hrcak.srce.hr/109692 (11 October 2016).

Travirk, A. (2008), *Trogir—Povijest, kultura, umjetnička baština*, Forum, Zadar.

Trogir City Council (n.d.a), 'Trogir turizam kroz povijest', Trogir City Council Web site, available at: http://www.trogir.hr/GradTrogir/turizam (accessed 27 November 2016).

Trogir City Council (n.d.b), 'Proračun grada Trogira', Trogir City Council Web site, available at: http://www.trogir.hr/GradTrogir/proracun (accessed 25 October 2016).

UNESCO World Heritage Centre (2015), 'Operational guidelines for the implementation of the world heritage convention (July)', p. 167, UNESCO, Paris.

UNESCO World Heritage Centre (2016), 'Historic city of Trogir, Croatia', Available at: http://whc.unesco.org/en/documents/102300 (accessed 23 October 2016).

Vlcko, J. (2004), 'Extremely slow slope movements influencing the stability of Spis Castle, UNESCO site', *Landslides*, vol. 1, no. 1, pp. 67–71.

Identifying Barriers to Remanufacturing in Nigeria which Hinders the Transition to a Green Economy

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Abstract:

Remanufacturing restores end of life products to almost new. It is a form of sustainability. The research set out to identify the barriers of remanufacturing which could hinder the transition to green economy. A questionnaire survey was used to establish the barriers of remanufacturing in Nigeria. Data analysis involving mean item score revealed lack of infrastructure to support remanufacturing as the most ranked variable and obsolescence of equipment as the least ranked variable. Factor analysis reveals five clusters named in the order of importance as Manufacturers barrier to remanufacturing, supply chain barriers to remanufacturing; component, government barriers to remanufacturing, and trade barriers to remanufacturing, low investment by manufacturers, as this clusters signify the classification of remanufacturing barriers in Nigeria.

Keywords: *Remanufacturing; Sustainability; Green economy*

1. Introduction

Remanufacturing is defined as an industrialized process where parts described as cores which have reached their end of life are restored to useful life or almost new (Lund, 1983). The steps associated with the restoration to useful life are inspection, disassembly, part replacement/refurbishment, cleaning, reassembly and testing to ensure the desired product standard is met (Sundin, 2004). Lund (1998) developed seven conditions for remanufacturing. The seven conditions are the following: the product should be durable; the failure of the product should be a functionality failure; the manufactured article is standardised and the components are exchangeable; the remaining value-added is high; the price to acquire the failed manufactured goods is lower as associated to the left over value added; the expertise for the product is steady; and awareness by customers that remanufactured goods exist.

Remanufacturing is a rapidly growing product recovery technique (PRT) in many nations like USA and Europe. This regrettably is currently not the situation in most emerging economies. The collaboration from the OEMs in instigating remanufacturing activities in the emerging countries is important (Nnorom and Osibanjo, 2010). Choudhary and Singh (2011) observed the roadblocks of executing remanufacturing in India and underlined nine key issues: negative user perception, no specific market, few customers, low expertise, the mind-set of

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customer is not like the west, number and quality of returns, uncertainty in the timing, reverse logistics cost, and the low adequacy of remanufactured product due to unawareness of its quality and price. A number of countries, including Brazil, China and Japan have banned or restricted imports for instance of used/refurbished/remanufactured medical equipment. Even when imports are permitted, government hospitals are unwilling to purchase them, raising deep worries about the quality and usability.

Trade in remanufactured products in several emergent economies like India, Brazil, Turkey is restricted. International regulatory, monetary and non-monetary barriers are a significant obstruction and bound trade in remanufactured products. Economic barriers like higher tariffs and fees and non-monetary constraints supposedly include prohibitive taxes, registration and difficult paperwork requirements, strict customs rules, certification, leads to national discrimination over imported ones.

A lot of these barriers probable happens as absence of common and worldwide recognised definition of remanufacturing and standards that distinguishes remanufactured products from used products. The aim of this study is to identify the barriers of remanufacturing in Nigeria.

2. Research methodology

Respondents were requested to indicate the degree of importance of each of the drivers of remanufacturing that play a role in the transition of green economy based on a five point Likert scale (strongly agree = 5, agree = 4, neutral, = 3, disagree = 2, strongly disagree = 1). Ninety-eight complete questionnaires were received signifying an 81% response rate.

The demographics of the respondents indicated that the majority of the respondents who participated in this survey were of the age range from (26-30) years to (31-35) years and had a work experience of (2-5) years and (6-10) years in the manufacturing industry.

2.1 Data Analysis

Two statistical analysis were carried out namely descriptive statistics in the mould of (mean item score) and factor analysis. The mean item score was used to find the importance of the variables. Whilst factor analysis was used in establishing which of the variables could be measuring the same underlying effect. The procedure, findings and relevant discussion follows.

The mean ranking of each attribute was presented to provide a clearer picture of the agreement reached by the respondents. A summary of the test result is shown in the tables below. The mean for each variable included the standard deviation.

Table 1. Results of mean item score

Barriers	**Mean**	**Standard deviation**	**Ranking**
Lack of infrastructure to support remanufacturing	4.74	0.545	1
Lack of Original equipment manufacturers participation	4.68	0.698	2
Threat of counterfeit products	4.65	0.576	3
Unorganised remanufacturing sector	4.64	0.616	4
Fear that remanufactured goods would be sold as new	4.62	0.620	5
Low investment from the manufacturers	4.59	0.625	6
Fear of transferring intellectual property rights to third party remanufacturers	4.57	0.812	7
Lack of remanufacturing strategies from companies	4.54	0.776	8
Lack of government support	4.50	0.834	9
Less awareness of remanufactured products	4.47	0.708	10
Lack of pre-defined standards for remanufacturing	4.43	0.626	11
Negative end-users perception	4.40	0.756	12
No agenda by government on remanufacturing	4.38	0.714	13
Reducing new manufacturing demand	4.36	1.192	14
Quality (reliability and durability) concerns	4.32	0.726	15
Policies restricting importation of cores	4.31	0.795	16
Unforeseen demand fluctuations	4.28	1.108	17
Limited availability of core for remanufacturing	4.18	0.956	18
Unwillingness of customer to return products	4.12	1.186	19
Trans-boundary pollutions	3.95	1.059	20
Limited availability of core for remanufacturing	3.91	1.158	21
Lack of government subsidy	3.87	1.419	22
Product design not conducive for remanufacturing	3.72	1.188	23
Obsolescence of equipment	2.70	1.168	24

2.1.2 Factor Analysis

Factor analysis was employed to establish which of the variables could be measuring aspects of the same underlying dimensions. Factor analysis is useful for identifying clusters of related variables and thus ideal for reducing a large number of variables into a more easily understood framework (Norusis, 2006). Tables 2-5 and Fig.1 presents the result. Average communality of the variables after extraction is as shown below (Table 2); the Kaizer-Meyer-Olkin (KMO) measure of sampling adequacy achieved a high value of 0.795 (Table 3); the Bartlett test of sphericity was also significant suggests that the population matrix was not an identity matrix (Table 3). Thus, the necessary tests in respect to adequacy of the sample size were favorable for the factor analysis to proceed. Cronbach's alpha of 0.845suggested the reliability of the study instrument used was good.

Table 2: Communalities

Communalities	Initial	Extraction
C1.2	0.428	0.674
C2.2	0.315	0.240
C2.3	0.435	0.269
C2.4	0.377	0.434
C2.5	0.417	0.735
C3.1	0.563	0.630
C3.2	0.530	0.503
C3.3	0.454	0.385
C4.2	0.405	0.377
C4.3	0.537	0.517
C4.4	0.366	0.377
C5.1	0.318	0.277
C5.2	0.321	0.269
C5.3	0.439	0.489
C5.4	0.511	0.616

C5.5	0.522	0.573
C5.6	0.410	0.382
C5.7	0.587	0.602
C5.9	0.455	0.430
C5.10	0.557	0.562

Table 3: KMO and Bartlett's Test

KMO and Bartlett's Test		
Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		0.795
Bartlett's Test of Sphericity	Approx. Chi-Square	588.667
	df	190
	Sig.	0,000

Table 4: Total Variance explained

Total Variance Explained									
Factor	Initial Eigenvalues			Extraction Sums Loadings of Squared			Rotation Sums Loadings of Squared		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	**5.953**	29.763	29.763	5.437	27.184	27.184	3.177	15.886	15.886
2	**2.164**	10.818	40.581	1.683	8.413	35.597	2.384	11.918	27.804
3	**1.375**	6.877	47.458	.874	4.371	39.968	1.802	9.011	36.815
4	**1.210**	6.052	53.510	.731	3.656	43.624	1.128	5.640	42.455
5	**1.056**	5.281	**58.791**	.617	3.087	46.711	.851	4.256	**46.711**
6	.988	4.940	63.731						
7	.849	4.244	67.975						
8	.808	4.038	72.013						
9	.739	3.695	75.708						
10	.704	3.522	79.230						
11	.690	3.451	82.681						
12	.603	3.017	85.698						
13	.545	2.727	88.425						
14	.467	2.334	90.759						
15	.431	2.156	92.915						
16	.364	1.820	94.736						
17	.326	1.632	96.368						
18	.270	1.349	97.717						
19	.241	1.204	98.920						
20	.216	1.080	100.000						
Extraction Method: Principal Axis Factoring.									

The data was subjected to principal component analysis (with varimax rotation). The eigenvalue and factor loading were set at conventional high values of 1,0 and 0,5 respectively. As shown in table 4, five components with eigenvalues greater than 1.0 were extracted using the factor loading of 0,5 as the cut-off point (see also scree plot in Fig 1). The total variance (see table 4) explained by each component extracted is as follows; factor 1 (29.763), component 2 (10.818), component 3 (6,877), component 4 (6.052) and component 5 (5.281) Thus, the final statistics of the principal component analysis and the components extracted accounted for approximately 46.711% of the total cumulative variance.

Definition

- C.1.2. Quality
- C.2.2. No agenda by government on remanufacturing
- C.2.3. Lack of predefined standards for remanufacturing
- C.2.4. Lack of government support
- C.2.5. Policies restricting importation of cores
- C.3.1. Unwillingness of customers to return products
- C.3.2. Negative end-users' perception
- C.3.3. Less awareness of remanufactured products
- C.4.2. Limited development of the availability of end of life products
- C.4.3. Unforeseen demand fluctuations
- C.4.4. Unforeseen availability of core for remanufacturing
- C.5.1. Unorganized remanufacturing sector
- C.5.2. Lack of remanufacturing strategies from companies
- C.5.3. Low investment from the remanufacturers
- C.5.4. Threat of counterfeit products
- C.5.5. Lack of original equipment manufacturers participation
- C.5.6. Fears of transferring intellectual property rights to 3rd party remanufacturers
- C.5.7. Fear that remanufactured goods would be sold as new
- C.5.9. Reducing new manufacturing demand
- C.5.10. Lack of infrastructure to support remanufacturing

Table 5: Rotated Factor Matrix^{a} for barriers of remanufacturing

Communalities	1	2	3	4	5
C5.4	**0.770**				
C5.7	**0.674**				
C5.5	**0.597**				
C5.10	**0.575**				
C3.2	**0.565**				
C5.6	**0.500**				
C5.1	**0.469**				
C2.3	**0.415**				
C5.2	**0.342**				
C3.1		**0.747**			

C4.3	**0.666**			
C4.4	**0.599**			
C4.2	**0.516**			
C2.4		**0.620**		
C3.3		**0.516**		
C5.9		**0.449**		
C2.2		**0.359**		
C2.5			**0.808**	
C1.2				**0.692**
C5.3				**-0.398**

Extraction Method: principal Axis Factoring.
Rotation Method: Varimax with Kaiser Normalisation
a. Rotation converged in 7 iterations

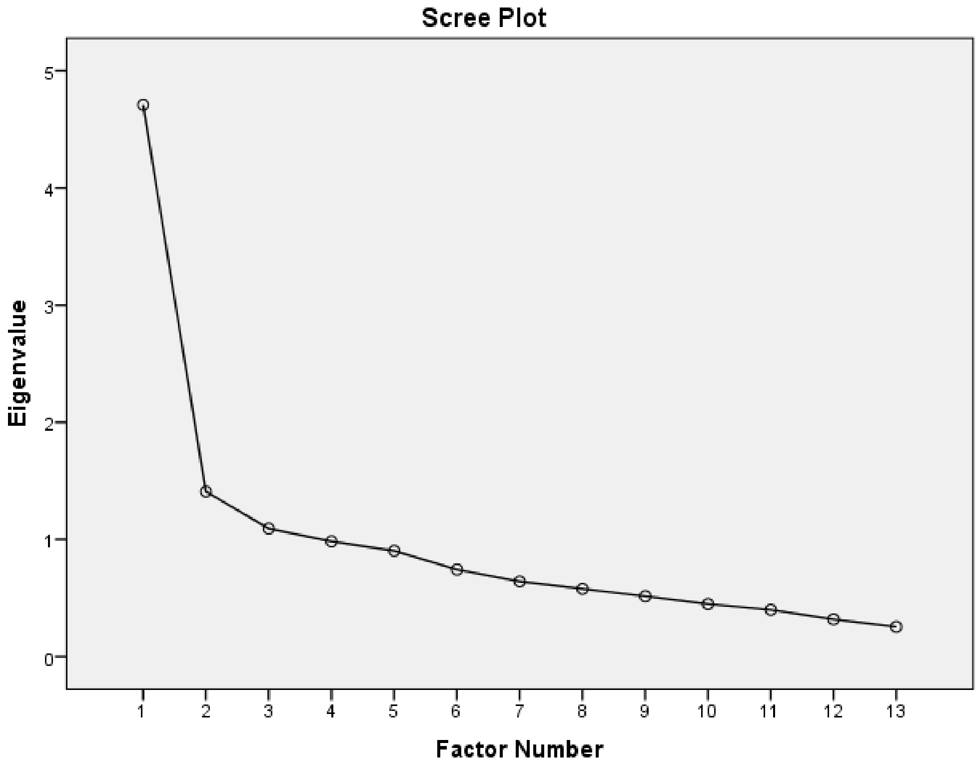

Fig 1. Scree Plot

3. Discussion of Result

Component 1: Manufacturers barrier to remanufacturing

The seven extracted barriers of remanufacturing for component 1 were threat of counterfeit products with (77,0%), Fear that remanufactured goods would be sold as new with 67,4%, lack of original equipment manufacturers with (59,7%), Lack of infrastructure to support remanufacturing (57,5%), Negative end-users' perception (56,5%), Fears of transferring intellectual property rights to 3rd party remanufacturers (50,0%), Unorganized remanufacturing sector (46,9%), Lack of predefined standards for remanufacturing (41,5%), Lack of remanufacturing strategies from companies (34,2%). This cluster accounted for 29, 76% of the variance (see table 6). These criteria share a common link to as manufacturers' barrier to remanufacturing as described by the United State International Trade Commission (2011), as most manufacturers are worried about the threat of counterfeit products for instance the case of the remanufacturing sector in India, “many original equipment manufacturers (OEM) like Canon and HP have found most of the refills are lined with inferior inks and remanufacturing methods which has led to the issue of counterfeit products. Lack of remanufacturing strategies for remanufactured products as argued by (Ostilin et al., 2009) often results in a lower demand, together with customers' little knowledge about the availability and quality of remanufactured products. Unorganized remanufacturing sector this was seen as the state of remanufacturing in Nigeria is still in its highly unorganized in nature, hence there is a need to develop a framework, drafting guidelines and policies for it.

As seen in India whereby The Associated Chambers of Commerce and Industry of India (ASSOCHAM, 2009), indicated that the state of remanufacturing is at a growing stage and highly disorganised in nature with the need to develop a framework, drafting guidelines and sketching policies for it. Negative end-users' perception studies has shown that customers have a perception about the quality and durability of remanufactured goods (Oakdene Hollins, 2007), thus leading to remanufactured goods labelled “second hand”, 'poor quality', 'inferior' and 'refurbished' (CRR, 2009; USITC, 2012a, b).

Component 2: supply chain barriers to remanufacturing

The four extracted barriers of remanufacturing for component 2 were unwillingness of customers to return products (74,7%), unforeseen demand fluctuations (66,6%), unforeseen availability of core for remanufacturing (59,9%), Limited development of the availability of end of life products (51,6%). This cluster accounted for 10,818%. Subsequently this component was labelled supply chain barriers to remanufacturing. Studies has shown that one of the major barriers facing remanufacturing is the demand for remanufactured goods and the supply of cores to be used for remanufacturing as evident in the four extracted barriers in component 2. Unwillingness of customers to return product stem from lack of awareness of remanufacturing and also some due to security reasons, unforeseen demand fluctuations is as a result of rate of technical development, the demand for a product might suddenly drop due to the technical development (Ostlin et al., 2009), further causes to the barrier of unforeseen demand fluctuations is a detailed forecasting is not possible to perform due to uncertainties regarding timing and quantities of the returned products (Ostlin et al., 2009). This causes has led to the unforeseen availability of core for remanufacturing as well as prohibition of remanufactured goods by government has also added to the unforeseen availability of core for remanufacturing.

Component 3: Government barriers to remanufacturing

The four extracted barriers of remanufacturing for component 3 were lack of government support (62%), less awareness of remanufactured products (51,6%), reducing new manufacturing demand (44,9%), No agenda by government on remanufacturing (35,9%). This cluster accounted for 6,88%. Subsequently this component was labelled government barriers to remanufacturing. Lack of government support from studies has been known to be a barrier to remanufacturing as policies to support remanufacturing is limited or not available thereby leading to less awareness of remanufactured goods as action plans for the implementation of remanufacturing and procurement of remanufactured goods is unavailable (Sharma et al., 2015).

Component 4: Trade barriers to remanufacturing

For component four, only one barrier was extracted. Which is policies restricting importation of cores (80,8%). This cluster accounted for 6,05%. Policies restricting is a common knowledge amongst countries which are not aware of remanufactured goods hence they set high tariff or outright ban on remanufactured goods (Melissen & Ron., 1999).

Component 5: low investment by manufacturers.

For component five, two barriers were extracted. Which were quality (69, 2%), low investment from the remanufacturers (39,8%). This is observed in independent remanufacturers who look to put little or no investment and reap more profit thus leading to low quality remanufactured goods

4. Conclusion

From the primary data, results have shown that the lack of participation of original equipment manufacturers has been known to be a barrier, as they refuse the participants in remanufacturing access to their equipment or sabotage them. It has also been found that most developing countries', remanufacturing has not been defined properly as they practise repairing, and refurbishing, amongst others, leading to its being an unorganized sector as found in Nigeria. Findings from the questionnaire indicated that a lack of infrastructure to support remanufacturing, a lack of original equipment participation, the threat of counterfeit products, and an unorganized remanufacturing sector have been highlighted as major barriers.

The barriers of remanufacturing can be classified into five cluster namely Manufacturers barrier to remanufacturing, supply chain barriers to remanufacturing, government barriers to remanufacturing, trade barrier to remanufacturing, low investment by manufacturers. These findings lend support to the current challenges facing remanufacturing in Nigeria.

References

Choudhary, N., Singh, N., and K. 2011: Remanufacturing in India: Approaches, Potentials and technical challenges, *International Journal Engineering Technology.* 3 (3) 223-227.

Centre Remanufacturing and Reuse, 2009: Remanufacturing in the UK e a Snapshot of the UK Remanufacturing Industry. Centre for Remanufacturing and Reuse. Available at: www.remanufacturing.org.uk. [accessed 10th September 2016]

Lund, R. 1983. *Remanufacturing: United States experience and implications for developing nations*. Washington, DC: The World Bank.

Lund, R.T. 1998. Remanufacturing: An American resource. *Proceedings of the Fifth International Congress for Environmentally Conscious Design and Manufacturing on 16–17 June 1998.* Rochester, RY: Rochester Institute of Technology.

Melissen, F.W. and De Ron, A.J. 1999. Defining recovery practices-definitions and terminology. *International Journal on Environmentally Conscious Manufacturing and Design*, 8(2), pp.1-18.

Nnorom, I.C. And Osibanjo, O. 2010. Overview of prospects in adopting remanufacturing of end-of-life electronic products in the developing countries. *International Journal of Innovation, Management and Technology,* 1(3), pp. 328.

Norusis, M.J., 2006. SPSS 15.0 guide to data analysis. Upper Saddle River, NJ: Prentice Hall.

Oakdene Hollins, 2007. An Introduction to Remanufacturing. Centre for remanufacturing and reuse". Available at. http://www.remanufacturing.org.uk/pdf/reman_primer.pdf. [10th September 2016]

Östlin, J., Sundin, E. and Björkman, M., 2009. Product life-cycle implications for remanufacturing strategies. Journal of cleaner production, 17(11), pp.999-1009.

Sundin, E. 2004. *Product and process design for successful remanufacturing*. Linkoping Studies in Science and Technology. Linkopings Universitet, Institute of Technology, Sweden. Dissertation No.906. ISSN: 0345-7524, ISBN: 91-85295-73-6.

United States International Trade Commission (USITC) 2012a. Remanufactured goods: An overview of the US and global industries, markets and trade. USITC publication 4356.

United States International Trade Commission (USITC) 2012b. Remanufacturing goods: An verview of the U.S. and global industries, market and trade.. Available online at: www.4-traders.com/news/U-S-International-Trade-CommissionRemanufacturing-Expanding-in-Many-U-S-Industrial-Sectors-Saye;1555216/ [Accessed 22nd March 2016].

World Trade Report, 2005. Market Access for Non-Agriculture Products. TN/MA/W/18/Add.11, pp. 1e6. Available at. http://www.reman.org/pdf/WTO-reman.pdf. [Accessed 21st October 2016].

How to Achieve "Proper" Sustainability in the Built Environment?

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Summary

Regardless of which approach in construction is being used, the common goal should always be to find and use the one that is both economical and energy efficient, but the one that it is not harmful and is in friendship with the environment, also one that is soothing to the soul and pleasant to behold. The fulfilment of these, nowadays still unusual requirements and reconciliation with all contradictions that arise from them is the ultimate goal of sustainable construction and makes its essence. This comprehensive task should always be in our mind and eventually will also become a liability of investors, designers, contractors and other participants in public construction sector, including local community, as well as private investors and end users. It is now only partially achieved through the construction of passive solar houses, the use of "green" materials, wastewater treatment facilities, wind power plants etc. But there is more and more of those who realise that this just aren't enough, but that the "proper" sustainability can be achieved only through a mind-set change of all participants. Is this possible? What should be done to achieve this? This article will try to give some answers.

Keywords: *sustainability, design, construction, environment, efficiency*

1. Introduction

Similarly to other developed countries around the world, the economic and social development of the Republic of Croatia (hereinafter referred to as the RC) has indicated the necessity of ensuring an environmentally sustainable area in which we live. Many generations of builders, architects and the other parties involved in building activities in the construction sector of the past decades have pointed to the need to develop and implement measures to ensure an environmentally sustainable space. In a professional and practical sense it is not negligible to remind that a functionally planned and built space provides a better quality of life. What the professional public has already knows for a long time, and only recently politics and the public has become aware of, is the fact that a high level of social awareness of the importance of the built-up space is a basic precondition for systematic application of the criteria of excellence. This can be done only by joined efforts of public and professional bodies, small, medium-sized and large entrepreneurs and also the public. As bearers for the implementation of this task, due to its complexity and multidisciplinary character, several ministries, chambers of commerce, universities and other educational institutions should be included. Their mission is to permanently store these objectives in consciousness of all the participants. Eventually, they will inevitably become an obligation for investors, designers, contractors and other public stakeholders in the construction sector, but also an obligation to the local and wider social

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community, private investors and end-users. In order for everyone to accept a new way of behaving that is required, they must feel that they are the part of this process. Therefore, it is necessity that the strategic approach is the result of cooperation and dialogue of all interested parties.

The paper will show where and how sustainable construction fits in to a wider image of the global economy. In several of the following points of the paper, sustainable construction principles are presented. The second part deals with sustainability and excellence of building and shaping of built-up space, observed through the broader social context, as this task is on the whole community to accurately and comprehensively develop new approaches and criteria in every area of social life. So, not only at the area of sustainability and excellence, but also in the culture of building and spatial development. Therefore, at all levels of society special attention should be paid to education, science and innovation.

2. Purpose and meaning of “proper” sustainable construction

Today, the concepts of "sustainable construction", "sustainable development", "sustainable design", "green construction" are increasingly popular and gradually more and more used words. Along with them, often lies the term "energy efficiency". The significance of these terms especially grows with increasing energy costs, especially fuel prices. It is commonly known that fossil fuels are not inexhaustible and will eventually run out. Unless new deposits of these or some other natural resources are found, and exploitation starts again and save the world economy for some short period. But this is very unlikely and something we should finally accept. It raises a question how these concepts fit into the "salvation" story of mankind, if things are viewed globally, and how an individual looks at it. How can they simultaneously help society as a whole and single individual? What does the word sustainability mean, how does it apply to society, to the lives of people, business community and ultimately on a survival of the species?

Just a quick search on the Internet will result in hundreds of thousands found web links. Everything is similar in a certain way but yet again different. The more we study this subject the more we become aware of a fact that many experts, engineers, architects, and others who have become specialists in this area differ in the notion of what is called “sustainable construction”. For some, it means using natural materials, for some reuse or recycle, or the use of alternative natural resources as a fuel, but also the avoidance of certain materials (egg. steel), which require the use of large amounts of energy for their production. For others, all mentioned before is not - because they are primarily focused on "green", whether are we talking of products, materials and natural resources, or technology. Yet, they agree and overlap in thinking with others how sustainable construction is all that is good for the environment and the planet Earth as a whole. Each of them are strongly united in the attitude that mankind, our civilization, should make a complete turnaround. It is obvious that the sustainable construction is a very complex area. Although its key aspect is environmental sustainability, it also includes other aspects, such as social and economic sustainability. So, sustainable construction implies its impact on the environment, that is, the impact of long-term use of buildings on the environment. But that raises a question whether the construction and maintenance of buildings is economically viable, whether it is sustainable in the social structure of the area where it is built. Also, does it include activities to increase energy efficiency, does it reduce the amount of energy the building will consume (in the long run), as well as sustainable materials (such as recycled and renewable) are being used.

In the paper below several, let say, "alternative" views will be displayed which should be respected in sustainable construction. These alternative perspectives consider the form of construction used in methods that are rarely used in typical construction nowadays. The term "typical construction" here implies a standard approach used in the construction of public, industrial and private buildings in the territory of the RC, the surrounding region, the EU and most of the "civilized" world. Therefore, the term "alternative" is usually interpreted as the type of building with which most of the parties involved in building activities are only partially use in their practice. Today, these perspectives are slowly but surely included in the area of sustainable construction. The indirect benefit of this mode of construction is that it can minimize or at least substantially reduce the use of natural resources.

3. The “proper” approach to the basic principles of the sustainable construction

The sustainable construction achieves great savings on business and public buildings. To what extent can this be achieved in our homes? The sustainable construction will help public and economic entities to reduce energy-related expenditure, reduce greenhouse gas emissions, and help to meet up EU energy policy objectives by improving efficiency. But how do the principles of the sustainable construction apply in a private sphere? Can it really fulfill its promises? The sustainable construction has never been purpose to itself, which indicates the fact that one of the most important choices in everybody's life is in what type of building lives in and works, as well as in what kind of built-up environment it is located. In fact, the paradox is that its importance has not been adequately and comprehensively understood so far.

Regardless of who are investors, ultimate contracting clients and designers, the building style is the one that directly affects the environment. In investment decisions making, in a design phase, in a construction phase, even during exploitation period of an object, mostly there are several choices that can make a big difference in the quality of life and expense of end users. Therefore, a proper implementation of the sustainable construction principles is slowly becoming part of the environmental care and global aspirations for implementing demands of sustainable development. Unfortunately, many existing trends in today's cultural and human activities are hard to avoid. They are the result of the contemporary challenges of a globalization process, the world market and a competition as such are not directed in the right direction, in terms of a sustainable future. As in all economic activities, the sustainable construction is subjected to economic valuation, and often is loaded with misunderstanding and mistrust by the economists, financiers and a top management of companies. Most often it is observed only through expense, rather than through well-being at a long run. In a way, it is understandable that efficiency and profitability are the most important business generators of each company. Regardless of the size and position of the market, every slightly bigger company is constantly looking to improve its own efficiency and increase its profitability. But, the problem is that most of them do not understand that a sustainability allows the development and implementation of policies and targets that take into account many legal requirements and all aspects of environmental protection. Both, sustainability and excellence can be integrated into all types and sizes of business organizations and be adapted to different geographic, cultural and social conditions. At the same time, to these companies they facilitate the determination of the objectives and processes of a business policy, and also taking necessary measures to improve their own environmental impacts and align their system with all the demands of modern society. Thus, the answer to the contemporary challenges can only be provided by an economy that values knowledge and innovation and invests considerable resources in research and sustainable development.

Therefore, the entire collective (negative) experience so far shows how they will have to accept a new set of principles. One of the concepts is 5R, which represents a practical upgrade and gives very concrete suggestions for a sustainable future. 5R means:

- Rethink (think twice)
- Reduce (time & money)
- Reuse (spaces, resources)
- Repair (& maintain)
- Recycle (materials)

3.1. Rethink

3.1.1. A proper assessment of the optimal structure size

Over the last few decades, the trend of construction has been the construction of larger, more imposing and demanding buildings to demonstrate that construction is at a higher level of development than in previous generations. Though this trend falls to the human ego, over time, this approach has proven to be unsustainable over a longer period, especially in light of frequent recessions and general crises in the world. So, this trend does not fit the position of a viable lifestyle. Large and demanding buildings, whether residential or business, generally require the use of huge amounts of energy for heating, cooling, even for "cold drives". This energy is largely used by combustion of fossil fuels, which, as it is now visible, are questionable in the long run and emit greenhouse gases and pollutants in the atmosphere. Also, for building larger and more demanding buildings, more building materials must be used, each of which has some environmental impact. Whether this reduces the amount of forests, whether by exploiting mineral and mineral riches of Earth and reducing future sources of raw material. Thus, constructed buildings, or spaces, should correspond to the real need of public, business or private users. The key is the efficient use of space by making reasonable investment decisions, good organization of design and construction, and implementation of real-level exploitation. Therefore, it is necessary to raise or continually develop the ecological awareness of all the participants in the construction on this issue.

Figure 1. The proper assessment of the optimal structure size

3.1.2. Using (positive) experience of the traditional way of building

The experience of traditional architecture has gradually disappeared over the last few decades, when the so-called modern construction methods prevailed. Simple construction concepts as well as natural materials proven throughout the history are much less used in designing. Local design solutions and techniques are also less and less applied. The fact is that many from older generations of designers have been more informed about this construction method, which implied the use of simple concepts and materials and which are energy efficient and sustainable for longer periods of time. With its interior design concepts, used forms, heating and cooling solutions, by use of materials, etc. traditional architecture, or traditional design approach, reminds modern architects and builders how they should built. In order to use the most of the technical solutions and materials that have been proven to be durable and resistant, and which avoid risks and the vulnerabilities of modern way of building, it is necessary to raise awareness of the designers.

Figure 2. Using (positive) experience of the traditional way of building

3.1.3. Using renewable natural materials and resources

In buildings or in areas where natural materials are used for construction, people feel most comfortable. When, for example, a natural tree or rock are under the feet one feels solidity and connection with nature. The main reason for choosing natural materials instead of the industrial ones is that the pollution caused by their production is minimal. It is known that for each ton of cement produced, the same amount of carbon dioxide is released into the air. If health is concerned, natural materials have a much less negative impact on it. But in all things, and here too, there should be a proper measure in exploitation. Today, the vast majority of people have become aware of and can witness the incredible degradation of natural resources. While wood to some extent can be considered a renewable source, some of the natural resources have been destroyed almost over the renewable boundary, by which a huge part of the ecosystem has been damaged. Therefore, when designing it is important to consider and use materials that are renewable.

Figure 3. Using renewable natural materials and resources

3.1.4. Using local building materials

There are several advantages of using local, indigenous material. First of all, they usually fit naturally into the "feel" of the place, its immediate surroundings. Also, so many fossil fuels are not used to transport on site and are likely to be less industrially processed. An example of building materials in the Croatia would be primarily stone and related stone materials, wood and wood products.

Figure 4. Using local building materials

3.2. Reduce

3.2.1. Focus on energy efficiency

Today mankind has found many aspects of "clean" energy, with the purpose of using less fossil fuels. Using sun, wind, and water to produce electricity are just some of them. If a public or private client / investor decides on this option, he will still have to think well, as it will depend on how the end user uses the energy during the exploitation. Namely, the energy source may in time be inadequate or limited.

However, whether the energy is from alternative sources or from the grid, it is worth choosing energy efficient devices. For example, new fluorescent lights should be designed and used, as they use approximately one-third of the electrical power than the standard ones. Many devices use a lot of energy just by plugging in the power source. Always make sure it is avoided.

Figure 5. Focus on energy efficiency

3.2.2. Using natural energy sources
(Natural illumination, warming and cooling of space)

Health effects of artificial warming, i.e. cooling the working spaces and the living spaces are already well-known. Even the use of advanced air-conditioning systems results in people's health and psyche, not to mention low-budget air-condition devices. In fact, there is no better alternative to natural warming or cooling in the dwelling.

Also, the illumination of space is an important factor, or one of the components of a healthy life. When designing, i.e. working areas and living spaces, wherever possible, the use natural resources should be taken in account, as well as geographic position, micro climate, altitude, seasons, terrain and relief configuration, orientation to world's cardinal directions etc.

The society has finally come to understand that nothing can be more comfortable for the mind and body than life and work in a naturally heated, cooled and lit place. The emphasis is on "natural" because the design is the key to the comfort of such a building or space. For example, it is not enough to design a so-called "Solar house" just because it's the instant hit and think it's all solved. In some of these "solar houses" users feel uncomfortable because the heating or cooling is made strictly "by textbook" without touching the actual situation on the ground. A good passive solar design will provide enough sunlight in the room, and in-space heating, for example, will have an absorption of the surrounding thermal mass (e.g. wall materials) so that the heat can gradually return to the room once the natural energy source E.g. the sun) does not supply the building. Properly selected thermal-building material will be a type of "thermal battery" that stores heat, absorbs the same, to prevent the area from taking over too much heat during a given day. Equally, in a complete solution, it is also important to have a thermal insulation material that keeps this heat inside the space. The thermal-building material must be insulated from the outside, otherwise the accumulated energy will only drop back into the surrounding area. It is commonly known that stone structures can have tons and tons of weight, but may be uncomfortably cold due to this energy outflow. Well-designed "natural design" will affect the building or space, warm when it is desired, but cooled as much as it wants. So, a good 'natural design' will use materials of the right kind, set in the right places, combining thermodynamics with eye-pleasing design.

Figure 6., 7. Using natural energy sources

3.2.3. Capacity sharing
(Energy / material / business / spatial)

Sharing existing capacity with other users is one of the basic principles of sustainability. If this is the case, unnecessary duplication of energy, material, business or space capacity can be avoided. Thus, investors, contractors, end users, etc. not only need a smaller number of facilities, installations, tools, etc. but at the same time they all have at their disposal a wider choice of resources. From the point of preserving the environment, through reduced harmful industrial activity, this is a good solution and from the position of social demands, as well as on the side of the end user - the individual and the collective provides more opportunities.

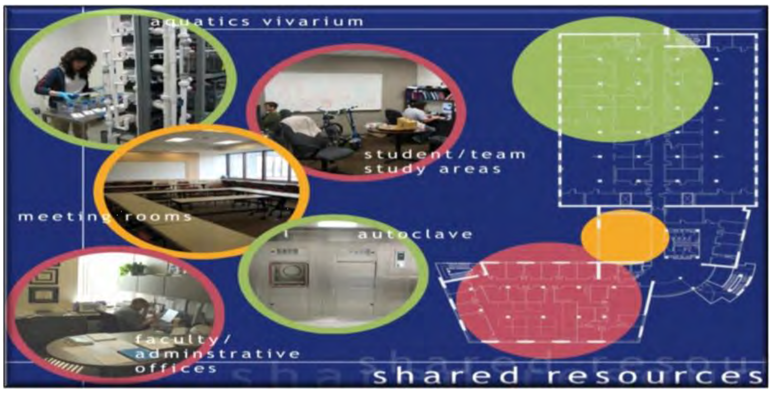

Figure 8. Capacity sharing

3.3. Reuse

3.3.1. (Efficient) Reusing once occupied space

In the context of conservation and the meticulous use of spatial resources of development activity, priority should be given to the already used space, whether it is the transformation of abandoned or insufficiently used spatial assemblies that are no longer in function of basic purpose, urban rehabilitation of areas of initially illegal construction or rehabilitation of parts of urban A territory with specific problems and needs. Particularly emphasized is the importance of activating abandoned and poorly utilized spatial units and public property and its associated task of recording, evaluating and planning new and sustainable forms of use while improving the quality of the settlement as a whole.

Figure 9. Reusing once occupied space

3.3.2. Reusing local natural resources

Already during the design phase of buildings, possibility of reuse of many natural resources should be reconsidered. Such rational use in building exploitation will greatly reduce costs for investors, as well as for end users, while also reducing the negative impact of waste materials and materials on the environment. They have long been in use of low flow toilets, tap aerators, the hand-held showers that reduce water flow. However, the use of local natural resources and their reuse is a more radical approach. This solution includes the redirection of lightly loaded water from swimming, washing clothes, water from sinks, sinkers and other home appliances, watering plants, collecting rainfalls from roofs and asphalted surfaces and reusing them in households and business premises for various purposes. This can be a very effective and safe way of saving, of course, if planning is done carefully to avoid chemical and bacterial infections. For example, landscaping with homegrown herbs can save you tremendous amount of water as well as move to composted toilets.

Figure 10. Reusing local natural resources

3.4. Repair

3.4.1. Build and maintain structures to last

Regardless of age, all older structures require maintenance during their lifetime. Often investors advocate that everything that is older than a few decades should be dropped and replaced with the new one. Sometimes this is needed for badly designed constructions or because of poor quality built-in materials. Materials that are resistant to increased heat, cold and humidity, as well as atmospheres should be used. Cracks, moisture, decay, fatigue, etc. can quickly cause great damage, almost insurmountable problems that require high repair costs. Properly designed, constructed and maintained building can last for centuries. Annual inspections and quick resolution of small deficiencies will help avoid significant and expensive works in the future. It is good practice to regularly set aside funds for repairs and to plan for these in advance.

Figure 11. Build and maintain structures to last

3.5. Recycle

3.10. Recycling of construction materials

If the material already exists, it may be recycled. That eliminates the need to exploit new resources and avoids the consequences of their processing. Also, the landfill or warehouse load is reduced for further processing. Many materials can be reused for construction, such as glass. It is known that dry wood does not degrade much and that old dried wood is much better than one that was freshly treated.

Figure 12. Recycling of construction materials

4. Proposals for implementation of sustainable construction

4.1. Small, medium-sized and large entrepreneurs and the public

How to change awareness and apply the principles of sustainable construction to economic entities? Consciousness of the individual has been growing steadily for a long time, as it has been forced to pay for construction costs and cost of exploitation of buildings. But how can sustainability be applied when it comes to business environment? The thing on which most companies "fall" is their inability to implement their ideas in the area of sustainable design and construction and get all their employees to actively participate in the vision of sustainability. One should be aware that this is a demanding and long-lasting process that depends on many factors, so its application needs to be accessed patiently, because for the success of accepting and introducing into practice any method is the key cooperation of all participants.

4.1.1. Proposals - the main guidelines and activities

Below are some starting points and stages for effective implementation of sustainable construction and design.

• Achieve the clear commitment of management, top and lower management. This will ensure that sustainable construction, i.e. sustainable design, has the same importance as the rest of the manufacturing or service activities of the company in management decisions. New corporate sustainability goals should be highly accepted by senior management so that all other executives and employees understand that these directives are not temporary and short-term;

• Determine an experienced management member for the implementation and coordination of all activities in this area;

• Design the most convenient ways of coordinating management, executives, department / sector manager and other experts;

• Establish a department or sector for sustainability or sustainable construction. This new part of the organizational structure should be responsible to top management, i.e. senior management. Appropriate authorizations to department / sector executives should be provided;

• Make multidisciplinary teams, so that all sectors or departments in a company are involved and connected in the process of change

• Raise the skills of all employees in this area, encouraging them to be the ones that will impact on improvements. All this is accomplished by providing relevant training in this area, according to the areas of work of employees;

• Utilize the creativity of employees, so that the working environment allows new ideas to be made and allows informal discussion about them, as well as establish a mechanism for analysing these ideas;

• Determine measurable goals that will be integrated with the existing core business of the company, finance, quality, security, cost, and any other data that is being monitored. The change plan must be designed in a simple way so that every employee can understand how his daily business is affecting sustainability.

4.2. Institutional implementation of sustainable construction

4.2.1. Legal and strategic framework
(Already in practice in public and professional bodies)

In the institutional implementation of sustainable construction principles, i.e. implementation by state and professional bodies, the things are slightly complicated. Report on the Spatial Situation in the Republic of Croatia 2008-2012 ("Official Gazette" no. 61/2013), considered and adopted by the Croatian Parliament, the elaboration of the new Croatian Spatial Development Strategy has been identified as a priority activity for further improvement of spatial development and protection of space and thus indirect and sustainable development and construction. Among the key reasons for the development of the new Strategy, phenomena and processes have been identified by monitoring the situation in built-up space, but also changes in the international context as compared to the previous period. This international context cannot bypass The Paris Climate Change Agreement. It has reached a global agreement with the action plan to reduce and limit global warming, which entered into force on November 4, 2016, 30 days after October 4 last year was met, i.e. after it was ratified by 55 states responsible for at least 55% of global greenhouse gas emissions. This agreement also adopted conclusions on financing. Public funds are important for implementation, and given the signing of the Paris

Agreement, the states will have to allocate considerable resources for the fight against climate change, as well as for sustainable development and construction.

4.2.2. The main thematic areas of sustainable construction by government and professional bodies

For the implementation of goals, regarding sustainability and excellence at the institutional level, some of the basic, inseparably linked thematic areas are essential. These are the development of social consciousness; Architectural heritage; Building and shaping of built-up space; Spatial and architectural forms; The legislative framework; Education; Housing; Development, planning and arrangement of built-up space; The architectural and urbanistic tendering solutions; Public works in built-up space. Below are some of the most important themes:

- The architectural heritage, i.e. the creation of a recognizable national identity through architecture, especially traditional construction, but also to revitalize the region through the proper development of rural tourism, which at the same time has long-term positive financial and social effects on the economy;
- Building and shaping of built-up space is focused on design, construction and spatial planning, with emphasis on excellence being observed in a wider context involving spatial organization, location selection, material and formatting composition. The main driver of all initiatives on this basis is the state administration that performs a precise and comprehensive elaboration of the construction criteria and aligns them with EU regulations, which will have to be followed by private investors and contractors. Among other things, this is the Regulation on Construction Products that defines this area of construction and has the force of law, and is already applied throughout the EU. All regulations are adapted to the requirements of the Regulation;
- Spatial and architectural forms are more detailed in the spatial development strategy of the RC. New standards have been laid down and a transition to a vertical graphic representation of spatial planning in the information system, which requires adaptation of the system of documents and plans both at the state, and at the county and local levels;
- The legislative framework and its application - this is a significant part of the area of architectural excellence, sustainable construction principles, energy efficiency, ecological acceptability, and the health and safety of end users. Following this is the institutional implementation of the competition and the selection of modern architectural solutions.
- Education of building participants, especially in the field of architecture, urbanism and engineering disciplines is also an important component - some of the challenges such as interdisciplinary, specialization, legal regulation and authority, an area of international comparability in the field of science are covered here. Among others, for the area of sustainability or sustainable construction, there is a significant institutional implementation of the National Guidelines for Continuing Education of Building Workers in Energy Efficiency, which are aligned with the implementation of EU policy goals 20-20-20;
- Housing - the excellence of each housing unit, building, and settlements as a whole must be based on architectural excellence, the principles of sustainability and excellence in performance. Given that housing is one of the most important components of social development of society, and thus economic progress, it certainly needs extraordinary attention in planning, designing and building;

All of these areas are closely linked to the goal of satisfying seven so-called “essential requirements for construction works” ("Official Gazette” no. 153/13), the properties that must be respected in respect of their essential characteristics and other technical requirements relating to structures and their construction. According to Article no.8 of this Act, this are: Mechanical resistance and stability; Fire safety, Hygiene, health and the environment; Safety and accessibility during use; Noise protection; Energy economy and heat retention, and Sustainable use of natural resources.

4.2.3. Key initiatives and activities of institutional implementation of sustainable construction

The most significant initiatives and activities on the implementation of sustainable construction principles that are already under way:

• Applying of EU guidelines and directives in the national spatial planning and construction
• Implementation or full establishment of the national platform for quality and culture of construction
• Ensuring the sustainable use of architectural heritage and its promotion for social and economic needs
• Involving architecture in creating a recognizable national identity

4.2.4. Proposals - activities of institutional implementation of sustainable construction

Initiatives and activities on the implementation of sustainable construction principles:

• Improvement of a professional and lifelong education of building participants, especially architects, spatial planners, landscape architects and engineers
• Continue to apply sustainable building principles
• Improvement of existing strategic documents and regulations in the field of construction, spatial development and public policies
• Improvement of the development of the Croatian construction sector

5. Findings

5.1. Critical constraints and obstacles analysis

• Many households cannot apply sustainable development principles due to extreme poverty and lack of access to credit
• Lack of entrepreneurial education resources and technical support
• It is necessary to carry out education over a longer period to achieve a satisfactory degree of excellence
• A satisfactory degree of excellence will not be achieved until it is professionally and socially accepted and becomes a standard in construction
• The program cannot be launched only in a particular local community, national level is needed to ensure the future of sustainable construction. Unfortunately, until now, the state administration has not done enough to remove critical constraints and obstacles in order to fully support sustainability and excellence
• While many of the improved technologies have proven their value in practice, it lacks mass production and wider market access

• The widening of the principle of sustainable construction depends on increasing the number of business entities and skilled workforce. It has been chronically missing in the last couple of years on the labour market due to EGP

5.2. Lessons learned

- Sustainable construction principles can be improved to a certain level, mainly through entrepreneurial and private financing
- Change in a mind-set of all participants in the area of sustainability and excellence cannot be achieved without the full engagement of the state administration and the whole society
- Sustainable construction principles can be applied to entrepreneurs and private individuals relatively quickly with relatively limited funds, but at national level the results will not be sensational
- Adequate training of each participant in the application of sustainable construction principles s is essential for successful building and sustainability
- Transferring information and experiences, then adapting the principle of sustainable construction to the site specificity will be of crucial importance

5.3. Estimate of practical implications

In reviewing the use of the proper sustainable construction principles, by examining users we would have reached a figure of about 3 percent. This is a matter of public private, business and private sector. It is to be expected that growth will be progressive rather than linear. When in the coming years practice through examples prove its worth, it would greatly increase the motivation for such a type of construction.

6. Conclusion

Work has provided an overview of sustainable construction at all levels of society, from state to economy and individual. It is intended to be a "springboard" for exploring this area. Also, it reflects on positive principles, but also on practical problems at application at all levels. It points out to the relationship between man and the environment and its impact on the state of construction. It raises the question of the benefits of technological advancement and the damage it has caused. When it comes to the whole, it's not hard to conclude that there is not much time left to change direction. It can only be said that natural processes are being started, the consequences of which can hardly be seen and which will have a negative sign for a long time. Since many of these processes are caused by human activity, it is inevitable for humanity to realize that damage is actually per se and not to the planet Earth. In hers history, she had already had much greater temptations she had overcome, and that humanity as a species even partly could not. Therefore, regardless of today's tough economic market conditions, including construction sector, everything must be done to make visible improvements, both in the ecological, as in a financial and organizational sense. Nevertheless, what still stands out in the positive light is the fact that something is being launched at a global level today, an example of this is The Paris Agreement. It will be interesting to observe its real use, especially in the light of its recent abandonment by the United States.

When it comes to an individual, there is a great deal of literature and appropriate technical material and other resources on this subject, especially on the web, which suggests that people's consciousness is gradually changing over the last few years. On the economic and public-political level, the process obviously lasts much slower. Since this is demanding on the one hand, and on the other hand a lengthy process that depends on many factors - social, social, geopolitical – one has to be patient. One has to be aware of the fact that in the history implementation of much smaller things were needed years and years, if not decades. The success of adopting and introducing the sustainable construction principles into practice will depend on all the participants in the construction and society. State and public institutions, investors, designers and contractors in the construction sector have certainly entered the new era and must decide and choose how and in what way to continue in this very important area of the economy.

It is not too exaggerated to say that sustainable construction, excellence and building culture generally determine the level of living standards. Therefore, there are a number of challenges facing the RC, the most important being the sustainable construction and excellence of all management systems. It is obvious that commitment to sustainable construction and excellence should become the responsibility of all actors in this business. As the public interest protects the spatial plans at the national and county level, whereby the state bodies and the academic community are responsible for realization, on the other hand, public and private investors, designers and contractors must bear the economic responsibility. This is the reason why it is insisting on the culture of building, as a prerequisite for achieving the excellence and functionality of the built space, from which later it will generate economic benefits by raising the standards of citizens and the stability of the national budget. The aforementioned demands include the spatial organization, improvement of design, quality of materials, and the professional and partner relationship of all actors.

Unfortunately, the inconvenient truth is that, despite great efforts, we have not yet achieved adequate sustainability and excellence in the built environment in the RC. The reason is obviously lack of full engagement in trying to change a mind-set of all participants. Let's hope that, in the time that follows, we will not have to spend too much time and effort to reach the desired goal.

References

Boyer, E.L.; Mitgang, L.D. (1996), "Building Community: A New Future for Architecture Education and Practice", Princeton (1996), The Carnegie foundation for the Advancement of Teaching, NJ. USA

Nicholas Ray, N. (2005), "Architecture and its Ethical Dilemmas", Taylor & Francis (2005), New York, NY.

Guy, S.; Shove, E. (2014) "The Sociology of Energy, Buildings and the Environment: Constructing Knowledge, Designing Practice", Taylor and Francis (2014), New York, NY.

Kibert, C.J. (2008), "Sustainable Construction - Green Building Design & Delivery" John Wiley & Sons (2008), Hoboken, N.J., USA

Williamson, T., Radford, A., Bennetts, H. (2003), "Understanding Sustainable Architecture", Spon Press (2003) London, England

MCPP, CCA (2013) "Architectural Policies of the Republic of Croatia 2013-2020 - National Guidelines for Building Excellence and Culture", Ministry of Construction and Physical Planning (MGiPU) (2013), Zagreb

Stulz R., Mukerji, K. (1993), "Appropriate Building Materials: A Catalogue of Potential Solutions", Swiss Centre for Appropriate Technology (SKAT) (1993), Gallen, Switzerland

The Paris Agreement, United Nations Framework Convention on Climate Change (UNFCCC), 21st Conference of the Parties of the UNFCCC in Paris, (adopted 12/12015), (went into effect on 11/4/2016)

Ministry of Construction and Physical Planning (MGiPU) (2015), "The Draft Proposal of the Strategy of Spatial Development of the Republic of Croatia", Croatian Institute for Spatial Development (2015)

Lynne, E., Adams, C. (20015), "Alternative Construction – Contemporary Natural Building Methods", John Wiley & Sons (2005), Hoboken, N.J., USA

International Organization for Standardization (ISO) (2015), ISO 14001:2015 - Environmental management systems – Requirements (2015-09), Technical Committee ISO/TC 207/SC 1 Environmental management systems

Woolley, T., Kimmins, S., Green Building Handbook (1997), "A Guide to Building Products and Their Impact on the Environment, Volume 2, Taylor and Francis (2005), New York, NY.

Long-Term Strategy for Mobilizing Investment in the Renovation of the National Building Stock of the Republic of Croatia (Official Gazette 74/14) (Long-Term Strategy)

Directive 2012/27/EU of the European Parliament and of the Council of 25 October 2012 on Energy Efficiency, amending Directives 2009/125/EC and 2010/30/EU and repealing Directives 2004/8/EC and 2006/32/EC Text with EEA relevance (Directive 2012/27/EU)

Directive 2006/32/EC of the European Parliament and of the Council of 5 April 2006 on Energy End-use Efficiency and Energy Services, repealing Council Directive 93/76/EEC ("Official EU Gazette" L 114, 27/04/2006)

Directive 2010/31/EU of the European Parliament and of the Council of 19 May 2010 on the Energy Performance of Buildings (recast) (Directive 2010/31/EU) ("Official EU Gazette" L 315, 14/11/2012)

Energy Efficiency Act ("Official Gazette" no. 127/14)

National Energy Efficiency Programme for 2008 – 2016 (NEEP), Ministry of Economy

Percel, D. (2012), „Is There a Sustainable Construction", Croatian Society for Quality, 12th Croatian Conference on Quality & 3rd scientific conference of CSQ, Brijuni, Croatia, published on May 13, 2012

Ministry of Construction and Physical Planning (MGiPU), "Physical Planning Act" (2014), available at: http://www.mgipu.hr/doc/Propisi/Physical_Planning_Act.pdf, (electronic source, accessed April 2017)

"Official Gazette" no. 97/14, 130/14 (2014), "Technical Regulation on the Rational Use of Energy and Thermal Insulation in Buildings" from http://narodne-novine.nn.hr/clanci/sluzbeni/2014_08_97_1938.html

Towards a Theory of Sustainability Governance in Mega Projects: An Exploratory Study

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Abstract:

It is no longer news that megaprojects are capable of undermining the attainment of society's sustainable development aspirations. What is news, however, is the overt reliance on traditional governance approaches by stakeholders in the construction in their attempt to integrate sustainable procurement, construction, and asset management practices during various phases of the asset's lifecycle. This appears to have brought about the prevailing instances of underwhelming sustainability performance in various megaprojects. This is especially the case in developing countries where the demand for critical infrastructure is driving the initiation of several greenfield projects. The need to put forward a governance approach that is contingent on the successful implementation of sustainable development ethos across the entire life cycle of infrastructure assets in developing countries thus becomes imperative. This is the central objective of this study. Relying on a review of relevant literature pertaining to themes such as sustainability governance, megaprojects and sustainable development, this qualitative study explores the utility of the theory of sustainability governance within the megaproject context. It is expected that this study will contribute to an emerging discourse on the need for the theory of sustainability governance in the construction industry and mega projects, in particular. Furthermore, it will propose a theoretical platform for the development of a mechanism for engendering sustainability governance in megaprojects.

Keywords: *Developing Countries, Mega Projects, Sustainability Governance, Sustainable Development*

1. Introduction

Society is witnessing a paradigmatic shift towards sustainability (Broman & Robèrt, 2017). Accordingly, several governments and organizations are beginning to embrace the sustainable development (SD) mantra. Apparently, this is in recognition of the unsustainable consumption patterns prevalent in contemporary times. Sustainability has been referred to as a state of utopia resulting from effective SD implementation, wherein society's consumption patterns are structured in a manner that provides effectively and efficiently for the present generation whilst not undermining the ability of the future generation to enjoy utility of the earth's resources (Frantzeskaki, Loorbach, & Meadowcroft, 2012). This is seen as a drive towards securing intra and inter-generational equity through the adoption of SD ethos. Therefore, various policy implementation frameworks have been initiated by national, regional and global bodies, especially the United Nations towards the attainment of sustainability. Recently, the sustainable development goals (SDG) initiative was launched, replete with milestones which the society has to meet in order to successfully attain sustainability by 2030.

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Also, prior to the determination of three sustainability dimensions- environmental, economic and social (Elkington, 1999b), the concept of sustainability was seen as a buzz word for policy makers, industry practitioners, academics etc. Till this moment, sustainability is still regarded as a fad and incapable of being realized or operationalized (Boström, 2012). This reputation stems from its indefinability. Scholars have referred to this notion as depriving the society of the desired benefits associated with sustainability (Sneddon, Howarth, & Norgaard, 2006). However, whilst society is being challenged to deliver on sustainability through SD, certain economic sectors associated with anthropogenic activities capable of undermining this aspiration have been identified. It is pleasing to note that efforts are on-going in such sectors to contribute towards sustainability (Pitt, Tucker, Riley, & Longden, 2009).

The construction industry happens to be one of such sectors (Ding, 2008). The industry's activities as well as the operation of the end products resulting from these activities make significant contributions towards the attainment of the sustainability agenda, either positively or adversely (Du Plessis, 2007). To stem this tide, stakeholders in the industry have resorted to exploring new ways of delivering and operating these assets. The adoption of new approaches to project delivery has led to the emergence of new taxonomies such as, *green construction*, *sustainable construction*, *sustainable procurement*, *lean production, green business models*, etc. However, despite several years after the adoption of these new practices, the industry has continued to record varied implementation performances as it concerns sustainability. In some instances, business as usual (BAU) has continued to prevail thus leading to a plethora of unsustainable developments in the industry. Africa and the rest of the developing world seem to be lagging behind their developed country peers in terms of the degree of significant improvements which have been achieved so far.

The relationship between infrastructure and economic growth has been buttressed severally in the literature (Esfahani & Ramírez, 2003; Munnell, 1992). Societies can only achieve desired levels of productiveness required to compete favourably in the comity of nations given the presence of adequate infrastructure. Therefore, the imperative nature of these assets cannot be overlooked. However, the delivery of these assets (usually as megaprojects) and their subsequent operation have the potential to detract from society's sustainability objectives as a result of the inherent anthropogenic activities (Kibert, 2007). Megaprojects are known for their highly complex nature (Kardes, Ozturk, Cavusgil, & Cavusgil, 2013). This attendant complexity along with the communication difficulties associated with them makes it difficult to achieve project objectives (Giezen, 2012). Owing to the nature of megaprojects, their failure will leave debilitating effects on the SD endeavour, hence the need to ensure that such does not occur. Succinctly put, megaprojects are too big to fail.

Yet, it has been observed that whereas other economic sectors have started to evolve new ways of governing their activities so as to achieve sustainability tenets, literature reveals that the governance of megaproject has continued in a manner which depicts BAU (Klakegg, 2009). It is pertinent to note, however, that the industry cannot achieve expected sustainable outcomes though overt reliance on conventional governance approaches, hence the need for the development of new governance approaches for megaprojects. This is the gap which this study seeks to contribute to, in theoretical terms.

To fulfil its objective, subsequent aspects of this exploratory study is structured as follows: a brief review of the concept of sustainability and sustainable development; mega projects and sustainable development; the case for sustainability governance of mega projects, and; concluding remarks with insights into further research.

2. Theoretical Perspective

2.1 Sustainability and Sustainable Development

The dual concepts of sustainability and sustainable development have assumed a frontline position in contemporary policy and development discourse across the globe. To this end, national and regional development strategies are being consistently woven around sustainability tenets. These concepts have since been described as a platform for engendering socio-ecological harmony. Issues such as poverty, lack of social inclusiveness, equity and justice as well as environmental degradation have been identified as threats to this socio-ecological harmony. The effective implementation of SD has been suggested as a panacea to the aforementioned threats.

But, the concept of sustainability suffers from the problem of indefinability which has continued to affect its optimal realization and operationalization. In its normal form, the sustainability and SD provides no concise framework detailing suitable approaches, plans or activities through which it can be operationalized (Ayre & Callway, 2013). This imbroglio has culminated in the development of a plethora of guidelines and context-dependent definitions hence making a widely acceptable definition difficult if not impossible. As it stands, the sustainability has to rely on the development of a common ontology among a diverse group of stakeholders to give it meaning. The achievement of such consensus and enhanced participation among stakeholders across multiple layers of society enables a more binding implementation framework among such groups. Although the dimensions provided by Elkington (1999a) appear to have gained traction amongst a large scholarly base, they do not sufficiently make up for the vagueness associated with the sustainability concept.

For optimal implementation of SD, advocates opine that the changes associated with sustainability should be embedded into all aspects of societal life such inherent activities, practices, communication and culture (Linnenluecke & Griffiths, 2013). In the construction industry, SD implementation can only be achieved through the integration of its aspects into the extant project management or project governance frameworks available to the industry. However, a careful look at relevant literature confirms the paucity of such integration. Whereas, an increasing advocacy for such integration into project management practices has been observed, same cannot be said regarding the integration into project governance structures. The non-integration of sustainability ethos into the governance of mega projects portends grave consequences for megaprojects from a sustainability perspective, especially considering the magnitude and costly nature of such projects.

2.2 Governance of Mega Projects

Mega projects are multibillion-dollar mega infrastructure projects mostly commissioned by the public sector and delivered through the private sector (Marcelino-Sádaba, González-Jaen, & Pérez-Ezcurdia, 2015). Such projects are often described as transformational and trendsetting, with planning, design, procurement and eventual delivery spanning several years. They are deemed to possess the capability to reshape contemporary society through the kind of services that they expected to deliver and the manner through which they are delivered. This implies the need for a different set of management approaches than will be utilized in conventional projects as they differ completely in scale and complexity from the latter. According to Flyvbjerg (2014) megaprojects are gradually becoming the preferred delivery models for goods and services across various economic sectors. Projects like civil infrastructure projects, water and energy infrastructure projects, transportation projects, industrial processing plants etc. have been categorized as megaprojects. Owing to the magnitude of these projects, their effects on the socio-ecological system can be better imagined.

With the widening global infrastructural deficit and the relationship between the provision of resilient and sustainable infrastructure on the one hand and the attainment of sustainable development goals (SDGs) on the other, several projects of this nature will be coming on stream in the future, bringing with them mixed effects on the state of the society. To curb the degree of debilitating effects which megaprojects may have on the socio-ecological system, there is need to take a cue from other sectors where new modes of governance have been adopted and implemented with the overall objective of attaining sustainability.

The theory of governance shares several attributes with sustainability and SD respectively. Whilst it has been described as occurring on the firmament at about the same period as sustainability, scholars proceed to state that it is being equally as vague as sustainability and lacking a widely accepted definition (Lange, Driessen, Sauer, Bornemann, & Burger, 2013). Buttressing this perspective, Stoker (1998) and (Türke, 2008) admit to the lack of uniformity within extant literature, among the various definitions of governance. Stoker (1998) agrees that the academic literature on governance was disjointed and eclectic, alluding to its theoretical roots which lie within the realms of institutional economics, international relations, organisational studies, development studies, political science, public administration and Foucauldian-inspired theorists.

The contribution made by the theory of governance is predicated on its value as an organizing framework, the capacity of governance to provide a framework for understanding and changing processes of governing an organisation. Some other scholars attempt to liken it to government and the role of government in the act of governing as constituting governance (Yencken, 2002). From these definitions, it is observed that governance involves the process of organizing and leading an entity towards the attainment of an established goal or objective such as sustainability in this case. However, this must be done through a collective resolve by the actors within the entity or system (Lange et al., 2013). Affirming this notion, Türke (2008), Kooiman (1993) and Stoker (1998) agree that governance requires a high level of interaction for it to be successful. Biesenthal and Wilden (2014) trace the evolution of the theory of governance as deriving from a coagulation of several theories such as the agency theory, the transaction costs theory, the stakeholder theory, stewardship theory and resource dependence theory. This provides a rationale for the encompassing nature of governance when analysing inter-party transactions, within projects or organizations.

Türke (2008) adopts a systemic view of the concept of governance. In this systems view, he identified a structure-oriented view and an actor-oriented view as two disparate governance modes applicable to social systems. Whereas the structure-oriented view involves the belief that social systems are self-governing and independent objects which govern themselves through circular, self-referential processes which highlight their identity, the actor-oriented view comprises of social systems composed not only of communications but also of actors as empirical subunits. Contributing, Shiroyama et al. (2012) posit that governance consists of several systems and actors operating outside government apparatus in a self-organizing manner as inter-organizational networks.

In the construction industry context, scholars have also made attempts to define governance from a project perspective (Pryke, 2004; Winch, 2001). They term this concept '*project governance*'. (Winch, 2001) observes that the project governance process can be approached from two perspectives, micro-analytical perspective, referring to inherent processes for conducting transactions between project actors, and; the macro-analytical perspective which focuses on the transaction procedures between institutions at a societal level. Cooke-Davies, Crawford, and Lechler (2009) on the other hand describe project governance as consisting of a set of institutionalized principles, structures and processes for undertaking and managing projects. In a nutshell, project governance consists of the elements necessary to enable an effective organization of interactions between various actors and processes on a multi-scale during the course of project delivery. It transcends project management which is only concerned with the management of project level activities. Elements of project governance consist of the following, namely: existence of contracts between involved actors, organization and conduct of procurement, procedure for the management of suppliers networks by project actors, risk allocation and management, monitoring and coordination of work during various phases of the project lifecycle, processes for collaboration among project stakeholders as well as the nature of communication between project actors (Ahola, Ruuska, Artto, & Kujala, 2014).

Based on the foregoing it can be seen that the governance of projects is a complex endeavour and even more so is the governance of megaprojects. The desire to attain improved sustainability performance during the delivery and management of megaprojects makes it imperative that governance approaches which are capable of managing increased levels of complexity be deployed in this case. But, Ahola et al. (2014) observe the inadequacy of extant governance approaches which rely on market, hierarchy or hybrid forms of governance in providing for megaprojects. This is occasioned by the nature of megaprojects as project coalitions or networks consisting of several interdependent organizations and processes which elucidate the degree of interconnectedness existing between them in aspects pertaining to communication, control, and coordination. Therefore, the strategies adopted therein by participating organizations will play a salient role in the governance of large projects. Too and Weaver (2014) maintain that governance is necessary to provide systems within which effective management decisions can be taken and carried out. Four key components required to support effective governance consist of portfolio management, project sponsor, project management offices and effective project management. Obviously, for effective sustainability governance to be achieved, SD ethos has to be mainstreamed into these four components.

Awuzie and McDermott (2015) posit that the choice of a governance approach for a project should be predicated on the nature of objectives are. Therefore, this implies that the bid to deliver megaprojects in a sustainable manner should take precedence during the selection of governance structures. This is necessary especially as various participating organizations have different worldviews concerning sustainability and SD, thus making them capable of working at cross-purposes with the project objectives. To avoid such an occurrence, there is need to evolve appropriate governance approaches for delivering on this critical agenda within the realm of megaprojects.

Extant construction, project management and built environment literature is largely silent on the integration of sustainability ethos into the conventional governance approaches (Eskerod & Huemann, 2013; Gareis, Huemann, Martinuzzi, Weninger, & Sedlacko, 2013; Silvius & Schipper, 2014). This observation makes this study imperative. The study seeks to contribute to the development of a theory of sustainability governance for megaprojects whilst relying on the plethora of studies on the sustainability governance in a socio-ecological context.

2.3 The Case for Sustainability Governance in Mega Projects

The way a sustainability-oriented project is organized and the way that leaders frame the issues that participants discuss, may affect if and how substantive sustainability aspects are considered within projects (Boström, 2012). Although there seems to a consensus that the sustainability outcome of a project is dependent upon the mode of governance adopted (Ayre & Callway, 2013), there is a paucity of literature among governance and sustainability seeking to explore or to perhaps empirically or theoretically support this nexus. Understanding this nexus is critical to the successful SD implementation as it enables stakeholders to determine suitable governance modes for delivering on their expected outcomes. Lange et al. (2013) highlight the need for this linkage and further posit that the potential of a governance mode to deliver on SD should be dependent upon the fulfilment of two criteria. These criteria include: consistency of the contents of the governance mode with the goals-functional and normative-resulting from the pursuit of SD, and; the presence of an induced form of transformative, collective action among the stakeholders. They maintain that only governance modes which fulfil these criteria would be able to deliver on SD objectives. In their contribution, Kemp, Parto, and Gibson (2005) suggest the absence of a widely accepted form of sustainability governance, especially as sustainability has remained context-dependent thereby possessing details which highlight different contexts. Yet, they opine that the development of a foundational strategy detailing structures and practices capable of engendering positive working practices among the multiplicity of stakeholders across a complex range of issues in an interconnected manner on multiple levels and scales with regard for contexts and uncertainties was necessary for effective sustainability governance. Furthermore, they allude to the notion that any governance mode possessing the aforementioned attributes will be capable of delivering on effective sustainability governance in any context.

Before proceeding to explore the suitability of the extant governance approaches in the construction industry to deliver on SD, especially within the realm of megaprojects, there is need to explore the concept of sustainability governance or governance for sustainability as many authors have termed it. Similar to the cases of sustainability, SD and governance, sustainability governance does not possess a concise and generally accepted definition as it is considered to be an evolving concept in its embryonic stage. Shiroyama et al. (2012) describe sustainability governance as a set of formal or informal networks existing between actors and the systems in which these networks are domiciled, that affect sustainability through the integration of various dimensions. They proceed to view the concept from the knowledge integration and multi-actor governance perspectives. Whereas the former concerns the integration of knowledge bases within a context to achieve a consensus on the multiple dimensions of sustainability and uncertainty, the latter involves the management of stakeholder interactions within these networks on a public-private, multi-level basis in manner that enables consensus on what sustainable actions to take among these actors, in designing and developing sustainable systems.

Meadowcroft (2007) describes governance for sustainable development as comprising of processes of socio-political governance oriented towards the attainment of sustainable development within a particular context. According to him, these processes occur along several levels, either local or international, affect different policy fields and refer to multiple temporal scales.

Lange et al. (2013) reiterate that despite the claims made in the sustainability governance literature concerning the adoption of certain governance modes as being appropriate for the delivery of SD, there is as yet no particular appropriate governance mode for governing sustainability both in projects and society. Designing such a governance mode for organizations, project-based organizations like megaprojects are not left out, entails the internalization of external costs, integration of policy considerations within the delivery system, development of common and shared SD objectives, selection of suitable sustainability-based criteria for planning as well as widely accepted indicators for measuring actionable progress towards sustainability, agreement concerning trade-offs, provision of information concerning available incentives for practical implementation and development of programmes for continuous system innovation (Kemp et al., 2005). Other scholars within the mainstream sustainability governance realm posit that governance modes emphasizing partnerships among multiple stakeholders across several policy levels should be relied upon for optimal SD implementation ((Frantzeskaki et al., 2012; Jordan, 2008; McAllister & Taylor, 2015; Shiroyama et al., 2012). Continuing, McAllister and Taylor (2015) suggest the need to conduct an evaluation of costs and benefits associated with partnerships, during the design stages before embarking on them as such understanding would engender enhanced cooperation among various stakeholders. They suggest that modes of governance which incorporate significant levels of partnership are capable of handling complexities occurring on a multi-scale, cross-sectoral and long-term temporal aspects of SD than the conventional and hierarchical modes of governance. Although as a downside, they elucidate the potential of such arrangements to obscure accountability and transparency in the delivery process, if not properly checked.

From the foregoing, it can be seen that the cardinal features of effective sustainability governance consist of effective partnerships within networked systems, imbued with significant degrees of reflexivity, participation, adaptability, social learning processes as well as knowledge integration and multi-actor management. In the absence of these features, the ability of conventional governance modes to achieve SD is truly questionable. Therefore, society's quest for sustainability through SD requires a transmogrification of the existing governance modes or hybrids of such modes to support this quest. In accordance to this viewpoint, Lange et al. (2013) traces the resurgence of the governance modes in the literature to the quest to attain societal sustainability in the short to long term. This implies that the SD concept propelled the present governance discourse, hence generating new insights into the development of the new approaches to governance.

In the governance of megaprojects, the need for sustainable development to be mainstreamed through the entire lifecycle is imperative. However, based on the studies reviewed to this point, it can be seen that the governance of megaprojects has remained fixated on issues relating to cost, timely delivery, quality as well as functionality whilst still laying claims to attempting to deliver on SD (Miller & Hobbs, 2005). Accordingly, the extant governance modes being applied in the delivery of megaprojects are incapable of achieving sustainability hence the case for a governance approach which appropriately captures the requirements necessary for the optimal integration of SD ethos in megaprojects which have been highlighted previously.

Socio-ecological systems have provided suitable approaches to sustainability governance like transition management (Kemp, Loorbach, & Rotmans, 2007). Having been applied towards enabling sustainable socio-ecological transitions, transition management has been suggested as capable of providing effective governance for similar transitions towards sustainable socio-technical systems (Smith & Stirling, 2008). Megaprojects are indeed socio-technical systems given their composition of interactions between social actors and technical aspects such as processes and machinery. Often times the social subsystem within the socio-technical system has been blamed for their failure to achieve optimal project performance. In the case of SD, actors representing various organizations on different levels are expected to have contrasting opinions concerning issues like; the meaning of sustainability, aspects of sustainability dimensions to prioritize and the phase of the delivery lifecycle to do so, how to mainstream agreed upon aspects of relevant dimensions etc. This disparity of views pertaining to a particular phenomenon renders the case for effective sustainability governance imperative. Advocating for the adoption of transition management as an appropriate governance mode for in socio-technical systems transitions, Smith and Stirling (2008) suggest that the governance arrangement provides a platform for deciphering who is responsible for governance, who’s system framings count, and who’s version of sustainability is going to get prioritized. According to them, the transition management approach seeks to achieve consensus on these questions among the various actors and to develop a common ontology among them during the initial stages of the megaproject (socio-technical system). Summarily, transition management seeks to develop and sustain the channeling of processes within a socio-technical system towards the attainment of a stated objective, hence controlling the dynamics of socio-technical change (Kemp et al., 2007).

Although the exemplar utilized by Smith and Stirling (2008) dwelt more on technology-oriented socio-technical systems, the same governance approach can be transposed to the megaprojects scenario as the same rules concerning complexity are prevalent. So adopting the transition management governance approach in megaprojects, a common ground has to be determined through consensus by all actors working on multi-levels in a manner that is identical to the concept espoused by Shiroyama et al. (2012). Such consensus will reflect on the development of the commonly shared sustainability performance indicator, shared understanding of the aspects of sustainability dimensions to be prioritized within various phases of the project, joint decision making on the most sustainable approach to utilize in integrating the agreed upon aspects with the indicators for measuring the degree of integration. In this situation, opportunities for reflexivity and sustained learning processes should be encouraged within the megaprojects to enable effective knowledge integration among actors, before, during and after the delivery of the megaproject.

3. Concluding Remarks and Further Research

Scholars have continued to reiterate the need for sustainability ethos to be mainstreamed into extant project management and governance approaches within the realm of megaprojects. Such advocacies stem from the notion that sustainable procurement, delivery and management of megaprojects will make significant contributions to the societal quest for sustainability. Megaprojects, due to the magnitude and scale have immense potential to affect this quest for sustainability if not properly organized. Whereas incessant calls have been made for the integration of sustainable practices into conventional project management to engender sustainable project management practice, a paucity of studies detailing such needs within the context of project governance for megaprojects has been observed. This observation makes this exploratory study, imperative.

Besides highlighting the elements of effective sustainability governance regimes, the study identified the features of the extant governance models and theoretically assessed them for their applicability and potential to enhance sustainability in megaprojects. Deficiencies such as the inability of these models to engender multi-level actor governance and knowledge integration was identified as capable of hindering the entrenchment of the ethos of sustainability governance in megaprojects.

Summarily, the study proceeded to propose the adoption of an established governance mode, transition management, which has been utilized in socio-ecological systems as a possible sustainability governance mode for megaprojects. This study draws attention to the shortcomings of the extant governance modes available for megaprojects and reiterates the need to start looking elsewhere for effective sustainability governance approaches to be integrated into the delivery of megaprojects and other infrastructure projects. Quite understandably, such approaches will be modified to suit megaproject context. It is expected that future studies would seek to empirically evaluate the applicability of the transition management governance mode in megaprojects through case studies, especially in developing countries where high rates of megaproject failure enjoy sufficient reportage.

References

Ahola, T., Ruuska, I., Artto, K., & Kujala, J. (2014). What is project governance and what are its origins? *International Journal of Project Management, 32*(8), 1321-1332.

Awuzie, B., & McDermott, P. (2015). A conceptual model for evaluating infrastructure-based temporary multi-organisations. *Built Environment Project and Asset Management, 5*(1), 103-120.

Ayre, G., & Callway, R. (2013). *Governance for sustainable development: a foundation for the future*: Earthscan.

Biesenthal, C., & Wilden, R. (2014). Multi-level project governance: Trends and opportunities. *International Journal of Project Management, 32*(8), 1291-1308.

Boström, M. (2012). A missing pillar? Challenges in theorizing and practicing social sustainability: introduction to the special issue. *Sustainability: Science, Practice, & Policy, 8*(1).

Broman, G. I., & Robèrt, K.-H. (2017). A framework for strategic sustainable development. *Journal of Cleaner Production, 140*, 17-31.

Cooke-Davies, T. J., Crawford, L. H., & Lechler, T. G. (2009). Project management systems: Moving project management from an operational to a strategic discipline. *Project Management Journal, 40*(1), 110-123.

Ding, G. K. (2008). Sustainable construction—The role of environmental assessment tools. *Journal of environmental management, 86*(3), 14.

Du Plessis, C. (2007). A strategic framework for sustainable construction in developing countries. *Construction Management and Economics, 25*(1), 10. doi:10.1080/01446190600601313

Elkington, J. (1999a). Triple bottom-line reporting: Looking for balance. *AUSTRALIAN CPA, 69*, 18-21.

Elkington, J. (1999b). Triple bottom line revolution: reporting for the third millennium. *Australian CPA, 69*(11), 75-76.

Esfahani, H. S., & Ramírez, M. a. T. (2003). Institutions, infrastructure, and economic growth. *Journal of development Economics, 70*(2), 443-477.

Eskerod, P., & Huemann, M. (2013). Sustainable development and project stakeholder management: what standards say. *International Journal of Managing Projects in Business, 6*(1), 36-50.

Flyvbjerg, B. (2014). What you should know about megaprojects and why: An overview. *Project Management Journal, 45*(2), 6-19.

Frantzeskaki, N., Loorbach, D., & Meadowcroft, J. (2012). Governing societal transitions to sustainability. *International Journal of Sustainable Development, 15*(1-2), 19-36.

Gareis, R., Huemann, M., Martinuzzi, A., Weninger, C., & Sedlacko, M. (2013). *Project management and sustainable development principles*.

Giezen, M. (2012). Keeping it simple? A case study into the advantages and disadvantages of reducing complexity in mega project planning. *International Journal of Project Management, 30*(7), 781-790.

Jordan, A. (2008). The governance of sustainable development: taking stock and looking forwards. *Environment and planning C: Government and policy, 26*(1), 17-33.

Kardes, I., Ozturk, A., Cavusgil, S. T., & Cavusgil, E. (2013). Managing global megaprojects: Complexity and risk management. *International Business Review, 22*(6), 905-917.

Kemp, R., Loorbach, D., & Rotmans, J. (2007). Transition management as a model for managing processes of co-evolution towards sustainable development. *The International Journal of Sustainable Development & World Ecology, 14*(1), 78-91.

Kemp, R., Parto, S., & Gibson, R. B. (2005). Governance for sustainable development: moving from theory to practice. *International journal of sustainable development, 8*(1-2), 12-30.

Kibert, C. J. (2007). The next generation of sustainable construction. *Building Research & Information, 35*(6), 7.

Klakegg, O. (2009). Pursuing relevance and sustainability: Improvement strategies for major public projects. *International Journal of Managing Projects in Business, 2*(4), 499-518.

Kooiman, J. (1993). Governance and governability: using complexity, dynamics and diversity.

Lange, P., Driessen, P. P., Sauer, A., Bornemann, B., & Burger, P. (2013). Governing towards sustainability—conceptualizing modes of governance. *Journal of Environmental Policy & Planning, 15*(3), 403-425.

Linnenluecke, M. K., & Griffiths, A. (2013). Firms and sustainability: Mapping the intellectual origins and structure of the corporate sustainability field. *Global Environmental Change, 23*(1), 382-391.

Marcelino-Sádaba, S., González-Jaen, L. F., & Pérez-Ezcurdia, A. (2015). Using project management as a way to sustainability. From a comprehensive review to a framework definition. *Journal of Cleaner Production, 99*, 1-16.

McAllister, R. R., & Taylor, B. M. (2015). Partnerships for sustainability governance: a synthesis of key themes. *Current Opinion in Environmental Sustainability, 12*, 86-90.

Meadowcroft, J. (2007). Who is in charge here? Governance for sustainable development in a complex world. *Journal of Environmental Policy & Planning, 9*(3-4), 299-314.

Miller, R., & Hobbs, J. B. (2005). *Governance regimes for large complex projects*.

Munnell, A. H. (1992). Policy watch: infrastructure investment and economic growth. *The Journal of Economic Perspectives, 6*(4), 189-198.

Pitt, M., Tucker, M., Riley, M., & Longden, J. (2009). Towards sustainable construction: promotion and best practices. *Construction innovation, 9*(2), 201-224.

Pryke, S. D. (2004). Analysing construction project coalitions: exploring the application of social network analysis. *Construction management and economics, 22*(8), 787-797.

Shiroyama, H., Yarime, M., Matsuo, M., Schroeder, H., Scholz, R., & Ulrich, A. E. (2012). Governance for sustainability: knowledge integration and multi-actor dimensions in risk management. *Sustainability Science, 7*(1), 45-55.

Silvius, A., & Schipper, R. P. (2014). Sustainability in project management: A literature review and impact analysis. *Social Business, 4*(1), 63-96.

Smith, A., & Stirling, A. (2008). Social-ecological resilience and socio-technical transitions: critical issues for sustainability governance.

Sneddon, C., Howarth, R. B., & Norgaard, R. B. (2006). Sustainable development in a post-Brundtland world. *Ecological economics, 57*(2), 253-268.

Stoker, G. (1998). Governance as theory: five propositions. *International social science journal, 50*(155), 17-28.

Too, E. G., & Weaver, P. (2014). The management of project management: A conceptual framework for project governance. *International Journal of Project Management, 32*(8), 1382-1394.

Türke, R.-E. (2008). *Governance: systemic foundation and framework*: Springer Science & Business Media.

Winch, G. M. (2001). Governing the project process: a conceptual framework. *Construction Management & Economics, 19*(8), 799-808.

Yencken, D. (2002). Governance for sustainability. *Australian Journal of Public Administration, 61*(2), 78-89.

Construction Design and Technology

Analysis of the Capital Expenditures Modern Methods for the Foundating of Family Houses

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Abstract:

The selection of a suitable foundation engineering economic, technological and technical point of view depends on several factors. Especially in cases where construction is proposed for structural systems belonging to modern methods of construction (MMC Modern methods of construction). Several structural systems belonging to address the MMC construction as a whole and therefore the foundation of the building. The article deals with the establishment of modern methods of family houses and describes the design and material variants foundation. For example, the model analyzed and then compare the cost of implementing the structure that meet the standard requirements for the construction of passive thermal resistance RR2 [Wm-2.K-1]. The result of the examination will analyze capital expenditures of selected modern methods of creation.

Keywords: *analysis of capital expenditures; realization of foundation structures; MMC technology*

1. Introduction

Analysis of capital expenditure modern methods of creation is directly related to technology and the design of foundation for building belonging to the modern methods of construction known as MMC (Modern methods of construction). One of the advantages of structures belonging to the modern methods of constructing a lower weight structures, and therefore may be dimensioned base construction subtle. A second important advantage is the lower time of construction services.

For buildings constructed with modern technologies, we can also see traditional foundation structures and MMC-based foundation structures. For example, the various assembled top-of-the-box construction systems belonging to the MMC group require that a baseboard that is made by traditional technology must be completed base plate, which is realized traditional technology.

Abroad is often used term "passive slab" as passive base plate used for the construction of using MMC technology. In Slovakia, the term reverse foundations is used when thermal insulation is placed under much reinforced concrete base plate. Abroad, such a board specified as ultra-modern and highly insulating. By designing a heat insulation with sufficient thickness and depositing it under the reinforced concrete slab, the heat loss of the floor can be minimized and the heat bridges interrupted. Among the constructions implemented by modern methods of construction MMC include, for example, is a lightweight wooden frame construction of vertical supporting structures, which usually does not require deep foundations. Using a lightweight

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wooden frame construction ensures a reduction in the amount of work and materials required for the foundation structure, as well as the need for a technological breakthrough after the casting process.

Modern methods for the establishment of houses based on the basic methods of founding and can be divided into several groups. According to Sedláková (Sedláková, 2014) modern methods of founding can be broken down into:

- Foundation with thermal insulation of foundation and perimeter wall
- Foundation with special fitting and insulation of base
- Foundation with foam block and insulation of base
- Foundation on broken from foam
- Foundation on extruded polystyrene
- Installation on pilots

In the following section, the underlying radiation structures are described among the modern methods of foundation, which are subsequently analyzed to be compared in terms of the cost of their implementation.

2. Methodology

The article deals with the analysis of capital costs of modern methods of model house building. The model example of a family house analyzes and compares five variants, namely:

- The base system with integrated insulation;
- Foundation with the raised floor of wooden trusses;
- Foundation on the foam glass;
- Foundation on a base of extruded polystyrene.

Selected foundation systems will be compared in terms of capital costs (cost of implementation), the calculation methodology being based on a comparison of the individual costs of realizing foundations that have comparable thermal and technical properties. A description of each variant will be described in Chapter 2. Variants of the construction design of the base structure.

In the first step, the thickness of the thermal insulation of the foundations is proposed in Chapter 3.1 based on the thermal-technical calculation. In the case of a variant of a foundation system with integrated insulation, the thickness of the entire foundation is proposed. The thermal and technical properties of the foundations are defined in STN 73 0540-3, which requires a thermal resistance for the floor of the heated space on the terrain $R_{r2} \geq 2,5$ W / (m^2.K). To compare each variant in terms of the realization cost of the base structures, the individual pieces will be designed with a resistance greater than or equal to the standard value R_{r2}.

The second step is to calculate the capital cost of each options in Chapter 3.2. In the final chapter 3.3 the capital cost of the founding systems on the model example are analysed.

Model example

A model example will be the construction of a single-storey unpopulated building with dimensions of 5m x 10m (Fig. 1). The foundation system with integrated insulation is designed as a base plate.

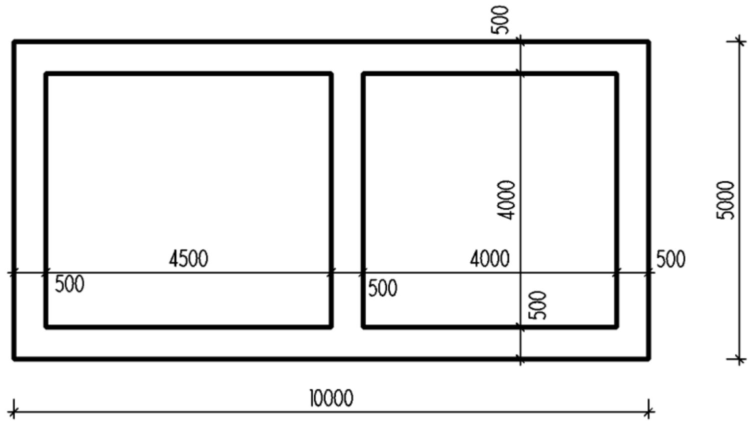

Figure 1. A model example of building - floor plan reinforced concrete foundations (Source: own)

A variant of the raised floor system made of wooden bundles is mounted on the separate footing (Fig. 2).

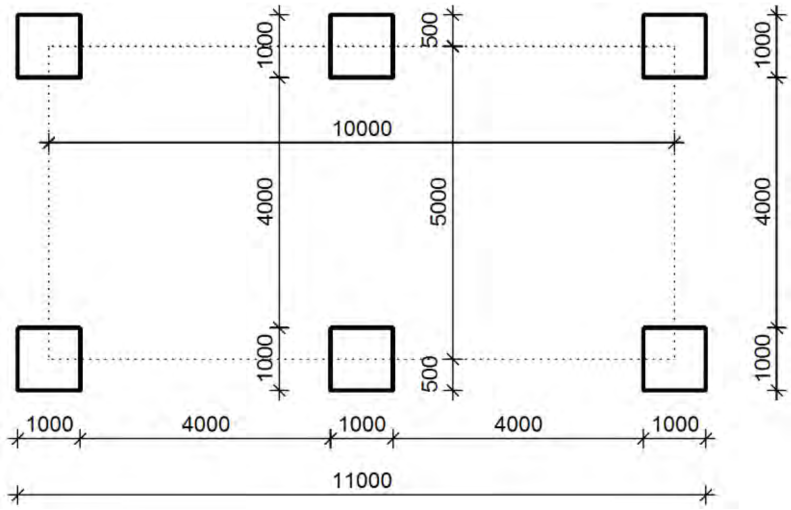

Figure 2. A model example of building - separate footings (Source: own)

3. Variants of the design of the base structure

Chapter 3 describes the chosen variants of the design the base structure of the model house namely:

- V1 - Base system with integrated isolating from Elegohouse;
- V2 - Establishment of the raised floor of wooden trusses from Krigger;
- V3 - Foundation on the foam glass for example. Foamglas;
- V4 - Foundation on a base of extruded polystyrene.

3.1 Base system with integrated insulation from Elegohouse

The base design with integrated isolation from Elegohouse combines the advantages of multiple systems. It is a foundation structures belts, but the upper concrete slab is designed as a "ceiling" structure. Ceiling structure is formed by beams of reinforced concrete and polystyrene inserts padding that serves as permanent formwork. Concrete slab is self-supporting, independent of the substrate, and there is no need to implement any bedding. Between the ground and the insulated is air gap, and therefore there is no infiltration of moisture into the structure from the ground. The only possible place capillary action is in the case contact the horizontal with the vertical load-bearing structure. The integrate base structure of the membrane shown in Fig. 3

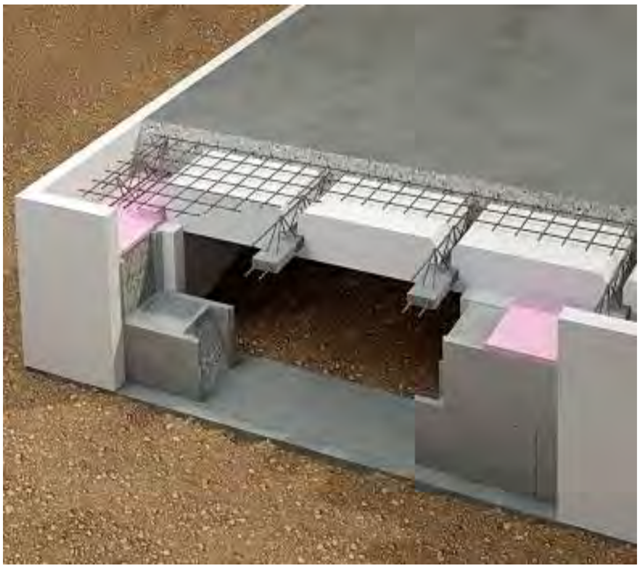

Figure 3. The base plate with integral insulation (source: Elegohouse)

The Elegohouse has 3 variants of the base plate thickness with the integrated insulation. The variants are labelled as Normal S160-20 thick. 180 mm, Nízkoenergetik S200-20 thick. 220 mm and liabilities S230-20 thick. 250 mm. On a model-building system was used Pasiv S230-20.

The use of a base plate with integral membrane has a number of advantages which are documented in Figure 4:

- Savings waterproofing, it is sufficient only to capillarity;
- Saving thermal insulation of the floor assembly;
- Reduce the thickness of the floor, with which they are associated reduced costs for external staircase and increased ground clearance floor.

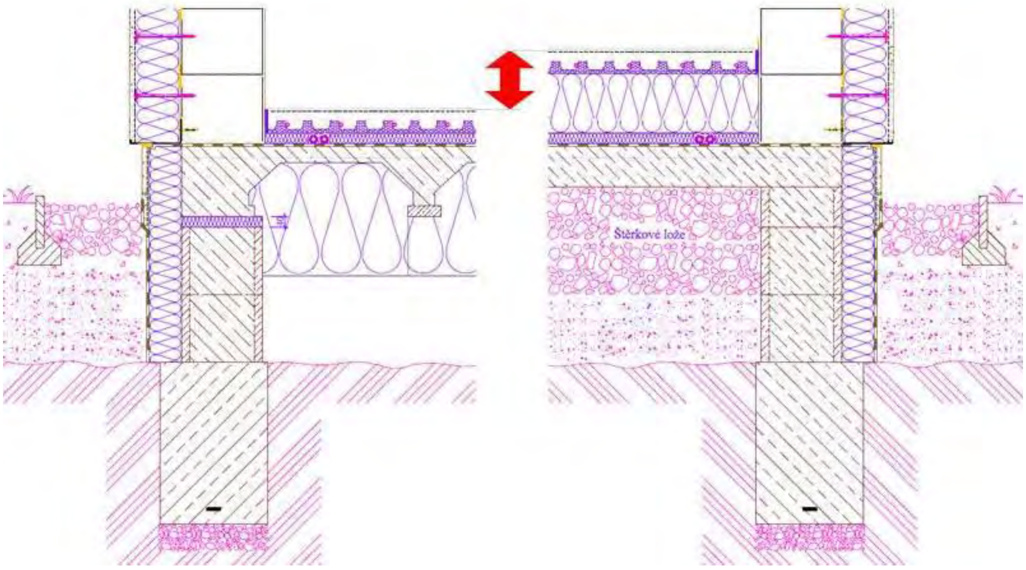

Figure 4. Comparison of the traditional base sheet to the base plate with a built-in insulation (source: Elegohouse)

3.2 Establishment of the raised floor of wooden trusses from Krigger

Establishment of the raised floor of wooden trusses from Krigger is setting up a system with the same principle as in the case of Elegohouse in section 3.1. The only difference is that in case of a system from Krigger the support structure Floor "ceiling" is composed of wooden bonded trusses (Figure 5). The truss is stored thermal insulation composed of meltblown cellulose or other similar thermal insulator.

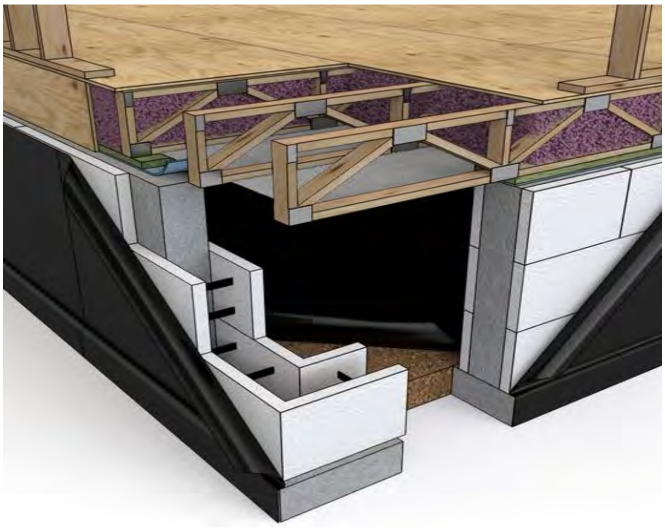

Figure 5. Formation of raised floor of wooden trusses (Source: Krigger, 2013)

The advantages of this system are similar to the system of company Elegohouse.

The establishment of the raised floor of wooden trusses has several advantages:

- Savings waterproofing, it is sufficient only to capillarity;
- Saving thermal insulation of the floor assembly;
- Subtle design of raised floor of wooden truss system over the company Elegohouse because the thermal insulation in the supporting parts of the floor "ceiling" of the materials that have superior thermo properties.
- As with Elegohouse the thickness of the floor is reduced and thus increases ground clearance floor.

Disadvantages of Kriger:

- Given that this is a wooden support structure is necessary to provide the required protection against fire by the protective coating, or by constructing a fireproofed
- The need to ensure protection against pests and fungi (eg. Rodent, wood borers ...)

3.3 Establishment of the foam glass

In the case the building foundation on foam glass it fulfils a double function, thermal insulation and at the same time provide a solid subsoil layer thickness about 30-50 cm (Šmid, 2013). Crushed glass foam is poured out into the tub, which is lined around the perimeter boards made of extruded polystyrene (Sedláková, 2014). On crushed glass foam is made of reinforced concrete base plate. The advantage of foam glass is its non-absorbability and drainage function.

A significant advantage of this system is the establishment of an inverted position to cover the thermal insulation property. Given that the thermal insulation is from the outside (in contact with the ground), the zero isotherm is in thermal insulation, and therefore it is not necessary to establish the depth of frost resistant. Therefore, it is possible to design subtle thick reinforced concrete tubs satisfactory static requirements and at the same time it is not necessary to isolate the reinforced concrete slab from the top side. As with the creation of a raised floor is not necessary thermal insulation in the floor, resulting in a saving thermal insulation in the floor structure. At the same time, in this case it increases headroom in the room. Advantage is also that position concrete slabs directly under foot traffic Coating interior and thus creating an accumulation layer. The storage layer helps the stability of the temperature in internal environment. Foundation for foam glass is shown in Fig. 6th

Figure 6. Establishment of the foam glass Source: Šmid, 2013

A disadvantage of using the building foundation to the foam glass the possibility of using this type of establishment only permeable soil, as in the case of the impermeable clay subsoils and may result in flooding of the trench with foam glass and thereby reducing its thermal performance (Šmid, 2013).

4. Comparison of capital costs to implement the basics

To determine the budgetary costs of foundation construction is necessary to compare the cost of similar, ideally in the same conditions. For this reason, the proposed structure will be a minimum value of thermal resistance of the floor heated space defined by STN 73 0540-2-2012.

The cost calculation of each foundation structures will be implemented on a model example by budgetary applications Cenkros4 the price structure TSKP (classification of structures and works) to the price level of 2017 first half.

4.1 Building Amendment physical thickness of the thermal insulation of options

The minimum value of the thermal resistance of the floor of the heated area on the ground R_{r2} is defined in the standard STN 73 0540-2-2012 (Table 1).

Table 1 Required thermal resistance of structures (Source: STN 73 0540 Tab. A1)

Type of building structures	Arterial resistance R_{r2} structure W / (m2 K)
The floor of the heated area at ground level to 0.5 m below the ground and the outside within 2.0 m from the inner surface of the outer wall	2.5
Heated floor space on the ground other cases	2.0

The most important component of the coefficient of heat transfer is the heat resistance R (unit m^2.K/W). Manufacturers of construction materials such resistance either directly presented for a particular structural system, and provides general material property (ideally independent of the shape of the structure) which is a thermal conductivity λ of the unit W/(mK). Between the two variables exists a session in the construction literature known as first Fourier's law (Hejhálek):

$$R = \frac{d}{\lambda} \quad \textbf{((1)}$$

wher

R - is the thermal resistance in m^2.K/W
d - is the thickness in m
λ - Structure it is thermal conductivity in W/(mK).

In designing each variant songs foundation structures model house was used for construction physics calculation of the thermal resistance of the heat program. In order to compare the various options in terms of price realization, were the songs foundation structures proposed in disgust R≥ 3.4 W/(m^2.K).

The calculated values the thermal resistance of options is presented in table 2 (Table 2)

Table 2 Calculated proposed thermal resistance of each variant Source: own

variant	variant Description	Insulation thickness (Structure) [m]	Thermal conductivity λ [W/(mK)]	The calculated thermal resistance of the structure R [W/(m²K)]
V1	Base system with integrated insulation from Elegohouse Pasiv	0.31 + 0.05	0,106	3.40
V2	Establishment of the raised floor of wooden trusses from Krigger	0.18	0,053	3.40
V3	Establishment of the foam glass for example. Foamglas	0.25	0,073	3.41
V4	Foundation for a bath of extruded polystyrene XPS	**0.12**	**0,035**	**3.42**

The calculated thermal resistance R of the structural variants V1 to V4 shown in Fig. 7.

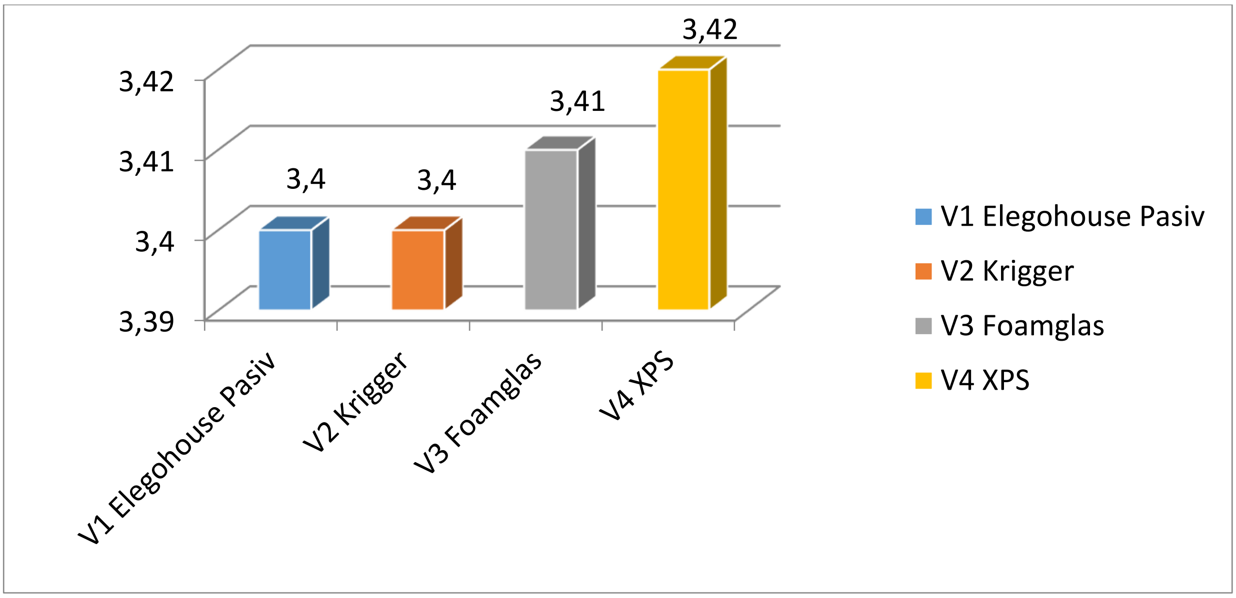

Figure 7. Calculated values the thermal resistance of each variant Source: own

For the calculation it shows that the most preferred alternative is alternative to the V4 establishment tub of extruded polystyrene rigid foam. The calculated variation of the thermal resistance of the structure V4 R = 3.42 W/(m^2.K).

4.2 Calculation of capital expenditures

Calculations of capital expenditures for the establishment of modern methods of family houses were set on indicative prices from the 1st quarter of 2017 the program Cenkros 4.

The calculated value of the cost of implementation and the calculated value of thermal resistance R base model house structures are shown in Table 3. At the same time the table shows the calculated average cost of 1 m^2 of built area.

Table 3 The cost calculation of one square meter frames from model home Source: own

Variants of construction foundations	The calculated thermal resistance of the structure R [W / (m^2K)]	The average cost of 1 m2 of built area of building [€/m^2] net	The total cost of the foundation structure of the house (50 m^2) [€] net
Elegohouse liabilities thick. 0.31 + 0.05 m	3.40	194.06	9 702.87
Krigger thick. therm. insul. 0.18 m	3.40	124.27	6 213.40
Foam glass thick. 0.25 m	**3.41**	**88.70**	**4 434.85**
XPS thick.0,12m	3.42	94.24	4 711.91

The resulting cost per unit of measurement €/m^2 for the base model house design variants V1 to V4 are shown in Figure 8th

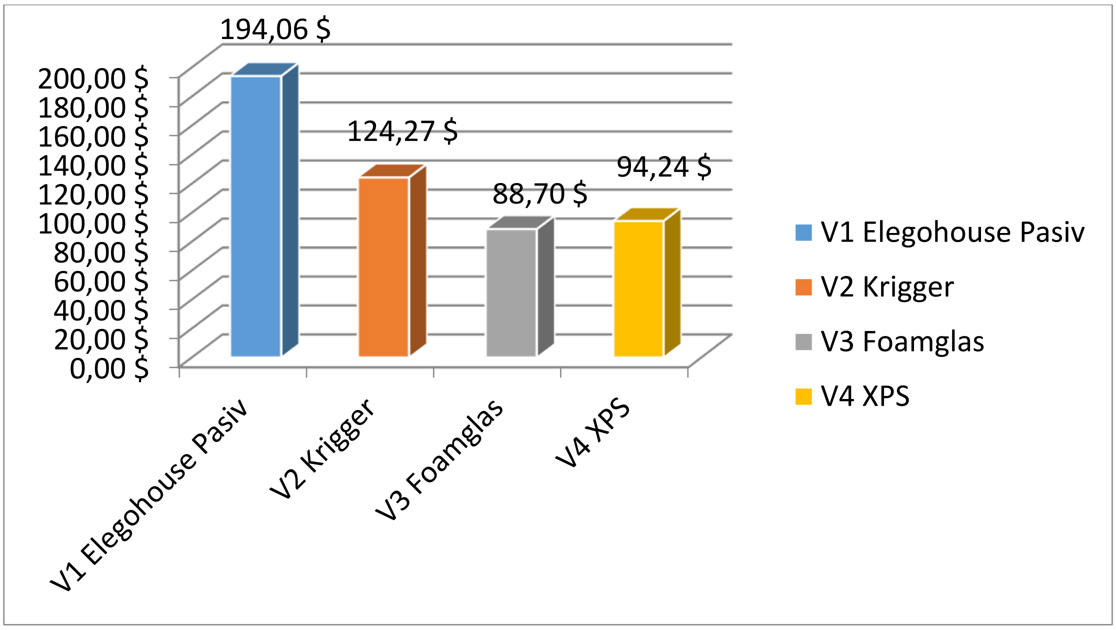

Figure 8. Calculation of cost per unit of measurement structures from model home Source: own

The resulting total cost of € for foundation construction model home variants V1 to V4 are shown in Figure 9th

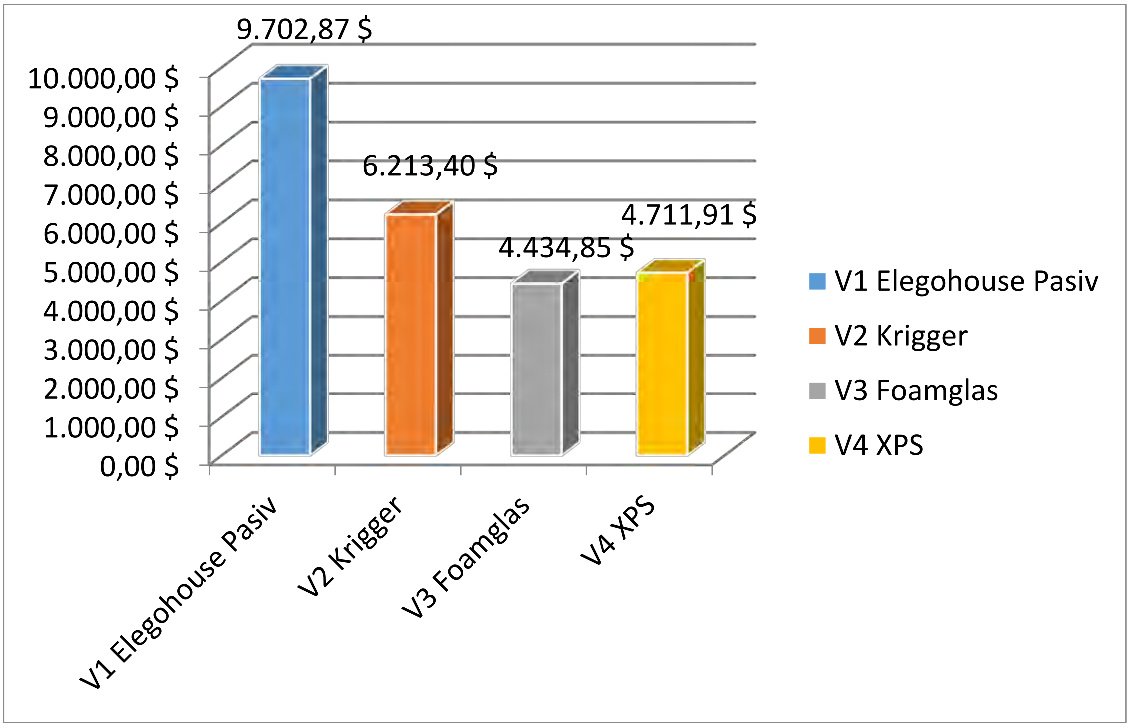

Figure 9. Calculating the total cost of construction from model home Source: own

Selected from the foundation structures are a part of modern methods of creation as the most preferred capital costs (cost of implementation structures) is the foundation on foam glass (version V3). The average cost of 1 m^2 of built area variant V3 is 88,70 €/m^2. The total capital cost variant V3 of the total built-up area of 50 m^2 are 4 434.85 €/m^2.

4.3 Analysis of capital expenditure establishment of selected modern methods of creation

Calculation of capital expenditures for the establishment of modern methods of family houses based on the calculation of the thermal resistance R of all variants. By calculating the cost of 1 m^2 Building area model object, the resulting capital expenditures creation of individual options translated on a total built area of that object model.

The most expensive foundation construction is based on calculations for model building using base isolation system with integrated (Elegohouse liabilities) with an average cost of 194.06 €/m^2 and a total cost of 9 702.87 €/m^2. As the most preferred options for the establishment of a model object in question came variants V3 despite only second best thermal properties (see Tab. 2). The calculated thermal resistance R V3 variant was 3.41 W/(m^2.K). The best thermal properties of the variant V4 thermal resistance R = 3.42 W/(m2.K)

5. Conclusion

This article its partial result builds on previous research comparing circuit construction of buildings completed chosen technologies MMC. The aim of the research is based on an analysis of partial parts of the building envelope construction process design works realized by modern methods of construction in terms of its economic efficiency, taking into account the costs of implementation and use of the building for the segment houses.

Article compares the selected base design model house belonging to the establishment of modern methods of family houses. Variants foundation structures have been designed with a comparable heat and technical parameters according to STN 73 0540-2. Based on a comparison of standard costs set by the budget applications with those of the first quadrant of 2017, the most preferred base design model for example is based on a reinforced concrete slab base foam glass known as variant V3.

The present article your results contribute to a basic comparison of the building envelope. Partial results of the research mentioned in the article are the basis for future research in the area of the proposal most advantageous packaging designs for houses implemented modern methods of construction and subsequent assessment of the overall capital cost of buildings. Then proceed to analyzing the entire life cycle cost structures implemented modern methods of construction.

Acknowledgment

The paper presents a partial research results of project VEGA 1/0828/17 "Research and application of knowledge-based systems for modelling cost and economic parameters in Building Information Modelling”.

References

Hejhálek, J (2016) "Heat transfer coefficient and is calculated as" available at: http://www.istavebnictvo.sk/clanky/sucinitel-prestupu-tepla-a-ako-sa-pocita/ (accessed 30 April 2017).

Kriger, J., "The Contradictions of Cold Climate Crawl Spaces", 2013, available at: http://blog.srmi.biz/contradictions-cold-climate-crawl-spaces/ (accessed 30 April 2017).

ELEGOHOUSE, "Base Board", available at: http://www.elegohouse.cz/zakladove-desky/typy-zakladovych-desek/zakladove-desky-elegohouse/ (Accessed 30 April 2017)

Sedláková A .: "Analysis of the possibility of structural formation of a new generation of lower structure for energy-efficient buildings." Available at:http://www.tzbportal.sk/stavebnictvo/analyza-moznosti-konstrukcnej-tvorby-novej-generacie-spodnej-stavby-pre-energeticky (Accessed 30 April 2017)

Šmid, D. "Loading energy efficient buildings." Available at: http://www.stavebnictvi3000.cz/clanky/zakladani-energeticky-uspornych-staveb/, 2013 (accessed 30 April 2017)

STN 73 0540-2 Thermal protection of buildings. Thermal performance of buildings and constructions. Part 2: Performance requirements, 2012

Planning and Control of Productivity of Construction Machinery through Use of Wireless Technology

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Abstract:

There are many crucial parameters that affect the productivity of the construction machinery. Although various methods and tools exist, available estimates of productivity lack a reliable and adequate prognostic model. Wireless technologies offer considerable potential for application with the purpose of planning and control of the productivity of construction machinery. Considering the fact that there are several types of wireless technologies, each with their own specific characteristics as well as advantages and disadvantages, it is necessary to analyze the adequacy of their application for the construction project at hand and the costs associated with them in order to make the most favorable selection. The paper gives an overview of the situation regarding the research on the issue of planning and control of productivity of construction machinery by applying the following wireless technologies: Radio Frequency IDentification Technology (RFID), Global Positioning System (GPS), and On Board Instrumentation (OBI). Assessment of the actual productivity of construction machinery is necessary in order to predict the required time and cost of construction.

Keywords: *productivity; construction machinery; wireless technology; RFID; GPS; OBI*

1. Introduction

The success of a construction project greatly depends on the productivity of construction machinery (Salem *et al.*, 2017). The key to profitability represents achieving the maximum possible productivity with appropriate quality (Sheikh *et al.*, 2016). There are many crucial parameters that affect the productivity of the construction machinery. For this reason, it is necessary to continually monitor a construction machinery during the execution of works on the construction site in order to obtain an estimate of their productivity and to identify the critical parameters that influence their productivity. Finding the critical parameters, it is necessary to explore opportunities to eliminate or minimize their adverse effects in order to increase the productivity of construction machinery and, by extension, achieving more successful realization of the construction project.

Although various methods and tools exist, available estimates of productivity lack a reliable and adequate prognostic model. They require a large amount of input data, long-term

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processing, and the end results are of questionable accuracy. Traditionally, the data is collected manually from the construction site and that's where the biggest danger lies for an incorrect interpretation of the conditions prevailing on the construction site.

The development of computer and communication technologies have enhanced the opportunities for the study of the economical use of construction machinery and productivity (Kannan, 2011). Despite this, very little attention is devoted to the automation of themeasurement of project progress and productivity (Navon *et al.*, 2012). Construction machinery shows a need for an automated system, which will collect data from the construction sites, a system that will be able to process large amounts of data and will make a correct assessment of productivity, calculate the time needed as well as the cost (Montaser and Moselhi, 2014).

Wireless technologies represent a fast-growing area with a continuous increase of possibilities and applications. The main characteristic of wireless technologies is to connect and establish communication between devices without the use of physical communication channels in the form of cables. Wireless technologies allow mobility and simplicity in use. The development of wireless technologies and computer programs enabled tracking the movement and operation of the construction machinery without disrupting their normal functioning. Wireless technologies offer considerable potential for application with the purpose of planning and control of the productivity of construction machinery. Except for the collection of data, wireless technologies provide opportunities for increasing productivity of construction machinery.

Considering the fact that there are several types of wireless technologies, each with their own specific characteristics as well as advantages and disadvantages, it is necessary to analyze the adequacy of their application for the construction project at hand and the costs associated with them in order to make the most favorable selection.

Some of the research carried through the application of wireless technologies reveal the following shortcomings: Global Positioning System (GPS) technology in a highly dense urban areas has a reduced accuracy when determining the current position of construction vehicles (Lu *et al.*, 2007), then, while some authors (Lu *et. al.*, 2011) highlighted the great potential of Radio Frequency IDentification Technology (RFID) and its insufficient implementation in the construction industry, others (Alshibani and Moselhi, 2016) point out that RFID cannot aid in the discovery of the causes of unacceptable work performance. Furthermore, On Board Instrumentation (OBI) technology is characterized by a high cost-price and the manufactures catalogues do not disclose its working methodology (Montaser and Moselhi, 2014).

The paper gives an overview of the situation regarding the research on the issue of planning and control of productivity of construction machinery by applying the following wireless technologies: Radio Frequency IDentification Technology (RFID), Global Positioning System (GPS), and On Board Instrumentation (OBI). The specified wireless technologies were selected based on their relatively quick and simple application.

2. Wireless technologies

Radio Frequency IDentification Technology (RFID) is a wireless communication technology between devices via radio waves. The basic components of the RFID technology are the RFID tag, RFID reader and the computer. The RFID tag is placed on the object that needs to be monitored. According to the mode of power supply RFID tags can be active or passive. Active RFID tags have their own power supply, most frequently via battery, and their range of transmission of the radio waves and communication with the RFID reader, can be up to several hundred meters. Passive RFID tags do not have their own power supply so they receive the power needed to operate from the RFID reader. The range of transmission of radio waves of passive RFID tags and communication with the RFID reader occurs only within a few meters. Because of their own power sources and a greater range of the transmission of radio waves, active RFID tags are more expensive than the passive RFID tags. RFID readers are used to receive and process data from RFID tags and to forward the data to a computer with the use of communication technology between devices; local area network - Ethernet or a wireless network - Wi-Fi. It is important to stress that the RFID technology can be applied in extremely harsh conditions on construction sites. The development of RFID technology is aiming to make the technology cheaper, to increase the device memory, to broaden the range of transmission of radio waves and power, and to speed up data processing.

Reliable and fast positioning is achieved through the application of global navigation satellite system, Global Navigation Satellite System (GNSS). The most significant representatives of GNSS technologies are the American Global Positioning System (GPS) and the Russian GLObal'naya NAvigatsionnaya Sputnikovaya Sistema (GLONASS). GPS has enabled a revolution in navigation technology. GPS consists of a group of artificial satellites that continuously broadcast radio signals, terrestrial control stations that are determining the position of the satellites and monitor their work, and the GPS receiver. A GPS receiver calculates its current position by analyzing radio signals it has received from the satellite. The radio signal contains encoded data about the current position of the satellites and the time of the transmission. There must not be any physical barriers on the trajectory of the radio signal to the GPS receiver. By connecting GPS with digital mobile telecommunication systems Global System for Mobile communications (GSM) and Geographic Information System (GIS), and with miniaturization of GPS receivers, a broad and indispensable application is achieved.

On Board Instrumentation (OBI) technology is a powerful measuring system for tracking and monitoring of machines while they are performing tasks and for computer data processing. Caterpillar and Trimble are leading companies when it comes to recommendation of OBI technology, but they keep the information needed to construct it, a secret. The OBI system is located on construction machines, and consists of a mobile computer with a screen, a GPS device, a laser, radio communications, etc. OBI systems enable accurate positioning of the machines and their tools, compares them with regard to the planned operation thus ensuring successful, quick and productive task performance. The sensors are responsible for monitoring the mechanical condition of the machines; for measurement of temperature, pressure, preventive maintenance, tire monitoring aimed at ensuring low fuel consumption, etc. Regular users of the OBI system claim that the productivity and the quality of construction works has increased, and that the possibility of errors decreased (Jonasson *et al.*, 2002). Even though the machines equipped with OBI system will achieve accurate and swift work performance and great productivity while performing the operation, it is not possible to calculate the time needed and the cost of the execution of works by using OBI system. The lack of OBI systems represents a high cost price and its economic viability is questionable.

2.1. Radio Frequency IDentification Technology (RFID)

Montaser and Moselhi (2012), presented the methodology for assessing the productivity of construction machinery through use of wireless RFID technology. The purpose of methodology of usage of the RFID technology is the early detection of discrepancies between the planned and actual execution of works, so that appropriate corrective measures could be carried out (Montaser and Moselhi, 2012).

Montaser and Moselhi (2012) applied their research to tipper trucks through the use of a passive RFID tag and two RFID readers. One RFID reader was placed on the loading area and its purpose was to measure the required time for the filling of empty box beds of tipper trucks, while the other RFID reader was placed on the dumping area and served to measure the required times for the emptying of full box beds of tipper trucks. RFID readers received signals from the passive RFID tag of a tipper truck while the tipper truck i.e. RFID tag was in the vicinity of a few meters to the RFID reader. Maximum range of transmission of radio waves of used RFID tag and its communication with the RFID reader occurred within a radius of three meters. During the time it was necessary for a full tipper truck to reach the dumping area and the time necessary for the return of an empty tipper truck to the loading area, RFID readers did not receive signals.

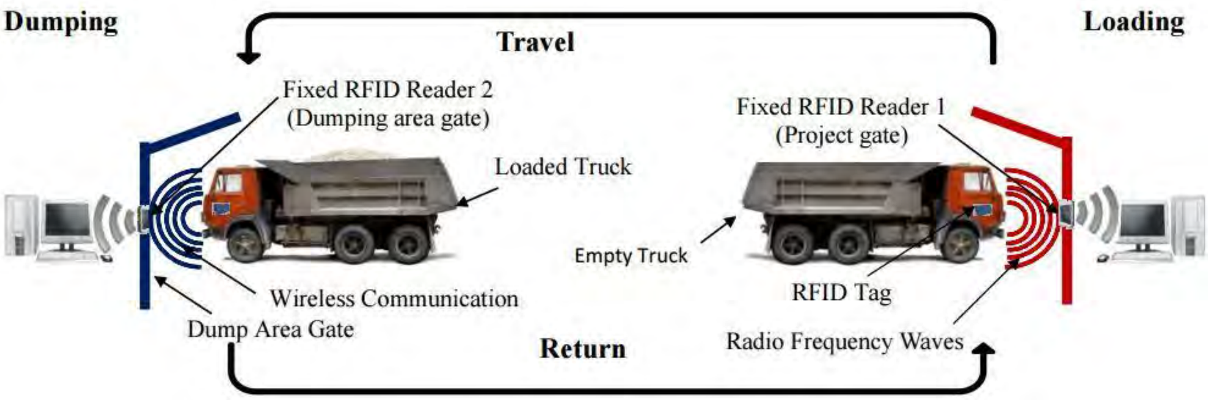

Figure 1. Overview of RFID technology (source: Montaser and Moselhi, 2012)

Cycle time of tipper trucks was calculated through time recordings of five events via RFID reader:

- The first event marked the beginning of charging process of the empty box beds and was recorded with the arrival of tipper trucks on the loading area,
- The second event marked the end of the filling of the box beds and was recorded with the departure of tipper trucks from the loading area,
- The third event marked the beginning of the emptying of full box beds and was recorded with the arrival of tipper trucks to the dumping area,
- The fourth event marked the end of the emptying of the box beds and was recorded

with the departure of trucks from the dumping area,
- The fifth event represented the end of the cycle time, or the return of the tipper trucks to the loading area.

Following the five recorded events and the mathematical operation of subtraction the time required for loading was determined as well as the travel time of the full tipper trucks, the time required for dumping and the time of return of the empty tipper trucks to the loading area:

- Loading Time = Event 2 – Event 1,
- Travel time = Event 3 – Event 2,
- Dumping time = Event 4 – Event 3,
- Return time = Event 5 – Event 4,

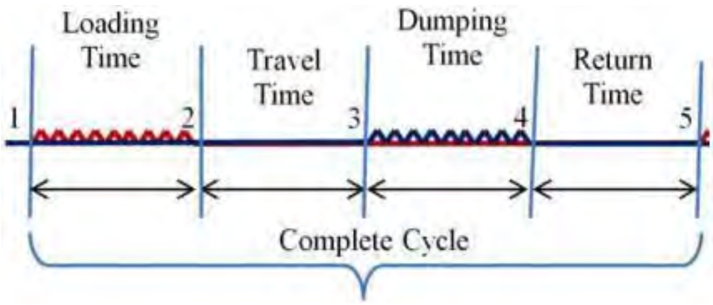

Figure 2. Diagram of five time events recorded by RFID readers (source: Montaser and Moselhi, 2012)

Through the calculation of the cycle time an estimate on the productivity of construction machinery can be achieved either deterministically or by performing simulations. RFID technology is a simple method for planning and control of productivity, but its application is not appropriate for the execution of linear buildings or roadways. Ibrahhim and Moselhi (2014) point out that it is not possible to use applied methodology in order to get a confirmation on whether a tipper truck box bed is loaded properly or if it is overloaded. In order to achieve the maximum possible effectiveness, a tipper truck box bed needs to be filled to its capacity. Overloaded box beds causes higher fuel consumption, extra strain on the tires, and increases the possibility of mechanical failure of the tipper truck.

Lu *et. al.* (2011) point to the possibilities of the application of RFID technology for tracking the position of construction machinery on large construction sites, in order to achieve a good work schedule. Furthermore, in order to ensure the reliability and functionality of the machines, they need to be regularly maintained and serviced. Lu *et. al.* (2011) suggest the use of RFID technology for the purpose of monitoring mechanical condition of the machines. After the inspections, all the data would be stored in the RFID tags with automatic updating of data through a central system. This would enable obtaining a record of all information regarding performed repairs and regular maintenance by scanning the RFID tag on a machine with a suitable RFID hand-held device.

Karthik *et. al.* (2014) demonstrate the use of RFID technology in open-pit mines. In addition to the fact that RFID technology can track the movement of construction machinery, it can serve the purpose of preventing collisions between vehicles as well. RFID tags are placed on all the machines, while RFID readers are placed on the machines with large blind spots. In this way RFID technology detects the presence of machinery and can prevent potential collisions.

2.2.Global Positioning System (GPS)

Alshibani and Moselhi (2016) presented a methodology for monitoring and estimation of the productivity of hauling units by using Global Positioning System (GPS) and Geographic Information System (GIS).

Geographic Information System (GIS) is a database oriented on real space. It contains a set of software tools that enable the creation of dynamic zones, distance measurement, and data management. Also, it allows the data about the space to be transformed and connected to time. GIS is a general term for a set of different processing and spatial data analysis.

The purpose of the proposed methodology of GPS application represents, in a practical and simple way (Alshibani and Moselhi, 2016), assessment of actual productivity of hauling units and a forecast of the required time and costs of their project activities. Also, the proposed methodology can aid in the discovery of causes of unacceptable behavior of hauling units.

GPS receivers are placed on hauling units to monitor the performance of the machines, and measure the time, speed and geographic location in order to determine the cycle time for each individual route as well as for repeated routes. Cycle time includes the time required for the loading of the hauling unit, driving time, the time required for dumping and the return time of hauling unit. The number of routes to be tracked via GPS are arbitrarily determined and are selected according to the need of the project. An example of the simplicity of the proposed methodology is evident in the fact that it is sufficient to set up a single GPS receiver on a single hauling unit which operates on and drives through the same route as the rest of the hauling units who participate in the execution of the observed activities (Alshibani and Moselhi, 2016). The estimated productivity of the tracked hauling unit represents the productivity of other hauling units with the assumption that all the machinery is in good working order, and there will be no malfunctions to any of the involved hauling units while they are working or travelling.

Alshibani and Moselhi (2016) presented sequencing of the proposed methodology summarized by steps:

- Step one: Collecting data from the construction sites by tracking hauling units with the help of GPS receivers,
- Step two: Mapping of data collected from the construction sites into a GIS map, followed by using the Graphical User Interfaces (GUI) modules, a graphic depiction of the routes, and after that the monitoring of the hauling units on the GIS map via the Internet,
- Step three: Defining the loading and dumping areas on the GIS map by using drawing tools in the GUI module.

Drawing tools, if necessary, allow defining different loading and dumping areas during the progress of the project.

- Step four: Analysis of the collected GPS data from the construction site and calculation of times for loading, driving, dumping and returning, i.e. the calculation of the cycle time of an hauling unit,

• Step five: Repeating the second and fourth step depending on an arbitrarily chosen number of routes that will be tracked via GPS technology.

In the Alshibani's and Moselhi's paper (2016) the number of tracked routes in first example is 30, and in the second example it amounts to 75, but the authors state that the proposed methodology is capable to handle a greater number of routes.

• Step six: Depending on the number of tracked routes, entering the obtained loading, driving, dumping and the return times in the computer software Cristal Ball,

• Step seven: Performing a simulation in computer software Cristal Ball and obtaining the stochastic estimation of the actual productivity of construction machinery, an index of productivity, cost and time estimates, as well as the values of variability of costs and time.

• Step eight: Analysis of the results of the simulation, and, if appropriate, implementation of corrective actions.

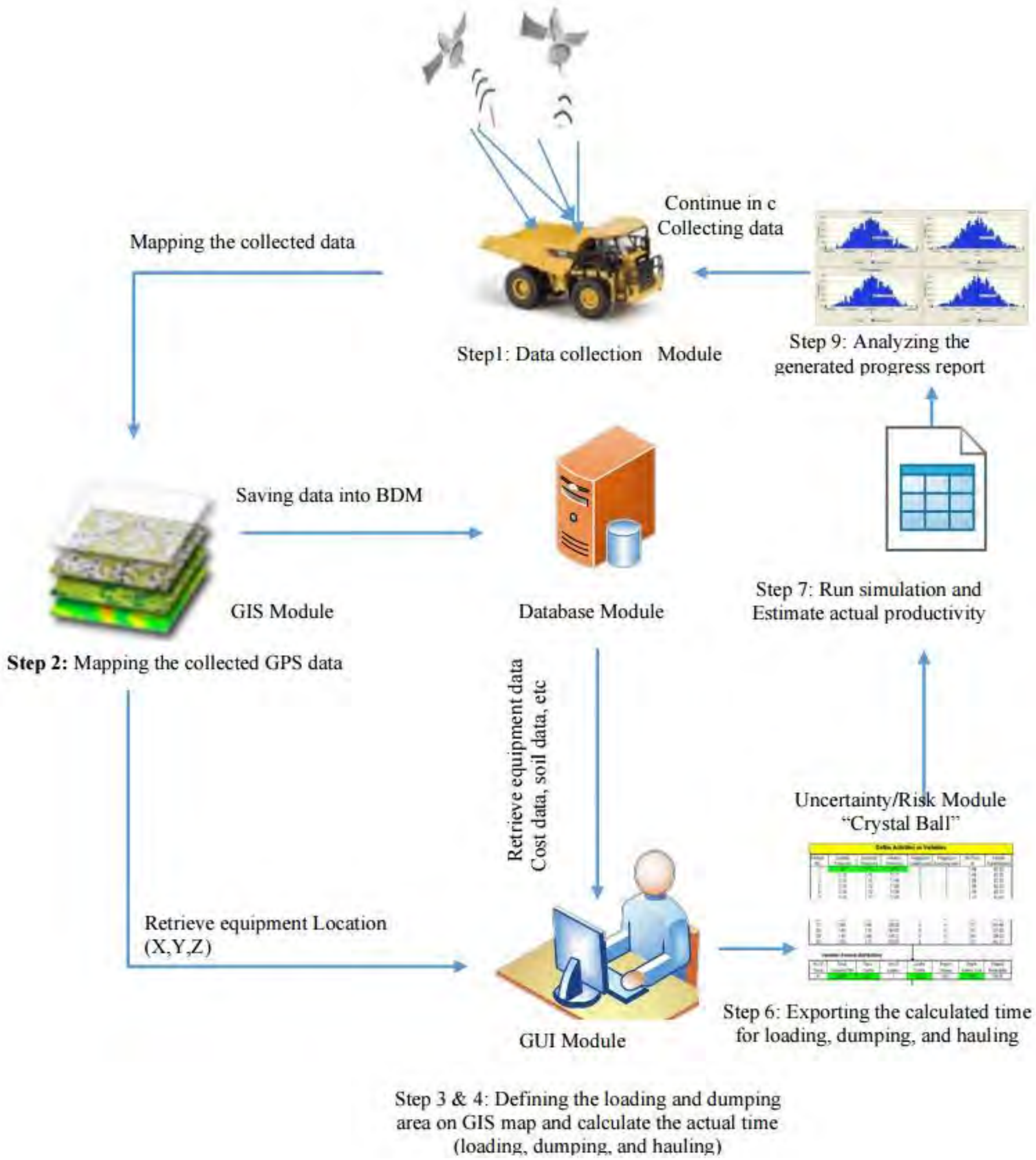

Figure 3. A review of the proposed methodology by using GPS and GIS (source: Alshibani and Moselhi, 2016)

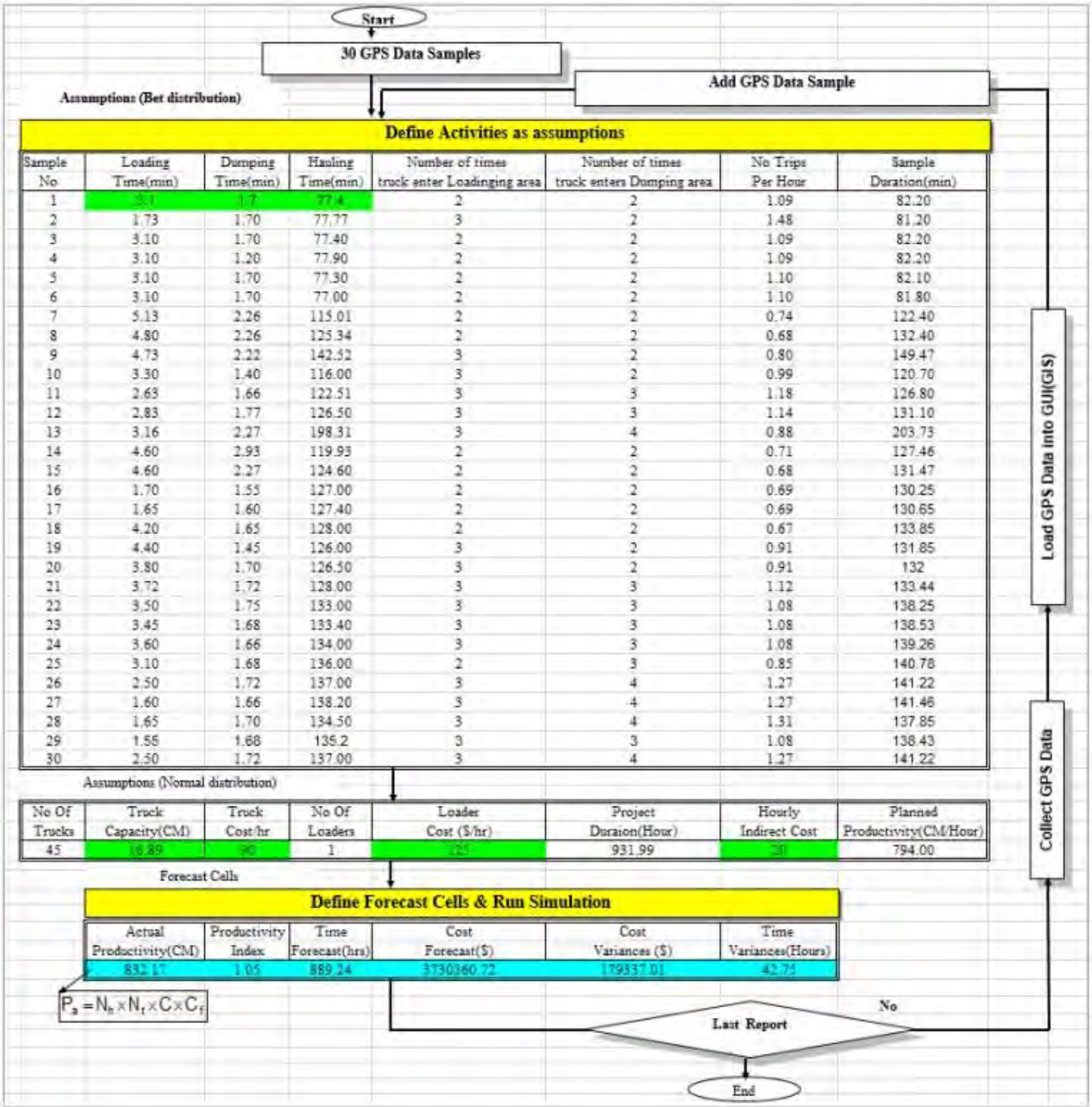

Figure 4. Stochastic estimation of actual productivity (source: Alshibani and Moselhi, 2016)

Alshibani and Moselhi (2016) point out that the methodology of applying GPS technology is currently limited to the works that involve the use a fleet of loaders and hauling units. Application on other construction machinery with cyclic modes of operation has not been explored yet. The cyclic mode of operation is necessary for the calculation of the cycle time. Also, the methodology is applicable only for open work areas, e.g. roads or highways, since tall buildings in urban areas can interfere with the reception of satellite radio signals. Therefore, the proposed methodology can be combined with the use of RFID technology.

The results of their research show that the methodology of applying the GPS can be successfully used for planning and control of productivity of hauling units. However, since the Alshibani's and Moselhi's research (2016) has been published only recently, there are currently no reviews of their work.

2.3. On board instrumentation (OBI)

Han *et al.* (2005) conducted a research in which estimates of productivity of construction machinery are compared by using conventional method and a method which they called the GPS-based earthmoving systems in their paper.

During planning and performance of earthmoving operations, conventional methods are largely influenced by the human factor. Accordingly, an increased possibility of project errors exists. By applying conventional methods in earthmoving operations, apart from construction machinery, a geodetic measurement of surfaces and planting of geodetic markers is needed. Geodetic markers serve as visual guides for the drivers of the machines in performing their tasks. If a geodetic mark is torn down during the performance of operational tasks, geodesists need to repair them or to plant them again which results in performance delays. High possibility of human errors as well as repairing of the incurred errors result in unproductivity, extension of the duration of the works as well as the higher cost of the construction project.

In the study by Han *et al.* (2005), the GPS-based earthmoving systems represents location tracking of the machinery via GPS and three-dimensional (3D) graphical representation of the machine work on the computer screen while the work is being executed. Computers are located in the machine and allow machine guidance in performing work operations, as well as the calculation of the volume of excavated material. Through the application of GPS-based earthmoving system there is no need for geodesists to plant geodesic markers. In this paper, research by Han *et al.* (2005), is considered as an On Board Instrumentation (OBI) system, due to its characteristics.

Han *et al.* (2005) used a simulation program Web CYCLONE that is based on assumptions, specifications of the machines and interviews to conduct a comparative assessment of productivity of construction machinery through usage of conventional and GPS-based earthmoving system. Simulation model of GPS-based earthmoving system was based only on a couple of well-known assumptions because the application of GPS-based earthmoving system at that point was of a too short duration to obtain larger quantities of data from a construction site. The results of the simulation models showed that the GPS-based earthmoving system is more productive than conventional methods for the assessment of productivity and related costs. However, when planning the choice of methods for the execution of works it is necessary to compare the expected profit achieved through productive performance of works with the high initial cost of GPS-based earthmoving system.

Han *et al*. (2008) complemented their research for conducting a comparative assessment of productivity of construction machinery through usage of conventional and GPS-based earthmoving system a few years later, with the aim of developing a more reliable methodology for assessing productivity-related costs. Based on the estimation of productivity and comparison of the expected profit and costs, the methodology should serve as support while choosing one of the two methods analyzed.

3. Conclusion and proposal for further research

Productivity assessment is a difficult task which requires continuous monitoring of construction machinery as a part of the complex environment prevalent at the construction site. By continuously monitoring construction machinery, a large amount of data is created which needs to be processed quickly and accurately.

Assessment of the actual productivity of construction machinery is necessary in order to predict the required time and cost of construction. Wireless technologies offer considerable potential for application with the purpose of planning and control of the productivity of construction machinery. Through application of wireless technology the possibility of human error is significantly diminished, also there is a need for a smaller number of samples and they display actual conditions at the construction site.

The paper gives an overview of the application of three different wireless technologies: Radio Frequency IDentification Technology (RFID), Global Positioning System (GPS), and On Board Instrumentation (OBI). The application of wireless technologies for the purpose of planning and control of productivity of construction machinery has not been sufficiently researched. Since the conducted research on the application of wireless technologies points to shortcomings and limitations, further research on their great potential is required.

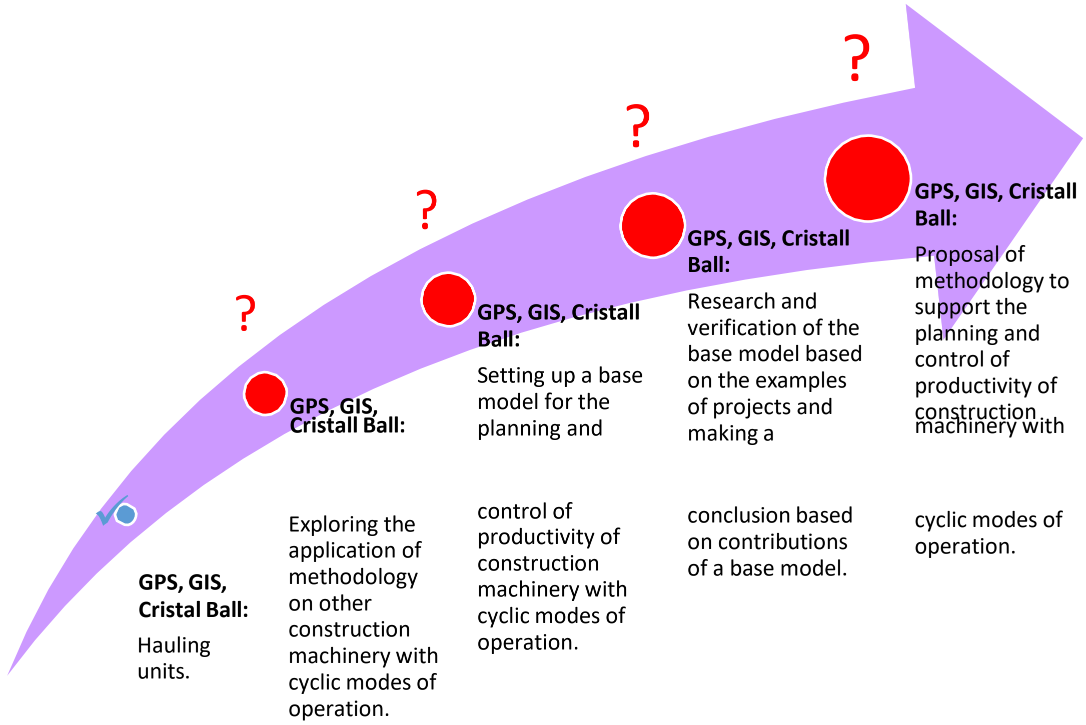

Figure 5. Proposal for further research

The authors Alshibani and Moselhi (2016), proposed a methodology for planning and control of productivity of hauling units. Their methodology consists of the application of GPS and GIS technology with the stohastic assessment of the productivity by conducting a simulation in computer software Cristal Ball. Since they have pointed out that their methodology is currently limited and has been under research exclusively taking into account works that include the use a fleet of loaders and hauling units, a proposal for future research is shown in Figure 5. and it can be summed up by following steps:

- Step one: Verifying the accuracy of the methodology of the authors Alshibani Moselhi (2016) by applying it to hauling units,

- Step two: Exploring the application of methodology of authors Alshibani and Moselhi (2016) on other construction machinery with cyclic modes of operation,
- Step three: Setting up a base model for the planning and control of productivity of construction machinery with cyclic modes of operation,
- Step four: Research and verification of the base model based on the examples of projects and making a conclusion based on contributions of a base model,
- Step five: Proposal of methodology to support the planning and control of productivity of construction machinery with cyclic modes of operation,
- Step six: Exploration of the customization of the methodology in order to support planning and control of productivity for other construction machinery.

The proposal of future research is based on the application of the methodology of authors Alshibani and Moselhi (2016), i.e. on the application of GPS and GIS technology with the stochastic assessment of productivity by conducting a simulation in computer software Cristal Ball. If, in the future research and verification of the basic model on project examples, an interruption in the reception of satellite radio signals and reduced accuracy when determining the current position would occur, GPS technology would be combined with the use of RFID technology.

The vision of the research proposal is the acquisition of an accurate and reliable methodology for the support in planning and control of productivity. The methodology would be firstly examined on the construction machines with cyclic modes of operation after which other options for customizing the methodology to support the planning and control of productivity in other construction machinery would be explored.

Given the great complexity of the environment of construction projects at their planning and execution level, finding an adaptive and applicable model for planning and control of productivity of construction machinery, would greatly contribute to making accurate decisions for problem-solving in the field of construction and it would pave the way for a successful realisation of construction projects.

References

Salem, A., Salah A., Ibrahim M. and Moselhi, O. (2017),"Study of Factors Influencing Productivity of Hauling Equipment in Earthmoving Projects using Fuzzy Set Theory", International Journal of Innovation, Management and Technology, Vol. 8 No. 2, pp. 151-154.

Sheikh, A., Lakshmipathy, M. and Prakash, A. (2016), "Application of Queuing Theory for Effective Equipment Utilization and Maximization of Productivity in Construction Management", International Journal of Applied Engineering Research, Vol. 11 No. 8, pp. 5664-5672.

Kannan, G. (2011), "Field studies in construction equipment economics and productivity", Journal of construction engineering and management, Vol. 137 No. 10, pp. 823-828.

Navon, R., Khoury, S. and Doytsher, Y. (2012), “Automated productivity measurement model od two-dimensional earthmoving-equipment operations”, International Journal of Architecture, Engineering and Construction, Vol. 1 No. 3, pp. 163-173.

Montaser, A. and Moselhi, O. (2014), "Truck+ for earthmoving operations", Journal of Information Technology in Construction (ITcon), Vol. 19 No. 25, pp. 412-433.

Lu, M., Chen, W., Shen, X., Lam, H. C. and Liu, J. (2007), "Positioning and tracking construction vehicles in highly dense urban areas and building construction sites", Automation in construction, Vol. 16 No. 5, pp. 647-656.

Lu, W., Huang, G. Q. and Li, H. (2011), "Scenarios for applying RFID technology in construction project management", Automation in Construction, Vol. 20 No. 2, pp. 101-106.

Alshibani, A. and Moselhi, O. (2016), "Productivity based method for forecasting cost & time of earthmoving operations using sampling GPS data", Journal of Information Technology in Construction (ITcon), Vol. 21 No. 3, pp. 39-56.

Montaser, A. and Moselhi, O. (2012), "RFID+ for tracking earthmoving operations", proceedings of Construction Research Congress 2012: Construction Challenges in a Flat World, American Society of Civil Engineers, Reston, VA, pp. 1011-1020.

Ibrahim, M. and Moselhi, O. (2014), "Automated productivity assessment of earthmoving operations", Journal of Information Technology in Construction (ITcon), Vol. 19 No. 9, pp. 169-184.

Karthik, G., Jayanthu, S., Rammohan, P. and Rahman, A. (2014), “Utilisation of mobile communication in opencast mines”, International Journal of Computer Science and Mobile Computing, Vol. 3 No. 7, pp. 373-378.

Han, S.W., Lee, S.Y. and Halpin, D.W. (2005), "Productivity evaluation of the conventional and GPS-based earthmoving systems using construction simulation", proceedings of Construction Research Congress 2005: Broadening Perspectives, American Society of Civil Engineers, Reston, VA, pp. 1-9.

Han, S., Hong, T. and Lee, S. (2008), "Production prediction of conventional and global positioning system–based earthmoving systems using simulation and multiple regression analysis", Canadian Journal of Civil Engineering, Vol. 35 No. 6, pp. 574-587.

Research and Education in Construction

Evaluation of Learning Outcomes in Civil Engineering Studies

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Abstract:

One of the goals of graduate civil engineering education is to develop generic and technical competences that will provide wider opportunities for graduates in finding good jobs and a higher chance of promotion. The traditional approach to civil engineering education in the Republic of Croatia and Bosnia and Herzegovina however has been more oriented towards the development of professional, engineering skills and competences. To identify what skills and competences are required by employers and to find the perceived expectation gap of civil engineering skills between academic preparation and market needs a number of approaches can be used. The approach applied in this paper is based on survey questionnaires with the purpose of identifying current and future skill needs as perceived by employers in the Republic of Croatia and Bosnia and Herzegovina. In this paper, a list of generic and technical skills and competences developed in the Republic of Croatia, with respect to instructions developed by European Civil Engineering Education and Training (EUCEET), is compared with a list of competences applied in Bosnia and Herzegovina to indicate the degree of similarity among the lists and the possible convergence among universities in these two countries. The survey asked employers to rate listed competences by its importance and the degree of achieving goals in the education process. The results of the survey are analyzed and examined to reveal the deficiencies of current civil engineering education in the Republic of Croatia and Bosnia and Herzegovina, and recommendations for improving the quality of civil engineering studies curricula are proposed.

Keywords: *learning outcomes; competences; evaluation; employers; civil engineering studies*

1. Introduction

The law of the Croatian Qualifications Framework (OG 22/13, 41/16) defines learning outcomes as the competences that a person has gained through learning and has proven after the learning process. In European higher education, the concept of learning outcomes is being actively considered since the Ministerial Conference in Prague in 2001. After the conference, each of the subsequent conferences has continued the process of defining and introducing learning outcomes into the national and European higher education policy. Conclusions and recommendations made after the Berlin Conference of Ministers responsible for Higher Education in 2003 encouraged member states to develop a framework of comparable and compatible qualifications for national higher education systems, which should aim to qualify the qualifications in terms of level, volume, profile and quality. The Bologna Process

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Monitoring Group has committed itself to elaborating a comprehensive framework of qualifications for the European Higher Education Area. Within this framework diplomas should have differently defined outcomes. The first and second cycle degrees should have different orientations and profiles to adapt to different individual and academic needs and labor market needs (Communiqué of the Conference of Ministers for Higher Education in Berlin). The informal group of experts gathered in the Joint Quality Initiative has developed criteria for distinguishing individual stages as a set of broad and general features. These criteria are known today as Dublin Descriptos (Tuning Educational Structures in Europe). In the coming years, curricula based on the learning outcomes and the development of student competences are being created in line with the needs of the labor market, increasing employability and competitiveness in the labor market.

It points to the importance and the need for curricula to align with the needs of society and the development of science and technology, to link higher education with other research sectors, and to improve the quality of doctoral studies (Bergen communiqué 2005, London communication 2007, Leuven & Louvain-la-Neuve communiqué 2009, Bucharest Conference 2012). This implies an innovative approach to teaching, curriculum development, teaching methods and work methods that are more focused on the student and a more innovative approach to teaching and research work with students to ensure a stimulating learning environment. Following the guidelines of the development of the Republic of Croatia and the guidelines of the European Social Fund, the county level policies for employment, education and social inclusion policies are analysed at the local level, articulated through the County Human Resources Development Strategy. These strategies clearly define the need to provide adequate education tailored to the needs of the labor market. Civil engineering higher education faces demands from the construction sector that sees engineers capable of analyzing, evaluating, criticizing and applying innovative solutions and the development of information technologies that significantly change the way students learn. This paper gives an overview of the activities related to the analysis of the learning outcomes of the construction studies conducted at the faculties of Croatia and in Bosnia and Herzegovina, that is, the University of Mostar. The aim of the paper is to systematize the results of research within the implemented projects and to provide an insight into the employers' expectations related to the competences of civil engineers.

2. Conducting research in Republic of Croatia and Bosnia and Herzegovina

Civil engineering faculties in the Republic of Croatia and Bosnia and Herzegovina continuously conduct research aimed to identify desirable competences of graduates from the employers' point of view. In addition, the focus of the research is the difference between the competences that are acquired by completing the study program and the employers' expectations. Employer expectations are determined in different ways, but the research method applied in this paper is survey questionnaires. The paper describes the approach to the research of the labor market needs with respect to the competences acquired by the student of civil engineering upon completion of the Graduate Study (Second cycle) completed at the civil engineering faculties in the Republic of Croatia and Bosnia and Herzegovina between 2008 and 2016 with the aim of improving the studies through the cooperation of higher education institutions and the employers (from the public and private sector).

2.1 *Conducting research on learning outcomes at the Faculty of Civil Engineering Mostar*

Within the research project *Improvement of Learning Outcomes at the Faculty of Civil Engineering Mostar*, a study was conducted on the learning outcomes among (i) **employers** who have employed civil engineers holding master's degrees - having completed graduate studies at the Faculty of Civil Engineering Mostar since 2010 (the year in which the first students graduated according to the curricula defined in the Bologna reform program); (ii) **civil engineers** holding master's degrees - having completed graduate studies at the Faculty of Civil Engineering Mostar on the curricula defined in the Bologna reform program; (iii) **students of the first year** of graduate study at the Faculty of Civil Engineering Mostar and (iv) **teachers and associates** of the Faculty of Civil Engineering Mostar. The research was funded by the Ministry of Education and Science of the Federation of Bosnia and Herzegovina.

The overall aim of the research was to determine the extent to which the competences, knowledge and skills acquired during the study at the Faculty of Civil Engineering Mostar are in line with the expectations of employers, graduates and current students and teachers to obtain guidelines for the curriculum improvement based on learning outcomes. The aim of the research of employers' and graduates' views was to determine the extent to which the competences of civil engineers gained during the study were matched with the expectations and requirements of the employers or the workplace for which the students were preparing during the study. The aim of the research of teachers' views was to determine the extent to which certain competences, knowledge and skills during the undergraduate and graduate university studies at the Faculty of Civil Engineering Mostar need to be developed and how compatible the positions of employers and graduates are. The aim of the research of student views was to determine the extent to which their knowledge and skills were developed in undergraduate studies and what their expectations were in terms of career challenges and career development.

The research was conducted by surveying the aforementioned groups. The survey was conducted in early 2016 and based on an online questionnaire survey at Kwiksurveys (https://kwiksurveys.com/), besides the classroom survey (paper-pencil survey). A total of 35 competences, knowledge and skills (classified into 18 specific and 17 generic) were compiled on the basis of a list of competences defined by the SOCRATES-ERASMUS 2006 Thematic Network Project: European Civil Engineering Education and Training 2006, and ASCE competences in the Civil Engineering Body of Knowledge for the 21st Century: Preparing the Civil Engineer for the Future of 2008 (see Table 1).

Table 1. Contents of the questionnaire for competences, knowledge and skills assessment

Specific competences	Generic competences
1. An ability to apply knowledge of mathematics, science, and engineering (applied physics, applied chemistry, geology, ecology). 2. An ability to apply knowledge of mechanics, applied mechanics and other fields relevant to civil engineering. 3. An ability to design a system, or a component, or process to meet desired needs. 4. An ability to identify, formulate and solve typical civil engineering problems. 5. An ability to identify, formulate and solve complex civil engineering problems. 6. An ability to design and construct buildings respecting the principles of environmental protection and architectural heritage (including aesthetic aspects). 7. An ability to design and conduct experiments, as well as analyze and interpret data. 8. An ability to identify the research needs and necessary resources. 9. An ability to use the techniques, skills and modern engineering tools necessary for engineering practice (including IT). 10. An ability to apply knowledge in specialized areas related to civil engineering: bearing structures, hydro engineering, transportation engineering, geotechnical engineering, environmental protection, construction organization and management. 11. An understanding of the elements of project and construction management of common civil engineering works. 12. An understanding of the elements of civil engineering project and managing the setting up of complex construction projects. 13. An understanding of professional and ethical responsibility of civil engineers. 14. An understanding of the technical, environmental, social, political, legal, aesthetic, economic and financial aspects of civil engineering works in the historical and present perspective. 15. An ability to communicate effectively: written and oral in mother tongue and one foreign language for a professional and unprofessional public (using Internet resources and other communication tools). 16. An understanding of the role of the leader and leadership principles and attitudes. 17. An understanding of the need and readiness to engage in life-long learning. 18. An ability to function on multi-disciplinary teams.	1. An ability to work in an interdisciplinary team. 2. Appreciation of diversity and multiculturality. 3. Basic knowledge of the field of study (general engineering priciples). 4. Basic knowledge of the engineering profession. 5. Capacity for analysis and synthesis. 6. Capacity for applying knowledge in practice. 7. Capacity for generating new ideas and solutions (creativity). 8. Capacity to adapt to new situations. 9. Capacity to learn. 10. Critical and self-critical abilities. 11. Decision making. 12. Elementary computing skills. 13. Respecting ethical principles of the profession. 14. Interpersonal skills. 15. Knowledge of a foreign language. 16. Oral and written communication in mother tongue. 17. Research skills.

The contribution and satisfaction of expectations were measured with the Likert scale ranging from 1 (totally dissatisfied) to 5 (full satisfaction). Employers' expectations, i.e. the importance of competences, knowledge and skills required for a civil engineer holding a master's degree in the employers' view as well as overall grades are presented in Table 2.

Table 2. Importance and overall grades of specific and generic competences by employers

most important **specific competences** for employers	most important **generic competences** for employers
4.29_an ability to use techniques, skills and modern engineering tools necessary for engineering practice (including IT) 4.23_an ability to apply knowledge in a specialized area relating to civil engineering 4.21_an ability to communicate effectively: written and oral in mother tongue and one foreign language 4.21_an understanding of the need and readiness to engage in life-long learning 4.14_an ability to identify, formulate and solve complex engineering problems	4.50_elementary computing skills 4.43_respecting the ethical principles of the profession 4.43_oral and written communication in mother tongue 4.36_critical and self-critical abilities 4.36_decision making

least important **specific competences** for employers	least important **generic competences** for employers
3.08_an ability to design and conduct experiments, as well as analyse and interpret data 3.46_an ability to apply knowledge of mathematics and other basic subjects 3.50_an understanding the technical, environmental, social, political, legal, aestetic, economic and finacial aspects of civil engineering works 3.75_an ability to identify researh needs and necessary resources 3.77_an ability to design and construct buildings respecting the principles of environmental protection and architectural heritage	3.54_research skills 3.71_capacity for analysis and sythesis 3.86_an ability to work in an interdisciplinary team 4.00_capacity for generating new ideas (creativity) 4.14_appreciation of diversity and multiculturality

2.2 Conducting research on learning outcomes at the Faculty of Civil Engineering Rijeka

During 2008 and 2009, the project *Learning Outcomes in Higher Education of Civil Engineers* was implemented at the Faculty of Civil Engineering, University of Rijeka. The project was funded by the National Foundation for Science, Higher Education and Technological Development of the Republic of Croatia within the framework of the Higher education based on learning outcomes. The result of the project is the knowledge, skills and competences of civil engineers at the level of university undergraduate and graduate studies at the Faculty of Civil Engineering, University of Rijeka.

In the framework of the project, teacher education was carried out through a series of workshops related to teaching methods and the application of learning outcomes in the teaching process. Apart from teacher education, the project also explored the sources related to the practice of defining and applying the learning outcomes of civil engineering studies and examining the views of teachers, employers and graduates on desirable competences for study as well where those competences are, in their view, prioritized.

The examination of the employers' views on the desirable competences of graduate students in civil engineering studies was conducted by surveying employers, graduates and teachers of civil engineering faculties in Croatia (three civil engineering faculties in Croatia: Rijeka, Zagreb and Osijek), members of the Alumni Club of the Faculty of Civil Engineering, University of Rijeka experienced in conducting internships) and graduate students (members of the Alumni Club of the Faculty of Civil Engineering, University of Rijeka, who have up to 8 years of working experience).

In the form of a questionnaire, a list of competences was offered to the aforementioned groups, taken from the EUCEET Tunning project and adapted to the research needs. Employers, teachers and graduates, on a scale from 1 to 4 (1 - no need to develop these competences or competences have not been developed to study up to 4 - extremely important competences, competences developed considerably through study), evaluated the competences listed in Table 3.

Table 3. Content of the competency evaluation questionnaire

Specific competences
1. An ability to apply knowledge of mathematics, science and engineering (applied physics, applied chemistry, geology, ecology).
2. An ability to apply knowledge of mechanics, applied mechanics and other subjects relevant to civil engineering: concrete structures, steel structures, geodesy, materials, computing, organization and technology management, roads, hydro technical constructions and systems.
3. An ability to design a system or a component taking into account the needs and legality of the profession.
4. An ability to identify, define and solve common engineering problem.
5. An ability to identify, define and solve complex engineering problem.
6. An ability to identify the research needs and necessary resources.
7. An ability to use the techniques, skills and modern engineering tools necessary for engineering practice (including IT).
8. An ability to apply knowledge in specialized areas related to civil engineering: bearing structures, hydro engineering, transportation engineering, geotechnical engineering, environmental protection, construction organization and management.
9. An understanding of the elements of project and construction management of common civil engineering works.
10. An understanding of the elements of project and construction management of complex construction projects.
11. An understanding of professional and ethical responsibility of civil engineers.
12. An understanding of impact of construction projects in wider social and cultural context, as well on the environment.
13. An ability to communicate effectively: written and oral in mother tongue and one foreign language.
14. An understanding of the role of the leader and leadership principles and attitudes.
15. An understanding of the need and readiness to engage in life-long learning.
16. An ability to function in multi-disciplinary teams.

The results of the research showed different positive and negative aspects of existing studies. The views of teachers, employers and graduates about the competences that students develop or should develop in civil engineering studies are presented in Figure 1. Although employers, on average, evaluate the final competencies of students better than graduates themselves, both groups perceive the same flaws in the study.

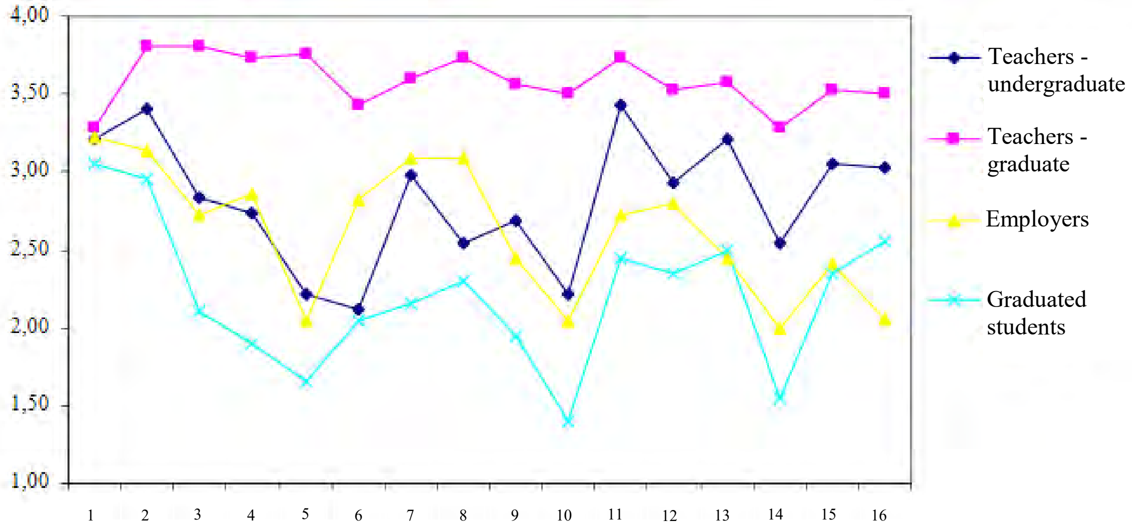

Figure 1. Results of examining the views of teachers, employers and graduates about the competences that students develop or should develop in civil engineering studies

The following were identified as the least developed competences: *an ability to identify and solve civil engineering problems*, *the management of construction projects and the skills required for project management*. Excerpts on the application of *knowledge from basic natural and technical disciplines* (mathematics, technical mechanics and the like) are well appreciated.

2.3 Research at the Faculty of Civil Engineering Osijek

Project *Development and implementation of the Croatian Qualifications Framework in the field of civil engineering studies* was carried out within the framework of the 2007-2013 Human Resources Development Operational Program during 2015 and 2016. The project was co-financed by the European Union from the European Social Fund. The project leader was the Faculty of Civil Engineering Osijek (FCE OS), which has realized the project activities with its partners - Faculty of Civil Engineering Zagreb (FCE ZG), Faculty of Civil Engineering Rijeka (FCE RI) and Faculty of Civil Engineering, Architecture and Geodesy Split (FCEAG ST).

As part of the project activity regarding development of the model of professional practice, a program of professional practices was implemented for 120 graduate university students who besides developing and establishing a model of professional practice aimed at evaluating the learning outcomes gained from the study. Evaluation of the learning outcomes was conducted by surveying the views of students and employers related to the assessment of acquired generic and specific competences in the field of bearing structures, transportation engineering, hydrotechnics and geotechnics. Upon completion of the student engagement, students and employers completed a survey through which they sought to examine how the students evaluate the generic and specific competences of the students gained during the previous study and to what extent additional employers' engagement for further training in the mentioned competences would be required. The questionnaires are composed by following the learning outcomes and competences provided by the existing study programs of civil engineering at Croatian universities, while respecting the European Civil Engineering Education and Training (EUCEET) guidelines.

2.3.1 Reseach of generic competences

The questionnaire that led to the study of generic competences was composed of two parts. In the first part, employers assessed the extent to which the students developed these competences. The response scale ranged from 1 to 4, where 1 indicates the statement "*the competences have not been acquired at all*", while 4 indicates the statement "*the competences have been acquired entirely*", with the additional response option "*cannot be evaluated*". In the second part of the questionnaire, they evaluated how much they would have to make additional efforts to develop the same competences in the engineers holding master's degrees. The response scale also ranged from 1 to 4, where 1 denotes the statement "*very little or no*" until 4 indicates the statement "*very much - practically all he/she needed to learn*", with an additional response option "*cannot estimate*". Overview of generic competences is presented in Table 4.

Table 4. Overview of generic competences

	Generic competences
1.	An ability to prepare documentation for realization of construction projects.
2.	Knowledge and skills in gathering relevant data, application of appropriate methodology of data collection and analysis, and critical thinking in solving building problems and designing solutions.
3.	An ability to identify and define problems in construction.
4.	An ability to analyze problems and set goals and at the project preparation stage.
5.	An ability to apply basic knowledge of mathematics, chemistry, physics, geology and ecology in modeling and solving building problems.
6.	An ability of analysis and selection of materials and constructions in the realization of construction projects.
7.	An ability to develop complex analysis of bearing capacity, stability, safety, protection (environment).
8.	An ability to analyze feasibility and cost-effectiveness of construction works.
9.	Knowledge (and the ability of using) new technologies and equipment in designing and carrying out works, forecasting risks and cost analysis.
10.	An ability of risk assessment, environmental impact, safety and sustainability at design phase.
11.	Knowledge of legal regulations and relevant regulations in civil engineering.
12.	An ability to design alternatives.
13.	An ability to run a limited complexity construction project including project team management and site management.
14.	An understanding of professional and ethical responsibility and the ability of ethical judgment and treatment.
15.	An ability to work in the multidisciplinary team.
16.	Communication skills required for good co-operation with various experts, including listening and understanding skills, negotiation, collaboration and expression.
17.	Presentation skills (written and oral).
18.	Readiness for life-long learning and training and autonomy in managing their own knowledge.
19.	Knowledge of foreign language (possibility of business communication with foreign experts).

Employers estimate that four faculties of civil engineering in Croatia have achieved these generic competences to a large extent: *readiness for life-long learning and training* (estimate 3.54 on a scale of 1 to 4), then *knowledge of foreign language* (estimate 3.53 on a scale of 1 up to 4), *an ability to work in the multidisciplinary team* (estimate 3.45 on a scale from 1 to 4) and *an ability to apply basic knowledge of mathematics, chemistry, physics, geology and ecology* (estimate 3.38 on a scale from 1 to 4) (Table 5).

Table 5. Best and worst rated generic competences by employers

best ranked generic competences	worst ranked generic competences
3.54_readiness for lifelong learning and training 3.53_knowledge of foreign language 3.45_an ability to work in multidisciplinary team 3.38_an ability to apply basic knowledge of mathematics, chemistry, geology and ecology	2.22_an ability to run a limited complexity construction project including project team management and site management 2.28_knowledge of legal regultations and relevant regulations in civil engineering 2.34_an ability to analyze feasibility and cost-effectiveness of construction works 2.49_knowledge and the ability of using new technologies and equipment

Employers estimate that students of all faculties of civil engineering in Croatia have least achieved these competences: *an ability to run a limited complexity construction project including project team management and site management* (estimate 2.22 on a scale of 1 to 4), *knowledge of legal regulations and relevant regulations in civil engineering* (estimate 2.28 on a scale of 1 to 4), *an ability to analyze feasibility and cost-effectiveness of construction works* (estimate 2.34 on a scale of 1 to 4) and *knowledge and the ability of using new technologies and equipment* (estimate 2.49 Scale from 1 to 4) (Table 5). A comparison of the employer's assesment of the student's generic competences among the faculties of civil engineering is presented in Figure 2.

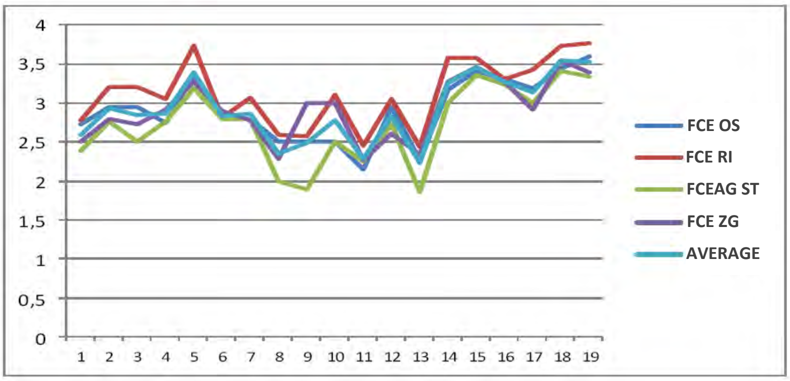

Figure 2. A comparison of the employer's assesment of the student's generic competences among the faculties of civil engineering (where FCE OS is Faculty of Civil Engineering Osijek, FCE RI is Faculty of Civil Engineering Rijeka, FCEAG ST is Faculty of Civil Engineering, Architecture and Geodesy Split amd FCE ZG is Faculty of Civil Engineering Zagreb)

2.3.2 Reseach on specific competences

Questionnaires with which professional competence studies have been conducted have been developed for four groups of specific competences - bearing structures, geotechnical hydrotechnical and transportation engineering (Table 6). As in the questionnaire for employers' views on generic competences, this questionnaire consisted of two parts.

Table 6. Specific competences in the field of bearing structures and transportation engineering

Specific competences_Bearing structures	Specific competences_Transportation engineering
1. An ability to apply knowledge of load types on load-bearing structures. 2. An ability to design a structural model and to evaluate the structure's response to a variety of actions. 3. Analysis of structural stability and its elements and the application of theoretical knowledge on structural stability in the construction of construction solutions. 4. An ability to design concrete and masonry elements and structures. 5. An ability to design steel members and cstructures. 6. An ability to design wooden elements and structures. 7. Selection of the appropriate connectors (joints) of the structural elements. 8. Knowledge of the essential parts and the level of the project of the bearing structure. 9. An ability to carry out construction work, management and implementation of expert supervision. 10. Knowledge and application of techniques and methods of structural testing for checking (proving) of mechanical resistance and stability. 11. Design of earthquake-resistant structures. 12. Design of structures on fire performance. 13. Design a system of structural protection measures.	1. Planning and design of urban road network taking into consideration all transport modes. 2. Development of the conceptual design of the roadway in accordance with geodetic inputs and local engineering practices. 3. Estimation of capacity and traffic safety of road network elements and design of different types of intersections. 4. An ability to choose the appropriate technology for the construction and organization of the construction or reconstruction of roads. 5. Design of different types of intersections in accordance with traffic safety and capacity demands. 6. Design of road subbase elements. 7. Averness of domestic engineering practices in designing roads in urban and non-urban areas. 8. Analysis and selection of adequate pavement structures in accordance with the purpose of the traffic object. 9. Planning and design of the railway infrastructure.

Table 7. Specific competences in the field of geotechnical and hydrotechnical engineering

Specific competences_Geotechnical engineering	Specific competences_Hydrotechnical engineering
1. An ability to analyze and interpret the results of geotechnical laboratory and field tests and to select the calculation models of the geotechnical profile of the soil for a particular geotechnical problem. 2. An ability of applying knowledge from geology and hydrogeology in solving building problems. 3. An ability to calculate the dynamic load and the analysis of stability of shallow and deep foundations in different of soil and rock and the slippage and bearing capacity of soil / rocks below / around the foundation 4. An ability to design and design suitable foundations with respect to the results of geotechnical investigations on the properties of the soil / rocks, the seismic location data and the construction requirements that relies upon them. 5. An ability to design basic geotechnical constructions (shallow and deep foundations, supporting structures, slopes, sloping structures) in accordance with the principles of Eurocode 7. 6. An ability to define the geotechnical problem and necessary investigative work, numerical	1. Implement hydraulic analysis and hydraulic calculations when proposing engineering solutions. 2. Analyzing hydrological and meteorological data, suggesting steps and implementing water resource management and management solutions. 3. Analysis, planning and design of hydro engineering buildings. 4. An ability to analyze surface / underground drainage and / or irrigation needs, propose solutions and predict their impact on the environment. 5. Implementation of sea water quality analysis, surface and groundwater as a consequence of water resources pollution, and proposing measures for protection against pollution. 6. An ability to analyze, program, model and perform hydrogeological backgrounds for the needs of various construction projects. 7. An ability to define the hydrotechnical problem and necessary investigative work, numerical modeling and data analysis, selecting the

modeling and data analysis, selection of appropriate solutions and technologies for its implementation and preparation of the entire project. 7. An bility to design geotechnical solutions in accordance with ecological requirements.	appropriate solution and technology for its implementation and the development of the entire project.

In the first part, employers assessed the extent to which students developed defined competences. The response scale ranged from 1 to 4, where 1 indicates the statement "*the competences have not been acquired at all*", while 4 indicates the statement "*the competences have been acquired entirely*", with the additional response option "*cannot be evaluated*". In the second part of the questionnaire, they evaluated how much more of an additional effort they would have to make to develop the same competences in the engineers holding master's degrees. The response scale also ranged from 1 to 4, where 1 denotes the statement "*very little or no*" until 4 indicates the statement "*very much - practically all he needed to learn*", with an additional response option "*cannot estimate*". It is important to note that due to the relatively small sample, which cannot be considered statistically relevant, it is necessary to analyze them with a certain margin of error. There are also differences in the results for individual faculties not analyzed in this paper.

2.3.2.1 Evaluation of specific competences in the field of bearing structures

A total of 36 surveyed employers indicate *an ability to apply knowledge on load types on load-bearnig structures* (estimate 2.63 on a scale from 1 to 4) and *an ability to design concrete and masonry elements and structures* (estimate 2.59 on a scale from 1 to 4) as specific competences that students of the four faculties of construction in Croatia have realized to the greatest extent in the field of bearing structures (Table 8).

Table 8. Evaluation of specific competences in the field of bearing structures

best ranked specific competences in the field of bearing structures	worst ranked specific competences in the field of bearing structures
2.63_an ability to applay knowledge on load types on load-bearing structures 2.59_an ability to design concrete and masonry elements and structures	2.04_design of structures on fire perfrmance 2.17_design of earthquake-resistant structures 2.19_an ability to carry out construction work, management and implementation of expert supervision

Employers have referred to the *design of structures on fire performance* (estimate 2.04 on a scale of 1 to 4), then the *design of earthquake-resistant structures* (estimate 2.17 on a scale from 1 to 4) and *an ability to carry out construction works, management and implementation of expert supervision* (estimate 2.19 on scale 1 to 4) as the least developed specific competences of students in the field of bearing structures (Table 8).

2.3.2.2. Evaluation of specific competences in the field of transportation engineering

A total of 21 interviewed employers indicate the *design of road subbase elements* (estimation 3.00 on a scale of 1 to 4) as a specific competence, which students of the four faculties of construction in Croatia have realized to the greatest extent in the field of transportation engineering (Table 9).

Table 9. Evaluation of specific competences in the field of transportation engineering

best ranked specific competences in the field of transportation engineering	worst ranked specific competences in the field of transportation engineering
3,00_design of road subbase elements	2.00_planning and design of the railway infrastructure 2.29_design of different types of intersections in accordance with traffic safety and capacity demands

Employers have referred to the *planning and design of the railway transport infrastructure* (estimate 2.00 on a scale from 1 to 4) and *designing different types of intersections in accordance with traffic safety and capacity demands* (estimate 2.29 on a scale of 1 to 4) as the least developed specific competence of the students in the field of transportation engineering (Table 9).

2.3.2.3. Evaluation of specific competences in the field of geotechnical engineering

A total of six surveyed employers mention the *ability to calculate the dynamic load and the analysis of the stability of shallow and deep foundations in different of soil and rock and the slippage and bearing capacity of soil / rocks below / around the foundation* (estimate 3.50 on a scale from 1 to 4) as specific competences that students of the four faculties of civil engineering in Croatia have realized to the greatest extent in the field of geotechnical engineering (Table 10).

Table 10. Evaluation of specific competences in the field of geotechnical engineering

best ranked specific competences in the field of geotechnical engineering	worst ranked specific competences in the field of geotechnical engineering
3.50_an ability to calculate the dynamic load and the analysis of stability of shallow and deep foundations in different of soil and rock and the slippage and bearing capacity of soil / rocks below / around the foundation	2.50_an ability to define the geotechnical problem and necessary investigative work, numerical modeling and data analysis, selection of appropriate solutions and technologies for its implementation and preparation of the entire project 2.50_an ability to design geotechnical solutions in accordance with ecological requirements

Employers have referred to the *ability to define geotechnical problems and required investigative works, numerical modeling and data analysis, selection of appropriate solutions and technologies for its implementation and the preparation of the entire project* (estimate 2.50 on a scale from 1 to 4) and *an ability to design geotechnical solutions in accordance with ecological requirements* (estimate 2.50 on a scale from 1 to 4) as the least developed competence student achieved in the field of geotechnical engineering (Table 10).

2.3.2.4. Evaluation of specific competences in the field of hydrotechnical engineering

A total of 17 employers surveyed stated that they were experts in hydrotechnical engineering, which the students of the four faculties of construction in Croatia realized to the greatest extent: the *ability to analyze, program, model and to perform the hydrogeological backgrounds for the needs of various construction projects* (estimate 3.08 on a scale from 1 to 4*), ability to define the hydrotechnical problem and necessary investigative work, numerical modeling and data analysis, selecting the appropriate solution and technology for its implementation and the development of the entire project* (estimate 3.04 on a scale of 1 to 4) *and hydraulic analysis and hydraulic calculations when proposing engineering solutions* (estimate 3.01 on a scale from 1 to 4) (Table 11).

Table 11. Evaluation of specific competences in the field of hydrotechnical engineering

best ranked specific competences in the field of hydrotechnical engineering	worst ranked specific competences in the field of hydrotechnical engineering
3.08_ability to analyze, program, model and perform hydrogeological backgrounds for the need of various construction projects 3.04_ability to define hydrotechnical problem and necessary investigation work, numerical modeling and data analysis, selecting the appropriate solution and technology for its implementation and the development of the entire project 3.01_impplementation of hydraulic analysis and hydraulic calculations when proposing engineering solutions	2.17_implementation of sea water analysis, surface and groundwater as a consequence of water resources pollution 2.17_proposing measures for protection against pollution

All employers include the *implementation of sea water quality analysis, surface and groundwater as a consequence of water resources pollution, and proposing measures for protection against pollution* (estimate 2.17 on a scale of 1 to 4) as specific competences that the students in the field of hydrotechnical engineering have achieved to a minimum (Table 11).

It is important to note that because of the small number of respondents in the fields of profession and the heterogeneity of the employers' activities, the results of this survey of assessments of the achievement of specific competence of civil engineering students can only be considered as a starting point for further and more detailed research.

3. Results analysis

The overall aim of the research conducted is to determine the extent to which a student is prepared for the labor market, or whether the market recognizes their competence and how much they consider them to be developed. Relevance of the conducted research in the field of generic and specific competences is based on a sample that encompassed all relevant stakeholders - employers, teachers, students, alumni association members. What deserves special attention is the matching of the views of employers and students to the perception of acquired generic and specific competences.

Identification of specific competences that employers recognize as being largely achieved according to their expectations after completion of the studies needed to perform specific tasks within the mentioned projects was carried out in the same way (Table 12). Respondents were offered a list of generic and specific competences through a questionnaire drawn up by the EUCEET-Tuning Task Force working group.

Table 12. Overview of the research of competences and applied methodology

project	duration	overall aim	applied methodology
Improvement of Learning Outcomes at the Faculty of Civil Engineering Mostar	during 2016.	To identify the extent to which the competences, knowledge and skills acquired during the study at the Faculty of Civil Engineering Mostar are in line with the expectations of employers, graduates and current students and teachers in order to obtain guidelines for the improvement of curriculum based on learning outcomes.	- survey of employers, civil engineers, students, teachers and associates of the Faculty of Civil Engineering Mostar - an online survey questionnaire in Kwiksurveys (https://kwiksurveys.com/), combined with a classical survey (paper-pencil). - a list of competences defined by the SOCRATES-ERASMUS Thematic Network Project: European Civil Engineering Education and Training from 2006 and ASCE Competence contained in the Civil Engineering Body of Knowledge for the 21st Century: Preparing the Civil Engineer for the Future.
Learning Outcomes in Higher Education of Civil Engineers	during 2008. and 2009.	Implementation of the concept of learning outcomes into valid study programs and improvement of studies at the Faculty of Civil Engineering Rijeka. Defining the learning outcomes for civil engineering studies (undergraduate, graduate, specialist, professional).	- survey of employers, graduates and teachers of civil engineering faculties in Croatia (three civil engineering faculties in Croatia: Rijeka, Zagreb and Osijek), members of the Alumni Club of the Faculty of Civil Engineering Rijeka and graduates - questionnaire - competences taken from the EUCEET Tuning project and adapted to the research needs
Development and implementation of the Croatian Qualifications Framework in the field of civil engineering studies	during 2015. and 2016.	To align civil engineering studies with new needs and qualification standards to achieve a socially acceptable level of knowledge - new tools, new education models aligned with strategic and development goals and labor market needs.	- questionnaires are composed by following the learning outcomes and competences provided by the existing study programs of civil engineering at Croatian universities, while respecting EUROEAN (Civil Engineering Education and Training)

The results of the research have shown that there is a correlation between the views of surveyed employers regarding the degree of competences acquired. Employers generally agree that students are largely able to apply knowledge in mathematics and other core subjects, apply knowledge in specialized areas of civil engineering, use techniques, skills and tools (including IT) necessary for engineering practice and are ready to participate in life-long learning programs (Table 13).

Table 13. Overview of the research results

project	*most important specific competences for employers*	*least important specific competences for employers*
Improvement of Learning Outcomes at the Faculty of Civil Engineering Mostar	[1] an ability to use techniques, skills and modern engineering tools necessary for engineering practice (including IT) [2] an ability to apply knowledge in a specialized area relating to civil engineering [3] an ability to communicate effectively: written and oral in mother tongue and one foreign language [4] an understanding of the need and rediness to engage in life-long learning [5] an ability to identify, formulate and solve complex engineering problems	[1] an ability to design and conduct experiments, as well as analyse and interpret data [2] an ability to apply knowledge of mathematics and other basic subjects [3] an understanding the technical, environmental, social, political, legal, aestetic, economic and financial aspects of civil eengineering works [4] an ability to identify research needs and necessary resources [5] an ability to design and construct buildings respecting the principles of environmental protection and architecutiral heritage
project	*most developed specific competences for employers*	*least developed specific competences for employers*
Learning Outcomes in Higher Education of Civil Engineers	[1] an ability to apply knowledge of mathematics, science and engineering (applied physics, applied chemistry, geology ecology) [2] an ability to use techniques, skills and modern engineering tools necessary for engineering practice (including IT) [3] an ability to apply knowledge in a specialized areas related to civil engineering [4] an understanding of professional and ethical responsibility of civil engineers [5] an understaning of impact of construction projects in wider social and cultural context, as well on the environment	[1] an ability to function in multi-disciplinaty teams [2] an understanding of the role of the leader and leadership principles and attitudes [3] an understanding of the elements of project and construction management of complex construction projects [4] an ability to identify, define and solve complex engineering problem
	best ranked generic competences	*worst ranked generic competences*
Development and implementation of the Croatian Qualifications Framework in the field of civil engineering studies	[1] readiness for life-long learning and training [2] knowledge of foreign language [3] an ability to work in interdisciplinary team [4] an ability to apply basic knowledge of mathematics, chemistry, geology and ecology	[1] an ability to run a limited complexity construction project including project team management and site management [2] knowledge of legal regulations and relevant regulations in civil engineering [3] an ability to analyze feasibility and cost-effectiveness of construction works [4] knowledge and the ability of using new technologies and equipment

Employers considered that additional efforts during the studies were needed to enable students to work in multidisciplinary groups to understand the role of the manager and the principles of proper management, understand elements of the construction project and the ability to manage complex buildings, and be able to identify, define and solve complex engineering problems. It should be borne in mind that conducting research on employers' concerns was hampered by the lack of appropriate databases. During these surveys it was not possible to identify a complete list of construction companies in which construction engineers are or were employed.

4. Conclusion

An analysis of employer surveys provides an insight into the employers' view of the competences expected of civil engineers. The results of the related research point to what competences are very well developed, which could be improved by introducing new content or methods and those which are unnecessarily developed. Employers in the Republic of Croatia and Bosnia and Herzegovina emphasize above all the necessity of life-long learning and improvement. The emphasis is placed on the need for a greater degree of formalization of knowledge and in connection with this higher application of knowledge in mathematics and other core subjects (applied physics, applied chemistry, geology, ecology), especially in specialized fields of construction, using modern techniques, skills and tools (including IT) and working in a multidisciplinary team. This suggests that defining learning outcomes in the education of civil engineers, faces, on one hand, pressures from the construction sector that require the engineer to have a wider formal basis of knowledge and, on the other hand, an information and communication revolution that basically changes the way a student learns and works later. Employers point out that engineers operate in a realistic environment and that a number of skills that they need cannot be taught in the classroom or the laboratory (by teaching science theory), but in a design studio, which simulates real engineering problems by learning based on Problem Based Learning (PBL) or at least on its hybrid called Project Based Learning. Employers want these views to be used in organizing studies to help students learn how to solve problems, get used to teamwork, and develop leadership skills.

The conducted research provides a good basis for the amendment of the study programs and for the changes in the teaching process by introducing new teaching strategies that can develop certain competences which employers consider to be less developed in existing studies. In particular, this involves the conceptualization of teaching and learning strategies, assessment strategies, the development of practical and transferable skills, especially communication and teamwork. Considering these points of view, one should bear in mind that the period in which engineers are educated in the Bologna process and employ and acquire work experience is still relatively short for a holistic analysis and more fundamental judgment. It is therefore necessary to continue with such research, in which the assessment and comparison of the competences of engineers can be assured by the implementation of competency research in other countries, especially those with a relatively similar business environment.

References

Zakon o Hrvatskom kvalifikacijskom okviru (NN 22/13, 41/16)

Communiqué of the Conference of Ministers responsible for Higher Education in Berlin on 19 September 2003, https://media.ehea.info/file/2003_Berlin/28/4/2003_Berlin_Communique_English_577284.pdf)

Uvod u projekt Usklađivanje obrazovnih struktura u Europi Sveučilišni doprinos Bolonjskom procesu, http://www.unideusto.org/tuningeu/images/stories/documents/General_brochure_Croatian_version_FINAL.pdf)

Deluka-Tibljaš, A., Karleuša, B., Štimac Grandić, I. (2011), “Definiranje ishoda učenja na studijima građevinarstva Sveučilišta u Rijeci”, *GRAĐEVINAR, 63* (1)

Domljan, I., Lovrić, I. (2016), Kompetencije građevinskih inženjera, Građevinski fakultet Sveučilišta u Mostaru

Hrvatski kvalifikacijski okvir – Uvod u kvalifikacije, Vlada Republike Hrvatske Ministarstvo znanosti, obrazovanja i športa (urednik: dr.sc. Mile Dželalija), Zagreb, 2009.

Lončar-Vicković, S.; Dolaček-Alduk, Z. (2009), Ishodi učenja – priručnik za sveučilišne nastavnike, Sveučilište Josipa Jurja Strossmayera u Osijeku

Dolaček-Alduk, Z.; Deluka-Tibljaš, A.; Galić, M.; Varevac, D.; Završki, I. (2016), Zbornik radova Okruglog stola „Vizija inženjrskog obrazovanja“, Osijek, 15. rujna 2016.

Project Management Research Workshop

PROJECT MANAGEMENT RESEARCH WORKSHOP

Potential of BIM and ERP Integration in Contractor Construction Companies

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1. Introduction

The majority of the companies found in the construction industry are small to medium size. Moreover, they are project-oriented with a focus on Project Planning, Project Management, Project Execution and Project Control. Furthermore, construction projects are transient in nature, variable in duration and costs, and require different internal or external resources (Shi, Halpin, 2003). Regardless orientation on the project, construction industry is inefficient in making successful organizational changes and has lack of investment in new technologies (Mêda, Sousa, 2012). To achieve progress in business and keep an important place on the market it is necessary to permit entry of Information Technology (IT). Currently two systems are finding their way into the construction, encompassing informatization of the business processes. Thus Building Information Modeling (BIM) and Enterprise Resource Planning (ERP) have begun to have wide application within construction industry.

BIM is one of the most advanced approaches of the Architectural, Engineering and Construction (AEC) industry today (Eastman, *et al.,* 2011; Kymmell, W., 2008). Implementation of BIM is steadily gaining popularity in construction industry replacing the current designing, structural analysis, scheduling, cost estimation, project management and many other tools. Benefits of BIM implementation are: reducing errors and omissions; improving collaboration within stakeholders during the design and construction phases; reducing rework, construction cost and the overall project duration; increasing cost control, predictability and profit of the company; etc. (Eastman, et al., 2011; Holness, G., 2006; Salleh, H., Phui Fung, W., 2014). In order to facilitate the application of BIM and achieve its benefits, many organizations put large effort to develop BIM standards. Furthermore, the governments of the most developed EU states have been trying to regulate implementation of BIM practices (BIM Levels, 2016; Hore, A.V., *et al*., 2016).

ERP is a concept for enterprise management. This is never-ending process of effective planning and controlling all resources needed, with the main task to integrate all the functions and business processes of the organization. Therefore, ERP concept is not software package but ERP systems are computer applications, which enable efficient resource planning, or ERP (Vuković *et al*., 2007; Rashid *et al*., 2002). As little number of ERP software have been specially developed for construction industry (Ahmed *et al*., 2003), in recent years, the major ERP vendors (e.g. SAP, Oracle) have tried to tailor their standard systems for construction market (Skibniewski, Ghos, 2009). Construction ERP (CERP) systems will enable information sharing which is important because of large number of participants involved in project. Moreover, they will improve transparency of management responsibilities and management efficiency (Shi, Halpin, 2003; Chung *et al.,* 2008).

Thus, in first part of this article previous research on BIM and ERP integration will be shown. In the second part potential of further BIM and ERP integration development will be presented. Focus of integration model deployment will be directed on their usage within contractor construction companies. Therefore, BIM model will represent specific project database while ERP system will represent database of contractor enterprise business.

2. Context of BIM and ERP Integration

As project is minor part of enterprise it is very courageously to expect of ERP systems to integrate all the project information. Furthermore, ERP systems currently do not provide sustainable solutions for construction management. Moreover, development of external application used in construction industry (e.g. scheduling, cost estimating, material takeoff, etc.) indicates growth of BIM concept (Gulliksen, 2012; Mêda, Sousa, 2012; Santos, 2009). The integration of these two concepts would thus enable construction companies to connect the organizational procurement processes with project management.

Čuš-Babič *et al.* (2010; 2014) proposed integration of resource production and construction using BIM. As cost of the new Information System (IS) could be obstacle in information technology (IT) investment, focus of the research was on the interconnection of company's already implemented subsystems through simple BIM (decentralized BIM where BIM model does not represent main repository of building information). In such limited environment, BIM integrates design (CAD tools), manufacturing (ERP system) and construction processes while data exchange with outside stakeholders is not considered. Moreover, in their case, detail design, prefabrication and construction was performed in the same company which was research limitation too (Čuš-Babič *et al.* 2010; Čuš-Babič *et al.* 2014).

Holzer (2016) investigated approaches for linking Product Lifecycle Management (PLM), BIM and ERP systems. Connecting BIM and PLM will enable synchronizing the data between BIM server (database) and PLM system while PLM and ERP integration present connection between product structure and production planning. As research focus was not directed on BIM and ERP integration, risk analysis of project case study revealed that linking between BIM and ERP was not achieved successfully (Holzer, 2016). To conclude, the current problem is how to recognize and exchange the crucial information (authoritative data) that allows organizations to communicate between systems BIM and ERP while the exchange has no bad impact on business processes execution (Santos, 2009; Holzer, 2016).

Ghos *et al.* (2011) study integration/interoperability issues (data exchange platforms; impact of Leadership in Energy and Environmental Design (LEED) required documentation; cost; Sustainable Design guidelines; Building Systems; Environmental Realities) between BIM and ERP systems thru sustainable filter. Through the research, they depicted three levels of challenges: ERP and BIM are currently not integrated; adopted systems and technology platforms are changeable through the time; systems should work in changeable business environment. Moreover, for sustainable IT deployment, they propose the governance involvement in corporate strategic and tactical level. Furthermore, governance is crucial to realize a common gaol which is fixing an organizational business process problem (Ghos *et al*., 2011).

3. Research Problems, Hypothesis and Goals

Although proposed research is in the early phases, initial research problems, hypothesis and goals are listed, but they will surely be changed as research will going on. Due to current literature review identified research problems are:

- Information within BIM and ERP database are interrelated and standard form for their integration still not exist, even though project execution and business processes (e.g. cost estimating, tendering, etc.) highly depend on their synergy.
- Lack of information integration result in communication problems amongst the project stakeholders.
- Site and project managers in contractor construction companies do not have accurate and real-time information about current project performance (planned vs. actual, trends, future plans etc.).
- Project execution control is thus based on the initially estimated data which differs from the on-site gathered information.

Proposed research hypothesis is: Integration of information within BIM and ERP systems will enhance construction project performance which will have positive impact on contractor's company business.

Finally, research goal is to form BIM and ERP database integration model to get timely information about project performance for better contractor's construction project monitoring.

4. Research Methodology

Proposed research methodology is shown on the figure 1 while explanations are given in addition. Detail literature review of BIM approach, construction ERP systems and their integration will contribute identifying literature gaps which will represent a start point in further research. Through the exploratory research, ERP vendors and managers from contractor construction companies will be interviewed to perceive problem of CERP development as well as CERP and BIM integration from different sides. Results of this exploratory research will be a list of possible problems and framed proposal of BIM and ERP integration which will define survey questions. Interest survey group will be different levels of managers in contractor construction companies which use ERP and/or BIM software. Detail analysis of literature review and literature gaps but also results of exploratory research and questionnaire will result with development of initial BIM and ERP integration model. At least, proposed BIM and ERP integration model will be adjusted due to selected project challenges. Verification and possible validation will be done on selected construction projects (case study) with a focus on project execution and monitoring of contractor construction company's business processes.

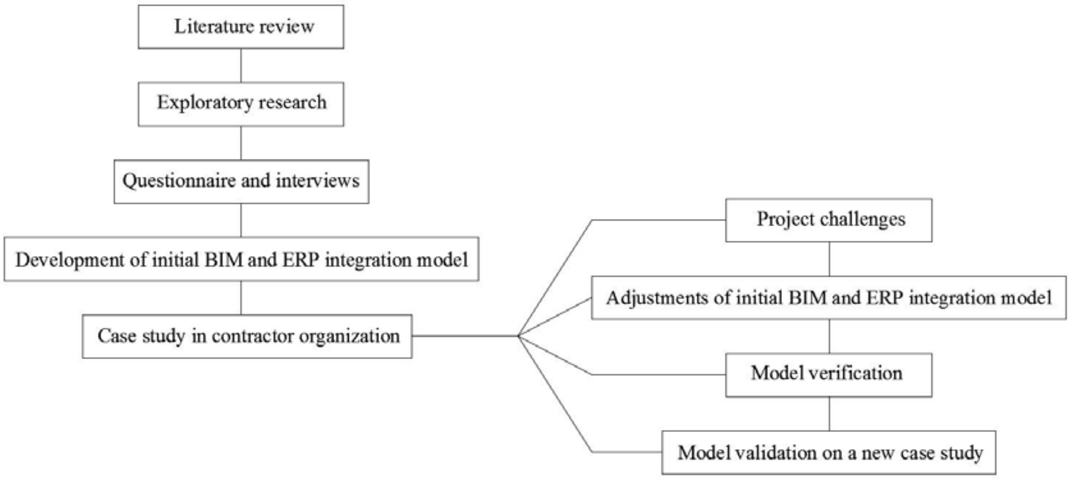

Figure 1. Research Methodology

5. Conclusion

To conclude, although this research is on early stages, answers on three key questions could be obtained and are listed in addition.

- WHAT? –> Impact of BIM and ERP integration on project execution and business process monitoring within contractor construction companies.
- WHY? –> Both systems (BIM and ERP) provide a wealth of information while their integration will have positive impact on project execution and business process monitoring.
  –> BIM represent a future development of construction industry but will also direct the way of future construction ERP software development.
- HOW? –> According to results of literature review, exploratory research, questionnaire, interviews and specific construction project analyses, model of BIM and ERP integration will be proposed. Furthermore, it will be verified and possibly validated on the real project of selected contractor construction company.

References

BIM Levels (2016), https://www.thenbs.com/knowledge/bim-levels-explained (accessed 25 June 2016).

Chung, B. Y., Skibniewski, M. J., Lucas, H. C., Kwak, Y. H., (2008). "Analyzing enterprise resource planning system implementation success factors in the engineering-construction industry", J. Comput. Civ. Eng., vol. 22, no. 6, pp. 373-382, Nov./Dec.

Čuš-Babič, N., Podbreznik, P., Rebolj, D. (2010). Integrating resource production and construction using BIM. Automation in Construction, 19(5), 539-543.

Čuš-Babič, N., Rebolj, D., Nekrep-Perc, M., Podbreznik, P. (2014). Supply-chain transparency within industrialized construction projects. Computers in Industry, 65(2), 345-353.

Eastman, C., Teicholz, P., Sacks, R., Liston, K. (2011). BIM Handbook: a guide to Building Information Modeling for owners, managers, designers, engineers, and contractors, Second edition, Wiley, Canada

Ghosh, S., Negahban, S., Kwak, Y. H., Skibniewski, M. J. (2011, June). Impact of sustainability on integration and interoperability between BIM and ERP-A governance framework. In Technology Management Conference (ITMC), 2011 IEEE International (pp. 187-193). IEEE.

Gulliksen, T. (2012). Interoperability between ERP System and Project Planning System. MS thesis. Institutt for bygg, anlegg og transport

Holness, G. (2006). Future Direction of the Design and Construction Industry: Building Information Modelling, ASHARAE Journal, 48 (8), pp. 38-46

Holzer, D. (2014, July). Fostering the link from PLM to ERP via BIM. In IFIP International Conference on Product Lifecycle Management (pp. 75-82). Springer, Berlin, Heidelberg.

Hore, A.V., Scott, L., Wes, R., Tibaut, A. (2016). Benefits of inter-institutional collaboration in the delivery of BIM education in Ireland: Reflections of an Irish masters program. // Proceedings of the Academic Interoperability Coalition: 10th BIM Academic Symposium, Orlando, Florida, pp.152-164

Kymmell, W. (2008). Building Information Modeling: Planning and managing construction projects with 4D CAD and simulations, McGraw-Hill

Mêda, P., Sousa, H. (2012). Towards Software Integration in the Construction Industry - ERP and ICIS Case Study, Proceedings of the CIB W78 2012: 29th International Conference –Beirut, Lebanon, 17-19 October

Rashid, M.A., Hossain, L., Patrick, J.D. (2002). The evolution of ERP Systems: A historical perspective in Enterprise Resource Planning: Global Opportunities and Challenges, Idea Group Publishing, pp. 1-16

Salleh, H., Phui Fung, W. (2014). Building Information Modeling application: focus-group discussion // Građevinar 66 (8), pp. 705-714

Santos, E.T. (2009). "BIM and ERP: finding similarities on two distinct concepts." 5th CIB W102 Conference: Deconstructing Babel: Sharing Global Construction Knowledge, Rio de Janeiro. 2009.

Shi, J.J., Halpin, D.W. (2003). Enterprise resource planning for construction business management, Journal of Construction Engineering and Management 129 (2), 214–221.

Vuković, A., Džambas, I., Blažević, D. (2007). "Development of ERP Concept and ERP System.", Engineering Review 27.2: 37-45.

PROJECT MANAGEMENT RESEARCH WORKSHOP

Ex-post Impact Evaluation Tool for Public Private Partnership Projects

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1. Introduction

Public Private Partnership (PPP) model of procurement is a way to deliver public infrastructure using private funding and managing risk for public purposes. Currently, PPPs have been criticized in the media, social media, and the academia. Their criticism can be divided in two levels: (i) problems in the performance of PPP (Heald, 2003), and (ii) a complete opposition to the development of PPPs, based on the argument that they do not achieve public welfare better than traditional procurement (Hall, 2015).

The problem to be addressed by this research is the lack of a method to assess the impact of the delivery and the outcome of an infrastructure PPP project on stakeholders. The existing approaches i.e. (European PPP expertise center, 2011; Langbein & Felbinger, 2006; Liu, Love, Davis, Smith, & Regan, 2014; Owen & Alkin, 2007) do not consider the complexity of having multiple stakeholders' perspectives as it is on a PPP project. Therefore, the aim of the research is to design an ex-post impact evaluation tool that can assess PPP projects from multiple perspectives to (i) improve future PPP developments employing clear lessons learnt from past project.

To address the research problem a design science approach is adopted (Hevner et al., 2004) with four main stages: (i) tool development stage, (ii) prototype stage, (iii) testing stage and (iv) validation stage. The research is currently in the development stage, in which the conceptual framework called "Project Success Evaluation Pyramid Model (PSEPM)" has been designed and presented to experts in Australia and Chile for validation.

The article focuses on the tool development stage; it describes the main components of the PSEPM based on the project management and program evaluation concepts.

2. Project Success Evaluation Pyramid Model (PSEPM)

Project success concept has been used to inform the tool development. Even though there is not yet an agreement in the literature about the definition of project success, many authors agree that "meeting of stakeholders' expectation" is central to any assessment of project success (Davis, 2013, 2016; de Wit, 1988; Koops et al., 2015). With this starting point, the PSEPM model is essentially a procedure that identifies a big spectrum of success criteria from each of the involved stakeholders and then employs a set of principles to assess the validity of all those criteria. The outcome of the framework is the process for reaching a judgment of project success, rather than the measurement of project success itself.

The PSEPM (Figure 3) analyses success using three components: (1) success criteria, (2) Stakeholders judgment, and (3) Stakeholder judgment principles. Each component/level of the pyramid informs and supports the next level in order to achieve a theoretical judgment of Project Success. The model illustrates that a set of success criteria (SC) informs a single stakeholder success judgment (SSJ); then, the combination of all the stakeholders success judgments are tested against a single "stakeholder judgment principle" (SJP); finally, all the stakeholder judgment principles inform a judgment of Project Success (PS).

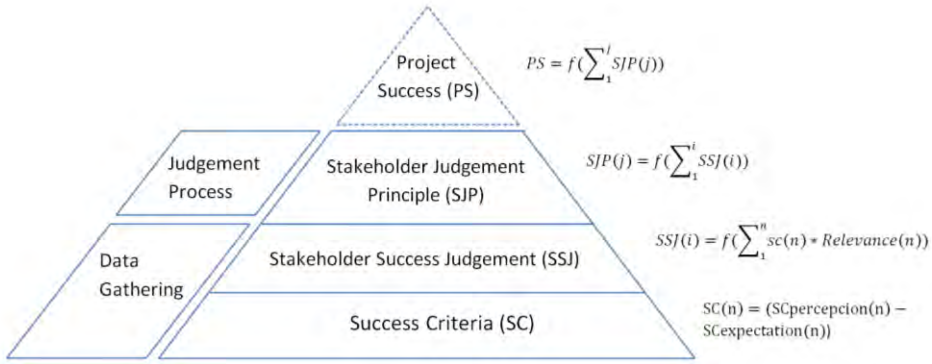

Figure 1. Project Success Evaluation Pyramid Model (Author's)

2.1. Success Criteria (SC)

The bottom of the pyramid represents all the existing success criteria that can be employed to measure project success, including time, cost, quality, safety, profit, environmental sustainability, etc. a specific subset of this pool of SC is what stakeholders use to inform a success judgment.

2.2. Stakeholder Success Judgment (SSJ)

Existing literature suggest that success depends on each stakeholder (Baccarini, 1999; Bourne & Walker, 2005; Davis, 2013; Müller & Jugdev, 2006; Shenhar, Dvir, Levy, & Maltz, 2001; Turner, 2009; Westerveld, 2003), which means that every stakeholder has a different judgment of success. However, it needs to be clarified (i) what are stakeholders' expectations and how can they be measured? and (ii) How to ensure the validity of the expectations?

Based on Xiong, Yuan, Li, and Skibniewski (2015), a gap in expectation can be expressed as the difference between what stakeholder expect and what they perceive in a specific success criteria. Every gap in expectation must be expressed in terms of quantitative and qualitative information to understand the gap, and assess its relevance and validity. A "j" gap in expectations is defined as follows:

$$GAP_j = (Stakeholder\ perception_j - Stakeholder\ expectation_j) \qquad (1)$$

A constraint must be considered to limit the expectations of the stakeholders. The addition of all the expectations should make the project feasible. For example, if a hospital is expected to have the newest technology, but it is also expected to be within a maximum budget that makes it the technology impossible to buy, then the project is not "feasible". Consequently, project success will never be reached even theoretically speaking. The overall purpose of the project (i.e. business case, contract, or approved scope) is the sources for validating the expectations. This constraint is expressed in the following equation for ‘n’ stakeholder with ‘j’ expectations:

$$\sum_{1}^{n}\sum_{1}^{j} Stakeholder\ expectation_{nj} \leq Feasible\ Project \qquad (2)$$

2.3. Stakeholder Judgment Principles (SJP)

Assuming that project success is a state of the project, it is necessary to unify the different stakeholder success judgments. For doing so, the concept of “stakeholder judgment principles” is proposed. Three principles are being developed to guide the judgment of success from a “high level of abstraction”.

- Willingness to repeat the project: Are the stakeholder willing to repeat the same project and receive the same outcomes assuming that they have opportunity to choose from the same original options? This willingness to repeat the project supports the assumption that the stakeholder can accept the gaps in expectations, when they are compared with the benefits they received.
- Fairness between Stakeholders: Are the stakeholder able to accept an exchange of roles with any of the other stakeholders (including exchanging impacts)? This requirement provides a minimum of “fairness” in which an excessive and evident negative outcome cannot be accepted.
- Best option: In the case that the project does not want to be repeated and is not considered fair; do the stakeholders think that the project is still the best option from the original alternatives that were available at the conceptualization of the project (including “do nothing” option)? Not having a better alternative is a strong argument for judging a project as successful.

Three limitations need to be considered for the principles: (i) they are guidelines to inform a judgment and not formulas, so they do not fit perfectly in every case; (ii) they are generic and should be adapted for each project and stakeholder; and (iii) it is also possible to add other principles (with a similar level of abstraction) for specific cases.

2.4. PSEPM Outcome

The outcome for determining the impact of the PPP on stakeholders is a judgment employing the selected stakeholder judgment principles (SJP); which are based on the set of gaps that were previously gathered and assessed. This outcome provides the details of the impacts for each stakeholder connected to an overall view of the project.

Specifically for PPP projects, it is important to take into account the fact that there is a difference between (i) the impact of the project on a stakeholder, and (ii) the impact of the procurement strategy (PPP) on that same stakeholder. This separation is relevant for avoiding the problem of assigning a negative or positive impact as a result of the PPP, whereas in reality it can be an impact that would have occurred with any kind of procurement method.

3. Conclusion

To address the complexity of multiple relevant perspectives inside a PPP, the project success concept is employed as a starting point for developing the Project Success Evaluation Pyramid Model (PSEPM).

The final aim of the research is to design (based on the PSEPM) an ex-post impact evaluation tool that can assess PPP projects by systematically gathering the multiple perspectives that the different stakeholders have, and then generate a validation process that leads into a judgment about the PPP.

This approach is new and different from existing evaluation methods, which generally include only the criteria that concerns the evaluation team without addressing, in a systematic way, all the existing multiple perspectives.

This article describes the general conceptual approach without going in-depth into the theory and reasoning that support each component of the model.

4. References

Baccarini, D. (1999), "The Logical Framework Method for Defining Project Success", Project Management Journal, 30(4), 25.

Bourne, L., & Walker, D. H. T. (2005), "Visualising and mapping stakeholder influence", Management Decision, 43(5), 649-660, doi:10.1108/00251740510597680

Davis, K. (2013), "Different stakeholder groups and their perceptions of project success", International Journal of Project Management, 32(2), 189-201. doi:http://dx.doi.org/10.1016/j.ijproman.2013.02.006

Davis, K. (2016), "A method to measure success dimensions relating to individual stakeholder groups", International Journal of Project Management, 34(3), 480-493, doi:http://dx.doi.org/10.1016/j.ijproman.2015.12.009

de Wit, A. (1988), "Measurement of project success", International Journal of Project Management, 6(3), 164-170, doi:http://dx.doi.org/10.1016/0263-7863(88)90043-9

European PPP expertise center. (2011), "Guide to guidance: how to prepare procure and deliver PPP projects", European investment bank.

Hall, D. (2015), "Why Public-Private Partnerships don't work", Retrieved from University of Greenwich, UK.

Heald, D. (2003)," Value for money tests and accounting treatment in PFI schemes". Accounting, Auditing & Accountability Journal, 16(3), 342-371.

Hevner, A. R., March, S. T., Park, J., & Ram, S. (2004), "Design science in information systems research", MIS Quarterly, 28(1), 75-105.

Koops, L., Coman, L., Bosch-Rekveldt, M., Hertogh, M., & Bakker, H. (2015), "Public Perspectives on Project Success – Influenced by National Culture?", Procedia - Social and Behavioral Sciences, 194, 115-124, doi:http://dx.doi.org/10.1016/j.sbspro.2015.06.126

Langbein, L. I., & Felbinger, C. L. (2006). Public program evaluation. [electronic resource] : a statistical guide", Armonk, N.Y. : M.E. Sharpe, c2006.

Liu, J., Love, P. E. D., Davis, P. R., Smith, J., & Regan, M. (2014), "Conceptual framework for the performance measurement of public-private partnerships", Journal of Infrastructure Systems.

Müller, R. A., & Jugdev, K. A. (2006), "A retrospective look at our evolving understanding of project success", IEEE Engineering Management Review, 110.

Owen, J. M., & Alkin, M. C. (2007), "Program evaluation: forms and approaches", New York : Guilford Press, c2007. 3rd ed.

Shenhar, A. J., Dvir, D., Levy, O., & Maltz, A. C. (2001), "Project Success: A Multidimensional Strategic Concept", Long Range Planning, 34(6), 699-725, doi:http://dx.doi.org/10.1016/S0024-6301(01)00097-8

Turner, J. R. (2009), "The handbook of project-based management. [electronic resource]", leading strategic change in organizations: New York : McGraw-Hill, [2009], 3rd ed.

Westerveld, E. (2003), “The Project Excellence Model®: linking success criteria and critical success factors”, International Journal of Project Management, 21(6), 411-418, doi:http://dx.doi.org/10.1016/S0263-7863(02)00112-6

Xiong, W., Yuan, J.-F., Li, Q., & Skibniewski, M. J. (2015), “Performance objective-based dynamic adjustment model to balance the stakeholders’ satisfaction in PPP projects”, Journal of Civil Engineering & Management, 21(5), 539-547, doi:10.3846/13923730.2014.895409

PROJECT MANAGEMENT RESEARCH WORKSHOP

Impact of Project Complexity on Rewarding Project Teams for Construction Projects Execution

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1. Introduction

The success of project oriented organizations depends on the individual success of their projects, both from a financial and a reputational point of view. Financial success, especially for construction projects, depends significantly on the members of the team implementing the project as well as on the existence of the system of their rewarding. In the case of construction projects, this is related mostly to the existence of financial rewards and incentives. A review of the literature will analyze the researches in the area of rewarding, the method of measuring execution efficacy in the construction industry and the elements of the project that influence its complexity. It will be established whether there are models of rewarding in construction that include the impact of the project complexity besides the results of performance measurement. Based on a review of the literature and research objectives, research hypotheses will be set and we will clarify the methodology which will attempt to reach the model for rewarding members of project teams for execution of construction projects.

The research result will be a model for rewarding project teams, which will take into consideration both the complexity of the project, and the way the project team manages the project and the results of performance measurement. Such a model will be used for equitable rewarding of project teams for project execution, regardless of the characteristics of projects entrusted to them for execution.

2. Literature review

1.1 Reward systems and performance management

Rewards may be defined as financial and non-financial benefits that are awarded in accordance with individual or team achievements (*Armstrong, 1993*). Kerr (*1985*) defined reward systems as mechanisms that shape the behavior of an individual through the strategy of the entire organization. Jacobsen and Thorsvik (*2002*) suggest that the reward system should consist of three elements shaped in the best possible way.

Figure 1:Overview of reward system (*Jacobsen & Thorsvik, 2002*)

When an organization makes a decision to reward then it approaches to determining the characteristics of the reward system. Based on the literature review, it was established that an organization should decide who will be rewarded, what will be rewarded, in which manner, to what extent, when and how often (*Beel, 2007*).

It is important to note that during the review of the literature, it was found that in the reward systems, the characteristics and special features of the project are not taken into consideration, except that the turning points and the completion of the project are represented as potential moments in time for rewarding teams (*Beel, 2007*). Based on the analyzed researches we are able to claim that the results of project teams for execution of a project depend greatly on the application of the reward system. Therefore, we may conclude that there is a strong interrelation between the reward system, the results of performance measurement and the success of the whole organization (Figure 2).

Figure2: Interrelation between reward systems and performance management (source:performancemagazine.org)

Literature related to performance measurement is quite comprehensive. Performance measurement in construction primarily focuses on time, cost and quality (*Love and Holt, 2000*; *Kagioglou et al., 2001*). The cases of the use of best-known models for measuring performance results in project management are also described in the literature for construction: Kagioglou et al. (*2001*) described the revised Balanced Scorecard for Construction; Watson and Seng (*2001*), and Beatham et al. (*2002*) showed that EFQM can be implemented in construction; Beatham et al. (*2003*) also identified and critically evaluated the use of KPIs in construction.

Based on the review of literature, Shaban (*2008*) made the KPI presence in models for monitoring construction projects (Figure 3).

Key Performance Indicators	Okuwoga (1998)	Dissanayaka And Kumaraswamy (1999)	Reichelt and Lyneis (1999)	Karim and Marosszeky (1999)	Brown and Adams (2000)	DETR (2000)	Lehtonen (2001)	Chan (2001)	Samson and Lema (2002)	Kuprenas (2003)	Cheung (2004)	Navon (2005)	Iyer et al (2005)	Love et al (2005)	Ugwu and Haupt (2007)	Hovichit (2007)	Added Factors
Cost	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓
Time	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓
Quality			✓			✓			✓	✓	✓	✓	✓		✓	✓	
Productivity		✓	✓						✓			✓	✓	✓	✓	✓	
Client satisfaction						✓			✓		✓		✓				
Regular and community satisfaction									✓				✓				✓
People									✓				✓			✓	✓
Safety and health			✓		✓	✓			✓		✓				✓		✓
Innovation and learning									✓				✓				
Environment											✓		✓		✓		

Figure 3: Summary of the main groups affecting the performance of construction projects (KPIs groups) and their references (*source; Shaban 2008*)

When conducting research and defining the model, key performance indicators will be used as one of the elements that affect the rewarding of project team members.

Based on the covered literature we can conclude that there is no model for rewarding project teams for execution of construction works that takes into account the complexity of the construction project being executed besides measuring the performance of project teams, in an adequate manner.

1.2 Project complexity

The project complexity consists of many different interconnected parts and may be operationalized in terms of differentiation and interdependence. The use of the term 'complexity' in construction is not thoroughly examined; however, it has been established that the process of construction by itself can be considered as a complex system (*Wood, Gidado 2008*).

In their study “Playing with complexity” Hertogh and Westerveld (2009) defined six elements of complexity: technical, social, financial, legal, organizational and time complexity.

When determining the impact of the complexity of the project on rewarding and creating a reward model, we will use a quantitative analysis of the impact of these elements on the complexity of the construction project.

3. Objectives and hypotheses

The subject matter of this paper is to determine the equitable model of rewarding members of project teams for executing construction projects, which will include the impact of performance measurement results, complexity of the project and of the mode of project management execution. In order to develop a reward model, the following hypotheses will be set:

- **H0**: It is possible to form an equitable system of rewarding members of project teams for executing of construction projects, which will include the results of execution efficacy measurement, the impact of the complexity of the project being executed and the way the project team manages it.

- **H1**: Existing reward systems for project team members for construction work rely only on the results of measuring execution efficacy without taking into consideration the impact of project complexity on the final results of project teams.
- **H2**: Complexity of construction projects has a major impact on the results of the measurement of the efficacy of project teams for their performance.

The aim of the paper is to examine in detail whether there is a defined reward model that adequately incorporates the impact of complexity of construction projects and analyze the concept of project complexity. The survey will determine what the concept of complexity represents for project managers and members of project teams. When integrating complexity into the reward model, qualitative analysis of the elements of project complexity will be used. The main and supporting scientific hypotheses will be confirmed based on the literature review and the results of the data obtained through the survey.

4. Methodology

The research will begin with a detailed review of literature related to rewarding, performance measurement and complexity of projects in construction projects. Based on a review of the literature, a survey questionnaire will be developed for project managers and project team members for construction projects. In the third step, the reward model will be defined. The impact of the results of measuring the performance indicators on the overall efficacy of the project teams for the execution of construction works and the extent of influence of the elements of project complexity on the overall complexity of the project being executed and, accordingly, on the model of rewarding members of project teams for project execution will be determined based on the review of the results of previous research and on the basis of the results of the survey of the questionnaire results through surveys to be carried out among the project team members for the management of construction projects. Besides the mentioned results of performance measurement with performance indicators and impact of the degree of complexity of the construction project being executed, the model of rewarding members of project teams to execute construction projects will also include an element that will depend on how the teams apply knowledge and techniques when executing the project.

5. Expected Contributions

The basic expected contribution of this paper is the formation of an equitable model for rewarding members of project teams for executing construction projects on the basis of literature analysis and the results of the survey conducted in construction organizations. The application of this reward model will enable further progress in increasing the efficacy of project teams and entire organizations for executing construction projects.

6. Literature

Armstrong, M. (1993). Managing Reward Systems .Open University Press, Buckingham, p2.

Beel, J. (2007), Project team rewards – Rewarding and Motivating your Project Team, CreateSpace LLC, Part of the Amazon.com group of companies 100 Enterprise Way, Suite A200, Scotts Valley, CA 95066, USA

Beatham et al (2003) The Cultural Web in Business Improvement - An Industrial Case Study. In:, 2nd International Conference on Innovation Developments in Architecture, Engineering and Construction, Loughborough, England, pp 749-760.

Hertogh, M. and Westerveld, E. (2009), Playing with Complexity – Management and organization of large infrastructure projects, unpublished thesis

Jacobsen, D-I., Thorsvik, J. (2002) Hur moderna organisationer fungerar, Lund, Studentlitteratur

Kagioglou et al (2001) Performance Management in Construction: a conceptual framework, Construction Management and Economics, Vol. 19, pp 85-95.

Kerr, J., (1985), "The need to motivate", Academy of Management Journal

Love, P. E. D. and Holt, G. D. (2000). Construction business performance measurement: The SPM alternative. Business Process Management Journal, Vol. 6, pp 408–416.

Shaban, S. (2009), Factors Affecting the Performance of Construction Projects in the Gaza strip, unpublished thesis

Watson, P. and Seng, L.T. (2001) Implementing the European Foundation for Quality Management Model in construction. Construction Information Quarterly, Construction paper 130.

Wood, H., Gidado, K. (2008) Project complexity in construction. COBRA 2008, pp 1–13.

PROJECT MANAGEMENT RESEARCH WORKSHOP

Alone or in Pairs: Agile Approach Improves Organizational Project Management Competences

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1. Introduction

This paper explores the parallel influence of organizational project management maturity and agile approach. The research was conducted in Serbia, among 128 project portfolio managers. A cross-sequential approach was taken to examine differences among traditional and agile oriented organizations according to maturity aspects. Maturity assessment included three scenarios: pesimistic, most likely and optimistic. This article argues that agile approach partially improve maturity, while the other side of organizational project management maturity component's improvement have higher maturity score through hybrid approach (agile and traditional combined).

As project management field developed side by side with the information technology field (Marchewka, 2012), maturity models and agile approaches have followed a similar trend. The general attitude in the last decade indicates that project management approach is slowly shifts from the standard project performance parameters (such as time, resources and expenses) to the excellence measurement, quality perception and value delivered. Much of muchness with maturity models, which is characterized by an appropriate maturity path, agile processes and practices are beginning to establish agile path draft in order to improve efficiency (Dingsoyr et al., 2012).

Agile methods and maturity model compatibility is often criticized by the practitioners and scientific community. Existing agile maturity models don't comply with the practical implementation, since it doesn't include lifecycle management (Schweigert, 2013). Maturity models suggest the appropriate path for reaching desired maturity, ignoring the fact that agile teams already following the defined processes and practices (Fontana et al., 2015b). Mapping the key agile and maturity practices arises as the core research problem (Farid et al., 2016). On the other hand, there is not enough well-defined relation between agile, traditional and hybrid approaches with specific maturity model aspects (Turner, 2002). The paper presents the integration of organizational project management maturity considerations and challenges in agile methodologies. The main assumption is: *Agile approach has positive impact on organizational project management maturity.*

2. Agile aspects in maturity development

Agile approach and maturity model integration include a higher project success rate (Soares & Meira, 2015), crowning achievement in desirable maturity level (Kahkonen & Abrahamsson, 2004), organizational ambidexterity (Fontana et al., 2015a), the stability and sustainability of the delivered solutions (Olague et al., 2006), system usability (Garrido et al., 2009), new product development (Wieder et al., 2009), improvements in organizational decision-making and knowledge management process (McKenzie, 2011).

Previous studies have shown that the integration of agile methods in the maturity framework is not widely accepted by experts in the software development field. Parsons et al. (2014) emphasize the organizational maturity as a key component in the application and accepting the agile methods and approach, pointing out that it may sometimes be a painful process for the organization. Challenges arising in transition from traditional to agile methodologies are: fundamental assumption, desired organizational form, quality control, management style, knowledge management and communication (Nerur et al., 2005). Usually, it is justified that agile methods are adaptive rather than predictive (Mishra & Mishra, 2011). Furthermore, agile teams require professional support in all maturity phases, to undoubtedly define and transfer “user stories” and precisely define the product’s requirements (Gregorio, 2012).

3. Research methodology

Measurement instrument. This study uses Organizational Competence Baseline (OCB) assessment components used and validated by IPMA (2013), including five project management components, with subcomponents, that were examined: Project, programme and portfolio (PPP) governance, PPP management, PPP organisational alignment, PPP people’s competences, PPP resources. 5-point scale used for data collection contained the following answers for each maturity level: "1 - initial", "2 - repeatable", "3 - defined", "4 - managed", "5 - optimizing". Cronbach's alpha coefficient for OCB scale is 0.89, indicating a high degree of internal consistency.

Sample. Survey was conducted in the period from March to September 2016. Participants were 128 project portfolio managers in 128 companies in Serbia, involved in project management software development and implementations in their companies. The sample was composed of 82.8% profit oriented companies and 17.2% public companies.

Procedure. Data analysis was prepared with SPSS 20.0 software. Man Whitney test was used for group comparison to determine differences between agile and traditional approach in accordance with organizational project management maturity aspects. Organizations are categorized according to seven groups of factors, with traditional and agile approach characteristics: 1) fundamental assumptions (predictable and adaptive system); 2) development model (life-cycle and evolutionary-delivery); 3) desired organizational form/structure (mechanistic and organic); 4) communication aspect (formal and informal); 5) management style (command and control and leadership and collaboration); 6) knowledge management (explicit and tacit); 7) quality control (strict control and continuous control). The research findings are described by mean and standard deviation, obtaining the observed effect according to p-value ($p \leq 0.05$).

4. Research results and conclusion

The results showed a statistically significant difference between adaptive and predictive control system in all aspects of measuring organizational project management maturity. Adaptive systems improve organizational maturity and thus indicate that agile systems in terms of fundamental standpoint illustrate better results. The results showed a statistically significant difference between life-cycle and evolutionary-delivery model in all aspects of measuring organizational project management maturity. Evolutionary-delivery model improve organizational maturity and thus indicate that agile systems in terms of development model verify better results.

The results showed a statistically significant difference between mechanistic and organic organizational form only in the maturity aspect - PP&P resources. Agile approach supplies maturity improvements only in the mentioned area. Hybrid approach (mixed agile and traditional) contributes almost completely in maturity improvements in the other areas. The results showed a statistically significant difference between formal and informal communication in the following aspects of organizational project management maturity: PP&P management and PP&P people's competences. Agile approach contributes partially in maturity improvements in the mentioned areas. On the other hand, hybrid approach (mixed agile and traditional) improve strategy, organizational alignment and PP&P resources maturity aspects.

The results showed a statistically significant difference between autocratic and collaborative approach in the following aspects of organizational project management maturity: project, portfolio and program (PPP) management, PP&P resources and PP&P people's competences. Agile approach contributes partially in maturity improvements in the mentioned areas. On the other hand, hybrid approach improves strategy and organizational alignment maturity. The results showed a statistically significant difference between explicit and tacit knowledge management in the following aspects of organizational project management maturity: strategy, organisational alignment, PP&P resources and PP&P people's competences. Agile approach contributes almost completely in maturity improvements in the mentioned areas. On the other hand, hybrid approach improves PP&P management maturity.

The results showed a statistically significant difference between strict and continuous quality control in the following aspects of organizational project management maturity: PP&P resources and PP&P people's competences. Agile approach contributes partially in maturity improvements in the mentioned areas. On the other hand, hybrid approach improves strategy, PP&P management and organizational alignment maturity aspects.

This study confirms some of the previous results from authors worldwide but also provides new information for the project management maturity models implementation. The significance of this research is supported by the fact that an increasing number of companies are using information technologies to facilitate the participants in the project. Also, there has been an increased requirement for IT projects in Serbia, where companies tend to structure and systematize approaches in the IT project implementation. This type of study was for the first time carried out in the Republic of Serbia. Also, this study may provide a basis for modeling and creating different patterns and guides that may have a positive influence on the organizational maturity and agile approach in different industries.

5. Literature

Dingsøyr, T., Nerur, S., Balijepally, V., & Moe, N. B. (2012). A decade of agile methodologies: Towards explaining agile software development. *Journal of Systems and Software*, *85*(6), 1213–1221.

Farid, A. B., ABB Elghany, A. S., & Helmy, Y. M. (2016). Implementing Project Management Category Process Areas of CMMI Version 1.3 Using Scrum Practices, and Assets. *International Journal of Advanced Computer Science and Applications*, *7*(2), 243–252.

Fontana, R. M., Meyer, V., Reinehr, S., & Malucelli, A. (2015a). Management Ambidexterity: A Clue for Maturing in Agile Software Development. In *Agile Processes, In Software Engineering, and Extreme Programming, XP 2015* (pp. 199–204). Springer.

Fontana, R. M., Meyer, V., Reinehr, S., & Malucelli, A. (2015b). Progressive Outcomes: A framework for maturing in agile software development. *Journal of Systems and Software*, *102*, 88–108.

Garrido, A., Rossi, G., & Distante, D. (2009). Systematic improvement of web applications design. *Journal of Web Engineering*, *8*(4), 371–404.

Gregorio, D. D. (2012). How the Business Analyst Supports and Encourages Collaboration on Agile Projects. In *EEE International Systems Conference (SYSCON)* (pp. 24–27). IEEE,

International Project Management Association. (2013). IPMA OCB - IPMA Organisational Competence Baseline - The standard for moving organisations forward. International Project Management Association.

Kahkonen, T., & Abrahamsson, P. (2004). Achieving CMMI level 2 with enhanced extreme programming approach. In *Product Focused Software Process Improvement* (pp. 378–392). Springer.

Marchewka, J. T. (2012). *Information technology project management - Providing Measurable Organizational Value* (4th ed.). John Wiley & Sons, Inc.

McKenzie, J., van Winkelen, C., & Grewal, S. (2011). Developing organisational decision-making capability: a knowledge manager's guide. *Journal of Knowledge Management*, *15*(3), 403–421.

Mishra, D., & Mishra, A. (2011). Complex software project development: agile methods adoption. *Journal of Software Maintenance and Evolution: Research and Practice*, *23*(8), 549–564.

Nerur, S., Mahapatra, R., & Mangalaraj, G. (2005). Challenges of migrating to agile methodologies. *Communications of the ACM*, *48*(5), 72–78.

Olague, H. M., Etzkorn, L. H., Li, W., & Cox, G. (2006). Assessing design instability in iterative (agile) object-oriented projects. *Journal of Software Maintenance and Evolution: Research and Practice*, *18*(4), 237–266.

Parsons, D., Susnjak, T., & Lange, M. (2014). Influences on regression testing strategies in agile software development environments. *Software Quality Journal*, *22*(4), 717–739.

Schweigert, T., Vohwinkel, D., Korsaa, M., Nevalainen, R., & Biro, M. (2014). Agile maturity model: analysing agile maturity characteristics from the SPICE perspective. *Journal of Software: Evolution and Process*, *26*(5), 513–520.

Soares, F. S. F., & Meira, S. R. D. (2015). An Agile Strategy for Implementing CMMI Project Management Practices in Software Organizations. In *Proceedings of the 2015 10th Iberian Conference on Information Systems And Technologies (CISTI 2015)*. IEEE.

Turner, R. (2002). Agile Development: Good Process or Bad Attitude? (pp. 134–144). Springer, Berlin, Heidelberg.

Wieder, C., Le Dain, M. A., & Blanco, E. (2009). Proposition of a Maturity Grid to Assess NPD Agility. In *Iced 09 - The 17th International Conference on Engineering Design, Vol 3: Design Organization and Management* (pp. 85–96). Design Society.

PROJECT MANAGEMENT RESEARCH WORKSHOP

Project Management For an Agro-food Cooperative

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Abstract:

The agro-business sector's environment is becoming more and more volatile and unpredictable, resulting in rapid changes for the agro-food system and presenting a challenge in terms of competitiveness. This situation requires more simultaneous projects and new forms of organization. As a result, the objective of this study is to understand the Project Management (PM) competences that the organization being researched needs to develop, and identify the initiatives which are focused on the context and the people. In order to do this, a qualitative study was designed and an agro-food cooperative in the Region of Murcia, Spain, was studied. The results highlight the importance of governance and demonstrate that social learning will play a significant role in the process.

Keywords: *project management; competences; agro-food cooperative*

1. Introduction

The agricultural sector is moving towards an era of rapid changes in the market, whilst technological, social and environmental circumstances are frequently developing at an unprecedented rate (Hall, 2007). This represents a challenge for the agro-food system which needs a sustainable model with an innovative focus on infrastructure, the organization, production, distribution and the product offering (Galanakis, 2016). In the face of these challenges, more innovative and flexible organization methods are required (Pettigrew, 2003), in which projects become strategically more important (Jamieson and Morris, 2004), and which incorporate a focus that extends beyond technical aspects. In this respect, the purpose of the study is to explore which competences are needed to introduce a project culture in an agro-food organization and which are the main strategic initiatives that add value to the sector taking into account the context and people.

2. Methodology

In order to achieve the study's purpose, based on a review of key literature, semi-structured interviews were designed based on key questions raised by the OCB (IPMA, 2016). This was implemented in July 2015 in "Camposeven", a Transformational Agricultural Society which produces ecological fruit and vegetables in the region of Murcia (Spain). 12 interviews were carried out, including with the governing board and board of directors, and information supplied by 10 of the members interviewed from a previous project was also used (Rethink Project: http://www.rethink-net.eu).

A qualitative methodology was adopted and MAXQDA software (version 12) was used to manage the data (http://www.maxqda.com). Using a deductive coding system based on the literature, a cyclical strategy was implemented to analyze the contents by coding the data (Saldaña, 2015); this resulted in the main dimensions and categories which are presented below.

3. Findings and discussion

In order to guide project management, the results indicate that governance and leadership will be vitally important, and it will be necessary to manage people's competences. As well as the mandatory technical aspects required to tackle the challenges being faced, the data also reveals that strategic initiatives should be integrated which support social and environmental value, and processes which facilitate social learning.

1.1 Governance

The analysis of the data highlights that the main elements that define governance include: 1) Definition of values and code of ethics; as well as giving people direction and putting limits on the behavior considered to be ethical, values should lay the foundations for the organization's decisions as it strives towards achieving its vision (Sidhu, 2003). Definition of mission, vision and strategy, involving key personnel and subsequently communicating this to all employees (IPMA, 2016). 3) Establish development objectives and key development indicators in order to reach the goals that were established, given that what can't be measured can't be controlled (Kaplan and Norton, 1992). 4) Leadership. With the aim of focusing a group's efforts on a common objective, this involves defining and clearly communicating the goals and expectations at all levels (PMI, 2013; IPMA, 2016). In this regard, the data analyzed highlights communication as its main characteristic.

The OCB (IPMA, 2016) explains that it is necessary for these elements to be aligned with the specific objectives for projects established by the organization.

1.2 Strategic initiatives with technical value

The elements which are specifically highlighted in this aspect are: 1) Innovation and technology. As well as innovation being essential for organizations' survival (Schumpeter, 2013), in the case of agro-food, their performance depends, to a great extent, on the effective application of existing technologies (Dennis, Aguilera and Satin, 2013) which improve productivity (Da Silva and Baker, 2013). 2) Quality, which should be a strategic decision, based on a Quality Control System (ISO, 2015) and under the focus on "Total Quality Management" (Gareis, 2005).

1.3 Strategic initiatives with social and environmental value

In order to meet the increasing demand for food, guaranteeing safety and respecting the environment, the data analysis highlights: 1) Actions for sustainable agriculture. As the intensification and extensification of agriculture is one of the culprits of the current global environmental problems (Matson and Vitousek, 2006). 2) University-company links. The data shows that this type of relationship is fundamental for strengthening technological advances related to ecological agriculture; as stated by Kanchiswamy et al. (2015), it is necessary to develop new sustainable strategies for protecting and improving crops that do not rely on genetic modification or harmful chemical substances.

1.4 Actions that generate social learning

Given that a focus that prioritizes people requires processes which facilitate social learning, incorporating their own values and knowledge with the expert knowledge of project planners and managers (Cazorla, De Los Ríos and Salvo, 2013); in the study, the actions which create a suitable environment for this relate to the exchange of information and experiences, as well as mutual assistance.

1.5 PM characteristics

The data analyzed indicates that within the organization, projects are confused with operations and with any type of initiative that the organization carries out with the best intentions of achieving the desired objectives. To avoid this situation, the literature suggests that a basic task is to distinguish between projects and those activities, and define different project categories (IPMA, 2016). Organizations which want to be successful in project management should meet certain standards and practices (Golini, Kalchschmidt and Landoni, 2015); although in order to integrate a project culture they must first define objectives for developing organizational competences in project management and managing their people's individual competences.

1.6 Management of people's competences

The results suggest that, in the study, people's competences are not managed, although their development is promoted in a spontaneous manner, according to the needs which arise. However, as projects are carried out by people, the OCB (IPMA, 2016) proposes different stages which should be taken into account. Furthermore, in order to be successful with projects, organized Human Resource Management is required (Huemann, 2010) which is aligned to the context and organizational strategy (Ulrich, 2013).

1.7 Organizational alignment

As the organization being studied does not yet manage itself through projects, there is no evidence of data on organizational alignment, which is the optimal competence proposed by the OCB (IPMA, 2016) for linking project culture with the organization's key elements. Before executing processes which relate to alignment, senior management should identify the current level of their competences and reflect on the level they want to reach; according to the business' needs and the competitive environment in which it operates.

4. Conclusions

In a changing and highly competitive context, and in light of the challenges facing the agro-food sector in terms of maintaining equilibrium between business strategies and protecting the environment, a project focus has become an innovative way for organizations to adapt and find new solutions. Given that in this new context the mere technical criteria are insufficient for leading organizations, it is necessary to incorporate strategic initiatives which add value, both socially and environmentally. However, to integrate a project culture and achieve its sustained success, related competences should be developed, at an individual and organizational level. This involves a process in which social learning will play a significant role, as it will be necessary to work in teams, exchange information and experiences, learning by doing and mutually assisting each other; which will lead to joint learning.

References

Cazorla, A., De Los Ríos, I. and Salvo, M. (2013), “Working With People (WWP) in rural development projects: A proposal from social learning”, Cuadernos de Desarrollo Rural, Vol. 10 No. 70, pp. 131–157.

Dennis, C., Aguilera, J. M. and Satin, M. (2013), “Tecnologías que dan forma al futuro”, in FAO (ed.), Agroindustrias para el desarrollo, FAO, Roma, IT, pp. 103–147.

Galanakis, C. M. (2016), “Challenges and Opportunities”, in Author (ed.), Innovation Strategies in the Food Industry: Tools for Implementation, Elsevier, pp. 293–304.

Gareis, R. (2005), *Happy Projects!* Manz, Vienna, AU.

Golini, R., Kalchschmidt, M. and Landoni, P. (2015), “Adoption of project management practices: The impact on international development projects of non-governmental organizations”, International Journal of Project Management, Vol. 33 No. 3, pp. 650–663.

Hall, A. (2007), Challenges to Strengthening Agricultural Innovation Systems: Where Do We Go From Here? UNU-MERIT (Working Paper Series), Maastricht, NL.

Huemann, M. (2010), “Considering Human Resource Management when developing a project-oriented company: Case study of a telecommunication company”, International Journal of Project Management. Vol. 28 No. 4, pp. 361–369.

IPMA (2016), Organisational Competence Baseline for Developing Competence in Managing by Projects –OCB, 1st edn., International Project Management Association, Amsterdam, NL.

ISO (2015), Sistemas de gestión de la calidad — Requisitos, ISO 9001:2015 (traducción oficial). ISO, Ginebra, CH.

Jamieson, A. and Morris, P. W. G. (2004), “Moving from corporate strategy to project strategy”, in Pinto, J. K. and Morris, P. (eds), The Wiley guide to managing projects. John Wiley & Sons, Hoboken, NJ, pp.177–205.

Kanchiswamy, C. N., Malnoy, M. and Maffei, M. E. (2015), “Chemical diversity of microbial volatiles and their potential for plant growth and productivity”, Frontiers in plant science, Vol. 6 No. 151, pp. 1–23.

Kaplan, R. S. and Norton, D. P. (1992), “The Balanced Scorecard: Measures that Drive Performance”, Harvard Business Review, Vol. 1, pp. 71–79.

Matson, P. A. and Vitousek, P. M. (2006), “Agricultural Intensification: Will Land Spared from Farming be Land Spared for Nature?”, Conservation Biology, Vol. 20 No. 3, pp. 709–710.

Pettigrew, A. M. (2003), “Innovative forms of organizing: progress, performance, and process”, in Pettigrew, A. M., Whittington, R., Melin, L., Sanchez-Runde, C., van den Bosch, F. A. J., Ruigrok, W., and Numagami, T. (eds), Innovative forms of Organizing: international perspectives, SAGE Publications Ltd, London, UK pp. 331–351.

PMI (2013), A Guide to the Project Management Body of Knowledge –PMBOK® Guide, 5th edn, Project Management Institute, Pennsylvania, USA.

Saldaña, J. (2015), The Coding Manual for Qualitative Researchers, SAGE Publications, Thousand Oaks, CA.

Schumpeter, J. A. (2013), Capitalism, socialism, and democracy. (Original work published 1943), Routledge.

Sidhu, J. (2003), “Mission statements: Is it time to shelve them?”, European Management Journal, Vol. 21 No. 4, pp. 439–446.

Da Silva, C. A. and Baker, D. (2013), “Introducción”, in FAO (ed.), Agroindustrias para el desarrollo, FAO, Roma, IT, pp. 1–10.

Ulrich, D. (2013), Human Resource Champions: The New Agenda for Adding Value and Delivering Results, Harvard Business School Press, Boston, MA.

PROJECT MANAGEMENT RESEARCH WORKSHOP

The Impact of Project Management on the Achievement of Quality at Construction Business Systems

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1. Introduction

The paper will present the basic motives, objectives, purpose of the research carried out for the needs of the PhD dissertation. Then the hypotheses and methodology of the conducted research will be presented.

Quality is considered important for modern organizations because it increases competitiveness and productivity, reduces costs and ensures a long-term cooperation with the customers (Dolaček-Alduk *et al.*, 2009). One of the researches does not indicate that risk, safety and quality are direct problems, but they are indirectly created by the organization of time and resources involved in the implementation of the project (Hoonakker, 2006)

According to Ogwueleki (Ogwueleka, 2013) project management can be improved through a process of quality management and so through proper project management the realization of the quality of the project can be improved.

2. The motives, objectives and purpose

After the analysis of the literature, there was no concrete knowledge of whether and how the quality of the project management process influences the quality of the products for the individual phases of the project or for the whole project.

Without the support of the top management, project management will not be adopted. Project management for them, does not represent almost anything or very little, as a result, there are shortcomings in projects. Research shows that small and medium-sized companies make up 99.8% of all companies in the EU, generate 56% of GDP and employ 70% of private ownership. But also the results have shown that in small and micro companies there is no tendency to use known tools and techniques for project management (Turner et al., 2010).

During the literature review were found many studies that were dealing with factor influence of Quality Management (quality factors), but we could not have found any study about explicit quality factors of project management process (Hoonakker, 2006) (Ogwueleka, 2013) (Joaquin et al., 2008) (Husin et al., 2008) (Kanagi, 2008) (Hoonakker et al., 2003) (Loushine et al., 2002) (Chan et al., 2000) (Quazij et al., 1998). Project management in this research is observed like a process, and at the end of each phase the project delivers products (i.e. product quality factors). In the Ogwueleka research (Ogwueleka, 2013), 27 factors ranking was done, which was also taken into account when analyzing and selecting the quality factors of the process (project management process) for PhD research.

The developing countries, and if they are more open to business, their attractive potential is not nearly as close to competitors in the industrialized world. The only way these countries can increase competitiveness, trade activity and develop a sustainable foundation is to improve the quality of their products and services that will affect the competitive price of the same (Mytelka *et al.,* 2004).

The main objectives of the PhD research is to use data from realized theoretical and practical research to show that:

• the quality of the project management process raises the overall quality of products,
• defining a factor that will clearly show the impact of the quality of the project management process in construction companies on the achievement of product quality i.e. project delivers products,
• define a set of key quality factors for project management processes and explore their relationship with product quality, and that will enable better control and improvement of them.

The secondary objectives are:

• identify the quality factors of the project management process that have the greatest impact on product quality factors by the different perspectives on the implementation of the project i.e. different project participants,
• different project participants differently perceive the importance of quality factors during the phases of the project,
• define the level of use of certain factors in the quality of the project management process in individual phases of the project.

3. The hypothesis and methodology

The research methodology was the following: analysis and synthesis of the literature overview, making and sending of the questionnaire, analysis of the results of the completed survey, discussion and conclusion creation, which was the first step of the research, followed by a factor analysis in order to group the factors of quality of the project management process that is used as an input during the modeling process. The next step was analysis of the results obtained from the interviews related to the " quality" of products for each phase of the project, which were also used as input data for the process of modeling. Afterwards, all the measuring variables were defined in order to be "recorded" through interviews during real projects and a hypothetical - zero model was created after that. The basic hypothesis to be used in research is:

The achievement of the quality of the delivered product is positively influenced by the increase in the quality of the project management process.

The subject, at the same time, the problem of the PhD research, refers to the study of key factors of the quality project management process and the factors of the products quality and that will be recognized and analyzed. Through direct analysis (case study capture) of projects and using statistical methods, there will be links between them.

4. Structure of the research

Figure 1 is a schematic representation and a sequence of steps in the development of this research. Also shown are the statistical methods used, as well as some objectives.

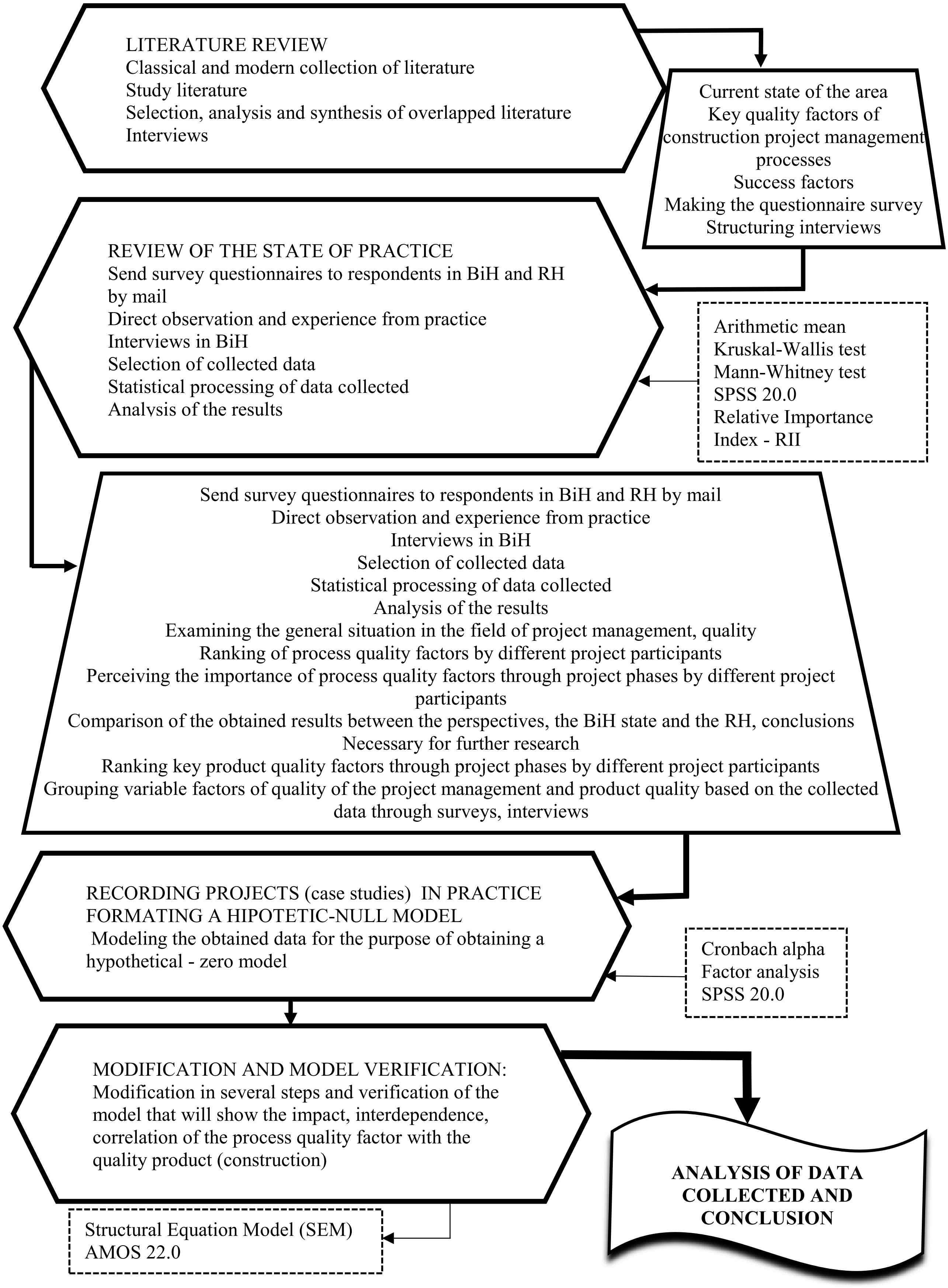

Figure 1. Steps in the preparation of PhD dissertation

5. Limitation of the research

Confidentiality of respondents sought to ensure, although the availability and readiness of the respondents was a great challenge. A relatively small number of samples (case study) is a limit to the formation of SEM model (Structural Equation Modeling).

Although the size of the sample is relatively small (for SEM), the quality of the response is considered highly reliable for analysis due to the relevant experience of the respondents, personal interactions (face to face) and clear understanding of the questionnaire (Xiong *et al.,* 2015).

In Bosnia and Herzegovina, there is no legal framework that the project manager must have certain knowledge, competencies or certificate in the field of project management, there are only coordinators of project. So research could not be realized only with project managers, as individuals involved in all project phases.

6. Guidelines for further research

Measures should be developed and improved to measure the quality factors of the project management process and product, or the delivery of a particular phase in the field.

In order to be able to measure the quality factor of the quality of the project management process, it is necessary to apply one of the competence models (emphasizing the importance of competencies), because the competences of the person providing data on measures for quality factors are important.

References

Xiong, B., Skitmore, M., Xia, B. (2015), A critical review of structural equation modeling applications in construction research, Automation in Construction, pp 59–70, 2015.

Chan, A.P.C., Tam, C.M. (2000), "Factors affecting the quality of building projects in Hong Kong", International Journal of Quality and Reliability Management, vol. 17, no. 4/5, pp. 423-441.

Dolaček-Alduk, Z., Mikulić, D., Radujković, M. (2009), "Quality cost management model for construction projects", Građevinar 61, 2, pp. 147-159.

Hoonakker, P.L.T. (2006), "Quality management in Construction Industry", Proceedings of ASQ World Conference on Quality and Improvement, Milwaukee, WI, USA, pp. 1 -9.

Hoonakker, P.L.T., Loushine, T., Kallman, J., Carayon, P., Kapp, A., Smith, M.J. (2003), "Accidents, Injuries, Worker's compensation, Safety and Safety Policy in Construction Industry: The effort/results paradox", Proceedings of the International Ergonomics Association (IEA) Conference, Seoul, Korea

Husin, N.H., Adnan, H., Jusoff, K. (2013), "Management of Safety for Quality Construction", Journal of Sustainable Development, pp. 41- 47.

Joaquin, D., Hernandez, D., Aspinwall, E. (2008), "A framework for building quality into construction projects- Part I, Total Quality Management", vol. 19, no. 10, pp. 1013-1028

Kanagi, K. (2008), "Critical factors of quality management used in research questionnaires: a review of literature", Sunway Academic Journal, 5, pp. 19-30.

Mytelka, L.K., Barclay, L.A., (2004), "Using foreign investment strategically for innovation", The European Journal of Development Research, pp 531-560.

Ogwueleka, A. C. (2013), "A Review of Safety and Quality Issues in the Construction Industry", Journal of Construction Engineering and Project Management, Korea, pp. 42-48.

PROJECT MANAGEMENT RESEARCH WORKSHOP

Early Warning System in Managing Construction Projects

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Summary of my doctoral dissertation

We live in a world of projects, so it is not surprising that project management has become a profession in center of present and future interest of many different economy branches, among which is civil engineering. Public projects, such as water projects, are especially complex, due to the fact that public good, satisfaction of society needs, environmental protection and contribution to politics (such as local, national, European or global) are ahead of traditional „iron triangle" project management model. Public projects' contexts go far more beyond strict measures of time, cost and quality, revealing an area of insufficiently explored criteria and factors that those projects have to fulfil or obtain in order to achieve success.

Because of particular significance and complexity of those projects, there is a continuous aspiration to improve existing tools, techniques and methods of their management. Solutions that will allow more quick and competent decision-making, higher quality of monitoring and control and increase chances for project management success as well as project success are needed.

These goals are fulfilled in the research by combining two areas of knowledge and scientific thoughts: those of project success and project management success, and those of early warning systems. Early warning systems are tools based on detection, validation and answer on early warning signs or signals. As such, they are known and widely used in crisis management, military, economy, medicine and catastrophe avoidance. Despite that, there have not been many studies on field of project management which explore their use on projects. But, most authors agree that early warning sings do exist on projects, and that a large number of traditional project management tools incorporate them, but not in the direct manner. This is especially evident in water sector, where early warning systems exist on the basis of regular operational activities in governing water resources (such as water temperature monitoring, flood warning, drought warning, water quality monitoring, pipe leak prevention, protection of water and sea from ecological catastrophes, etc.). None of these systems deals with management of construction projects within the field.

Therefore, research niche is evident, but has also been validated through comprehensive literature review on the field of project success, project management success, project success criteria, project success factors as well as early warning signs and early warning systems. Through the literature review, it is stated that early warning signs in terms of project management can be seen as project success factors. Project success factors are elements which, if present on project, can enhance project success. On the other hand, if they are present in small amount or not present on projects at all, they can be an accurate warning that project success may be in danger. What is the exact amount important for preservation and enhancement of project success, depends on the type of construction projects. Therefore, an universal methodology for early warning systems' creation is made, and is based on indicators of construction projects success. The methodology consists of seven steps:

1. Definition of success factors relevant for specific group of construction projects
2. Evaluation of measure in which factors were present on unsuccessful, successful and averagely successful projects within field
3. Detection of success factors which explain project success on best manner
4. Detection of set of variables which explain the most important factors in previous step
5. Creation of module for early warning detection
6. Creation of module of early warning validation
7. Creation of module of early response

Presented methodology is made on the basis of construction projects success and construction projects management success, as stated earlier. In application of the methodology, it is important to note that factors to be researched can be specific for the type of projects in research focus, as well as their specific importance in terms of influence on the final project outcome. In order to explore those areas, a specific field of water projects was taken into consideration. By the means of expert group, a creation of list of potential critical success factors on water projects was made. Those factors were then evaluated on 93 water projects, third of which were perceived unsuccessful, third successful, and one third averagely successful. In this part of the study, other relevant information on project success, project management success, project tools, methods and techniques in use, as well as knowledge on early warning systems was collected. By the use of statistical methods (descriptive and inferential) results were given, and belonging conclusions were drawn. The most important conclusions from this part of the study were:

• Todays' methods and tools of managing water projects are not on the level which satisfies needs of water sector, due to which many problems in project management arise (such as schedule and budget exceeding, not fulfilment of stakeholder needs, failure to achieve satisfactory level of project communication, etc.)

• In the Republic of Croatia there is no early warning system applicable on managing all water projects.

• There is no research finding regarding relationship between water projects' success and water project management success in the Republic of Croatia.

• Five most critical project success factors on water projects are:

  • Project manager coordinates the work of project participants successfully.
  • Construction site is being managed effectively.
  • There is a political support to the project on state level.
  • Communication between project participants is effective.
  • Relationship between client/investor and other project participants are of a high-quality.

These five critical factors can be explained through those factors that affect them the most, based on the results of regression analysis. In that sense, a set of 27 different success factors was made. Those factors were the basis in creation of detection module of early warning system, and their „statistical importance“(explained through B coefficients) were basis for validation of the strength of the early warning signals. Early response was then made through three dimensions:

• Management of risks, constraints and changes
• Strengthening of missing competence of project manager (technical, behavioral and contextual)
• Tools, methods and techniques for effective project management.

After creation, early warning system was tested on three water projects. Based on information project managers provided, it was stated that it is possible to increase project management success by the creation and implementation of early warning system in managing projects.

Main scientific contribution of the research is creation of findings which contribute to todays' knowledge on early warning systems in managing construction projects. Based on these findings it is possible to create an early warning system for project management, based on real significance of project success indicators, which was tested on water projects in the Republic of Croatia.

This is first such management tool in water projects management in Croatia. Further, this is one of meager example of early warning systems in project management, in which early warning signs are not only indirectly analyzed inside project context. Early warning system, made and tested through this research, combines not only early warning signs and project success factors, but also three important dimensions of project management activities: risks, constraints and changes management; technical, behavioral and contextual competences; and project management tools, techniques and methods. Besides, theoretical systematization of up to date research on the relevant fields is made.

Future research should be based on this research cognition with an aim of creation of comprehensive platform for development and integration of early warning in construction management.

Aim of the research

Main aim of the research is to contribute to development of methodology for creation of early warning system, which will be based on indicators of construction project success, whose use will improve momentary praxes in project management, increase quality of project monitoring and control, and increase chances for project success and project management success.

Research hypothesis

Main hypothesis: It is possible to increase success in managing water projects by creation and implementation of early warning system.

Sub-hypotheses 1: Todays method and tools of managing water projects are not on a level which satisfies needs of water sector, which fore many problems in managing those projects occur, and are concerned with non-fulfilment of planned deadlines and budget, non-fulfilment of stakeholder needs, not achievement of satisfactory level of project communication, etc.

Sub-hypotheses 2: There is no early warning system applicable on managing all kinds of water projects in the Republic of Croatia.

Sub-hypotheses 3: There is no research knowledge on mutual relationship between project success and project management success in water sector in the Republic of Croatia.

PROJECT MANAGEMENT RESEARCH WORKSHOP

Modelling the Productivity of Construction Machinery by Using RFID technology

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1. Introduction

Assessment of actual productivity on a construction site is a complex task which requires continuous and careful monitoring of the overall construction contents and, in particular, construction machinery. With accurate assessment of actual productivity it is possible to predict the necessary time, and expenses of construction, therefore, a successful realization of the construction project is achieved. Current estimates of the actual productivity lack an appropriate, reliable, trustworthy, fast, and economical methodology.

Wireless information and communication technologies represent an area with wide possibilities and potential for application with the purpose of measuring, assessing, planning, monitoring and control of productivity of construction machinery. Characteristics of wireless information and communication technologies is their mobility, usage of all kinds of information, and their continuous and rapidly growing development. Although they provide considerable potential, application of wireless technologies with the purpose of measuring, assessing, planning, monitoring and control of productivity of construction machinery is insufficiently researched. Also, previous studies are indicative of the shortcomings and limitations.

Radio Frequency Identification Technology (RFID) is an example of wireless information and communication technology that uses radio frequency waves to identify and track objects. The basic components of the RFID technology are the RFID tag, RFID reader, and a computer. RFID tags, according to their mode of power supply, can be active or passive, and are set on the object that needs to be monitored. Active RFID tags have their own power supply, most frequently via battery, and their range of transmission of radio waves and communication with the RFID reader, can be up to several hundred meters. Passive RFID tags do not have their own power supply, so they receive the power to operate from the RFID reader. The range of transmission of radio waves of passive RFID tags and communication with the RFID reader, occurs within a few meters. Active RFID tags are more costly in relation to the passive RFID tags, they also have a significantly greater memory capacity, and better usability in an environment with obstructive factors such as electromagnetic noise, metal, humidity. RFID readers are used for receiving and processing data from RFID tags, and forwarding data to a computer with the help of communication technology between devices such as, local area network-Ethernet, wireless network-Wi-Fi, via an USB.

1.1 An overview of the former research in literature

By reviewing the literature in the research of the application of RFID technology, the authors Lu *et. al.* (2011) highlighted the great potential of RFID technology and its insufficient application in construction industry. The authors Montaser and Moselhi, (2012 and 2013) who presented a methodology for assessing the actual productivity of construction machinery, particularly stand out.

2. Defining key concepts and problems in the research

2.1 Assessment of the actual productivity of tipper trucks

Montaser and Moselhi (2012) have proposed a methodology for the assessment of the actual productivity of tipper trucks during the execution of works, through the use of RFID technology. The purpose of their methodology is early detection of discrepancies between the planned and actual work execution, so that appropriate corrective measures could be carried out in a timely manner (Montaser and Moselhi, 2012). Their research was conducted by measuring the duration of cycle times of tipper trucks by using a passive RFID tag placed on a tipper truck, and two RFID readers. One RFID reader was set at the loading area, while the other was set at the dumping area. An estimate of the productivity of construction machinery can be achieved through the calculation of the cycle time, either deterministically or by performing simulations.

The authors Alshibani and Moselhi (2016) have pointed out that, although the RFID technology with the use of passive RFID tags has a low cost price, its disadvantage is reflected in the fact that it cannot determine what causes unacceptable work performance during the driving time of the full tipper trucks to the dumping area, and during the return time of the empty tipper trucks to the loading area, since the RFID readers can't communicate with RFID tags during that period. The authors Ibrahim and Moselhi (2014) object that the information regarding whether a tipper truck bed is overloaded or is insufficiently filled, cannot be obtained through applied methodology. Also, they point out that its application is impractical for the execution of long linear buildings and roadways.

2.2 Assessment of actual productivity for the scraper-pusher fleet combination

Montaser and Moselhi (2013) have also proposed a methodology for the assessment of the actual productivity of scraper and pusher dozer through the use of RFID technology. A scraper-pusher fleet combination during excavation, reduces scraper tires wearing, speeds up the time of excavation and, thus, increases the productivity during execution of construction works. Through time recording of pusher activities and scraper bowl status, scraper cycle time was measured. When monitoring the work of the scrapers and pushers, a passive RFID tag was used along with the RFID reader and a switch limit which registered when the scraper bowl was open, or closed. The passive RFID tag was placed on the rear side of the scraper while a RFID reader was placed on the front of the pusher.

The authors of Montaser and Moselhi (2013) suggest the use of a weight sensor to confirm whether a scraper bowl is overloaded or filled insufficiently, and a digital camera to track machine performance more accurately, in order to improve the methodology of RFID technology use. They also suggest the integration of RFID technology, Global Positioning

System (GPS), and Geographic Information System (GIS) to obtain more information during work performance and overview of the entire process of machine performance.

3. Research proposal

Proposal of the research is, on the basis of continuous reviewing of literature, conducting interviews with the participants in accordance with their respective roles and importance, and by defining the crucial insights and hypothesis of RFID technology application, the development of the base model that will be able to track the key construction mechanization during the work execution. First, RFID technology would be used to track the performance of standard construction machinery with cyclic mode of operation, and after that, the possibilities of adapting the model to other construction machinery should be explored. By computer processing with required accuracy, of the data from the construction sites, the actual productivity of construction machinery would be obtained.

By exploring the base model on the examples of various projects, the base model would evolve, be augmented, improved, and verified. Through application and improvement of the base model in different projects, data would be collected and analysed, thus enabling the possibility for the development of the proposal of methodology to support the measurement, assessment, planning, monitoring, and control of construction machinery.

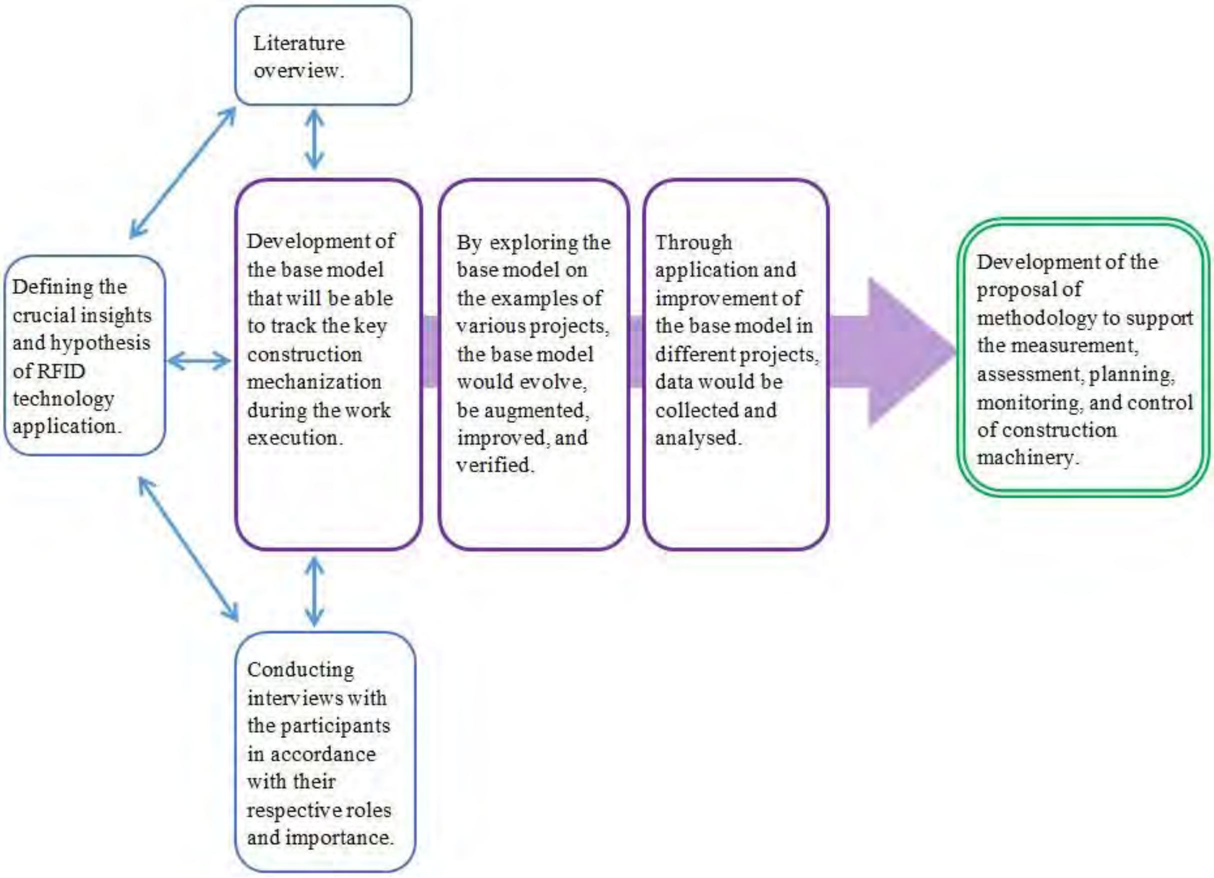

Figure 1. Research proposal

The focus of the research is the use of RFID technology for the development of an appropriate, applicable, customizable, accurate, reliable, fast and cost-effective methodology, which will allow an assessment of the actual productivity of the construction machinery, necessary for the prediction of the required time and cost of construction.

The development of exemplary methodology for the assessment of the actual productivity of construction machinery is of crucial importance for effective management of construction projects. An assessment of actual productivity, necessary for the prediction of the required time and costs, enables the right decision-making and corrective measures in a timely manner. Also, the basis for planning and management of the activities of future similar projects would be created, leading to a more accurate assessment of the duration of the activities, the necessary costs and resources, risk, appropriate decision-making, and the expected dynamics of realization.

Furthermore, the successful management of construction projects requires appropriate computer support such as Building Information Modelling (BIM) tools. BIM represents a modern and promising method of modeling in the construction industry. Its use is envisaged from the very start of planning a future building, design, construction and execution, or, finally, managing the overall life span of the building project. One of the technological advantages of the BIM is the compatibility with different information systems. Therefore, it would be desirable to explore the possibilities of merging the methodology for the assessment of actual productivity through RFID technology with BIM tools. By merging organizational and technological approaches, along with the cooperation of all the participants who use specific tools, the fulfillment of all of project objectives is facilitated, and an increase of the quality of management and execution of construction projects is ensured.

Literature

Alshibani, A. and Moselhi, O. (2016), "Productivity based method for forecasting cost & time of earthmoving operations using sampling GPS data", Journal of Information Technology in Construction (ITcon), Vol. 21 No. 3, pp. 39-56.

Ibrahim, M. and Moselhi, O. (2014), "Automated productivity assessment of earthmoving operations", Journal of Information Technology in Construction (ITcon), Vol. 19 No. 9, pp. 169-184.

Lu, W., Huang, G. Q. and Li, H. (2011), "Scenarios for applying RFID technology in construction project management", Automation in Construction, Vol. 20 No. 2, pp. 101-106.

Montaser, A. and Moselhi, O. (2012), "RFID+ for tracking earthmoving operations", proceedings of Construction Research Congress 2012: Construction Challenges in a Flat World, American Society of Civil Engineers, Reston, VA, pp. 1011-1020.

Montaser, A., Bakry, I., Alshibani, A. and Moselhi, O. (2012), "Estimating productivity of earthmoving operations using spatial technologies", proceedings of Canadian Society for Civil Engineering Annual Conference (CSCE 2011), Canadian Journal of Civil Engineering, Vol.39 No. 9, pp. 1072-1082.

Montaser, A. and Moselhi, O. (2013), „Tracking Scraper-Pusher Fleet Operations Using Wireless Technologies“, proceedings of Canadian Society for Civil Engineering Annual Conference (CSCE 2013), 4th Specialty Conference (Construction), conference paper.

Montaser, A. and Moselhi, O. (2014), "Truck+ for earthmoving operations", Journal of Information Technology in Construction (ITcon), Vol. 19 No. 25, pp. 412-433.

PROJECT MANAGEMENT RESEARCH WORKSHOP

Stakeholder Management in Large Construction Projects

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1. Introduction

Stakeholder management (SM) has received great interest as a research topic, which can be seen in literature review papers on this subject (Littau et al., 2010, Mok et al., 2015, Yang et al., 2011a). Stakeholders are important because lately in addition to the “hard” project success criteria, time, quality and cost, “soft” dimensions of project success are put in focus (Turner and Zolin, 2012). Soft success criteria are related to perceived success from stakeholders point of view (Burcar Dunovic et all, 2015) and according to (Bal et al., 2013, Olander and Landin, 2005) stakeholder are vital to successful completion because their unwillingness to continuously support the vision or objectives of the project leads many projects to fail. Although this specific topic receives a great attention, projects and their managers are still struggling with ambiguous expectations of various stakeholders. This is due to the fact that in construction industry stakeholder management is still in its infancy (Rowlinson et al., 2010) or it could be said that it is under-researched and still has huge research potential (Chinyio and Olomolaiye, 2010). Those statements are confirmed with fact that many gaps are detected in previously mentioned literature review papers.

Issues of SM are even more stressed in mega construction projects due to inter-organizational collaboration and large number of parties (stakeholders) involved in project and thus in those projects SM is much more complicated (Mok et al., 2015). When there are many stakeholders involved, potential for their stakes to conflict with each other is relatively higher (Lynch 2006). Stakeholder management of large scale project is often part of complex public or corporate governance model which is seen in fact that vital part of project governance is development and implementation of stakeholder engagement strategies (Burcar 2012). Governance can be defined as management of management (Muller, 2009) and project governance is defined as a framework in which project decisions are made, i.e the process of making project decisions and established framework, models or structures to enable implementation of those processes. (Garland 2009). To be able to fully understand stakeholders and to develop quality SM we need to ask ourselves not only how stakeholders operate but also why they operate. This can be observed through sustainability approach aiming to detect stakeholder vested interest through long-term economic, ecologic and social aspects of large construction project (Bal et al., 2013).

To achieve project objectives, it is essential to formulate proper model for SM (Chinyio and Akintoye, 2008) which main tasks are stakeholder analysis and engagement (Yang et al. 2011b) and quality of this SM model can be increased by taking wider context and sustainable aspects of project into account.

2. Literature review - presenting the research field and research topic

In this thesis, as a part of literature review, topics concerning SM will be explored in order to explain its context and to show theoretical and practical importance of this field. These topics are: project governance and sustainability in construction followed by more specific topics of SM in construction field, and detailed exploration of stakeholder analysis and stakeholder engagement, which represents two main operational activities of SM.

We already stated that main concerns that need to be deal with in SM are how and why project stakeholders operate in particular way. Sustainability in construction projects aims to deliver long-term affordability, quality and efficiency, value to client and users whilst decreasing negative environmental impacts (Bal et al., 2013). Mathur et al. (2008), which deals with stakeholder engagement, states that sustainability is an ambitious goal, which requires new kinds of governance and decision-making processes involving a large variety of stakeholders. Sustainability in construction aims on greater stakeholder involvement and benefit for all stakeholder and SM is way to achieve project goals, which includes satisfaction of stakeholders. Thus, connection between these 2 areas is strong. SM is defined as "*continuing development of relationships with stakeholders for the purpose of achieving a successful project outcome*" (McElroy and Mills, 2000). In large construction projects, SM is seen in concepts of public and corporate governance where project governance determines regulation regarding project decision making process and framework of stakeholder relationships (Garland 2009). Stakeholder management approach to governance entails long-term social exchange between parties and cooperative problem solving (Rowlinson and Cheung, 2008) and this is very important in large scale projects because of their complexity and numerous stakeholders.

Taking into account SM in construction field in last 10 years there were attempts to synthesize this field through literature review papers which aims to explain processes of SM and methods used in this process, stakeholder relationships, stakeholder interests and influences, stakeholder analysis and engagement (Yang et al. 2011a, Mok et al. 2015.). Yang (2011b) explored operational approaches on stakeholder analysis and engagement and detected 30 approaches confirmed by practitioners but that alone does not solve problem. In the end, they concluded that approaches depend on lots of internal and external factors and that it is necessary to combine them, thus pointing out on unresolved problems with stakeholder analysis and engagement. Problems in stakeholder analysis arise already in the very definition stakeholders because the fundamental proposition of this area is not fully resolved, or it could be said that interpretations of scholars are insufficiently conceptually rigorous and often are limited and superficial (Stoney and Winstanley, 2001). Some scholars take power, legitimacy and urgency from Mitchell et al. (1997) salience model, while some scholars build their theories on power-interest-attitude matrix (Murray-Webster and Simon, 2005), presenting this as starting point of SM activities. Prebanic and Burcar (2017) detected gap of numerous stakeholder characteristics which are partly defined and often used by scholars for different purposes so there is need to classify them and have mutual agreement about their meaning. Mok et al (2015) detected gap in field of engagement and pointed to further development of large databases of stakeholder characteristics and information on which engagement strategies could be devised. Stakeholder engagement strategies and best practices are developed separately in several countries so this has yet to be consolidated.

These detected problems and gaps lead us to goals and hypothesis of this thesis.

3. Research goals and hypothesis

This research aims to improve stakeholder management in large construction projects by detecting various characteristics of stakeholders and linking them with particular engagement strategies and based on this correlation provides guidelines for successful stakeholder engagement. According to this research objective, hypothesis at this early stage of research is: "There is a correlation between the characteristics of stakeholders and a specific stakeholder engagement strategy during project lifecycle that will ensure meeting both hard (short-term) and soft (long-term) project success criteria in the large construction projects." Goals of this thesis are:

- Systemize and categorize stakeholders' characteristics and determine which characteristics of stakeholders can and should be observed and evaluated in which project phase
- Detect and analyze existing strategies for involving and engaging stakeholders in large construction projects and define main constructs of this strategies
- Determine the nature of the correlation between the stakeholder characteristics and the particular stakeholder engagement strategies
- Investigate and determine how stakeholder engagement is integrated in project governance of large construction projects
- Develop guidelines for successful stakeholders' engagement for large construction project in order to meet short-term and long-term project success criteria with purpose reaching sustainability in construction projects

4. Methodology and research plan

The main steps of the research methodology, which is currently planned for this thesis are portrayed in Fig.1. An overview of existing literature in project governance, front-end concept, stakeholder management, particularly stakeholder analysis and engagement will be conducted. The elaboration and explanation of the research problem, objective and methodology of research will be provided in second chapter. Based on literature review and analysis on stakeholder identification and analysis approaches, framework for stakeholder characteristics will be developed taking into account their relationships as well. Literature review on stakeholder engagement and project governance will result with identification of variables for the data collection, in addition to data on stakeholders based on developed framework. Correlation between stakeholder characteristics and engagement strategies will be identified based on data collected through international survey. Survey will be sent to project managers, owners and experts. The correlation model will be verified and validated using pre-selected case studies.

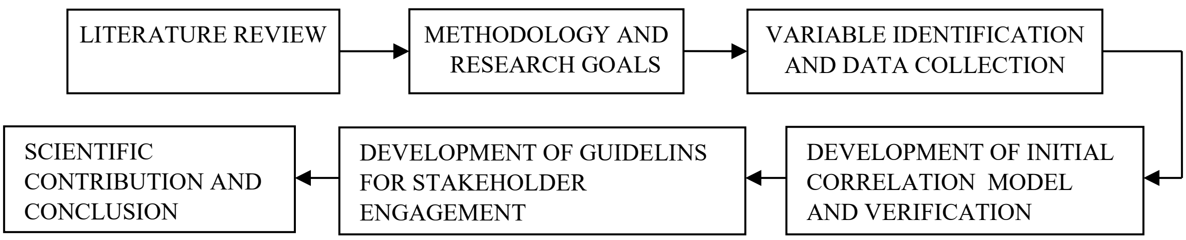

Figure 1 Methodology and research plan of doctoral thesis

Based on correlation model and data collected guidelines for successful stakeholder engagement strategies in large construction projects will be offered. The guidelines will take into account project governance models with a goal to achieve long-term sustainable development by taking into account interests of entire stakeholder environment.

5. Conclusion

Implication on theoretical concepts of SM should be seen in systematization, synthesis and further development in topic of stakeholder analysis and stakeholder engagement. Implication on practice of SM in large construction projects should be seen through developed guidelines for successful stakeholder engagement. Goal is to make these guidelines comprehensive considering wider context of project governance and sustainability in construction. Guidelines will be step forward in making SM in large construction projects more operational.

Literature

Bal, M., Bryde,D., Fearon, D., Ochieng, E., 2013., Stakeholder Engagement: Achieving Sustainability in the Construction Sector, Sustainability, 6, 695-710.

Burcar Dunovic, I., Colombo, R., Mancini, M., Littau, P., 2015. A case study approach to megaprojet stakeholder analysis through sustainability issues, in: Proceedings of IRNOP 2015.

Burcar Dunovic, I., 2012. Risk Management For Large Infrastructure Project., Doctoral thesis, Faculty of Civil Engineering

Akintoye, A., Chinyio, E. A., 2008 Practical approaches for engaging stakeholders: findings from the UK. Construction Management and Economics, 26(6), 591–9.

Chinyio, E.A., Olomolaiye, P., 2010, Construction stakeholder management, Wiley-Blackwell, Oxford, U.K., 377-380.

Garland, R., Project Governance: A Practical Guide To Effective Project Decision Making. 2009, London and Philadelphia: Kogan Page Limited.

Littau, P., Jujagirl, N.J., Adlbrecht, G., 2010. 25 Years of Stakeholder Theory in Project Management Literature (1984-2009). Proj. Manag. J. 41, 17–29.

Lynch, R., 2006 Corporate Strategy, 4th edn, Pearson Education Limited, Harlow.

Mathur, V. N., Price, A. D. F., Austin S., 2008., Conceptualizing stakeholder engagement in the context of sustainability and its assessment, Constr. Manag. Econ., 26, 601-109.

McElroy, B., Mills, C., 2000. Managing stakeholders, in: Turner, R.J., Sinister, S.J. (Eds.), Gower Handbook of Project Management. Gower Publishing Limited, p. 757–75.

Muller, R., 2009, Project Governance. Fundamentals of Project Management., Surrey: Gower Publishing

Mok, K.Y., Shen, G.Q., Yang, J., 2015. Stakeholder management studies in mega construction projects: A review and future directions. Int. J. Proj. Manag. 33, 446–457.

Olander, S., Landin, A., 2005. Evaluation of stakeholder influence in the implementation of construction projects. Int. J. Proj. Manag. 23, 321–328

Prebanic, K., Burcar I. B., 2017. Re-investigating Approaches On Defining Stakeholder Characteristics, proceeding of Organization, Technology and Management in Construction conference, September 2017., Porec, Croatia

Rowlinson, S., and Cheung, Y. K. F. 2008. Stakeholder management through empowerment: Modelling project success., Constr. Manage. Econ., 26(6), 611–623.

Rowlinson, S., Koh, T. Y., and Tuuli, M. M. 2010, Stakeholder management in the Hong Kong construction industry. Construction stakeholder management, E. Chinyio and P. Olomolaiye, eds., Wiley-Blackwell, Oxford, U.K., 216–239.

Stoney, C. and Winstanley, D.: Stakeholding: confu- sion or utopia? Mapping the conceptual terrain. Journal of Management Studies, **38**(5), (2001.), 603–26.

Turner, J.R., Zolin, R., 2012. Forecasting Success on Large Projects: Developing Reliable Scales to Predict Multiple Perspectives by Multiple Stakeholders Over Multiple Time Frames. Proj. Manag. J. 43, 87–99.

Yang, J., Shen, G.Q., Ho, M., Drew, D.S., Xue, X., 2011. Stakeholder management in construction: An empirical study to address research gaps in previous studies. Int. J. Proj. Manag. 29, 900–910.

Yang, J., Shen, G.Q., Bourne, L., Ho, C.M., Xue, X., 2011. A typology of operational approaches for stakeholder analysis and engagement. Constr. Manag. Econ., 29, 145-162

Papers in Croatian language

General Management and Economics in Construction

Primjena PUG i FIDIC-a u građevinskim sporovima

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Sažetak:

Građevinski sporovi su na sudovima sporovi sa najvećim vrijednostima, te je stoga i njihov ishod značajan za cjelokupno gospodarstvo. U praksi se u velikom broju tih sporova javljaju kao sporna neka od pitanja koja ćemo u ovome radu razmotriti sa aspekta primjene Posebnih uzanci o građenju i FIDIC-a.

Za početak pojavljuje se pitanje tumačenja što su radovi koje je zbog tehnoloških razloga nužno izvesti, a nisu predviđeni troškovnikom, jesu li to nepredviđeni radovi, naknadni radovi ili nešto treće.

Također, u situaciji kada dođe do propuštanja očitovanja nadzora ili naručitelja na zahtjev izvođača za produženje roka, a ugovorom nije definirano ostaje nejasno koja je točno posljedica tog propuštanja.

Nerijetko nakon što se sklopi ugovor, pojavi se pitanje tko je dužan osigurati izvedbeni projekt. Po tom pitanju ugovorne strane često ništa u ugovoru ne definiraju, pa je u takvim situacijama nejasno je li to obaveza naručitelja i projektanta ili je to pak obaveza izvođača.

Za stranke je vrlo bitno pitanje plaćanja, međutim, stranke često ugovorom ne urede rješenje situacije kada nakon što izvođač dostavi naručitelju situaciju, naručitelj u roku za ovjeru niti prizna niti ospori tu situaciju - smatra li se da je takva situacija ovjerena i priznata ili pak suprotno, neovjerena i nepriznata.

Nejasno je i pitanje je li nadzor u ime naručitelja ovlašten naručiti radove ili prihvatiti ponudu izvođača za izvođenje VTR (i nepredviđeni i naknadni radovi) ili samo nepredviđenih, a ne i naknadnih radova.

Ključne riječi: *naručitelj, izvođač, FIDIC, posebne uzance o građenju, sporovi*

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1. Uvod

Rijetko je koje područje gospodarskog djelovanja dosegnulo tako visok stupanj ugovorne regulacije kao što je to slučaj sa ugovorima o građenju, obzirom da je riječ o odnosu koji je s jedne strane dugotrajan (ne jednokratan kao npr. kupoprodaja), a s druge strane vrlo promjenjiv (ne stabilan kao npr. kreditni odnos). Mnogi instituti ugovora o građenju idu upravo za time da se predvide i reguliraju mnoge situacije gdje nužno mora doći do promjene odnosa među strankama.

Poseban status u strukturi zakonskih propisa i drugih ugovornih podloga koji uređuju ugovore o građenju imaju, kolokvijalno nazvano - uvjeti FIDIC-a, koji danas imaju neizmjeran utjecaj na praksu građenja - oblik i sadržaj ugovora o građenju u cijelome svijetu.

U slučaju kad je u konkretnom odnosu ugovorena primjena hrvatskog prava otvoreno je pitanje može li pojedina odredba FIDIC ugovora isključiti primjenu hrvatskog Zakona o obveznim odnosima (dalje ZOO). Načelno, niti jedna ugovorna odredba (ne samo temeljena na uvjetima FIDIC) ne može isključiti primjenu kogentnih odredbi zakona, neovisni čije je nacionalno pravo ugovoreno. Temelji, razvoj i ustrojstvo FIDIC uvjeta je poznato, te ovim radom dajem osvrt na dvojbe koje se pojavljuju u primjeni općih uvjeta FIDIC.

2. Primjena OU FIDIC u odnosu na propise

FIDIC opći uvjeti ugovora temelje se na engleskom zakonodavstvu, koje teži očuvati fair play prema svim sudionicima pri podjeli obaveza, odgovornosti i rizika. Ipak za primjenu kroz tzv. kontinentalno prava sadrži ujedno i velik broj nedovoljno definiranih pojmova kao što su: pošteno, prikladno, dovoljno, odgovarajuće, pogodno, dokazivo, primjereno, s dužnim poštovanjem, iskusan izvođač, znao ili trebao znati itd. (Safu.hr, Internet stranica).

Problem nejasnih termina ima jednako tako i ZOO i to već u odredbi koja definira što je to ugovor o građenju. Tako članak 621. ZOO definira što je to „građevina“, a građevina je nužan element pojma ugovora o građenju definiranog člankom 620. ZOO.

U ovom slučaju zakon određuje da je za „građevinu“ potrebno da se radi o „većim i složenijim“ radovima. Dakle, manji ili jednostavniji radovi nisu predmet ugovora o građenju. Suvišno je zaključiti da nije moguće postaviti granicu između većih i manjih, te složenijih i jednostavnijih radova. Ova distinkcija ponekad u praktičnoj primjeni može biti i važna jer neki formalno nazvani ugovori o građenju su sadržajno ipak samo ugovori o djelu što im daje bitno drugačije zakonske okvire (npr. rok zastare). Takvi ugovori se često odnose na završne građevinske radove, koji su sukladno ujednačenoj praksi Visokog trgovačkog suda RH ipak samo ugovori o djelu.

Naš temeljni zakon koji uređuje ugovor o građenju – ZOO ujedno uređuje i opće uvjete ugovora u čl. 295. i 296. U tom dijelu ZOO radi zanimljivu iznimku od pravila, te dopušta utvrđenje ništetnosti općih uvjeta ugovora, ako su suprotni načelu poštenja i savjesnosti, neovisno što su formalno ugovoreni.

Međutim, opće uvjete FIDIC-a ne bi se smjelo smatrati općim uvjetima koje predviđa naš ZOO. Razlika je u tome što ZOO ima u vidu opće uvjete koje jedan poslovni subjekt određuje za svoju djelatnost i nudi prema principu „uzmi ili ostavi“ širokom krugu ugovaratelja, najčešće kupci njegove robe ili korisnici njegove usluge. Opći uvjeti FIDIC-a u svakom slučaju nisu uvjeti koje naručitelj u svojoj djelatnosti nudi širokom krugu izvođača. Među ostalim i zato što niti jedan naručitelj ne može biti tzv. profesionalni naručitelj, već se svaki ugovor o gradnji odnosi na individualno određenu situaciju.

Na primjer, ako se Hrvatske željeznice pojave u ulozi naručitelja radova i ugovore primjenu općih uvjeta FIDIC-a tada to nisu opći uvjeti prema ZOO, već bi opći uvjeti prema ZOO bili uvjeti za prijevoz putnika i robe koje primjenjuju Hrvatske željeznice u svojoj djelatnosti.

Suprotno tome, pravnu prirodu općih uvjeta FIDIC-a tumačili su neki autori, te su dopuštali mogućnost utvrđenja ništetnosti općih uvjeta FIDIC-a putem suda. „Kod ocjene ništetnosti sud bi morao imati u vidu čl. 296., ako su ugovorne strane pojedinačno pregovarale o uvjetima." (Vukmir, 2009.).

3. Posebne uzance o građenju iz 1977. godine i OU FIDIC

Osim općih uvjeta ugovora i njihove razrade u ZOO na ugovore o građenju u hrvatskoj legislativi kao dopuna se primjenjuju i Posebne uzance o građenju. Primjena Posebnih uzanci o građenju dobila je svoju faktičnu reafirmaciju temeljem ZOO-a 2005. godine kada je ponovno određeno da se isti primjenjuju među trgovcima, ako se izrijekom ili prešutno ne isključuju. ZOO u članku 12. propisuje primjenu običaja i prakse. To znači da su Posebne uzance kodificirani trgovački običaji. U posljednjih 10 godina nije primijećeno u praksi da bi se Posebne uzance o građenju ugovorima izrijekom isključivale.

U prethodnom tridesetogodišnjem razdoblju ZOO je primjenu Posebnih uzanci određivao, suprotno gornjem, tek ukoliko se iste izrijekom ugovore. U tom smislu sada, odnos uvjeta FIDIC-a treba načelno promatrati i u odnosu na zakonske odredbe, ali i u odnosu na odredbe Posebnih uzanci o građenju.

Posebne uzance o građenju donesene su 1977. godine i nakon toga nisu ni na koji način mijenjane ili dopunjavane. Ova činjenica sam po sebi ukazuje da taj akt nije u dovoljnoj mjeri usklađen sa potrebama današnjih odnosa koji nastaju u graditeljstvu. Pitanje Posebnih uzanci o građenju u tom smislu prepoznao je i zakonodavac te je posljednjim Zakonom o gradnji određeno da se Posebne uzance trebaju ponovno utvrditi i objaviti upravo stoga kako bi se ažurirale sa današnjim potrebama, a moguće u određenoj mjeri i sa uređenjima OU FIDIC-a.

U tom smislu prije dvije godine osnovana je radna skupina radi utvrđivanja prijedloga teksta novih Posebnih uzanci o građenju. Ono što ne postoji uobičajeno u praksi, neovisno koliko je kvalitetno, ne može biti uzanca, već može eventualno biti dobra odredba nekog budućeg ugovora ili budući propis. Stoga se uzance ne mogu predlagati, niti može postojati autor uzanci

Kao što je ranije navedeno ZOO sada pretpostavlja primjenu običaja i uzanci neovisno jesu li one posebno ugovorene. To bi značilo da se i primjena uvjeta FIDIC-a može čak smatrati ugovorenom i u onim odnosima gdje su stranke prethodno primjenjivale FIDIC, a nisu izrijekom za taj odnos ugovorile FIDIC.

Do dvojbenih situacija može doći ukoliko uvjeti FIDIC-a nisu u cijelosti sukladni uvjetima Posebnih uzanci o građenju. Tako na primjer može se postaviti pitanje „konačnog obračuna" na način kako ga predviđaju Posebne uzance (br. 110. i 111.) u odnosu na Izvještaj o završetku i Završni izvještaj. Može se zaključiti da uređenje „konačnog obračuna“ nije istovjetno niti jednom od gore navedena dva izvještaja sukladno FIDIC-u. Na temelju uzance br. 116., konačnim obračunom obuhvaćaju se svi radovi izvedeni na temelju ugovora, uključujući i nepredviđene i naknadne radove, bez obzira na to jesu li radovi obuhvaćeni privremenim situacijama. Uzanca br. 119. nabraja stavke koje konačni obračun treba obuhvatiti.

Premda sukladno ZOO-u ugovor o građenju mora biti sastavljen u pisanoj formi, u slučaju izvantroškovničkih radova ili kolokvijalno „VTR“-a primjenjuje se članak 294. (ranije 73.) ZOO koji dopušta izostanak pisane forme, ako je obveza sadržajno ispunjena. To su radovi koji često nisu ni na koji način ugovoreni i pravni status tih radova može biti dvojbenim upravo stoga jer su izvan svakog ugovornog odnosa.

Neka od pitanja koja se mogu pojaviti prilikom primjene Posebnih uzanci o građenju se navode niže u tekstu.

3.1. Sastavni dijelovi ugovora

Sadašnjom posebnom uzancom o građenju br. 11. predviđeno je što se smatra bitnim sastojcima ugovora o građenju.

Kao nebitni sastojak ugovora uzanca br. 12. predviđa dinamički plan radova, a ovo se vidi iz toga jer je predmetnom uzancom predviđeno da je taj plan sastavni dio ugovora, samo ako su stranke tako ugovorile.

Ova uzanca može stvoriti određenu koliziju sa ZOO-om i sudskom praksom. Nerijetko u ugovorima nije rok definiran uz riječi „bitan sastojak ugovora“, iako se očekuje da je takav. Sadašnja uzanca uputila bi na suprotan zaključak.

3.2. Rokovi

U pogledu rokova postoje mnogi pristupi, koji nerijetko idu ka što jasnijem određivanju kojim bi se prekludiralo sudionike u pravima. Uzor tome je počesto ustroj iz općih uvjeta FIDIC što u svrhu takvog standardiziranog ugovora može biti poželjno, jer je to ipak ugovor. Neovisno o tome, što npr. „žuti“ FIDIC u točki 20.1. daje definiciju gubitka prava za tzv. notice, ali ne i kod roka za tzv. claim, pri čemu nije moguće dati jednoznačan pravni stav, jesu li oba roka prekluzivna ili samo jedan ili ni jedan.

Vrlo često pitanje u arbitražnim sporovima temeljem OU FIDIC-a jest kako pravno tumačiti prekoračenje roka od strane izvođača za predaju tzv. notice. Iako FIDIC ovdje ima jasnu odredbu, arbitri se u pravilu nađu u slijedećoj dilemi – je li pravno pravilno osloboditi naručitelja obveze čak i kad je tzv. claim izvođača opravdan, u velikim vrijednostima, ali je prethodno predan tzv. notice sa vrlo malim kašnjenjem u odnosu na propisanih 28 dana.

Dilema je, hoćemo li FIDIC tumačiti „razumno“ ili „kako piše“. Ako tumačimo „razumno“ ulazimo u nesigurnost tumačenja FIDIC-a i prepuštamo se neizvjesnoj volji arbitra. Ako tumačimo „kako piše“ spremni smo prihvatiti da će arbitar zbog formalnosti biti spreman svjesno legalno oštetiti jednu stranu i to za visoke novčane iznose.

Međutim, rješenje ovog pitanja nije moguće tražiti kroz opće uvjete FIDIC-a i njihova tumačenja. Rješenje je moguće jedino kroz definiranje posebnih uvjeta FIDIC-a gdje obje ugovorne strane imaju slobodno pravo same regulirati one odredbe općih uvjeta FIDIC-a koje same po sebi uzrokuju sporove.

Navedena točka 20.1. glede diskutabilnih posljedica kod prekoračenja roka je jedan od više primjera dvojbenih odredaba općih uvjeta FIDIC-a, a daljnji primjeri se neće zbog cilja ovog rada detaljno obrazlagati, već se samo primjerice navode. Na primjer:

- Pitanje ovlasti inženjera koji je angažiran od naručitelja i dužan je štititi interes naručitelja, a suprotno tome točka 3.5. „…inženjer će donijeti pravednu odluku…“ (FIDIC – Žuta knjiga, 1999.).
- Uzance i pravna praksa predviđaju odgovornost naručitelja za stanje tla i hidrološke uvjete, a suprotno tome točka 4.10. „…izvođač je odgovoran za tumačenje podataka (tla)…“ (FIDIC – Žuta knjiga, 1999.).
- Inženjer ne može naručivati naknadne radove niti mijenjati glavni projekt ili izvedbeni projekt, a suprotno tome točka 13.1. „…izmjene može inicirati inženjer…“ (FIDIC – Žuta knjiga, 1999.).
- Ovjera situacije prema uzancama i sudskoj praksi ima značaj priznanja situacije, a suprotno tome točka 14.6. „…ovjerena situacija ne predstavlja prihvaćanje, odobrenje ili suglasnost inženjera…“(FIDIC – Žuta knjiga, 1999.).

Svakako da postoji velik broj ovakvih primjera, a svima je zajedničko proturječnost između hrvatske pravne prakse i uzanci o građenju na jednoj strani, u odnosu na opće uvjete FIDIC-a na drugoj strani.

Naša praksa tj. običaji nisu ustrojili jedinstvene rokove koji bi se mogli usuglašeno odrediti na točan dan. Jedan od razloga za kašnjenje izvođača može biti i izvođenje naknadnih i nepredviđenih radova, a pri čemu nije moguće u pravilu zaključiti da su to razlozi koji predstavljaju krivnju izvođača.

Poseban uzrok mnogih spornih odnosa između naručitelja i izvođača predstavlja pitanje – koja ovlaštenja ima nadzorni inženjer u ime naručitelja, a prema izvođaču. Tumačenjem ZOO-a pravilan zaključak bi bio da nadzorni inženjer nije zakonski zastupnik naručitelja, niti ima ovlaštenja „po zaposlenju“ (jer nije zaposlen kod naručitelja), niti se ugovorom o građenju predviđa da bi on mogao u ime naručitelja ugovarati dodatne radove.

Međutim, uobičajena praksa pri realizaciji ugovora o građenju jest da nadzorni inženjer uz priznavanje tzv. više radnji i nepredviđenih radova zahtjeva i izvođenje naknadnih radova.

Točno je da nerijetko nije moguće lako razlučiti predstavljaju li konkretni radovi nepredviđene radove koje je trebalo nužno izvesti iz tehnoloških razloga ili su to radovi koji moguće i nisu nužni, ali ih zahtjeva nadzor naručitelja. Ponekad nije niti dvojbeno da nadzor naručitelja zahtjeva naknadne radove. U svakom slučaju, izvođač u pravilu u praksi nema uvjeta inzistirati na sklapanju novog ugovora ili aneksa ugovora, već prihvaća takav nalog iako se nesporno radi o radovima koji nisu opisani u troškovniku tj. ne možemo ih zvati „ugovoreni radovi“. Formalno su takvi radovi naručeni od neovlaštene osobe, te iako su izvedeni takav odnos predstavlja rizik jer te radove ne prati nikakva ugovorna regulacija.

Kvalitetniji pristup ovom pitanju će biti ako naručitelj i izvođač izrijekom ugovorom definiraju ovlasti stručnog nadzora. Svakako da zakonski propisi u tom smjeru sada ne daju rješenje.

3.3. Ugovorna kazna (penali)

Na pitanje rokova se prirodno nadovezuje pitanje ugovorne kazne. Sadašnje uzance u članku 51. definiraju ugovornu kaznu na način koji je gotovo neprovediv, ako nije ugovor jasno definiran. Razlog za ugovornu kaznu definiran kao „neuredno ispunjenje" vrlo teško može biti usuglašen između naručitelja i izvođača i konkretnom slučaju. Kako su vrijednosti ugovorne kazne u pravilu ukupna dobit izvođača na tom poslu, jasno je da takvo uređenje sadašnjih uzanci vodi ka sporu.

Prijedlog novog uređenja, u članku 45. određuje onaj razlog koji jasnije određuje razlog za ugovornu kaznu, a to je zakašnjenje. Pri tome se dodano određuje da se neznatni nedostaci koji ne sprječavaju funkcionalnu uporabu, ne smatraju zakašnjenjem.

Također, samo kao primjer može se istaknuti i pitanje do kada naručitelj može podnijeti izvođaču zahtjev za naplatu penala. Sadašnje uzance (PUG 1977) neopravdano taj rok izvođaču ostavljaju do „završetka konačnog obračuna". Svakako da je takvo rješenje iniciralo mnoge sporove jer je naručitelju dalo prekomjerno pravo – da drži u neizvjesnosti izvođača nakon primopredaje radova u pogledu financijskog protuzahtjeva.

Penale svakako treba razumjeti kao vrlo životno pravo naručitelja tj. kao ono pravo koje naručitelj gotovo u pravilu konzumira ako ima ikakve uvjete na njega, a s druge strane u financijskom smislu korištenje tog prava u pravilu anulira bilo kakvu svrhu izvođača iz ugovora tj. anulira dobit izvođača.

Pitanje penala se nerijetko površno pojednostavljuje i pokušava se tumačiti kao puki matematički izračun dana kašnjenja sa ugovorenim vrijednostima (postoci ili promili). Naravno da takav pristup nije dostatan i može samo uzrokovati vrlo skupe sporove.

3.4. Posebna ovlaštenja nadzora

Poseban uzrok mnogih spornih odnosa između naručitelja i izvođača predstavlja pitanje – koja ovlaštenja ima nadzorni inženjer u ime naručitelja a prema izvođaču. Tumačenjem ZOO-a pravilan zaključak bi bio da nadzorni inženjer nije zakonski zastupnik naručitelja, niti ima ovlaštenja „po zaposlenju" (jer nije zaposlen kod naručitelja), niti se ugovorom o građenju predviđa da bi on mogao u ime naručitelja ugovarati dodatne radove. Međutim, uobičajena praksa pri realizaciji ugovora o građenju jest da nadzorni inženjer uz priznavanje tzv. više radnji i nepredviđenih radova zahtjeva i izvođenje naknadnih radova.

Točno je da nerijetko nije moguće lako razlučiti predstavljaju li konkretni radovi nepredviđene radove koje je trebalo nužno izvesti iz tehnoloških razloga ili su to radovi koji moguće i nisu nužni, ali ih zahtjeva nadzor naručitelja. Ponekad nije niti dvojbeno da nadzor naručitelja zahtjeva naknadne radove.

U svakom slučaju, izvođač u pravilu u praksi nema uvjeta inzistirati na sklapanju novog ugovora ili aneksa ugovora, već prihvaća takav nalog iako se nesporno radi o radovima koji nisu opisani u troškovniku tj. ne možemo ih zvati „ugovoreni radovi".

Formalno su takvi radovi naručeni od neovlaštene osobe, te iako su izvedeni takav odnos predstavlja rizik jer te radove ne prati nikakva ugovorna regulacija.

Prijedlog novih uzanci u tom smislu člankom 96. prihvaća takvo ovlaštenje za stručni nadzor u cilju prilagodbe uobičajenim pravilima struke.

Kvalitetniji pristup ovom pitanju će biti ako naručitelj i izvođač izrijekom ugovorom definiraju ovlasti stručnog nadzora. Svakako da zakonski propisi u tom smjeru sada ne daju rješenje.

3.5.Kriteriji razlikovanja isprava uređenih OU FIDIC i PUG

Nastavno na prethodnu analizu nekih pitanja koja se pojavljuju pri primjeni Posebnih uzanci o građenju postavlja se i pitanje kako pravilno odrediti mjesto i pravni značaj određenim važnim ispravama koje se ugovaraju prema uvjetima FIDIC-a sa ciljem da se takve isprave mogu dalje tumačiti prema hrvatskim pozitivnim propisima i da ima se može konačno dati konkretan pravni značaj te odrediti njihove pravne posljedice.

Naravno, nije sporno različito nazivlje tih isprava, već određenje njihovog sadržaja, vremenskog izdavanja i konačnog pravnog značaja. Kako se ugovaranjem ovih ključnih isprava ujedno prirodno isključuje primjena standardnih isprava poznatih u legislativi hrvatskih građevinskih propisa očito se otvara pitanje tumačenja pravnog značaja isprava predviđenih uvjetima FIDIC-a.

Dobivanje odgovora na pitanje koje odredbe zakona ili drugog prisilnog propisa treba smatrati kogentnima, a koje dispozitivnima, odmah zatim pitanje mogu li se određeni uvjeti FIDIC-a podvesti upravo pod te odredbe, nije moguće nije moguće kroz analizu sudske prakse iz razloga što se ugovori temeljeni na uvjetima FIDIC-a prvenstveno sklapaju za veće građevinske poduhvate, kakvih na objektivno malom hrvatskom tržištu ne može biti mnogo.

U tim slučajevima se nadalje najčešće ugovara nadležnost arbitražnog sudišta, a ne redovnog suda, koje sudište ima bitno manji volumen postupaka od redovnih sudova, a i koje sudište za sada nema javno dostupnu svoju sudsku praksu. Zbog navedenog, praktično nije moguće obrađivati sudska shvaćanja niti sudsku praksu, što ne znači da se ta pitanja praktične ne pojavljuju kao prijeporna bilo u fazi uređivanja odnosa u postupcima nagodbenog uređivanja odnosa među strankama ili kasnije u pojedinačnim arbitražnim postupcima.

4. Pitanje tumačenja nekih standardnih isprava FIDIC /Red book, 1987/

Uvjeti FIDIC-a za razliku od uobičajenih ugovornih uvjeta ugovora o građenju prema hrvatskom pravu poznaju veći broj pojedinačnih isprava nego što je to uobičajeno u ugovorim o građenju oslonjenim isključivo na naše propise.To već samo za sebe ukazuje na činjenicu da nije moguće sve standardne isprave FIDIC-a povezati sa identičnim ispravama uobičajenim u ugovornoj praksi oslonjenoj na hrvatske propise.

Kako su neke od tih isprava od izuzetnog značenja, te su upravo one odredišne točke za primjenu i kasnije tumačenje mogućih prijepornih odnosa među strankama, u nižim točkama 3.1 i 3.2 selektiraju se dvije isprave koje se smatraju važnijima kao primjer koja su moguća različita tumačenja njihovog značaja sa osvrtom na posljedice u primjeni. U tom smislu selektirane su isprave kojima naručitelj i izvođač u bitnome uređuju način verificiranja završetka radova i to ne samo terminski, već što je mnogo važnije i složenije kvalitativno i kvantitativno.

Poznato je iz same prirode građevinskog pothvata da se mnogi čimbenici mijenjaju tijekom izvođenja radova, te da nije razumno niti očekivati izvršenje pothvata na način da u njemu neće doći do promjena po nekoj od bitnih osnova. Tako npr. tijekom izvršenja posla, cijene materijala mogu rasti i padati, projekt se može mijenjati, vremenski uvjeti mogu uvjetovati brzinu izvedbe, promjena građevinskih, poreznih i drugih propisa može imati utjecaj na odnos stranaka, izvođač može imati zakašnjenja tijekom međurokova po terminskom planu uzrokovana i neuzrokovana vlastitom krivnjom, kao i mnoge druge relevantne okolnosti koje su podložne promjenama tijekom izvršenja posla.

Isprave kojima se uređuje definiranje završetka radova stoga imaju poseban značaj, jer se njima rezimiraju važne činjenice i što je posebno važno usklađuju stavovi oko svih relevantnih okolnosti, koje nisu mogle biti unaprijed ugovorene već su mogle biti samo ugovorom okvirno predviđene.

4.1. Izvještaj o završetku (Statement at Completion)

Prva od dvije važne isprave u smislu utvrđenja završetka radova je „Izvještaj o završetku" koja se obrađuje pod ovom točkom, a druga je „Završni izvještaj" koja se obrađuje u slijedećoj točki.

Prije svega, pažnju privlači jezična vrlo slična terminologija koja u praksi lako doprinosi nejasnoćama zbog miješanja ova dva termina. Pitanje kvalitete prijevoda hrvatske inačice uvjeta FIDIC-a je vjerujem poznato, te se često kao primjer toga uzima riječ „poslodavac" koja označuje naručitelja, što je dakako neprikladno za preciznu pravnu uporabu.

Pitanje prijevoda ipak nije bezazleno jer se može ugovarati kao mjerodavan jezik ugovora npr. hrvatski, osobito ako se ugovara primjena hrvatskog prava i nadležnost arbitražnog sudišta u RH. Moguće je zaključiti da ne bi bilo dobro nesustavno prevoditi uvjete FIDIC-a za potrebe pojedinačnih ugovora jer bi to uzrokovalo još veći broj različitih naziva za iste standardne isprave, te daljnju nesigurnost. U tom pogledu bilo bi bolje rješenje kojim će se sustavno i dosljedno koristiti isti pa i nekvalitetni prijevodi nekih termina, sve dok se ne uredi novi sustavni prijevod, a koji je upravo i u najavi.

Isprava pod nazivom „Izvještaj o završetku" (*engl. Statement at Completion)* određena je člankom (ili točkom) 60.5 crvene knjige te u bitnom ima za cilj da izvođač preda dokument kojim će odrediti da je završio ugovorene radove, ali ne kao obavijest ili poziv na primopredaju radova (uređen posebnom ispravom Certifikat o preuzimanju), jer je pitanje primopredaje radova preduvjet te izjave, već kao određena vrsta obračuna radova i bitnih okolnosti radi praćenja prava i obveza među strankama.

Brojevi članaka općih uvjeta ugovora koji se primjenjuju u pojedinačnim ugovorima o građenju ponekad ne odgovaraju brojevima članaka koji su označeni u uvjetima FIDIC-a. To stoga što stranke imaju pravo određene članke izostaviti ili dodati svoje članke, a ponekad stranke koriste i jedan od obrazaca koje su koriste razvojne banke (IBRD, EBRD, EIB ili sl.). U tom slučaju dolazi do novog numeriranja ugovora.

Članak 60.5. općih uvjeta ugovora za građevinske radove (četvrto izdanje, ponovno tiskano 1987, 1992, tzv. Crvena knjiga), odnosno u izvorniku Conditions of Contract for Works of Civil Engineering Construction (4th Edit. 1987 reprinted, 1992 Red Book) glasi:
„Ne kasnije od 84 dana nakon izdavanja od Certifikata o preuzimanju vezano uz Radove, Izvođač je dužan Nadzornom inženjeru dostaviti Izvještaj o završetku, u broju kopija navedenom u Dodatku ponudi s pratećim dokumentima koji detaljno navode, u obliku kojega odobrava Nadzorni inženjer,
a) konačnu vrijednost svih radova u skladu s Ugovorom do datuma navedenog u Certifikatu o preuzimanju;
b) sve dalje iznose koje Izvoditelj smatra prispjelim; i
c) procjenu iznosa za koje Izvoditelj smatra da će dospjeti za plaćanje temeljem Ugovora.
Procijenjene iznose treba zasebno prikazati u Izvještaju o završetku. Nadzorni inženjer je dužan ovjeriti plaćanje u skladu s Točkom 60.2“ (FIDIC – Crvena knjiga, 1999.)

Odnosno, izvorno na engleskom jeziku:
„Not later than 84 days after the issue of the Taking-Over Certificate in respect of Completion the whole of the Works, the Contractor shall submit to the Engineer six copies of a Statement at Completion wiith supporting documents showing in detail, in the form approved by the Engineer:
a) the final value of all work done in accordance with the Contract up to the date stated in such Taking-Over Certificate,
b) any further sums which the Contractor considers to be due, and
c) an estimate of amounts which the Contractor considers will become due to him under the Contract. The estimated amounts shall be shown separately in such Statement at Completion. The Engineer shall certify payment in accordance with Sub-Clause 60.2.“ (FIDIC – Crvena knjiga, 1999.).

Iz članka 60.5 nije jasno značenje dokumenta pod nazivom Izvještaj o završetku (*Statement at Completion*), u smislu isprava koje poznaju hrvatski propisi i običaji u normiranju odnosa iz ugovora o građenju. Jednako tako ne postoji dokument u standardnoj praksi koji bi se mogao proglasiti ekvivalentom Izjave o završetku. Prema sadržaju zadanom točkama a, b i c; zapravo se radi o prijedlogu obračuna nakon preuzimanja radova. Moguće je i tumačenje da se u biti radi o posljednjoj privremenoj obračunskoj situaciji, budući da je prema članku 60.2 potrebno izdati privremenu obračunsku situaciju kao zaseban dokument.

Ni u kojem slučaju ne može biti govora o konačnom obračunu ili prijedlogu konačnog (okončanog) obračuna vrijednosti radova. Naša praksa i zakonski okvir određuju da se konačni obračun radi nakon primopredaje radova, nakon čega se ugovor zaključuje.

Ovaj moment može izazvati dvojbe jer se „Izvještaj o završetku„ predaje također nakon primopredaje radova. Međutim, odgovor na pitanje radi li se o tzv. okončanom obračunu, na temelju koje se zaključuje okončana situacija među strankama trebalo bi tražiti kroz analizu slijedeće isprave opisane ovdje pod točkom niže kao „Završni izvještaj“.

Primjetno je da „Završni izvještaj“ ima više elemenata okončanog obračuna, ali svakako da bi se moglo prihvatiti i tumačenje da se radi o dvije isprave koje zajedno uređuju pitanja koja u hrvatskoj praksi uređuje jedna isprava, okončani obračun. Koje god tumačenje da se prihvati kao pravilnije izvjesno je samo da ne postoji ekvivalent u hrvatskoj praksi, što odmah otvara pitanje primjene, budući da naši propisi ne poznaju ovu situaciju niti o njoj postoji sudska praksa.

4.2. Završni izvještaj (Final statement)

Razdoblje odgovornosti za skrivene nedostatke odnosno tzv. garantni rok regulirano je u cijelosti ZOO-om i u nekom uobičajenom ugovoru koji nije temeljen na uvjetima FIDIC-a najčešće stoje 2 do 3 kratke tehničke odredbe.

Suprotno tomu, Opći uvjeti FIDIC 1987, a jednako tako i novijih izdanja (tzv. FIDIC Rainbow Suite iz 1999.g.), propisuju da se konačni obračun provodi nakon isteka razdoblja odgovornosti za skrivene nedostatke. Isto je vidljivo iz članka 60.6 Final Statement, prema Općim uvjetima Conditions of Contract for Works of Civil Engineering Construction (4th Edit. 1987 reprinted, 1992 Red Book):

„Not later than 56 days after the issue of the Defects Liability Certificate pursuant to Sub-Clause 62.1, the Contractor shall submit to the Engineer for consideration six copies of a draft final statement with supporting documents showing in detail, in the form approved by the Engineer:

a) the value of all work done in accordance with the Contract, and

b) any further sums which the Contractor considers to be due to him under the Contract or otherwise.

If the Engineer disagrees with or cannot verify any part of the draft final statement, the Contractor shall submit such further information as the Engineer may reasonably require and shall make such changes in the draft as may be agreed between them. The Contractor shall then prepare and submit to the Engineer thefinal statement as agreed (for the purposes of these Conditions referred to as the "Final Statement").

If, following discussions between the Engineer and the Contractor and any changes to the draft final statement which may be agreed between them, it becomes evident that a dispute exists, the Engineer shall deliver to the Employer an Interim Payment Certificate for those parts of the draft final statement, if any, which are not in dispute. The dispute may then be settled in accordance with Clause 67.“ (FIDIC – Crvena knjiga 1999.)

Dakle, u roku od 56 dana nakon izdavanja Potvrde o otklanjanju nedostataka prema članku 62.1, koja označava istek razdoblja odgovornosti za skrivene nedostatke, Izvođač je dužan dostaviti Final Statement, ili kako je u Ugovoru prevedeno Završni izvještaj. Nakon toga (slijedeći članak 60.7) Izvođač daje izjavu o namirenju (Discharge) a tek potom, u razdoblju od slijedećih 28 dana, izdaje Okončanu situaciju (Final Payment Certificate, pod-članak 60.8).

Nakon toga slijedi pod-članak 60.9 Cessation of Employer's Liability iz Općih uvjeta Conditions of Contract for Works of Civil Engineering Construction (4th Edit. 1987 reprinted, 1992 Red Book): „The Employer shall not be liable to the Contractor for any matter or thing arising out of or in connection with the Contract or execution of the Works, unless the Contractor shall have included a claim in respect thereof in his Final Statement and (except in respect of matters or things arising after the issue of the Taking-Over Certificate in respect of the whole of the Works) in the Statement at Completion referred to in Sub-Clause 60.5.“. (FIDIC – Crvena knjiga, 1999.).

Članak 60.9 Prekidanje odgovornosti:
„Poslodavac nije odgovoran izvođaču niti za koju stavku ili stvar koja proizlazi iz ili u vezi s Ugovorom ili izvršenjem radova, osim ako je izvođač u vezi s time bio dužan postaviti zahtjev u svom Završnom izvještaju i (osim vezano uz stavke ili stvari koje nastaju nakon izdavanja Certifikata o preuzimanju vezano uz cjelinu Radova) u Izvještaju o završetku 60.5 “ (FIDIC – Crvena knjiga, 1999.).

Prema tome, uvjeti FIDIC-a čine jasnu distinkciju između Final Statement/Završnog izvještaja i Statement at Completion/Izvještaja o završetku. Članak 60.9 standardnih Općih uvjeta, ne dopušta naručitelju (Poslodavac) odricanje odgovornosti prema zahtjevu kojeg izvođač postavi u Završnom izvještaju (Final Statement).

Posebno je pitanje u analizi „Završnog izvještaja“ garantni rok jer tek nakon njegovog isteka se predaje „Završni izvještaj“. On najčešće predstavlja dvogodišnje razdoblje odgovornosti za nedostatke, mada ukoliko to nije ugovorom definirano, praksa Visokog trgovačkog suda RH ukazuje na trogodišnje razdoblje uz tumačenje da se radi o pravu naručitelja koji u zastarnom roku od 3 godine ima pravo zahtijevati od izvođača ispunjenje obveze. Jedna od obveza izvođača je svakako i otklanjanje nedostataka nakon predaje radova.

Naručitelj je dužan izdati Potvrdu o otklanjanju nedostataka (*Defect Liability Certificate*). Ukoliko je to učinio, Izvođač ima pravo u roku od 56 dana izdati prijedlog konačne situacije, što mi se čini najprimjerenijim prijevodom Završnog izvještaja.

S obzirom na navedeno, izvođač u ovoj situaciji (a suprotno primjeni hrvatskih propisa) nema razloge niti ugovornu obvezu dostavljati Završni izvještaj (*Final Statement*) prije isteka garantnog roka. Izvođač ima priliku dostaviti Završni izvještaj (*Final Statement*), prvo navedeni dokument u članku 60.9 standardnih općih uvjeta, i u njemu iskazati zahtjev za na primjer promjenom cijene. Čak i ukoliko ga je već dostavio bez iskazanog zahtjeva, ima ga pravo revidirati unutar 56 dana od izdavanja Potvrde o otklanjanju nedostataka.

Načelno, razlika između Završnog izvještaja i Izvještaja o završetku može nastati samo iz okolnosti koje su se dogodile između primopredaje radova i isteka razdoblja odgovornosti za nedostatke. Međutim, izvođač se može pozvati i na činjenicu da su podaci nužni za npr. obračun razlike u cijeni (statistički indeksi) postali dostupni u vremenu nakon što je naručitelj izdao Certifikat o preuzimanju radova.

Dakle, u svemu gore navedenom je očito da postoji izuzetna razlika u primjeni ove dvije isprave kako ih predviđaju uvjeti FIDIC-a i srodnih isprava (okončani obračun i okončana situacija) kako ih predviđaju pozitivni hrvatski propisi i pravna praksa. Ako ni zbog čega drugoga, tada imajući u vidu činjenicu da se vrlo bitno prava izvođača odgađaju na kraj garantnog roka umjesto na ugovorno dovršenje posla.

Kako su uvjeti FIDIC-a (Crvena knjiga) ciljani prvenstveno na zaštitu investitora, gornje ne treba tumačiti kao prednost izvođača, jer se isto može shvatiti da su prava izvođača odgođena, a jedno od prava izvođača je i pravo na naplatu koje je također dijelom odgođeno, a kako bi se bolje osigurala prava naručitelja tijekom garantnog roka.

5. Zahtjevi izvođača (*Contractror's Claims)*

Što se tiče pitanja je li izvođač zakasnio s prijavom potraživanja npr. zahtjeva za povećanjem cijene s naslova troška, članak 53.1. općih uvjeta ne eksplicira gubitak prava na ispunjenje zahtjeva izvođača u slučaju njegovog propusta pravovremen prijave istog. Naime, članak 53.4 (*Failure to Comply*), upravo suprotno, daje naznaku postupanja u slučaju izvođačevog propusta da postupi po bilo kojem dijelu cijelog članka 53., čime otvara prostor za priznavanje izvođačeva zahtjeva.

Stoga ukoliko se članak općih uvjeta 53.1 u eventualnim posebnim uvjetima ne dopuni na ovaj ili sličan način, pravo izvođača nije ukinuto zbog njegovog propusta da ga pravovremeno prijavi. Odredba o vremenskom ograničenju prava na dostavu zahtjeva je u općim uvjetima direktivna, odnosno svrha joj je urediti procese, na način koji se preporuča, usmjerava.

Postupanje (nadzornog) inženjera je diskrecijsko, odnosno on ima obvezu razumno ocijeniti da li postoje razlozi za razmatranje zahtjeva izvođača. Na primjer, opći uvjeti FIDIC 1987 u članku 44.2 *Contractor to Provide Notifications and Detailed Particulars*, koji se odnosi isključivo na zahtjeve izvođača za produženje roka za izvođenje radova, oslobađa inženjera obveze da donosi odluku osim ukoliko izvođač nije:

a. u roku od 28 dana nakon što se je takav slučaj prvi put pojavio obavijestio inženjera, uz kopiju naručitelju, i

b. u roku 28 dana ili takvog razumnog drugog roka koji bi mogao utvrditi inženjer, nakon što je takva obavijest dostavljena inženjeru s prikazom pojedinosti za ono produženje roka za koje on smatra da ima pravo, kako bi se takav zahtjev mogao u to vrijeme ispitati.

Ne postoji analogna zakonska odredba za eventualni izvođačev zahtjev za nadoknadom troška, osim općih odredbi ZOO o zastari, te stajališta sudske prakse koje zauzima stav da je izdavanjem okončane situacije izvođač odustao od daljnjih zahtjeva koji su mu bili ili mogli biti poznati do izdavanja okončane situacije. Ovdje treba dodati okolnost da hrvatsko pravo ne poznaje niti prekluzivan rok za izdavanje okončane situacije.

Iako je kod nas najzastupljenija primjena FIDIC općih uvjeta iz 1987. Taj će se obrazac koristiti sve rjeđe nakon izdanja FIDIC uvjeta iz 1999. godine. Izdanje FIDIC 1999 ima odredbu koja propisuje vremensko ograničenje u članku 20.1 Općih uvjeta i jednoznačno oslobađa naručitelja svih obveza i odgovornosti u vezi zahtjeva izvođača.

6. Anketa o pet spornih pitanja

Kako je prethodno spomenuto u tekstu tijekom izrade prijedloga novih Posebnih uzanci o građenju, a što je vidljivo na mrežnim stranicama Hrvatske gospodarske komore (Hgk.hr, Internet stranica), provedena je ciljana anketa radi definiranja stručnog stava o izabranih pet dvojbenih situacija koje se javljaju u građevinskim sporovima.

U tu svrhu održana su brojna predstavljanja i savjetovanja diljem Republike Hrvatske vezano uz izradu novog teksta Posebnih uzanci o građenju, a na kojim predavanjima su polaznicima bili dani na ispunjavanje anketni listići sa nekim od bitnih pitanja koja se pojavljuju kao sporna u građevinskim predmetnima.

Rezultati ovog ispitivanja su bili takvi da je od 172 ispitanika, koji su pretežito građevinske struke ili rade u građevinskom sektoru, takvi da na čak 4 posljednja pitanja su odgovori bili podjednaki. Odnosno jednak je bio omjer odgovora pod a, b i c, te je jedino za prvo pitanje skoro polovica odgovorila jednako i to da bi odgovor bio a.

Tako primjerice na prvo pitanje što su radovi koje je zbog tehnoloških razloga nužno izvesti, a nisu predviđeni troškovnikom, skoro polovica ispitanika odgovorila da su to nepredviđeni radovi, dok je ostatak ispitanika se podjednako opredijelio za dva preostala odgovora da su to naknadni radovi ili da to nije niti jedno od navedenog.

Nadalje nejasno je i struci koje su to posljedice propuštanja očitovanja nadzornog inženjera ili naručitelja na zahtjev izvođača za produženje roka ako nije ugovorom definirano. Ovo stoga jer su se ispitanici podijelili podjednako u sličnim omjerima na sva tri odgovora, tako da jedna trećina smatra da se tada zahtjev smatra prihvaćenim, druga trećina smatra da se zahtjev smatra suprotno – ne prihvaćenim, dok jedna trećina smatra da će tada zahtjev ostati sporan.

Povodom pitanja tko je dužan osigurati izvedbeni projekt ako nije ugovoreno odgovori su također podjednako podijeljeni među ispitanicima, pa tako jedan dio smatra da je odgovoran naručitelj i projektant, dok ostatak smatra da je odgovoran izvođač, a jedan dio smatra da će i ova situacija ostati sporna.

U situaciji kada naručitelj nije u roku za ovjeru niti osporio niti ovjerio situaciju, a nije ugovorom definirano što tada, jedna trećina ispitanika smatra da će se tada ta situacija smatrati kao da je ovjerena i priznata, dok s druge strane druga trećina ispitanika smatra suprotno, odnosno da će se tada ta situacija smatrati neovjerenom i nepriznatom, dok ostatak ispitanika smatra da nije niti jedno od navedenog te da će ovo pitanje ostati sporno.

U praksi se također kao važno pitanje javlja i opseg ovlasti nadzora, odnosno koje radove je u ime naručitelja nadzor ovlašten naručiti odnosno za koje radove je ovlašten prihvatiti ponudu izvođača. Tako u ovom slučaju jedna trećina ispitanika smatra da je nadzor ovlašten naručiti izvođenje VTR-ova (i nepredviđeni i naknadni radovi), dok druga trećina smatra da je ovlašten naručiti samo nepredviđene, ali ne i naknadne radove. Ostatak ispitanika smatra da nje ovlašten niti jedno od navedenog, te da će takav prihvat ponude ostati sporan.

Stoga, obzirom na ovakve rezultate i podijeljenog mišljenja same struke trebalo bi svaki ugovorni odnos individualno uređivati ovisno o okolnostima konkretnog slučaja, te se ne mogu unaprijed definirati univerzalni uvjeti i pravila za sve.

7. Zaključak

U pogledu primjene određenih instituta FIDIC-a, i to prvenstveno u dijelu standardiziranih isprava nameće se potreba da se u slučaju primjene hrvatskog prava, npr. kroz posebne uvjete FIDIC-a odredi analogija sa srodnim ispravama hrvatskih propisa i to osobito onima koje su nužne zakonske isprave u građevinskom pothvatu.

U dijelu tumačenja uvjeta FIDIC-a kao široko primijenjenih pravila, a ne kao proizvoljno jednokratno određenih ugovornih uvjeta, može se zaključiti da je potrebna posebna pozornost prije mogućeg nekritičkog formalnog tumačenja. Nerijetko se zaboravlja kako načelo „pacta sunt servanda“ (ugovoreno obvezuje) nije jedino a time niti apsolutno načelo. Naša sudska praksa koja je harmonizirana sa sada EU praksom npr. poznaje i načelo razmjernosti. To u bitnome znači da čak i neke odredbe zakona, a time i ugovora, mogu biti tumačene drugačije od onoga što je formalno napisano.

U tom procesu nužno je i razumijevati, kako citirani uvjeti FIDIC-a ponekad ne mogu derogirati zakonske odredbe koje se tiču gubitka prava ugovornih strana zbog propusta radnje u određenom roku. To stoga jer se uglavnom radi o odnosima koji su u pravilu uređeni prisilnim propisima, te se ne mogu mijenjati ugovornim odredbama.

S druge strane ugovorne odredbe kojima na primjer naručitelj (poslodavac) gubi određena prava prema Izvođaču zbog propusta radnje u roku u uvjetima FIDIC-a u pravilu nema, a čime se može dovesti u pitanje načelo Zakona o obveznim odnosima o jednakosti ugovornih strana.

U tom smjeru je najbolji pokazatelj tumačenje gubitka prava, kako je naprijed navedeno po pitanju povrede uvjeta FIDIC-a u dijelu propusta rokova. Prema stajalištu aktualne hrvatske pravne prakse svaki ugovorni rok sam za sebe nužno ne uzrokuje posljedicu gubitka prava, već jedino ukoliko se isti može smatrati bitnim elementom ugovora.

Svakako bi u primjeni ugovaranja uvjeta FIDIC-a bitno pomoglo dopunsko ugovaranje odredbi koje bi povezale i harmonizirale odnos uvjeta FIDIC-a sa hrvatskim prisilnim i dispozitivnim propisima, na način da se određeni opći uvjeti FIDIC-a ne ugovaraju nekritično kao obvezujući, u dijelu gdje prisilni propisi zakona to ne omogućavaju. Jednako tako, dopunskim odredbama bilo bi potrebno urediti i značenje pojedinih isprava koje uređuju uvjeti FIDIC u odnosu na isprave koje poznaje naše pravo.

Dugotrajan i opsežan rad na novim Posebnim uzancama o građenju, stručni skupovi te anketiranje struke pokazali su da postoje otvorena pitanja koja ne bi bilo pravilno unaprijed definirati niti zakonom, niti uzancama o građenju niti uvjetima FIDIC-a. To zato jer bi time bila nerijetko pogrešno definirana slobodna volja naručitelja i izvođača u konkretnim situacijama.

U tom smislu, pravilan pristup i shvaćanje kako uzanci o građenju, tako i općih uvjeta FIDIC-a jest da se oni uvijek razmotre za konkretan ugovorni odnos u cilju kako bi se ugovorom izmijenile i dopunile njihove norme ovisno o stvarnoj volji i cilju ugovaratelja.

Konačno, nakon proteka relevantnog perioda i dostatnog broja sudskih odluka na temu usklađenja proturječnosti hrvatskih propisa i općih uvjeta FIDIC-a bilo bi korisno koordinirati nadležne institucije u cilju izrade preporučenih standardiziranih ugovora o građenju. To kao određeni oblik „hrvatskog FIDIC-a", a kako su to određene zemlje već učinile. Takvi preporučeni ugovori bili bi svakako od značajne koristi za javne naručitelje gdje se očekuje usklađenost u ugovaranju poslova gradnje.

Reference

Vukmir, B. (2009), Ugovori o građenju i uslugama savjetodavnih inženjera, RriF-plus d.o.o., Zagreb.

FIDIC – Uvjeti ugovora o građenju za građevinske i inženjerske radove po projektima naručitelja, izdanje 1987, tzv. Crvena knjiga

FIDIC – Uvjeti ugovora o građenju za građevinske i inženjerske radove po projektima naručitelja, izdanje 1999, tzv. Crvena knjiga

FIDIC – Uvjeti ugovora za postrojenja i projektiranje i građenje za elektrotehničke i strojarske građevinske i inženjerske radove po projektima izvođača, izdanje 1999, tzv. Žuta knjiga

Safu.hr, (2012). Službena internet stranica SAFU dostupno na www.safu.hr/datastore/filestore/332/Provedba_ugovora_o_gradenju.pdf (internetska stranica posjećena 08.08.2017.)

Hgk.hr, (2017). Službena internet stranica HGK dostupno na https://www.hgk.hr/hrvatska-gospodarska-komora/savjetovanje-registracija (internetska stranica posjećena 08.08.2017.)

Zakon o obveznim odnosima (NN 35/05, 41/08, 125/11, 78/15)

Posebne uzance o građenju (Sl. list SFRJ broj 18/77)

Model procjene tržišne vrijednosti stanova nakon energetske obnove

Ratko Matotek[a1]

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Sažetak:

Energetska sigurnost i sprječavanje klimatskih promjena u velikoj mjeri ovise o znatnom poboljšanju energetske učinkovitosti u zgradama. Države Europske unije su kao cilj postavile 20% smanjenja energetske potrošnje do 2020. godine. Prema preuzetim obvezama iz EU Direktive o energetskoj učinkovitosti, Vlada Republike Hrvatske je 2014. godine donijela Dugoročnu strategiju za poticanje ulaganja u obnovu nacionalnog fonda zgrada (NN br. 74/14). Višestambene zgrade građene prije 1987. godine imaju najveće vrijednosti potrebne godišnje toplinske energije za grijanje i potrebnu godišnju konačnu energiju za grijanje, hlađenje, pripremu potrošne tople vode i rasvjetu pa time i najveći potencijal ušteda. U radu će biti prikazan prijedlog modela procjene tržišne vrijednosti stanova nakon energetske obnove toplinske ovojnice višestambenih zgrada uz primjenu metoda iz Zakona o procjeni vrijednosti nekretnina (NN br. 78/15) i pripadajućeg Pravilnika o metodama procjene vrijednosti nekretnina (NN br. 105/15). Primijenit će se sve tri propisane metode, odnosno poredbena, troškovna i prihodovna. Međutim, rezultati modela moći će se potvrditi tek nakon dovoljnog broja prikladnih kupoprodaja poredbenih nekretnina s dovoljno podudarnih obilježja, odnosno stanova u energetski obnovljenim zgradama.

Ključne riječi: *energetska obnova; nekretnina; procjena; stan; tržišna vrijednost*

1. Uvod

Energetska sigurnost i sprječavanje klimatskih promjena u velikoj mjeri ovise o znatnom poboljšanju energetske učinkovitosti (EnU) u zgradama. Države Europske unije (EU) su kao cilj postavile 20% smanjenja energetske potrošnje do 2020. godine. Dugoročni cilj je do 2050. godine smanjenje emisije CO_2 iz sektora zgradarstva od 80 do 95% u usporedbi s 1990. godinom. Prema preuzetim obvezama iz Direktive 2010/31/EU Europskog parlamenta i Vijeća od 19. svibnja 2010. o EnU zgrada (preinaka) (SL L 153, 18.6.2010. Direktiva), Vlada Republike Hrvatske je 2014. godine donijela Dugoročnu strategiju za poticanje ulaganja u obnovu nacionalnog fonda zgrada (NN br. 74/14, Strategija).

U sektoru zgradarstva nalaze se veliki potencijalni uštede energije, stoga je važno djelovati, ne samo na nove zgrade, već i na poboljšanje EnU postojećih zgrada. U pogledu zakonodavnog okvira za EnU u zgradarstvu, Zakonom o gradnji (NN br. 153/13 i 20/17) prenesena je Direktiva, određeni su temeljni zahtjevi za građevine među kojima gospodarenje energijom i očuvanje topline, te je dana osnova da se podzakonskim aktima može detaljno urediti područje EnU. Poboljšanjem EnU zgrada ostvaruju se ciljevi EU, a ujedno i nacionalni ciljevi. U ovom trenutku zgrade, kao najveći individualni potrošač konačne energije, u središtu su politike EnU

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u EU. U Republici Hrvatskoj (RH) zgrade troše čak 43% neposredne potrošnje energije i kao takve predstavljaju velik potencijal za energetske, ekonomske i ekološke uštede. Energetskom obnovom zgrada javnog i stambenog sektora, osim doprinosa nacionalnim ciljevima za EnU i smanjenju emisija CO_2, postižu se i dodatne koristi kao što su stvaranje novih radnih mjesta, razvoj ESCO (Energy Service Company) tržišta, poticanje gospodarskog razvoja kao i smanjenje energetskog siromaštva (Hrs Borković, 2014).

U radu će biti prikazan prijedlog modela procjene tržišne vrijednosti stanova nakon energetske obnove toplinske ovojnice višestambenih zgrada uz primjenu metoda iz Zakona o procjeni vrijednosti nekretnina (NN br. 78/15) i pripadajućeg Pravilnika o metodama procjene vrijednosti nekretnina (NN br. 105/15).

2. Stambeni fond u Republici Hrvatskoj

U Strategiji je dan pregled nacionalnog fonda zgrada u RH, koji sadrži podatke o broju, površini, te građevinskim i energetskim karakteristikama, podijeljen prema namjeni u slijedeće kategorije:

- Višestambene zgrade,
- Obiteljske kuće,
- Zgrade javne namjene i
- Zgrade komercijalne namjene.

Obiteljska kuća je zgrada koja je u cijelosti ili u kojoj je više od 50% bruto podne površine namijenjeno za stanovanje te ima najviše dvije stambene jedinice, izgrađena na zasebnoj građevnoj čestici i građevinske bruto površine do 400 m^2. Višestambena zgrada je svaka ona zgrada koja je u cijelosti ili u kojoj je više od 50% bruto podne površine namijenjeno za stanovanje te ima tri ili više stambenih jedinica, a kojom upravlja upravitelj zgrade koji je pravna ili fizička osoba prema odredbama Zakona o vlasništvu i drugim stvarnim pravima (NN br. 91/96, 68/98, 137/99, 22/00, 73/00, 129/00, 114/01, 79/06, 141/06, 146/08, 38/09, 153/09, 143/12 i 152/14).

Za navedene kategorije zgrada je u Strategiji dan pregled prema razdoblju izgradnje u ovisnosti o načinu gradnje, primijenjenim građevinskim materijalima i važećim tehničkim propisima. Prema provedenoj analizi, zgrade građene prije 1987. godine imaju najveće vrijednosti potrebne godišnje toplinske energije za grijanje i potrebnu godišnju konačnu energiju za grijanje, hlađenje, pripremu potrošne tople vode i rasvjetu pa time i najveći potencijal ušteda.

Tablica 1. Stambeni fond RH prema godini izgradnje (izvor: Strategija, 2014)

Godina izgradnje	Višestambene zgrade			Obiteljske kuće		
	Broj	Površina m^2	%	Broj	Površina m^2	%
do 1940.	37.201	5.830.983	10	64.391	10.092.805	12
od 1941. do 1970.	85.959	13.473.337	24	151.507	23.747.572	27
od 1971. do 1980.	59.882	10.398.113	19	93.109	16.167.887	18
od 1981. do 1987.	44.434	9.401.527	17	68.348	14.461.473	17
od 1988. do 2005.	38.358	8.177.401	15	75.615	16.120.249	19
od 2006. do 2009.	18.256	6.199.252	11	13.762	4.673.079	5
od 2010. do 2011.	6.600	1.957.449	4	4.976	1.475.551	2
Ukupno	290.690	55.438.062	100	471.708	86.738.616	100

Generalno se može zaključiti da su glavne prepreke obnovi nacionalnog fonda zgrada RH legislativne i financijske prirode, ali i da integralnu energetsku obnovu zgrada u velikoj mjeri koči neupućenost i nedovoljna motiviranost investitora, javnosti i interesnih grupa.

Energetska sigurnost i sprječavanje klimatskih promjena u velikoj mjeri ovise o znatnom poboljšanju EnU u zgradama, stoga je vrlo važno naći poticajne mjere za ulaganje u obnovu postojećih zgrada jer su upravo one pojedinačni sektor s najvećim potencijalom za uštedu svih tipova energije te posljedično tome od ključne važnosti za smanjenje emisija stakleničkih plinova u EU (Strategija, 2014).

3. Energetska učinkovitost u zgradarstvu

Zelene ili održive zgrade koriste resurse kao što su energija, voda, materijali i zemljište učinkovitije od zgrada izgrađenih prema važećim minimalnim standardima, proizvodeći manje otpada i emisija te potencijalno nude bolju unutarnju radnu okolinu, što doprinosi zdravlju kao i ostalim koristima (TEGoVA, 2016).

Zelena gradnja se stvara sustavnom primjenom postupaka koji su ekološki i resursno učinkoviti tijekom životnog vijeka zgrade počevši od prostornog planiranja pa sve preko projektiranja, građenja, upravljanja, održavanja i obnove do uklanjanja. Sve je više ovakvog načina gradnje, kojom se nadopunjuje tradicionalna. Zelena gradnja je također poznata kao održiva odnosno visoko EnU (AI Dictionary, 2015). Trenutačno je to jedna od najbrže rastućih aktivnosti u sektoru zgradarstva. Aktivnosti zelene gradnje jest puno više od prolaznog trenda jer je to neposredan odgovor na probleme glede zaštite okoliša te ekonomske i društvene koristi, poboljšavajući zdravlje uz smanjenje troškova građenja i energije (Simmons, 2010).

3.1 Vrednovanje nekretnina

Danas se izuzetno puno govori o održivom razvoju i održivosti, kao pojmovi koji ubrzano postaju sintagme utkane u sve aspekte ljudskog ponašanja. Do danas još ne postoji potpuni dogovor oko definicije održivog razvoja ili održivosti. Najčešće citirana definicija kao *"razvoja koji zadovoljava potrebe sadašnjih bez ugrožavanja mogućnosti budućih generacija za zadovoljavanjem svojih potreba"* dana je 1987. godine u izvještaju Naša zajednička budućnost Svjetske komisije za okoliš i razvoj (Brundtland komisija). U relevantnoj literaturi može se naći razmjerno velik broj različitih metodoloških pristupa problemu ocjene održivosti, a obuhvaća kvalitativni i/ili kvantitativni postupak vrednovanja. Niz metodologija je razvijen s ciljem pokušaja vrednovanja održivosti u zgradarstvu, kao što su:

- Leadership in Energy and Environmental Design (LEED),
- Label for Environmental, Social and Economic Buildings (LENSE),
- Building Research Establishment Environmental Assessment Methodology (BREEAM),
- Sustainable Building Tool (SB TOOL),
- Deutsche Gesellschaft fur Nachhaltiges Bauen (DGNB SYSTEM) i
- Open House.

Svaka od navedene metodologije ima niz odabranih društvenih, ekoloških i ekonomskih indikatora koji sudjeluju u ocjeni stupnja održivosti, najčešće izražene u vrijednosti od 0 do 100. Postizanje stanja održivosti u graditeljstvu danas je teško ostvarivo, a put prema tome ostvaruje se mjerama koje se odnose primjerice na racionalizaciju upotrebe neobnovljivih prirodnih resursa, EnU i slično (Halkijević *et al.,* 2014).

Prema (Adomatis, 2014) u Sjedinjenim Američkim Državama (SAD) su razvijeni i drugi certifikati ocjene održivosti zgrada, kao što su:

- The ICC 700 National Green Building Standard,
- International Code Council (ICC) i
- Energy Star.

Ostali poznati standardi su HQE u Francuskoj, CASBEE u Japanu, te Green Star i NABERS u Australiji. Pojedine države imaju vlastite standarde, a svaki se razlikuje po tome što i kako se vrednuje. Energetski certifikati nude normativni pristup kod energetskih ocjena u EU, dok je u SAD-u razvijen tzv. Go Green sustav. Svi se pristupi različito primjenjuju u raznim državama, tako da čak i energetski certifikati variraju među državama članica EU, što predstavlja probleme za procjene vrijednosti nekretnina prilikom uspoređivanja podataka (TEGoVA, 2016). Različiti modeli vrednovanja nekretnina jedan je od većih problema s kojima se susreću procjenitelji kada uspoređuju podatke prilikom procjenjivanja vrijednosti nekretnina (Adomatis, 2014).

3.2 Vrednovanje nekretnina u Republici Hrvatskoj

U RH je vrednovanje EnU nekretnina regulirano Zakonom o gradnji (NN br. 153/13 i 20/17) prema kojem je između ostaloga u pravni poredak prenesena Direktiva. Svaka građevina, ovisno o svojoj namjeni, mora biti projektirana i izgrađena na način da tijekom svog trajanja ispunjava temeljne zahtjeve za građevinu. Higijena, zdravlje i okoliš te gospodarenje energijom i očuvanje topline, kao i održiva uporaba prirodnih izvora, tri su od sedam temeljnih zahtjeva. Građevine i njihove instalacije za grijanje, hlađenje, osvjetljenje i provjetravanje moraju biti projektirane i izgrađene tako da količina energije koju zahtijevaju ostane na niskoj razini, uzimajući u obzir korisnike i klimatske uvjete smještaja građevine (Zakon, 2013).

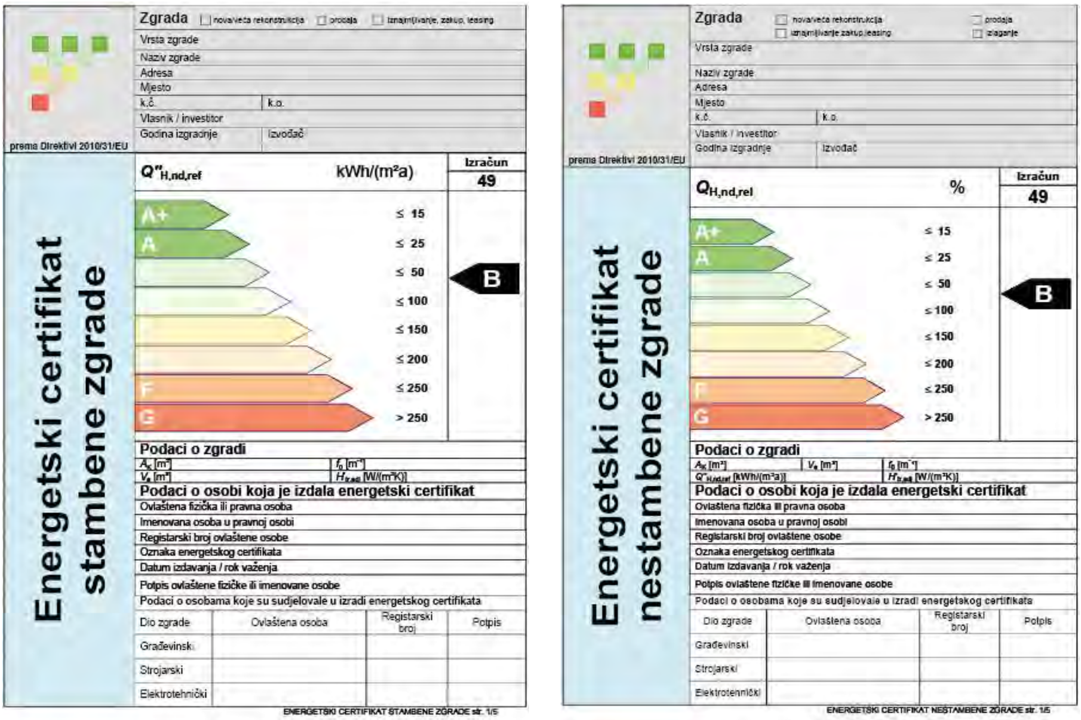
Energetski certifikat predočuje energetska svojstva. Izdaje se za zgradu, odnosno njezin poseban dio za koji je potrebno koristiti energiju za održavanje unutarnje projektne temperature u skladu s njezinom namjenom (Zakon, 2013). Posebni dio zgrade čini samostalna uporabna cjelina zgrade kao što su stan odnosno apartman, poslovni prostor i slično unutar zgrade, a predviđena je ili preuređena za zasebno korištenje (Pravilnik, 2014).

Stambene i nestambene zgrade svrstavaju se u 8 energetskih razreda prema energetskoj ljestvici od A+ do G. Energetski razred zgrade jest indikator energetskih svojstava zgrade koji se izražava preko godišnje isporučene energije za referentne klimatske podatke. Za stambene zgrade uključuje energiju za grijanje, hlađenje, pripremu potrošne tople vode i ventilaciju. A+ označava energetski najpovoljniji razred, a G energetski najnepovoljniji (Pravilnik 2014).

Energetski certifikat sadrži prijedlog mjera koje utječu na energetski razred i koje ne utječu na energetski razred, a odnose se na troškovno optimalno ili troškovno učinkovito poboljšanje energetskih svojstava (Pravilnik, 2014). Prijedlog mjera u energetskom certifikatu uključuje:

- mjere koje se provode na dijelovima zgrade i
- optimalnu kombinaciju mjera.

Energetski certifikat važi 10 godina od dana njegova izdavanja. Vlasnik ga je dužan prije prodaje, iznajmljivanja, davanja u zakup ili davanja na leasing zgrade ili njezinoga posebnog dijela pribaviti te kupcu, najmoprimcu, zakupcu, odnosno primatelju leasinga predati certifikat ili fotokopiju. Isto tako je dužan u oglasu koji se objavljuje u medijima navesti energetski razred (Zakon, 2013).



Slika 1. Obrasci energetskih certifikata za stambene i nestambene zgrade (izvor: Pravilnik, 2014)

4. Energetska obnova

Graditeljstvo će biti ključna industrijska grana budućnosti. Zgrade s visokom EnU važne su u realizaciji novog energetskog sustava koji će zamijeniti fosilnu energiju i riskantne nuklearne tehnologije. Zgrade koje se danas grade ili obnavljaju bit će u uporabi slijedećih 50 do 100 godina. Većina njih bit će uporabljiva i onda, kada se više neće primjenjivati energija fosilnih goriva za stvaranje udobnosti unutarnjih prostora, a energetska obnova značajno smanjuje potrošnju energije za grijanje i hlađenje te tako štedi novac (Schild, 2014).

4.1 Stanje u Europskoj uniji

Na razini EU postignut je značajan napredak u smanjenju potrošnje energije. U razdoblju od 2005. do 2013. godine konačna potrošnja energije ukupno se smanjila za 7%. U kućanstvima se konačna potrošnja energije 2013. godine smanjila za 3% u usporedbi s razinom iz 2005. godine. Potrošnja energije po kvadratnom metru smanjila se u svim državama članicama od 2005. do 2013. godine, osim u Italiji, gdje se povećala za 10%, kao i u Estoniji, gdje se nije promijenila. Do sveukupnog smanjenja uglavnom je došlo zahvaljujući mjerama za poboljšanje EnU, posebno s obzirom na potrošnju energije za grijanje. Niža potrošnja energije može se objasniti i strožim zahtjevima za EnU zgrada, uređaja i tehnologija grijanja, djelomično zbog sve bolje provedbe Direktive (Izvješće, 2015a).

Države članice utvrdile su 2013. godine nacionalne indikativne ciljeve povećanja EnU. Cilj je potrošnju energije odvojiti, zahvaljujući povećanju učinkovitosti, od gospodarskog rasta. U tom kontekstu indikativni ciljevi koje su postavile Hrvatska, Cipar, Finska, Grčka, Italija, Portugal i Rumunjska nisu dovoljno ambiciozni jer je predviđena konačna potrošnja energije viša od prognoziranog rasta BDP-a od 2014. do 2020. godine (Izvješće, 2015a).

Zaključak Europske komisije je da države članice moraju bolje informirati potrošače o mogućnostima EnU i dodatno poboljšati uvjete za ulaganja privatnih vlasnika kako bi se ubrzala trenutačno vrlo spora obnova postojećeg fonda nekretnina u EU. U tom su sektoru potrebne ciljane mjere jer kućanstva slabije reagiraju na povećanje cijena energije nego, primjerice, energetski intenzivna industrija. Osim toga, potrebne su usmjerenije mjere za osjetljive potrošače kako bi se učinkovito riješilo energetsko siromaštvo i poboljšao životni standard. Na primjer, korisna bi bila mjera poput beskamatnih kredita (Izvješće, 2015a).

Cjelovita energetska obnova zgrada ne utječe samo na smanjenje potrošnje energije, emisiju CO_2 i troškove korištenja zgrada, nego i na poboljšanje uvjeta za korisnike kao i na vrijednost samih nekretnina. Energetski visokoučinkovite novogradnje su dnevna građevinska praksa u EU radi povećanja potražnje za nekretninama, koje su bolje od minimalnih zahtjeva glede EnU. Korištenje suvremenih tehničkih rješenja na novim zgradama su se na neki način odrazili i u obliku neposrednog poticaja na kvalitetniju i cjelovitiju energetsku obnovu postojećih nekretnina. Potencijal ušteda je kod obnove puno veći zbog lošijeg polazišta. Prosječna postojeća zgrada koristi barem tri puta više konačne energije u odnosu na novogradnju s minimalnom razinom EnU. Zbog toga je segment energetske obnove zgrada prepoznat u EU kao područje s najvećim potencijalom za energetske uštede (Praznik i Veršić, 2016).

4.2 Stanje u Republici Hrvatskoj

Zgrade izgrađene prije nekoliko desetljeća veliki su potrošači toplinske energije, a samim time takve zgrade ne ispunjavaju zahtjeve vezane uz EnU koji su trenutačno na snazi. Udio stambenih jedinica izgrađenih do 1995. godine u RH u ukupnom fondu postojećih zgrada prema podacima iz 2010. godine iznosi 91,18%. Većina tih zgrada će se i dalje koristiti u budućnosti iako ne budu rekonstruirane u smislu povećanja EnU pa će i dalje nepotrebno trošiti velike količine energije za grijanje i hlađenje. Prilikom planiranja i davanja preporuka o mjerama poboljšanja potrebno je voditi računa o isplativosti, koja se procjenjuje na osnovi jednostavnog perioda povrata (JPP) investicije za svaku od predloženih mjera i za sve mjere zajedno (Krstić i Teni, 2016).

Za potrebe energetske obnove zgrada pozornost se usmjerava na zgrade građene prije 1987. godine te na njihovu obnovu na niskoenergetski standard i postizanje energetskog razreda B, A ili A+. Preduvjet za provođenje mjera je izrađena projektna dokumentacija u skladu s relevantnim zakonodavstvom. Također, preduvjet provedbe je i proveden energetski pregled zgrade koji uključuje razradu preporučenih mjera i uspostavu sustava gospodarenja energijom. Mjere za poticanje obnove višestambenih zgrada obuhvaćaju:

- energetski pregledi i energetsko certificiranje zgrada,
- potpore za izradu projektne dokumentacije za obnovu zgrade i
- poticanje integralne obnove višestambenih zgrada (Strategija, 2014).

Različiti modeli ulaganja u održivu obnovu zgrada daju različite rezultate u pogledu visine, strukture i dinamike ulaganja, no, svi oni proizvode neposredne učinke na:

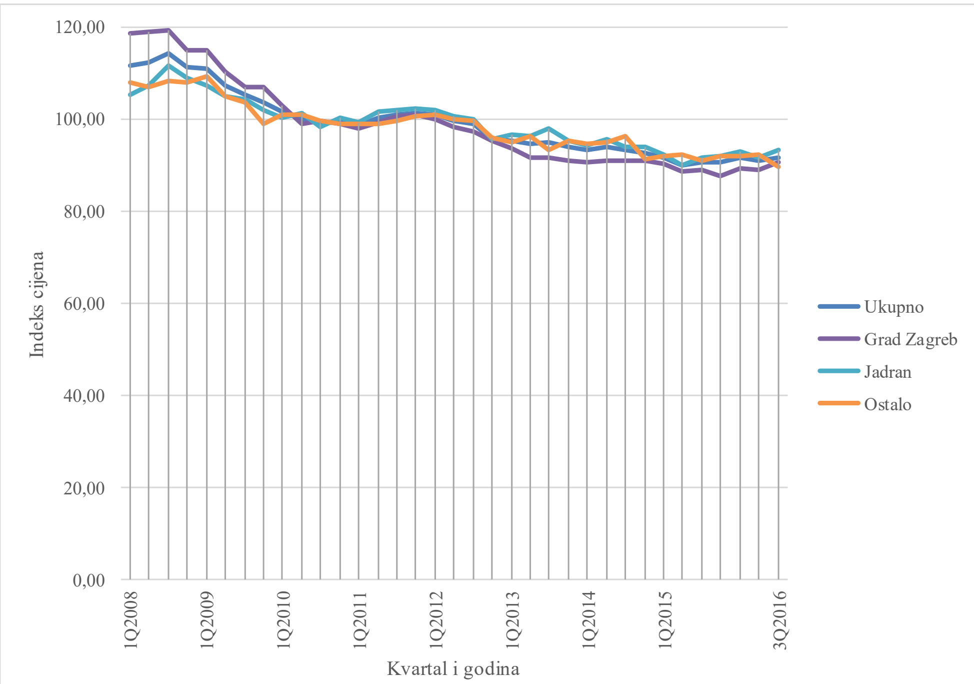
- stabilizaciju i povećanje gospodarske aktivnosti,
- zapošljavanje,
- javne (proračunske) prihode,
- poboljšano zdravlje ljudi,
- smanjenje energetskog siromaštva i
- povećanje vrijednosti nekretnina (Strategija, 2014).

Važan segment koji se ostvaruje provedbom programa energetske obnove zgrada je širenje tržišta rada kroz osiguranje posla za energetske certifikatore, projektante, izvođače i proizvođače opreme i materijala. Također se poboljšava stanje i tržišna vrijednost nekretnina, a dodatni pozitivni učinci kroz utjecaj na zapošljavanje i proračun daleko premašuju uložena sredstva (Hrs Borković, 2014).

5. Tržište nekretnina u Republici Hrvatskoj

Snažno izražen dugoročni građevinski i poslovni ciklus utjecao je na kretanje cijena nekretnina u RH. Pad cijena uslijedio je nakon cjenovnog vrhunca 2008. godine u Zagrebu i 2009. godine na Jadranu. Do kraja 2013. godine cijene su pale u odnosu na maksimum za oko 32%. Prema međunarodnoj bazi cijena nekretnina za 54 države, slični su se padovi cijena u istom razdoblju dogodili i u Sloveniji, Rumunjskoj, Latviji, Grčkoj, Estoniji i Bugarskoj, te za određene tipove nekretnina u Danskoj i Japanu (Strategija, 2014).

Opisani cjenovni ciklus ne može se objasniti samo ukupnom gospodarskom situacijom i napuhavanjem cjenovnog balona prije krize jer se u državama slične makroekonomske dinamike javljaju vrlo različite cjenovne amplitude. U RH su one izraženije nego u drugim državama sličnih makroekonomskih karakteristika (Strategija, 2014).



Slika 2. Indeksi cijena stambenih nekretnina (ICSN) 2010. = 100 (izvor: DZS, 2016)

Prednost vlasništvu nad nekretninom kod novijih generacija s neiskorištenim kreditnim potencijalom uzrokovala je razmjerno veću potražnju za novogradnjama nego za obnovom. Pretjerani naglasak na novogradnje i zanemarivanje obnove doveli su do izraženijih cjenovnih oscilacija u RH. Prestankom potražnje nastale su zalihe neprodanih stanova, pa time i pad cijena koji je dodatno izražen kod starijih nekretnina koje su u međuvremenu slabije održavane. Zanemarivanje obnove ima utjecaj i na tržište rada, gdje su znanja i napori usmjeravani k novogradnjama, dok su zanemarena neka specifična znanja i vještine u adaptacijama i rekonstrukcijama, osobito vezana uz energetsku obnovu. Kako se ova pogreška može ispraviti poticanjem rekonstrukcijskih aktivnosti, potrebno je mjerama politike osigurati stabilan tok tih poslova (Strategija, 2014).

6. Metode procjene vrijednosti nekretnina

Tržište nekretnina obiluje ponudom niza zemljišnih čestica različite kakvoće, ali i posebnih odnosa. U cijenama koje se navode u ugovorima (kupovnim cijenama) često je teško otkriti objektivne i subjektivne čimbenike koji su utjecali na utvrđivanje kupovne cijene. Temeljno pravilo za procjenu vrijednosti neke nekretnine je procjena koristi koja se može ostvariti njenom uporabom. Procjena realne vrijednosti nekretnine ubraja se u složene zadaće jer je tržište nekretnina s mnogo nepoznanica i niza posebnih odnosa (Krtalić, 2008).

Zakonom o procjeni vrijednosti nekretnina (NN br. 78/15, Zakon) određuju se metode procjenjivanja vrijednosti nekretnina te načini procjene vrijednosti prava i tereta koji utječu na vrijednost nekretnine, procjene iznosa naknade za izvlaštene nekretnine kao i prikupljanja, evidentiranja, evaluacija i izdavanje podataka potrebnih za procjene vrijednosti nekretnina za sve nekretnine u RH, neovisno u čijem su vlasništvu. Na osnovi Zakona Pravilnik o metodama procjene vrijednosti nekretnina (NN br. 105/15, Pravilnik) razrađuje osnovne metode, poredbena, troškovna i prihodovna. S obzirom na to da se Zakon primjenjuje samo kada je potrebno odrediti tržišnu vrijednost nekretnina, ključna je definicija tog pojma, koja je preuzeta iz Uredbe (EU) br. 575/2013, i glasi: *"Tržišna vrijednost nekretnine je procijenjeni iznos za koji bi nekretnina mogla biti razmijenjena na dan vrednovanja, između voljnog kupca i voljnog prodavatelja, u transakciji po tržišnim uvjetima nakon prikladnog oglašavanja, pri čemu je svaka stranka postupila upućeno, razborito i bez prisile."* Takva definicija identična je u EVS-u (European Valuation Standards) te IVS-u (International Valuation Standards) (Uhlir, 2015). Važno je naglasiti da vrijednost ne predstavlja stvarni iznos novca koji je potrebno platiti u nekoj transakciji između dvije strane (TEGoVA, 2016).

Procjena vrijednosti nekretnina je multidisciplinarna djelatnost koja zahtjeva specifična znanja, vještine i iskustvo. Procjenitelj bi trebao poznavati osnove prava, ekonomije, graditeljstva i prostornog uređenja te posjedovati dovoljno iskustva kako bi mogao ta svoja znanja korisno upotrijebiti (Uhlir, 2015). Popis potrebnih kompetencija za procjenitelje vrlo dobro je sistematiziran u MER (Minimum Educational Requirements):

- Procjenitelji moraju razumijevati načela ekonomske teorije, primijenjenu ekonomiju nekretnina te poslovanje i financije.
- Procjenitelji moraju imati opće znanje o oglašavanju nekretnina, EnU, zaštiti okoliša, gradnji i konstrukcijama (zgradama i građevinama) te prostornom planiranju.
- Procjenitelji moraju imati dubinsko znanje o pravnim propisima o nekretninama, propisima koji uređuju gradnju i prostorno uređenje, javnim politikama, profesionalnoj

praksi vrednovanja, propisanim načelima i metodama procjene vrijednosti nekretnina (TEGoVA, 2016).

6.1 Poredbena metoda

Poredbena metoda u prvom je redu primjerena za utvrđivanje tržišne vrijednosti neizgrađenih i izgrađenih zemljišta, a koristi se i za procjenu vrijednosti samostojećih, poluugrađenih i ugrađenih obiteljskih kuća, obiteljskih kuća u nizu, stanova, garaža kao pomoćne građevine, garažnih parkirnih mjesta, parkirnih mjesta i poslovnih prostora. Poredbenom metodom tržišna se vrijednost određuje iz najmanje tri kupoprodajne cijene (transakcije) poredbenih nekretnina (Pravilnik, 2015).

Treba naglasiti ispravno korištenje podataka o poredbenim nekretninama, odnosno korištenje onih nekretnina koje imaju dovoljno podudarajućih obilježja s procjenjivanom nekretninom (Uhlir, 2015).

6.2 Troškovna metoda

Troškovna metoda u prvom je redu primjerena za utvrđivanje tržišne vrijednosti izgrađenih građevnih čestica na kojima se nalaze zgrade javne namjene i druge građevine koje svojim oblikovanjem nisu izgrađene sa svrhom stvaranja prihoda. Isto tako je primjerena i pri procjeni vrijednosti šteta i nedostataka na građevinama te naknadnih ulaganja u građevine (Pravilnik, 2015).

Kod troškovne metode dolazi se do vrijednosti nekretnine preko troškova gradnje i pripadnog zemljišta. S obzirom na to da utrošak rada i materijala za gradnju ništa ne govore o tržišnoj vrijednosti te nekretnine, potrebno je korigirati tako dobiven rezultat prema tržišnim uvjetima. Troškovna metoda dobro se dopunjuje poredbenom metodom, upravo zbog tržišne koncepcije (Uhlir, 2015).

Normalni troškovi gradnje su troškovi koji bi na tržištu nastali za građenje novih građevina a pripadaju im i obično nastali uzgredni troškovi. Prilagođavaju se cjenovnim odnosima na dan vrednovanja uz pomoć prikladnih indeksnih nizova za cijenu gradnje. Obuhvaćaju uobičajene troškove gradnje u određenom razdoblju uključivo iznos odgovarajuće stope poreza na dodanu vrijednost u odnosu na vrstu građevine, godinu izgradnje i standard gradnje procjenjivane građevine (Pravilnik, 2015).

6.3 Prihodovna metoda

U prihodovnoj se metodi vrijednost utvrđuje temeljem prihoda koji se postižu na tržištu (održivi prihodi). Prihodovna vrijednost se prema Pravilniku može utvrditi na temelju 3 metode:

- opća prihodovna metoda (tzv. dvotračna prihodovna metoda),
- pojednostavljena prihodovna metoda (tzv. jednotračna prihodovna metoda) i
- periodična prihodovna metoda.

Općom prihodovnom metodom se vrijednost utvrđuje temeljem postignutih prihoda na tržištu iz utvrđene vrijednosti zemljišta uvećane za kapitaliziranu razliku čistog prihoda (razlika između ukupnog godišnjeg prihoda i troškova gospodarenja) i odgovarajućeg ukamaćivanja vrijednosti prema općenitom izrazu:

$$PV = (PG - VZ \times p/100) \times M + VZ; M = (q^n-1)/(q^n(q-1)); q = 1 + (p/100) \quad (1)$$

gdje su: PV – prihodovna vrijednost nekretnine, PG – čisti godišnji prihod građevine,
VZ – vrijednost zemljišta, M – multiplikator, p – kamatna stopa na nekretnine,
n – predvidi ostatak održivog vijeka korištenja građevine (OOVK).

Periodična prihodovna metoda sastoji se od razmatranog i preostalog razdoblja, a vrijednost se računa prema slijedećem izrazu:

$$PV = \sum_{i=1}^{b} PG_i \times q^{-i} + PRV \times q^{-b} \quad (2)$$

$$PRV = PG_{PR} \times M_{PR} + VZ \times q^{-PR}; PR = n - b \quad (3)$$

gdje su PV – prihodovna vrijednost nekretnine; PG_i – čisti periodični prihod građevine unutar razmatranog razdoblja (na godišnjoj osnovi); PG_{PR} – čisti prihod nakon isteka razmatranog razdoblja; PRV – preostala vrijednost katastarske čestice; VZ – vrijednost zemljišta bez samostalno iskoristive djelomične površine; q^{-i} – diskontni faktor za pojedinačne periode unutar razmatranog razdoblja; q^{-b} – diskontni faktor za razmatrano razdoblje; q^{-PR} – diskontni faktor za preostalo razdoblje; M_{PR} – multiplikator za preostalo razdoblje; i – periodi (godišnji) unutar promatranog razdoblja; p – kamatna stopa na nekretnine; n – predvidivi ostatak održivog vijeka korištenja građevine; b – broj perioda (kod godišnjeg razmatranja) unutar razmatranog razdoblja; PR – preostalo razdoblje.

Važno je za napomenuti da se vrijednost zemljišta uvijek izračunava poredbenom metodom.

Ukupni godišnji prihod uključuje sve na tržištu ostvarive buduće prihode tijekom jedne godine od korištenja nekretnine, ostvarenih uz primjereno gospodarenje i dopušteni način korištenja, osobito od najamnine i zakupnine, uključujući i naknade (Zakon, 2015).

Troškovi gospodarenja nekretninom odnose se na godišnje izdatke koji se uzimaju u obzir i koji nastaju na tržištu uz primjereno gospodarenje i dopušteni način korištenja nekretnine, a nisu pokriveni davanjima ili drugim uzimanjima, te obuhvaćaju troškove upravljanja nekretninom, troškove održavanja, rizik od gubitka najamnine i/ili zakupnine i pogonske režijske troškove (Zakon, 2015).

Financijski pokazatelji investicijskih ulaganja razvijenih zemalja u stambeni fond pokazuju da sredstva uložena u održavanje postojećih zgrada sve više premašuju sredstva uložena u izgradnju novih (Krstić i Marenjak, 2012). Do prije nekoliko godina sva je pozornost investitora, projektanata i izvođača bila usmjerena na smanjivanje troškova građenja, a malo je sudionika posvećivalo pažnju smanjivanju troškova gospodarenja ili još važnije, smanjivanju ukupnih troškova projekata. Promatrano sa stajališta održive gradnje, proračun troškova gospodarenja ima veliku važnost budući da su zgrade jedan od najvećih potrošača energije, a najveći dio potrošene energije odnosi se na toplinske potrebe (Krstić i Marenjak, 2012a).

Pravilnikom je propisana procjena predvidivog ostatka održivog vijeka korištenja (OOVK) primjenom faktora korištenja (FK) kao stupnja uporabivosti, koji navodi u kojoj mjeri zgrada odgovara i dalje može odgovarati zahtjevima za suvremenim uvjetima stanovanja i rada, tj. u kojoj mjeri trajno i gospodarski može ispunjavati svrhu korištenja. To je u suštini broj godina u kojima je građevinu moguće još gospodarski koristiti dopuštenim načinom korištenja, a može se produžiti održavanjem, rekonstrukcijom i osuvremenjivanjem, odnosno bitnim poboljšanjem uvjeta uporabe, osobito u pogledu povećanja EnU ili se može i skratiti izostankom navedenih mjera ili neprikladnim aktivnostima (Zakon, 2015).

6.4 Procjena energetski učinkovitih nekretnina

Zelena gradnja predstavlja nove prilike za procjenitelje zgrada stambene namjene (Simmons, 2010). Kako je potrošnja energije jedan od najznačajnijih troškova u korištenoj nekretnini, potencijalne kupce i najmoprimce osim dostupnosti zanimaju i režijski troškovi. EU i pojedine države se nadaju kako će imati utjecaj na korisnike nekretnina u promjeni svojeg ponašanja, smanjenje potrošnje, poboljšanje EnU i što veće korištenje obnovljivih izvora energije. Na taj način zgrade imaju znatno duži vijek trajanja. Europska komisija očekuje kako će od 75% do 90% sadašnjih zgrada biti u uporabi do 2050. godine s godišnjom stopom uklanjanja od 0,1%, te sa stopom obnove od 1,2% (TEGoVA, 2016).

Procjenitelj svoje mišljenje o vrijednosti nekretnine daje na temelju dostupnih podataka, uključujući podatke s tržišta, što je ključno za koncept tržišne vrijednosti. Troškovi energije i EnU su jedno od mnogih pitanja koje procjenitelj treba uzeti u obzir (TEGoVA, 2016). Prilikom procjenjivanja nekretnina lokalnog tržišta, vrijednost EnU nekretnina ovisi o tome da li je tržište takvih nekretnina izdvojeno na tržištu, odnosno da li se radi o tržištu samo EnU nekretnina ili svih nekretnina (Simmons, 2010).

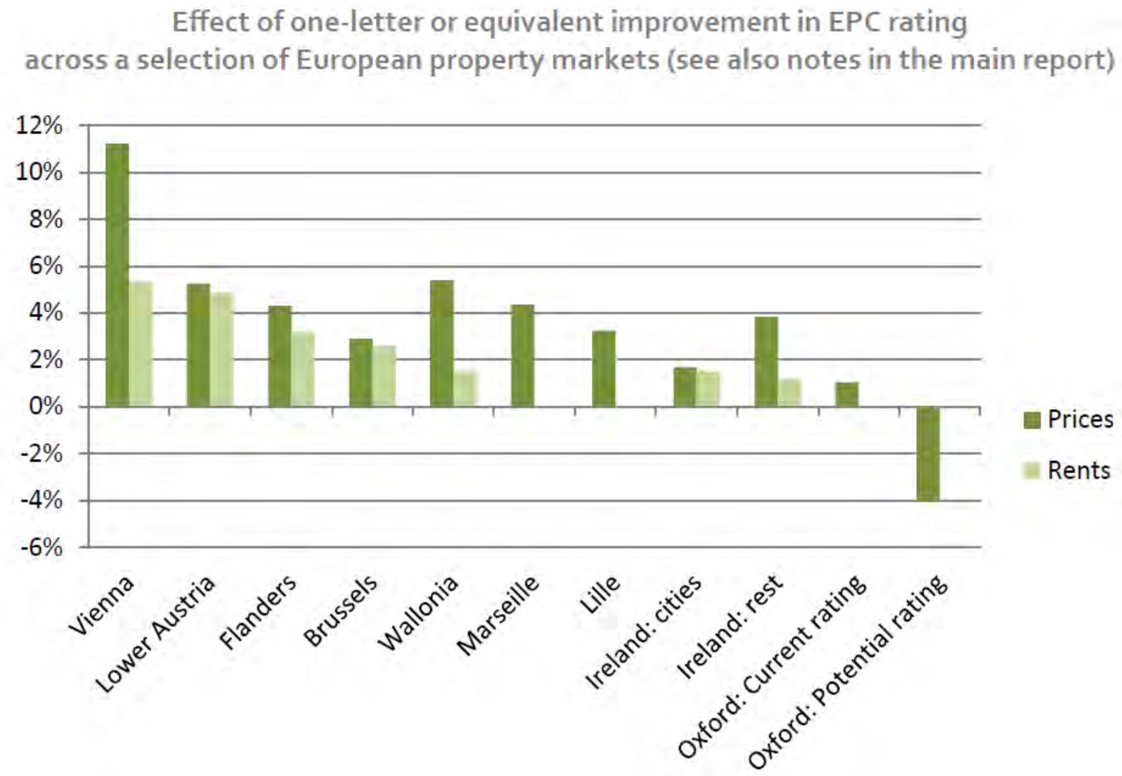
Povoljan učinak ulaganja u obnovu zgrada u tom će se slučaju pojaviti i zbog smanjenih kolebanja cijena i povećanja vrijednosti obnovljenih nekretnina u budućnosti. Učinak povećanja vrijednosti obnovljenih nekretnina može se procijeniti, no zahtijeva složenije modeliranje. Potrebno je prikupiti podatke o transakcijama pojedinih nekretninama, zatim podatke o kvaliteti i ulaganjima u predmetne nekretnine, te uz kontrolu učinaka makroekonomskih čimbenika poput BDP-a i kamatnih stopa, procijeniti koliko ulaganje utječe na postignutu tržišnu cijenu (Strategija, 2014).

Brojne studije su pokazale da se energetskom obnovom i dovođenjem zgrade iz lošeg energetskog razreda D, E, F ili G u bolji C, B, A ili A+ povećava vrijednost nekretnine u prosjeku za 16% (Hrs Borković, 2015).

Analize u SAD-u pokazuju da zgrade zelene gradnje sa certifikatom postižu 4,8% veću cijenu a na tržištu se oglašavaju 25% kraće vremena u odnosu na slične nekretnine, koje nemaju certifikate (Simmons, 2010).

Prema istraživanju koje je provedeno pod pokroviteljstvom RICS (Royal Institution of Chartered Surveyors) i Intelligent Energy Europe, analizirani su modeli kojima se prilikom vrednovanja nekretnina može obuhvatiti utjecaj EnU. Ovisno o razvijenosti tržišta nekretnina, tj. evidencije i kvalitete podataka na tržištu, predložena je podjela na razvijeno i nerazvijeno tržište i prema njima prilagođeni postupci kojim se, u okviru metoda za vrednovanje nekretnina, pronalazi utjecaj EnU na vrijednost nekretnine. Rezultati navedenog istraživanja pokazali su opće stanje na tržištu nekretnina EU za koje još nije prikupljeno dovoljno podataka kako bi se nedvojbeno mogao odrediti utjecaj EnU na vrijednost nekretnina. Eksperimentalni primjeri korišteni u istraživanju pokazali su kako je za izrazito EnU zgrade, s jasno iskazanim uštedama, moguće povećanje vrijednosti između 5% i 10%. Navedeno upućuje na rijetku potrebu provjere dodatnog utjecaja EnU pa ako procjenitelj prema raspoloživom energetskom certifikatu i stanju nekretnine prepozna visok stupanj EnU koji znatno odstupa od pretežitog na lokalnom tržištu nekretnina, tada postoji racionalan razlog za provjeru utjecaja EnU na vrijednost nekretnine (Majčica i Uhlir, 2016).

Slično istraživanje, provedeno pod pokroviteljstvom Europske komisije (DG Energy), upućuje na razlike između država članica i potrebu da svaka država provede svoju detaljnu analizu (Majčica i Uhlir, 2016). Prema rezultatima istraživanja u Austriji, za područje Beča i šire okolice, poboljšanje za jedan energetski razred utječe na povećanje cijena prodanih nekretnina za 8% a najamnina za 4,4%. Slično tome, analize u Belgiji pokazuju jasan odnos između EnU te tržišnih cijena i najamnina. Tako se poboljšanje EnU za 100 bodova povezuje s 4,3% višim cijenama prodanih nekretnina, dok utjecaj na povećanje najamnina iznosi 3,2%. U Francuskoj je vrlo snažan pozitivan odnos između EnU i cijena stanova u Marseillesu. Poboljšanje za jedan energetski razred povezano je s 4,3% višim cijenama, dok za Lille povećanje iznosi 3,2%, što je u suprotnosti s intuicijom da će EnU biti više prepoznata u područjima s većom ovisnošću o energiji. U Irskoj se učinak poboljšanja za jedan energetski razred procjenjuje na 2,8% veće cijene u prodaji i za 1,4% prilikom iznajmljivanja. Uspoređujući navedene rezultate za prodajne cijene i najamnine uočava se značajna razlika između neposrednih kratkoročnih koristi kao što su uštede na računima i dugoročnih koristi koje se odnose na veće vrijednosti nekretnina prilikom prodaje (DG Energy, 2013).



Slika 3. Utjecaj poboljšanja za jedan energetski razred na prodajne cijene i najamnine (izvor: DG Energy, 2013)

Tržišne analize u nekim dijelovima SAD-a potvrđuju da su kupci spremni platiti više za nekretnine s nekim od certifikata, kao što je LEED. Međutim, procjenitelji trebaju za svako tržište pažljivo uzimati u obzir zelenu gradnju. U kontekstu profesionalnih procjenjivačkih standarda procjena zelene gradnje je složena zadaća jer najvjerojatnije uključuje manjkave tržišne podatke te zahtjeva od procjenitelja posebna dodatna znanja i iskustvo. Tržište određuje vrijednosti, dok procjenitelji razvijaju mišljenja o vrijednostima temeljeno na tržišnim podacima upotrebom različitih metoda (Adomatis, 2014).

S obzirom da je zelena gradnja novost na mnogim lokacijama, tržišne aktivnosti i podaci su ograničavajući. U nekim slučajevima se može dogoditi da se tek prva nekretnina procjenjuje od nekoliko postojećih EnU u području. U takvim slučajevima će procjenitelj trebati upotrijebiti poredbene nekretnine sa šireg područja ili će možda biti primoran na kraju upotrijebiti podatke o zgradama izgrađenima i na tradicionalni način i na EnU. Tržište vezano za obnovu postojećih stambenih zgrada je u porastu i nastavit će se u razdoblju koje slijedi. Međutim, razlike u tržišnoj vrijednosti se ne mogu mjeriti ako voljni kupac nije svjestan koristi zelene gradnje u odnosu na tradicionalnu (Simmons, 2010).

7. Analiza slučaja

Za analizu slučaja odabrana je višestambena zgrada u Čakovcu, sagrađena 1964. godine. Izgrađena je u etažama suterena sa spremištima, prizemlja i 2 kata sa stanovima, iznad kojih se nalazi tavanski prostor. Organizacijski se sastoji od dva zasebna stubišta (ulaz lijevo i desno) s dva stana na svakom katu pojedinog ulaza. Ukupno se radi o 12 stanova, svaki grijane korisne površine od 51,07 m^2. Za zgradu je 2015. godine izdan energetski certifikat oznake P_99_2011_350_SZ2, kojim se svrstava u energetski razred F sa $Q''_{H,nd,ref}$ od 239 kWh/(m^2a). Osim toga, izrađeni su i energetski certifikati za svaki stan zasebno, što je omogućeno Zakonom o gradnji jer se radi o samostalnim uporabnim cjelinama.

U tablici 2. su prikazane geometrijske karakteristike zgrade te stvarni koeficijenti prolaska topline prema građevnim dijelovima, uz usporedbu s dopuštenima kao i drugi podaci.

U tablici 3. su prikazani energetski razredi za svaki stan zasebno. Do razlika u potrebnoj godišnjoj toplinskoj energiji za grijanje dolazi, osim zbog položaja stanova, i zbog toga što su neki vlasnici već zamijenili postojeće prozore novima. Tako npr. stan u prizemlju lijevo na ulazu lijevo ima bolji energetski razred od stana u prizemlju desno na ulazu desno, jer je vlasnik zamijenio prozore. Stanovi s manjom ploštinom ovojnice imaju značajno bolji energetski razred zbog položaja u zgradi, a to su stanovi na 1. katu, jer nemaju negrijani podrum ispod ili pak provjetravani tavan iznad grijanog prostora. Kako prozori nisu zajednički dio zgrade, na svakome je od vlasnika pojedinog stana da li će ih zamijeniti energetski učinkovitijim. Što se pak tiče vanjskih zidova, odnosno fasade, radi se o zajedničkom dijelu zgrade.

Predložena mjera obnove toplinske ovojnice vanjskih zidova ETICS sustavom debljine toplinskog sloja od 14 cm s λ=0,037 W/(mK), daje energetski razred E tj. $Q''_{H,nd,ref}$=162 kWh/(m^2a) uz JPP od 12 godina. Kombinacijom svih predloženih mjera (izoliranje vanjskih zidova, stropa prema negrijanom podrumu i provjetravanom tavanu te zamjena prozora i vrata) moguće je postići energetski razred B tj. $Q''_{H,nd,ref}$=48 kWh/(m^2a). U primjeru su sve analize rađene na temelju predložene mjere obnove vanjskih zidova (fasade).

Tablica 2. Glavne karakteristike zgrade (izvor: autor, 2015)

Ploština korisne površine zgrade A_k:		612,84 m^2
Ploština toplinske ovojnice A:		1.496,56 m^2
Ploština vanjskih zidova (fasada):		726,72 m^2
Obujam grijanog dijela zgrade V_e:		2.200,46 m^3
Faktor oblika zgrade f_0:		0,68 m^{-1}
Orijentacija zgrade:		N, S, E i W
Koeficijent prolaska topline [W/m^2K]:	Stvarni U	Dopušteni U_{max}
- vanjski zidovi:	1,25	0,30
- strop prema provjetravanom tavanu:	1,71	0,25
- strop prema negrijanim prostorijama:	1,53-1,83	0,40

- zid prema negrijanim prostorijama:	1,30	0,40
- prozori:	3,60	1,40*
- vrata:	3,50	2,00
Godišnja toplinska energija za grijanje $Q_{H,nd}$ [kWh/m^{2}a]:		235,37 kWh/(m^{2}a)
Energetski razred:		F

** prema uvjetima u vrijeme izdavanja certifikata (trenutno iznosi 1,60 W/m^{2}K)*

Tablica 3. Energetski razredi po stanovima (izvor: autor, 2015)

Stubište:	Ulaz lijevo		Ulaz desno	
Položaj stana na etaži:	Lijevo	Desno	Lijevo	Desno
Orijentacija:	ugaoni N, S i E	poprečni N i S	poprečni N i S	ugaoni N, S i W
Prizemlje:	F	E	E	G
1. kat:	D	C	C	D
2. kat:	G	E	F	G

7.1 Poredbena metoda

Poredbenom metodom u tablici 4. izračunata je tržišna vrijednost stana prije obnove. Korišteni su ulazni podaci o ostvarenim kupoprodajama iz sustava eNekretnine. Pomoću indeksa cijena stambenih nekretnina (ICSN) Državnog zavoda za statistiku (DZS) izrađeno je međuvremensko izjednačenje na dan vrednovanja, odnosno treći kvartal 2016. godine (3Q 2016). Jedinična cijena od 698 €/m^2 odgovara cijenama stanova na lokaciji višestambene zgrade u primjeru. Utjecaj neuobičajenih okolnosti nije prepoznat jer su pojedinačna odstupanja kupoprodajnih cijena manja od ±30% od prosječne kupoprodajne cijene poredbenih nekretnina nakon provođenja međuvremenskog izjednačenja. Isto tako pojedinačna odstupanja kupoprodajnih cijena su manja od ± dvostrukog standardnog odstupanja od prosječne kupoprodajne cijene poredbenih nekretnina nakon provođenja međuvremenskog izjednačenja (pravilo 2-sigma).

Tablica 4. Poredbena metoda za jednu stambenu jedinicu prije obnove (izvor: autor)

Poredbena nekretnina:	Stan 1	Stan 2	Stan 3
Datum kupoprodaje:	11.02.2016.	02.02.2015.	02.12.2013.
Kupoprodajna cijena [kn]:	214.000,00	276.986,30	213.662,82
Srednji tečaj prema HNB-u [kn/€]:	7,642121	7,694064	7,630815
Kupoprodajna cijena [€]:	28.002,70	36.000,00	28.000,00
Ploština korisne površine stana A_K [m^2]:	39,88	49,90	37,66
Cijena stana po ploštini [€/m^2]:	702,17	721,44	743,49
Kontrola (čl.4. st.1. Pravilnika ≤ ± 30%):		5,56%	
$ICSN_1$ na dan kupoprodaje:	91,87	91,85	95,34
$ICSN_2$ na dan vrednovanja:		89,60	
Međuvremensko izjednačenje ($ICSN_2$/$ICSN_1$):	0,98	0,98	0,94
Međuvremenski izjednačena cijena [€/m^2]:	688,13	707,01	698,88
Srednja vrijednost cijene [€/m^2]:		698,01	
Pojedinačna odstupanja od srednje vrijednosti [€/m^2]:	-9,88	9,00	0,87
Relativna odstupanja od srednje vrijednosti:	-1,42%	1,29%	0,12%
Dvostruka standardna devijacija [€/m^2]:		15,46	

7.2 Troškovna metoda

Troškovnom metodom će se izračunati tržišna vrijednost stana prije i nakon energetske obnove. Vrijednost nekretnine će se povećati za vrijednost nove fasade, kao predložena mjesta na dijelu zgrade.

Prema nekim istraživanjima, karakteristične vrste radova, koje pripadaju završnim radovima pri građenju stambenih zgrada su izolaterski, stolarski, soboslikarski, ličilački, bravarski, keramičarski, parketarski, fasaderski, limarski i kamenorezački radovi. Tri stavke koje nose otprilike 80% udjela završnih radova su fasada, prozori i vrata te završna obrada podova. Može se zaključiti da obrada pročelja i zatvaranje (vrata i prozori) nose znatan udio u troškovima završnih radova, ali i građevinsko-obrtničkih radova općenito (Burilo *et al.,* 2012). Za cijenu građenja primijenit će se podatak iz biltena Standardna kalkulacija radova (SKR) u visokogradnji. Osnovni cilj i namjera biltena je optimizacija projektnih rješenja što se tiče opisa, normiranja i strukturiranja radova. Sadrži i obrađuje tipske građevine prema postojećoj strukturi izgrađenih stambeno-poslovnih građevina u RH, kao odraz stvarnog stanja na tržištu. U biltenu se prikazuju tipske građevine podijeljene prema mikrolokaciji i okruženju izgradnje te su klasificirane kao TIP I, TIP II, TIP III i TIP IV. Tipski troškovnik biltena sadrži otprilike 250 različitih radova (stavaka), grupiranih u 9 temeljnih grupa radova. Stavka fasada i fasadni elementi ima prosječan udio od 25,97%. Za svaku stambeno-poslovnu zgradu, sveobuhvatnim i analitičkim pristupom, moguće je odrediti relativno mali broj karakterističnih stavaka koje čine vrlo velik udjel u ukupnoj vrijednosti (Ajduković *et al.,* 2011).

U tablici 5. je prikazan izračun tržišne vrijednosti stana prije energetske obnove troškovnom metodom. Da bi se troškovna vrijednost uskladila s tržišnom, dobivenom poredbenom metodom, izračunat je koeficijent prilagodbe koji iznosi 1,07.

Ploština vanjskih zidova u primjeru iznosi 726,72 m^2, što uz primjenu jedinične cijene od 400,00 kn/m^2 daje troškove izvođenja fasade od 290.688,00 kn, odnosno 298,75 kn/m^2 bruto građevinske površine zgrade pa povećanje cijene građenja iznosi 5,25%. Kada se troškovi izvođenja fasade stave u omjer korisne površine stanova dobiva se povećanje cijene od 474,33 kn/m^2 ili 63,24 €/m^2. Pribrajanje dobivene vrijednosti početnoj tržišnoj cijeni stana od 698 €/m^2 za postojeće stanje, rezultira cijenom od 761 €/m^2, odnosno daje povećanje tržišne vrijednosti stana nakon obnove za 9,03%.

Tablica 5. Troškovna metoda za jednu stambenu jedinicu prije obnove (izvor: autor)

Vrijednost zemljišta VZ: 405 m^2 × 750 kn/m^2	=	303.750,00 kn
Ploština građevinske (bruto) površine zgrade:		973 m^2
Cijena građenja SKR 12/2015 za tip III:		5.692,94 kn/m^2
(1) Troškovi građenja: 973 m^2 × 5.692,94 kn/m^2	=	5.539.230,62 kn
(2) Uzgredni troškovi: 5% × 5.539.230,62 kn	=	276.961,53 kn
Bruto volumen zgrade:		3.336 m^3
(3) Komunalni doprinos: 3.336 m^3 × 40 kn/m^3	=	133.440,00 kn
(4) Vodni doprinos: 3.336 m^3 × 7,88 kn/m^3	=	26.287,68 kn
(5) Troškovi komunalnih priključaka: 30.000,00 kn/stan × 12 stanova	=	360.000,00 kn
(6) Ukupni troškovi gradnje: (1) + (2) + (3) + (4) + (5)	=	6.335.919,83 kn
Odabrani faktor korištenja FK (A=2; B=1,5; C=3):		3
Starost zgrade G: 2016 - 1964	=	52 godine
Održivi vijek korištenja OVK(Prilog 9. Pravilnika):		80 godina
Relativna starost: Rs = G/OVK = 52 / 80	=	65,0%
Predvidivi ostatak održivog vijeka korištenja OOVK (Prilog 10. Pravilnika):		42,0%
Predvidivi OOVK = 42,0% × 80 godina	=	34 godine
Zamjenska starost zgrade: Gz = OVK – OOVK = 80 – 34	=	46 godina
Linearno umanjenje vrijednosti gradnje: U = Gz / OVK = 46 / 80	=	57,5%
(7) Preostala vrijednost: (100% – U) × (6) = 42,5% × 6.335.919,83 kn	=	2.692.765,93 kn
Troškovna vrijednost nekretnine: VZ + (7) = 303.750,00 kn + 2.692.765,93 kn	=	2.996.515,93 kn
Ploština korisne površine stanova A_K:		612,84 m^2
Jedinična cijena stanova: 2.996.515,93 kn / 612,84 m^2	=	4.889,56 kn/m^2

Primijenjeni srednji tečaj:		7,50 kn/€
Jedinična cijena TV: 4.889,56 kn/m² / 7,50 kn/€	=	652 €/m²
Tržišna cijena Cp izračunata poredbenom metodom:		698 €/m²
Koeficijent prilagodbe kpt (čl. 25. i 33. Pravilnika): Cp / TV =	=	1,07

Dobiveni rezultat je u skladu s provedenim studijama u SAD-u koje pokazuju da su troškovi građenja zelenih zgrada prosječno od 1% do 5% veći od tradicionalnog građenja. (Simmons, 2010). Isto tako, dobri primjeri građevinske prakse dokazuju da je moguće najpovoljnije projekte energetski visokoučinkovite gradnje izvesti već s manje od 10% dodatnog investiranja u samu gradnju (Praznik, 2012).

7.3 Prihodovna metoda

Koristi EnU gradnje su vjerojatno najviše neposredno mjerljive u prihodovnoj metodi jer prema usporedbi s tradicionalnom gradnjom, EnU nekretnina može imati višu najamninu te manje upražnjenih mjesta, troškove gospodarenja kao i manji rizik od gubitka najamnine. Sve navedeno rezultira većim čistim godišnjim prihodom. Utjecaj EnU je više neposredan i lakše ga je vrednovati u prihodovnoj metodi nego u ostalim metodama. Procjenitelj treba imati na umu tko plaća režijske troškove, vlasnik ili najmoprimac, kako bi mogao vrednovati koristi od manjih troškova energije, kao jedno od najizraženijih neposrednih koristi zelene gradnje (Simmons, 2010).

U tablici 6. je prikazan izračun vrijednosti za jednu stambenu jedinicu prije energetske obnove primjenom opće prihodovne metode. Može se reći da se dobiveni rezultat jedinične cijene od 702 €/m² podudara s onim dobivenim poredbenom metodom od 698 €/m². Režijski troškovi grijanja su uračunati s jedne strane kao prihod a s druge pak strane kao trošak jer uobičajeno u ugovorima o najmu stanova te troškove snosi najmoprimac. Ukoliko te troškove plaća vlasnik, tada bi se za taj iznos povećala najamnina. Nakon isteka JPP-a manji režijski troškovi za grijanje neposredno povećavaju prihod vlasniku.

Tablica 6. Opća prihodovna metoda za jednu stambenu jedinicu prije obnove (izvor: autor)

Godišnji prihod:		
- najamnina: 51,07 m² × 4,75 €/m² × 12 mjeseci	=	2.910,99 €
- režijski troškovi najmoprimca: 235,37 kWh/m² × 51,07 m² × 0,03 €/kWh	=	360,61 €
(1) Godišnji prihod ukupno:	=	3.271,60 €
Troškovi gospodarenja:		
- upravljanje nekretninom: 2% × 3.271,60 €	=	65,43 €
- održavanje (pričuva, naknada za uređenje voda i komunalna naknada):		168,36 €
- pogonski (režijski) troškovi za grijanje koje plaća najmoprimac:		360,61 €
- rizik od gubitka najamnine: 2% × 3.271,60 €	=	65,43 €
(2) Godišnji troškovi gospodarenja ukupno:		659,83 €
(3) Čisti godišnji prihod PG: (1) – (3) = 3.271,60 € – 659,83 €	=	2.611,77 €
Prilagođena kamatna stopa na nekretninu p (Prilog 13. Pravilnika):		6,5%
(4) Oportunitetni trošak zemljišta: p × VZ/broj stanova = 6,5% × 40.500 € / 12	=	219,38 €
(5) Čisti prihod građevine: (3) – (4) = 2.611,77 € – 219,38 € =	=	2.392,39 €
Predvidivi ostatak održivog vijeka korištenja OOVK (FK=3, OVK=80 i G=52):		34 godine
Multiplikator M (Prilog 14. Pravilnika):		13,58
Prihodovna vrijednost građevine: (5) × M = 2.392,39 € × 13,58 =	=	32.488,66 €
Vrijednost zemljišta VZ za jedan stan: 40.500 € / 12 stanova	=	3.375,00 €
Prihodovna vrijednost nekretnine PV:		35.863,66 €
Multiplikator najamnine GRM (gross rent multiplier): PV / mjesečna najamnina	=	148
Prihodovna vrijednost nekretnine po m² korisne površine: PV/A_K	=	702 €/m²

Za izračun prihodovne vrijednosti nekretnine nakon energetske obnove primijenit će se periodična prihodovna metoda. Odredbom čl.42. st.1. Pravilnika opća formula prihodovne vrijednosti "razbijena" je u dvije faze:

- razmatrano razdoblje (od približno 10 godina, preračunato na dan vrednovanja) i
- preostalo razdoblje (do isteka OOVK).

U razmatranom razdoblju detaljnije se obuhvaćaju godišnji tijekovi čistoga prihoda. Pretpostavka je da odstupajući čisti prihodi u kraćem razdoblju mogu biti vrlo pouzdani pa se upravo takvi računski uzimaju u obzir i čak ne moraju biti konstantni, odnosno mogu i međusobno znatno odstupati. Različito se postupa u preostalom razdoblju, odnosno do kraja OOVK. Prihodovni tijekovi u preostalom razdoblju temelje se na prihodima koji se uobičajeno postižu na tržištu te se sažimaju u preostalu vrijednost, tzv. blokovski model (Majčica i Uhlir, 2016).

Ukoliko se pretpostavi da JPP investicije za energetsku obnovu fasade iznosi 10 godina, što odgovara duljini razmatranog razdoblja, tada će se u primjeru iz ušteda na režijskim troškovima plaćati troškovi obnove, dok će se u preostalom razdoblju prihodi povećati za uštede na troškovima za grijanje, odnosno za mogućnost povećanja najamnine. Kako se radi o poboljšanju za jedan energetski razred, uzeta je razlika najveće i najmanje vrijednosti specifične godišnje potrebne toplinske energije za grijanje za referentne klimatske podatke $Q''_{H,nd,ref}$ unutar jednog razreda od 50 kWh/(m^{2}a) što uz primjenu jedinične cijene prirodnog plina od 0,03 €/kWh i površinu stana od 51,07 m^2 daje uštede od 76,61 € godišnje, odnosno prihode veće za 3% u iznosu od 2.688,38 €. Kamatna stopa obnovljene nekretnine će se prilagoditi za -0,5% radi bolje kvalitete zgrade nakon obnove u odnosu na postojeće stanje, tako da iznosi 6,0%.

U tablici 7. je prikazan izračun vrijednosti stana nakon energetske obnove primjenom periodične prihodovne metode, koji daje povećanje vrijednosti za 7,41% u odnosu na postojeće stanje. Ukoliko bi kamatna stopa na nekretnine od 6,5%, kao i za postojeće stanje, ostala nepromijenjena, tada bi jedinična cijena stana nakon obnove iznosila 712 €/m^2, odnosno 1,43%, što je manje od vrijednosti dobivene troškovnom metodom.

Tablica 7. Periodična prihodovna metoda za jednu stambenu jedinicu nakon obnove (izvor: autor)

a) sadašnje vrijednosti razmatranog razdoblja od 10 godina uz p=6,0%

Godina	Čisti godišnji prihod PG		Diskontni faktor q^{-i}		Sadašnja vrijednost čistih godišnjih prihoda
1.	2.611,77 €	×	0,943396226	=	2.463,93 €
2.	2.611,77 €	×	0,889996440	=	2.324,47 €
3.	2.611,77 €	×	0,839619283	=	2.192,89 €
4.	2.611,77 €	×	0,792093663	=	2.068,77 €
5.	2.611,77 €	×	0,747258173	=	1.951,67 €
6.	2.611,77 €	×	0,704960540	=	1.841,19 €
7.	2.611,77 €	×	0,665057114	=	1.736,98 €
8.	2.611,77 €	×	0,627412371	=	1.638,66 €
9.	2.611,77 €	×	0,591898464	=	1.545,9 €
10.	2.611,77 €	×	0,558394777	=	1.458,4 €
	Zbroj sadašnje vrijednosti čistih godišnjih prihoda:				19.222,86 €

b) preostala vrijednost

PRV × q^{-b} = 2.688,38 € × 12,55 × 0,558394777 + 3.375,00 € × 0,137911531	=	19.305,23 €

c) prihodovna vrijednost

Prihodovna vrijednost nekretnine: PV = 19.222,86 € + 19.305,23 €	=	38.528,09 €

Prihodovna vrijednost nekretnine po m² korisne površine: PV/A_K	=	754 €/m²
Multiplikator najamnine GRM: PV / mjesečna najamnina	=	159
Povećanje vrijednosti nekretnine: (38.529,09 € - 35.863,66 €) / 35.863,66 €	=	7,41%

Mjesečne uštede energije mogu se prikazati kao doprinos vrijednosti EnU nekretnina pomoću multiplikatora najamnine (engl. GRM gross rent multiplier), koji je jednak omjeru tržišne vrijednosti i mjesečne najamnine, jer vlasnici ili kupci nekretnina očekuju mjesečne uštede ili dodatni prihod (Adomatis, 2014). Za stan u primjeru prije energetske obnove GRM iznosi 148 a nakon obnove 159, što daje povećanje za 7,43%.

Ukoliko se u istom primjeru primijeni razmatrano razdoblje od 15 godina, kao jednako očekivanom JPP investicije, tada se dobiva povećanje vrijednosti nekretnine za 6,98%.

U tablici 8. su prikazani rezultati predloženog modela s utjecajem poboljšanja energetskog razreda na vrijednost nekretnine uz JPP od 10 i 15 godina i primijenjenu kamatnu stopu na nekretnine nakon obnove od 6,0%.

Tablica 8. Utjecaj poboljšanja energetskog razreda na vrijednost nekretnine (izvor: autor)

Energetski razred:	F (početno stanje)	E	D	C	B
Jedinična cijena [€/m2] uz JPP=10 godina:	702	754	765	775	786
Povećanje u odnosu na početno stanje:	-	7,41%	8,97%	10,40%	11,97%
Povećanje u odnosu na jedan energetski razred:	-	7,41%	1,46%	1,31%	1,42%
Jedinična cijena [€/m2] uz JPP=15 godina:	702	751	758	765	772
Povećanje u odnosu na početno stanje:	-	6,98%	7,98%	8,97%	9,97%
Povećanje u odnosu na jedan energetski razred:	-	6,98%	0,93%	0,92%	0,92%
Razlika JPP=10 godina i JPP=15 godina [€/m2]:	-	3 0,40%	7 0,92%	10 1,31%	14 1,81%

Slika 4. Višestambena zgrada (izvor: autor, 2015)

8. Zaključak

EU propisi izvor su sve većeg broja lokalnih zakona o nekretninama koji podupiru procjenu i time mogu uvjetovati ishode koji nisu uvijek očiti na tržištu, a EnU je primjer toga. Europski standardi za procjenu vrijednosti nekretnina (ESPV) pomažu pri podizanju svijesti procjenitelja o pitanjima EnU i instrumentima kao što su energetski certifikati i preporuke za poboljšanje, no istovremeno ističu znanstvenu i profesionalnu obvezu procjenitelja da procjeni i EnU na način da postavljene vrijednosti moraju odražavati istinsko stanje na tržištu. Održivost, EnU i zelena gradnja mogu se odraziti na procjeni samo kada istu podržavaju mjerljivi tržišni dokazi. Nema razloga za pretpostavku kako će zadovoljavanje ili nezadovoljavanje bilo kojeg aspekta održivosti rezultirati povećanjem ili sniženjem vrijednosti nekretnine (TEGoVA, 2016).

Na modelu procjene tržišne vrijednosti stana u višestambenoj zgradi nakon energetske obnove uz poboljšanje za jedan energetski razred i pretpostavku JPP-a od 10 godina, periodičnom prihodovnom metodom dobiveno je povećanje tržišne vrijednosti nekretnine za 7,41%. Duže razdoblje JPP-a od 15 godina rezultira povećanjem vrijednosti nekretnine za 6,98%. Poboljšanje za interval od jednog razreda donosi povećanje vrijednosti u prosjeku za 1,40% kod JPP-a od 10 godina i za 0,92% kod JPP-a od 15 godina. Svi izračuni su izrađeni bez utjecaja promjene cijene energije u odnosu na dan vrednovanja. Obzirom na prognozu rasta cijena energenata, koristi energetski obnovljenih zgrada će tada biti još izraženije.

Rezultati predloženog modela moći će se potvrditi tek nakon dovoljnog broja prikladnih kupoprodaja poredbenih nekretnina s dovoljno podudarnih obilježja, odnosno stanova u energetski obnovljenim zgradama, jer pitanje na koje je potrebno pronaći odgovor glasi: *"Koliko je kupac spreman platiti više za nekretninu s većom EnU?"* (Majčica i Uhlir, 2016). Kako je energetska obnova u RH tek uzela svoj zamah, potrebno je proći određeno vrijeme za potvrdu ili korekciju predloženog modela.

Literatura

Adomatis, S. (2014), Residential Green Valuation Tools, Appraisal Institute AI, Chicago, IL.

Ajduković M., Hrnjak Ajduković, N. i Martinec, N. (2011), "Troškovi građevinsko-obrtničkih radova stambeno-poslovnih građevina", Građevinar, Vol. 63 No. 6, pp. 573-577.

Burilo, D., Dolaček-Alduk, Z., Galić, M. i Knežević, A. (2012), "Završni radovi u visokogradnji – planiranje troškova", Elektronički časopis Građevinskog fakulteta Osijek, No. 4, pp. 93-101.

Dugoročna strategija za poticanje ulaganja u obnovu nacionalnog fonda zgrada Republike Hrvatske, Narodne novine broj 74/14.

DZS (2016), Državni zavod za statistiku, www.dzs.hr.

Energetski certifikat broj P_99_2011_350_SZ2 izdan od MEĐIMURJE-INVESTA d.o.o. Čakovec od 17.11.2015.

Energy performance certificates in buildings and their impact on transaction prices and rents in selected EU countries – Final report prepared for European Commission (DG Energy), Bio Intelligence Service, Ronan Lyons IEEP, 2013.

Europski standardi za procjenu vrijednosti nekretnina (2016) Europski standardi za procjenu vrijednosti nekretnina, osmo izdanje, The European Group of Valuers' Associations TEGoVA, Belgija.

Halkijević, I., Kuspilić, M. i Vuković, Ž. (2014), "Održivi razvoj i graditeljstvo", u Hrvatski graditeljski forum 2014: Izazovi u graditeljstvu 2, 2014, Hrvatski savez građevinskih inženjera HSGI, Zagreb, pp. 140-157.

Hrs Borković, Ž. (2015), "Problematika realizacije projekata energetske učinkovitosti u Hrvatskoj", u Hrvatski graditeljski forum 2015: Izazovi u graditeljstvu 3, 2015, Hrvatski savez građevinskih inženjera HSGI, Zagreb, pp. 44-58.

Izvješće broj 350/2015 o energetskom pregledu višestambene zgrade u Čakovcu, Tome Masaryka 11 izrađen od MEĐIMURJE-INVESTA d.o.o. Čakovec od studenoga 2015.

Izvješće komisije Europskom parlamentu i Vijeću: Ocjena napretka država članica u postizanju nacionalnih ciljeva energetske učinkovitosti za 2020. i u provedbi Direktive o energetskoj učinkovitosti 2012/27/EU kako se zahtijeva člankom 24. stavkom 3. Direktive o energetskoj učinkovitosti 2012727/EU, 2015a, Bruxelles.

Krstić, H. i Marenjak, S. (2012), "Analiza troškova uporabe građevina Sveučilišta Josipa Jurja Strossmayera u Osijeku", u Sabor hrvatskih graditelja 2012: Graditeljstvo – poluga razvoja u Cavtatu od 15. do 17. studenoga, 2012, Hrvatski savez građevinskih inženjera HSGI, Zagreb, pp. 373-379.

Krstić, H. i Marenjak, S. (2012a), "Analiza troškova održavanja i uporabe građevina", Građevinar, Vol. 64 No. 4, pp. 293-303.

Krstić, H. i Teni, M. (2016), "Analiza osjetljivosti jednostavnog perioda povrata investicije na promjene zrakopropusnosti zgrada", u Sabor hrvatskih graditelja 2016: EU i hrvatsko graditeljstvo u Cavtatu od 17. do 18. listopada, 2016, Hrvatski savez građevinskih inženjera HSGI, Zagreb, pp. 371-382.

Krtalić, V. (2008), "Utjecaj urbanističkog planiranja na tržišnu vrijednost nekretnina", u Sabor hrvatskih graditelja 2008: Hrvatsko graditeljstvo pred izazovom europskih integracija od 6. do 8. studenoga u Cavtatu, 2008, Hrvatski savez građevinskih inženjera HSGI, Zagreb, pp. 819-830.

Majčica, B. i Uhlir, Ž. (2016), Priručnik za procjenu vrijednosti nekretnina, Društvo građevinskih inženjera Zagreb DGIZ, Zagreb.

Pravilnik o metodama procjene vrijednosti nekretnina, Narodne novine broj 105/15.

Pravilnik o energetskom pregledu zgrade i energetskom certificiranju, Narodne novine broj 48/14, 150/14, 133/15, 22/16, 49/16, 87/16 i 17/17.

Praznik, M. (2012), "Koncepti i smjernice za razvoj energetsko učinkovitih zgrada – aktivna kuća i pasivna poslovno stambena zgrada", u Sabor hrvatskih graditelja 2012: Graditeljstvo – poluga razvoja u Cavtatu od 15. do 17. studenoga, 2012, Hrvatski savez građevinskih inženjera HSGI, Zagreb, pp. 53-62.

Praznik, M. i Veršić, Z. (2016), "Napredno energetsko modeliranje cjelovite energetske obnove zgrada", u Sabor hrvatskih graditelja 2016: EU i hrvatsko graditeljstvo u Cavtatu od 17. do 18. listopada, 2016, Hrvatski savez građevinskih inženjera HSGI, Zagreb, pp. 897-890.

Schild, R. (2014), "Energetska revolucija kroz učinkovitost", u Hrvatski graditeljski forum 2014: Izazovi u graditeljstvu 2, 2014, Hrvatski savez građevinskih inženjera HSGI, Zagreb, pp. 132-138.

Simmons, A. (2010), An Introduction to Green Homes, Appraisal Institute AI, Chicago, IL.

The Dictionary of Real Estate Appraisal (2015) "Green building", 6th ed., The Dictionary of Real Estate Appraisal, Appraisal Institute AI, Chicago, IL, pp. 338.

Uhlir, Ž. (2015), "Zakon o procjeni vrijednosti nekretnina – primjena u praksi", u Hrvatski graditeljski forum 2015: Izazovi u graditeljstvu 3, 2015, Hrvatski savez građevinskih inženjera HSGI, Zagreb, pp. 60-78.

Zakon o gradnji, Narodne novine broj 153/13 i 20/17.

Zakon o procjeni vrijednosti nekretnina, Narodne novine broj 78/15.

Research and Education in Construction

Podizanje razine znanja o kulturi građenja kroz e-učenje

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Sažetak:

Termin 'kultura građenja' u proteklih pet godina postao je prepoznatljiv i ušao je u standardnu uporabu. Vezan je između ostalog uz procese obrazovanja i stalnog stručnog usavršavanja. Stalno učenje i nadopunjavanje postojećih znanja, ne samo profesionalaca neposredno uključenih u procese građenja, nužno je kako bi krajnji korisnici mogli razumjeti prostor kojim su okruženi. Uvođenjem aktivnosti i novih oblika postupanja kojima se stručna i šira javnost može aktivno uključiti u kreiranje izgrađenog prostora može se doprinijeti boljem razumijevanju procesa i aktivnosti koje su dio kreiranja prostora u kojem živimo.

Načini i oblici učenja mogu se konstantno razvijati u skladu s vremenom u kojem živimo. Stoga korištenje interneta i interaktivnih radionica, kroz predavanja i slične oblike prenošenja znanja, može doprinijeti da se ostvari velika dostupnost sadržaja za informiranje kao i proširenje postojećih obrazovnih programa vezanih uz podizanje svijesti o 'kulturi građenja'. Platforma se može organizirati kroz rad institucija ili neformalnih organizacija a služila bi za podizanje svijesti društva u cjelini, kao i za cjeloživotno obrazovanje svih dionika u gradnji uvođenjem novih načina provođenja obrazovnih procesa, usklađenih sa suvremenim tehnologijama i principima.

Ključne riječi: *kultura građenja; obrazovanje; stalno stručno usavršavanje; e-učenje*

1. Uvod

Stvaranje izgrađenog prostora jedinstven je proces koji obuhvaća različite aktivnosti i znanja, počevši od usklađivanja različitih interesa investitora i korisnika prostora, preko programiranja i projektiranja pa sve do izvedbe gradnje i kasnijeg korištenja same zgrade ili vanjskog izgrađenog prostora. Kako bi se taj proces nesmetano i s dugoročno kvalitetnim rezultatima mogao provoditi nužno je zadovoljiti niz elemenata. Usklađivanje interesa između logike kapitala, interesa investitora, javnih interesa i stvaranja kvalitetne arhitekture započinje već pri oblikovanju projektnog zadatka i traje sve do izvedbe, a u procese su uključeni ne samo profesionalci već i korisnici prostora, odnosno društvo u cjelini. Svi uključeni u programiranje, planiranje i gradnju moraju biti svjesni dugoročnog utjecaja gradnje na vanjski javni ili polujavni prostor. Svi vanjski kontaktni prostori, kao i unutarnji prostori, moraju biti oblikovani jednako pozorno kao i sama zgrada. Oblikovanje, funkcija, održivost, javnosti namijenjen vanjski prostor – sve su to samo neki elementi koji značajno utječu na zgradu, kao i na prostor u koji su interpolirani. A izgrađeni prostor neposredno i posredno djeluje na korisnike.

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Kako bi svi pozvani dionici mogli znanja trajno nadograđivati potrebno je na nove načine organizirati i učiniti dostupnim ideje i znanja koja se vežu uz ‘kulturu građenja’ kroz stalno stručno usavršavanje i cjeloživotno obrazovanje. Kultura građenja je danas prepoznatljiv pojam koji obuhvaća velik broj aktivnosti s konačnim ciljem poboljšanja stanja u prostoru. Kroz petogodišnje sustavno sistematiziranje i analizu ostvarenih pomaka u djelovanju svih dionika uključenih u implementaciju stavova i znanja koje promiče ‘kultura građenja’ dolazimo do potrebe uključivanja novih načina obrazovanja, ne samo formalnog, već i neformalnog. Prateći iskustva drugih europskih zemalja i trendove u obrazovnim sustavima nameće se potreba organiziranja interaktivnih radionica na temu građenja, i sa građenjem povezanim aktivnostima za sve zainteresirane dionike. Organizacija može biti prepuštena različitim institucijama, strukovnim organizacijama i udrugama koje na taj način mogu pridonijeti širenju svijesti o ‘kulturi građenja’ i graditeljstva u cjelini. Put su različiti oblici digitalnog učenja, kao i stvaranje preduvjeta za učenje pomoću alata koji stoje na raspolaganju kroz digitalizaciju. Kroz pojedinačna predavanja i kompletne kolegije prilagođene različitim profesijama u graditeljstvu može se ostvariti velika dostupnost novih sadržaja za proširenje postojećih obrazovnih programa vezanih uz cjeloživotno obrazovanje. Također, određeni oblici takvih predavanja, nadalje pojednostavljeni i prilagođeni javnosti, dodatno mogu pospješiti podizanje društvene svijesti o ‘kulturi građenja’.

2. Značenje ‘kulture građenja’

Aktivnosti koje se na kraju procesa očituju kao izgrađeni prostor, moraju osigurati da bude ne samo upotrebljiv, učinkovit, funkcionalno besprijekoran, tehnički zaokružen i ekonomski prihvatljiv, već da uz sve to ima kulturnu i estetsku nadgradnju. Arhitektonska uspješnost je krajnji cilj, a kako do realizacije uspješnih primjera, kompleksno je i kontinuirano pitanje koje se provlači kroz direktni i indirektni utjecaj i odgovornost koju svaki dionik ima, ili može imati kroz neposredno profesionalno djelovanje, ili kao pojedinac, odnosno određena društvena grupa. Djelovati se može kroz obrazovni proces, kroz zakonodavnu domenu, kao i kroz domenu uprave. (Grakalić Rački, 2015) Sve su to elementi i modaliteti koji nam stoje na raspolaganju kako bi u konačnici došli da onoga što ima za cilj oblikovanje primjerenog, održivog i kvalitetnog izgrađenog prostora. (Bobovec, 2012)

Arhitektonske politike i do danas stvorena nadogradnja, pružaju okvir koji omogućava približavanje arhitekture svima, a ne samo onima koji su direktno uključeni u proces planiranja, projektiranja i građenja. Cijeli postojeći sistem cjeloživotnog obrazovanja stvorio je nišu za ovu temu kojoj je konačni cilj upoznati arhitekturu te podići opću stručnu i društvenu svijest o vrijednosti prostora. Znanje i razvijanje interesa za izgrađeni prostor omogućava da svi dionici i korisnici izgrađenog prostora mogu detektirati svoju interesnu sferu i identificirati se s tom temom.

Primjeri visoko vrijedne ‘kulture građenja’ stvarani su dugi niz godina na svim prostorima Hrvatske. Društvo u cjelini, kao i pojedinci, mora se kompetentno i odgovorno brinuti za naslijeđene prostorne odnose i pojedinačne zgrade. Ovdje značajnu ulogu imaju lokalne vlasti koje u svojim sredinama moraju raditi na stalnom osvještavanju građanstva. Učvršćivanju ideje ‘kulture građenja’ svakako su potrebni dobro informirani, kritični i predani građani - ljudi koji doprinose i osjećaju se odgovornima, a potreban im je prostor za komunikaciju i aktivnosti. Za očekivati je da javne institucije reagiraju i cijene njihovu predanost. Uključivanje građanstva u procese planiranja pomaže pri poistovjećivanju i prihvaćanju projekata. Kroz takav način djelovanja osigurava se legitimitet u donošenju odluka i unapređenja procedura i rezultata. (Milonja i Pozojević, 2012) Da bi sustav na taj način mogao funkcionirati potrebni su obrazovani pojedinci - profesionalci i osviješteno društvo u cjelini.

3. Instrumenti podizanja razine znanja

Učenje i obrazovanje tijekom čitavog života je prepoznato kao ključni instrument kojim se utječe na podizanje razine osviještenosti kompletnog društva o kvaliteti i značaju prostora, a za ostvarivanje i stalno unaprjeđivanje kvalitete prostora neophodno je kvalitetno obrazovanje svih pojedinaca. (The Danish Government, 2014)Tu su uključeni ne samo arhitekti i drugi inženjeri koji sudjeluju u planiranju, projektiranju i gradnji, već i cjelokupno društvo koje koristi izgrađeni prostor. (Bobovec i Bajić, 2015) „Obrazovanje u predškolskoj i osnovnoškolskoj dobi o kulturi i kvaliteti prostora treba biti obvezno kako bi omogućilo da djeca u budućnosti, kao odrasli građani, izraze svoje mišljenje, donose i utječu na političke, gospodarske i socijalne odluke kojima se djeluje na stanje u prostoru. Srednjoškolsku naobrazbu potrebno je unaprijediti u pogledu spoznaja o vrijednosti prostora, načinu korištenja prirodnih resursa i zaštiti okoliša.” (Knifić Schaps i Bobovec, 2014)

Još uvijek se kao društvo nismo opredijelili za sistemsko uvođenje znanja o prostoru u obavezni obrazovni proces, već se arhitektura i izgrađeni prostor može sporadično susresti u različitim nastavim predmetima uz učenje drugih gradiva. Ideja koja se provlači kroz dokument ApolitikA nije gomilanje novih sadržaja i novih predmeta, već dostupnost znanja kroz baš te predmete uz koje je vezana arhitektura i izgrađeni prostor, ali kroz smišljenu i svuda istoznačno provedenu politiku obrazovanja. Postoji višegodišnja aktivnost, međutim, u konačnici je vezana uz sporadične aktivnosti pojedinaca i grupa zainteresiranih stručnjaka da djeluju na tom planu. Od projekta „Hura arhitektura” iz 2009.godine, pa sve do aktivnosti koje trajno provodi Društvo arhitekata Zagreba, Hrvatska komora arhitekata kao i Ministarstvo graditeljstva i prostornoga uređenja.

Međutim, ministarstvo zaduženo za obrazovanje nije na adekvatan način uključeno u aktivnosti koje trebaju doprinijeti sustavnom prepoznavanju mjesta na kojima se kroz obrazovni sustav može poboljšati opće znanje i zainteresiranost za prostor u kojem živimo. Znanje o vrijednosti prostora u cjelini omogućilo bi i veću zainteresiranost, iz čega proizlazi i neposredna briga za izgrađeni prostor. (Weeber and Weeber, 2007) Slijedeća stepenica koju je potrebno svladati odnosi se na izradu materijala koji će prenositi znanja o kulturi prostora na način primjeren različitim obrazovnim skupinama, u odnosu na uzrast i ostala znanja koja posjeduju. Na taj način moguće je popularizirati ‘kulturu građenja’ i podići razinu općeg obrazovanja stanovništva o potrebama razvoja, korištenja i zaštite prostora. (Bobovec i Bajić, 2015)

Prvi korak je educiranje javnosti o mogućnosti sudjelovanja u raspravama o prostornom uređenju i građenju, što za cilj ima ostvariti aktivnije učešće svih korisnika prostora u donošenju odluka o značaju kvalitete izgrađenog prostora. Nadalje, obrazovanje odraslih o prostornom razvoju, treba biti namijenjeno općoj i političkoj javnosti. Ovakav pristup bi kao rezultat trebao imati razumijevanje složenih procesa planiranja, projektiranja i odlučivanja na području prostornog razvoja i gradnje, te na taj način doprinijeti boljoj brizi za izgrađeni prostor na svim razinama, kao i čuvanju identiteta prostora koji imamo. (Bašić i dr, 2014) U svakom od ovih segmenata edukacije, moguća su i poboljšanja, odnosno uvođenje novih načina provođenja obrazovnih procesa, usklađenih sa suvremenim tehnologijama i principima.

4. Nadogradnja znanja e-učenjem

Kroz dokument „Arhitektonske politike Republike Hrvatske 2013-2020, ApolitikA, Nacionalne smjernice za vrsnoću i kulturu građenja“ razrađene su inicijative koje jasno i nedvosmisleno mogu poslužiti kao putokaz koji upućuje kako treba razvijati odnos prema učenju i obrazovanju u cjelini. Navedene su aktivnosti koje započinju provođenjem procesa obrazovanja o arhitekturi i kulturi prostora kroz nacionalni kurikulum i kontinuirano unaprjeđivanje cjeloživotnog profesionalnog obrazovanja arhitekata i drugih struka koje sudjeluju u gradnji, te potrebe izrade nacionalnog programa za obrazovanje odraslih u području izgrađenog i kulturnog krajolika. Dio koji je u ovom razmatranju najvažniji odnosi se na uključivanje obrazovnog sustava u nacionalnu mrežu za kulturu građenja kao jednog od njenih nositelja. (Bašić i dr, 2014)

Tu dolazimo do odrednice koja se odnosi na približavanje učenja svim dionicima, odnosno, kako na zanimljiv i dinamičan način govoriti o ‘kulturi građenja’. Kroz modele interaktivnog načina učenja otvara se put novim idejama i mogućnostima. „Digitalizacijom učenja o kulturi građenja otvara se mogućnost korištenja bogatstva dostupnih ili izrade vlastitih multimedijskih sadržaja koji mogu olakšati ilustracije pozitivnih i negativnih primjera, kao i stvaranje vlastitih estetskih kriterija polaznika.“ (Bobovec i Bajić, 2015) Imajući u vidu da je internet dostupan svuda i da ga bez problema koristi velik broj građana kroz ideju korištenja brzog i zanimljivog sadržaja može se u kratkom roku utjecati na opću zainteresiranost kroz kratke prezentacije kao i kratke filmove koji na taj način postaju široko dostupni. Brzina kojom je internet ušao u opću uporabu, govori o tome da je informacija koja putem njega stiže do pojedinca, i društva u cjelini, prihvaćena i često rabljena.

Kvaliteta ovakvog pristupa nalazi se u mogućnosti brzog i jednostavnog mijenjanja i nadopune određenih tema, ovisno o ciljanoj skupini, odnosno kako se obrađuju i nastaju, ili se prikupljaju novi materijali. Digitalno učenje obuhvaća različite alate koji se temelje na novim tehnologijama sa ciljem da podrže proces lakšeg i jednostavnijeg učenja, a korištenjem suvremenih tehnologija ubrzava se proces učenja, naročito kod mlađih generacija koje su rasle uz nove tehnologije (Gašparović, 2017), što se može ostvariti kroz masovne otvorene mrežne tečaje – MOOC (2) kojima je osnovna značajka dostupnost svima bez naknade, posebnih ograničenja ili potrebnih predznanja. Primjenjujući ovakav način može se ostvariti distribucija materijala o ‘kulturi građenja’ kojima je omogućen pristup u bilo koje vrijeme. Stvaranjem različitih razina mogu se postavljati informacije, pojedinačna predavanja ili čitavi moduli, ovisno o vrstama i količini znanja koja se pripremaju za ciljane skupine. „Integracijom MOOC-a i računalnih igara s društvenim mrežama može se postići efekt brzog širenja informacije o postojanju i dostupnosti obrazovnih sadržaja o kulturi građenja.“ (Bobovec i Bajić, 2015)

Osim o životu suvremenog društva u izgrađenom okolišu, koji je tema kroz promicanje ‘kulture građenja’, možemo govoriti i o „tehno-okolišu kao o permanentnoj odrednici društva“. (Grakalić Rački, 2017) Kako je tehnologija prisutna u svim segmentima života, dolazimo do novih pojmova, „poput online društva, virtualne realnosti te već gore navedenog tehno-okoliša. U ovom kontekstu raspravlja se o pojmu ‘digitalna kultura’ kao onome koji bi najbolje mogao opisati našu suvremenost. Digitalne kulture isprepleću tri uloge njezinih aktera – sudjelovanje (aktivnost osoba na internetu), usavršavanje (unaprjeđenje ili apsorpcija starih medija u nove oblike), te kolažiranje (miješanje tema i formata što rezultira hibridizacijom sadržaja), a koje valja gledati u međusobnoj interakciji.“ (Grakalić Rački, 2017) Na taj način tehnologija postaje novi poligon koji omogućava kvalitetnije i brže plasiranje činjenica i znanja, što može biti posebno zanimljivo u kontekstu stalnog stručnog usavršavanja i cjeloživotnog obrazovanja. Takvi načini učenja skraćuju vrijeme koje je potrebno da bi se usvojila nova znanja i smanjuju troškove zainteresiranih korisnika. „Polaznik sustavu pristupa sa svojeg računala i uključuje se u proces nastave u vrijeme kada to njemu najviše odgovara. Prema programu nastave odabire modul za učenje i pristupa nastavi. Proces je kontroliran i praćen. Evidentira se vrijeme pristupa modulu, uspješnost nastavnih koraka, provedeno vrijeme, završni rezultati. Podaci se pohranjuju u bazu podataka i dostupni su za analizu i prezentaciju različitim korisnicima (voditelj projekta, mentor nastave, management…). Sustav prati sve polaznike unutar predviđenog vremena, omogućava komunikaciju po sistemima: one to one, one to all, all to all, pruža uvid u podatke prijašnjih nastava i iskustva polaznika iz drugih skupina.“ (1)

Takvi oblici učenja mogu se neposredno primijeniti i u sustavima koji su vezani uz dobrovoljne i obavezne oblike učenja, kao i polaganja ispita koji mogu biti obavezni ili neobavezni. U dijelu koji se odnosi na moguće smanjenje troškova za polaznike tečajeva stalnog stručnog usavršavanja i cjeloživotnog obrazovanja, posebne koristi mogu se prepoznati u dijelu koji se odnosi na upoznavanje sa novom zakonskom regulativom (zakonima i podzakonskim aktima, tehničkim propisima i normama) te pripremu arhitekata i drugih inženjera u graditeljstvu za polaganje stručnih ispita, kao u konačnici i polaganja samog stručnog ispita ‘online’. Ovakav način može biti i dodatno motivirajući za pristupnike obzirom da se učenje, odnosno priprema za ispit može provesti od kuće ili iz ureda na jednostavniji, jeftiniji i zanimljiviji način. Pri donošenju odluka o kretanju u ovom smjeru, potrebno je voditi računa da je ovakav oblik pristupanja učenju, kao i u konačnici, polaganja samih ispita u kontroliranom okruženju, primjereniji suvremenim trendovima i oblicima uspostavljanja sustava koji podržavaju i kontroliraju obrazovne procese.

5. Zaključak

Vrijednost elemenata koji formiraju e-učenje u odnosu na širenje svijesti o ‘kulturi građenja’ i podizanju općeg znanja o prostoru u kojem živimo može se jednostavno i bez ulaganja značajnih financijskih sredstava koristiti u dopuni postojećih programa koji su pokrenuti sa ciljem edukacije sadašnjih i budućih korisnika prostora kako bi mogli razumjeti izgrađeni prostor koji ih okružuje. Aktivnim sudjelovanjem u njegovu kreiranju pridonose boljem i kvalitetnijem izgrađenom prostoru budućnosti, što će biti jednostavnije ukoliko budu stekli osnovna znanja o prostoru i prostornim odnosima kroz načine učenja koji nisu obavezni, ili ne zahtijevaju značajna financijska sredstva, a mogu se aktivirati u vremenu koje odgovara svakom pojedinom zainteresiranom članu zajednice i društva u cjelini.

Interaktivne radionice na teme koje su vezane uz ‘kulturu građenja’ i građenje kao fizički čin kojim se opredmećuje projekt, mogu biti organizirane putem raznih institucija, strukovnih organizacija i udruga koje na taj način mogu pridonijeti širenju svijesti, važnosti i utjecaja graditeljstva na život pojedinca i zajednice. Odlukom da se krene putem implementacije različitih oblika digitalnog učenja, a osobito korištenjem mogućnosti koje daje internet kroz učenje na daljinu kroz kolegije prilagođene različitim profesijama u graditeljstvu može se ostvariti velika dostupnost sadržaja za nove i drugačije načine organizacije i dostupnosti programa vezanih uz cjeloživotno obrazovanje. U vremenu u kojem je djelovanje pojedinca opterećeno nizom parafiskalnih nameta, omogućavanje stjecanja novih i učvršćivanje postojećih znanja bez ulaganja značajnih financijskih sredstava otvara put ka obrazovanom pojedincu i osviještenom društvu.

6. Literatura

Bašić, S., Bobovec, B., Horvat,T., Knifić Schaps, H., Mlinar, N., Mrak-Taritaš, A., Pletikapić, Z. (2013), Arhitektonske politike Republike Hrvatske 2013-2020, ApolitikA, Nacionalne smjernice za vrsnoću i kulturu građenja Hrvatska komora arhitekata and Ministarstvo graditeljstva i prostornoga uređenja, Zagreb, pp. 92-100

Bobovec, B. (2012), „Arhitektonske politike Republike Hrvatske 2013-2020“, Croatian Real Estate Newsletter, No. 71, pp. 5-7

Bobovec, B. and Bajić, M. (2015), „Digitalno učenje o Kulturi građenja“, in Žiljak Vujić, J. (Ed.), Printing & Design 2015 proceedings of the international scientific conference in Zagreb, Hrvatska, March 27th-28th 2015, Tehničko veleučilište Zagreb, Zagreb, pp. 239-245

The Danish Government (2014), “Architecture meets people – children, youth, and adults”, in Danish architectural policy - Putting people first, Ministry of Culture, Copenhagen, pp. 14-23

Gašparović, Z. (2015), „Digitalno i onlajn učenje“, available at: https://prezi.com/zx64bidy2pfj/digitalno-i-onlajn-ucenje/ (accessed 5 January 2017)

Grakalić Rački, G. (2015), „Iz hi-tech učionice“, available at: http://www.zarez.hr/clanci/iz-hi-tech-ucionice (accessed 10 January 2017)

HABITAT III nacionalni doprinos Republike Hrvatske (2016), “Unapređenje urbanog zakonodavstva” in Vranek, J. (Ed.) HABITAT III nacionalni doprinos Republike Hrvatske, Hrvatski zavod za prostorni razvoj, Zagreb, pp. 32-34

Knifić Schaps, H. and Bobovec, B. (2014), „ApolitikA – tijek i rezultati implementacije“, in Lakušić, S. (Ed.) Izazovi u graditeljstvu 2. Hrvatski graditeljski forum 2014 proceedings of the conference in Zagreb, Hrvatska, November 18th-19th 2014, Hrvatski savez građevinskih inženjera, Zagreb, pp. 446-455

Milonja, I., Pozojević, A. (2012), „ApolitikA, platforma za kvalitetu i kulturu građenja, Interview: Borka Bobovec“, Presjek, No. 07, pp. 119-124

Weeber, R., Weeber, H. (2007), “Technology and Ecology”, in Weeber R. and H. (Ed.) Baukultur! – Planning and Building in Germany, Federal Ministry of Transport, Building and Urban Affairs, Berlin, pp. 48-55

(1)„Algebrin e-learning model“, available at: *http://www.algebra.hr/elearning/* (accessed 27 January 2017)

(2)„Massive open online course“, available at: *http://en.wikipedia.org/wiki/massive open online course* (accessed 4 March 2015)

Construction Design and Technology

Odabir optimalnog strojnog sustava na projektima s izraženim zemljanim radovima

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Abstract:

U praksi odabir optimalnog strojnog sustava se u glavnom svodi na odabir financijski najpovoljnijeg strojnog sustava, ili na izbor dostupnih strojeva pojedinog izvođača. Ovakav pristup sa sobom nosi velik broj nepoznanica, obzirom su projektne cijene i količine u glavnom samo procjena realnog stanja materijala, strojeva i njihove interakcije. U radu se nudi drugačiji pristup za odabir optimalnog strojnog sustava, a koji u obzir uzima i pouzdanost strojnih sustava.

Istraživanje se provelo na projektu hidrotehničkog nasipa duljine 2,5km. Za potrebe istraživanja za izbor optimalnog strojnog sustava ponuđene su tri varijante strojnih sustava koji izvršavaju rad na izvedbi hidrotehničkog nasipa. Za svaku od ponuđenih varijanti procijenjena je vrijednost radova, te pouzdanost strojnih sustava. Usporedbom rezultata analize vrijednosti radova i pouzdanosti odabran je optimalni strojni sustav. Nadalje, kako bi se prikazala potencijalna netočnost analize projektantskih procjena troškova u radu se analizira i raspon u troškovima koji se mogu dobiti samo neadekvatnim odabirom koeficijenata rada pri procjeni učinka strojnih sustava.

Keywords: *pouzadnost; troškovi rada; strojni sutavi; optimalan izbor; varijantna rješenja*

1. Uvod

Odabir optimalne varijante najčešće se temelji samo na praktičnom učinku stroja odnosno strojnog sustava iz razloga što je najčešće vrijeme, odnosno vremenski rok ograničavajući parametar u planiranju izvođenja radova. Uz praktični učinak stroja, kao relevantna za odabir promatra se naravno i cijena koštanja strojnog sustava, a pokazat će se da se može promatrati i njegova pouzdanost. Provedeno je nekoliko studija o razvoju alata i metodologija koji za cilj imaju optimizaciju strojnog sustava, a ovo će se istraživanje nadovezati na studiju Bezaka i Linarića (2009) koji su u svom su radu opisali metodologiju izračuna cijene koštanja radnog sata strojeva s naglaskom na primjenjivost metodologije u području izgradnje vodnogospodarskih građevina.

Cilj ovog rada je izbor strojeva koji najviše odgovaraju tehničkim karakteristikama projekta uzimajući u obzir učinak, trošak i pouzdanost strojeva kao glavna mjerila opravdanosti odabira. Glavna pretpostavka je da superpozicija tih mjerila daje dovoljan podatak na temelju

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kojeg je moguće odabrati optimalan strojni sustav i u slučajevima kada usporedba učinaka i troškova rada ne daju dovoljnu količinu podataka da bi se omogućio jednostavan odabir, a koji ne zahtjeva ekspertno znanje i iskustvo.

Istraživanje se provodi na projektu hidrotehničkog nasipa duljine 2,5 km. Za analizu u okviru istraživanja za izbor optimalnog strojnog sustava ponuđene su tri varijante strojnih sustava koji izvršavaju rad na izvedbi hidrotehničkog nasipa. Za svaku od ponuđenih varijanti procijenjena je vrijednost radova te pouzdanost strojnih sustava. Usporedbom rezultata vrijednosti radova i pouzdanosti odabran je optimalni strojni sustav. Nadalje, kako bi se pobliže prikazali potencijalni nedostaci analize projektantskih procjena troškova, u radu se analizira i raspon u troškovima koji mogu nastati samo neadekvatnim odabirom koeficijenata rada pri procjeni učinka strojnih sustava.

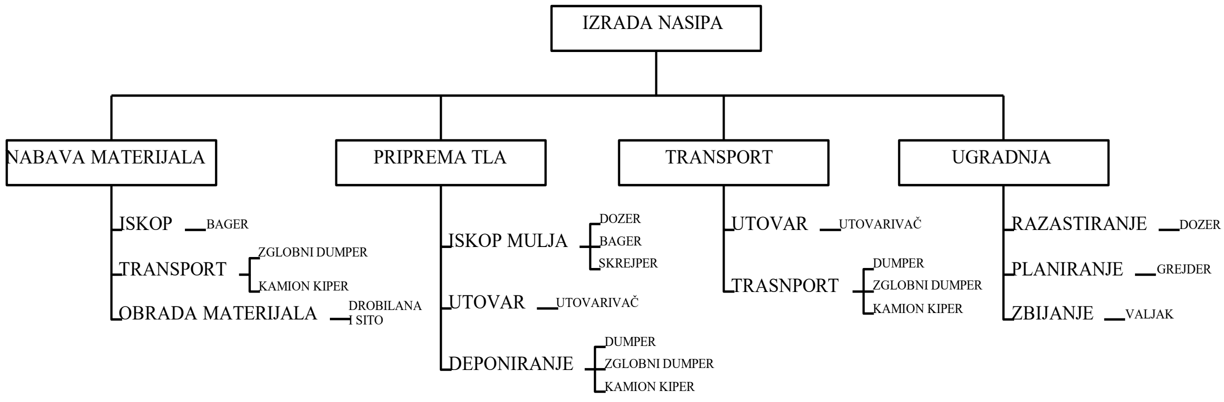
2. Materijali i metode

Projekt koji je poslužio kao podloga istraživanju je projekt izgradnje nasipa u duljini od 2,5 km. Razlog tome je primjenjivost metodologije za rad strojeva na projektima sa zemljanim radovima velikog obujma s naglaskom na vodno-gospodarskim objektima što rezultira značajnom zastupljenošću strojnog rada. Istraživanje je započelo identificiranjem aktivnosti izgradnje i njihovih radnih operacija kako bi se svakoj od njih aplicirao adekvatan stroj za izvršenje pojedinog rada. Tako je u konačnici dobivena jedna od varijanti strojnog sustava, a na isti način kreirane su i dodatne dvije kombinacije. Potom je za svaku od kombinacija, na temelju očekivanih građevinskih uvjeta, izračunat učinak stroja, a zatim i strojnog sustava nakon čega je slijedio izračun cijene radnog sata strojeva te na kraju izračun pouzdanosti stroja i strojnog sustava. Ova tri parametra svedena su zatim na jedan, na temelju kojeg je izvršen konačni odabir.

U drugom dijelu istraživanja provest će se analiza kojom će se prikazati raspon procijenjenih troškova s obzirom na odabir vrijednosti koeficijenata rada u metodološkom pristupu Z Linarića (2007). Analizirat će se utjecaj organizacije gradilišta, radnog vremena i radnog prostora na troškove triju različitih strojeva.

3. Rezultati istraživanja

Kao prvi korak u analizi, proveden je odabir strojeva i definiranje varijanti strojnih sustava. Kreirane su tri varijante s razlikama u aktivnostima i izvršiteljima. Određen je broj strojeva za svaku aktivnost i učinak strojnog sustava pojedine aktivnosti.



Ilustracija 1. WBS – širi izbor strojeva

Tablica 1. Učinak strojeva i strojnih sustava

Varijanta	**Aktivnost**	**Operacija**	**Stroj**	**Učinak [m³]**	**Količina**	**Učinak radne grupe [m³]**
1	Nabava materijala	Iskop materijala	Bager	138,24	3	414,72
		Transport	Kamion kiper	74,87	6	
		Obrada materijala	Postrojenje za obradu	689,66	1	
	Prirpema tla	Iskop mulja	Dozer	366,39	1	366,39
		Utovar	Utovarivač	210,76	2	
		Deponiranje	Zglobni damper	75,01	5	
	Transport	Utovar	Utovarivač	200,22	2	389,46
		Transport	Zglobni damper	64,91	6	
	Ugradnja	Razastiranje	Dozer	418,46	1	410
		Planiranje	Grejder	205	2	
		Zbijanje	Valjak	212,35	2	
2	Nabava materijala	Iskop materijala	Bager	138,24	3	414,72
		Transport	Kamion kiper	74,87	6	
		Obrada materijala	Postrojenje za obradu	689,66	1	
	Prirpema tla	Iskop mulja, deponiranje	Skrejper	90,61	4	362,44
	Transport	Utovar	Utovarivač	200,22	2	399,91
		Transport	Kamion kiper	57,13	7	
	Ugradnja	Razastiranje	Dozer	418,46	1	410
		Planiranje	Grejder	205	2	
		Zbijanje	Valjak	212,35	2	
3	Nabava materijala	Iskop materijala	Bager	155,52	3	457,25
		Transport	Zglobni damper	91,45	5	
		Obrada materijala	Postrojenje za obradu	689,66	1	
	Prirpema tla	Iskop mulja	Bager	155,52	3	439,46
		Deponiranje	Zglobni damper	62,78	7	
	Transport	Utovar	Utovarivač	200,22	2	389,46
		Transport	Zglobni damper	64,91	6	
	Ugradnja	Razastiranje	Dozer	418,46	1	410
		Planiranje	Grejder	205	2	
		Zbijanje	Valjak	212,35	2	

Sljedeći parametar koji se analizira je cijena radnog sata stroja, pri izračunu koje je korištena metodologija Bezaka i Linarića prema kojoj izračun obuhvaća četiri vrste troškova: obveze (css_o), troškove održavanja stroja (css_{od}), troškove pogona stroja (css_p) i troškove rada strojem (css_R). U izraz za izračun cijene radnog sata potrebno je uvrstiti i dobit (d), koja se računa kao određeni postotak od zbroja troškova obveza, održavanja i pogona stroja pa tako dobivamo:

$$pcss = css_o + css_{od} + css_p + css_R + d \quad (1)$$

Cijene radnih sati 8 korištenih strojeva dane su u sljedećoj tablici:

Tablica 2. *Cijene radnog sata strojeva*

Stroj	**Cijena radnog sata [kn]**
Bager	857,07
Dozer	1.538,85
Skrejper	1.711,10
Utovarivač	983,3
Zglobni damper	1.214,34
Kamion kiper	756,98
Grejder	709,45
Valjak	460,72

Zadnji korak analize je izračun pouzdanosti strojeva koja se može definirati kao vjerojatnost da će stroj izvršiti zadani zadatak uzimajući u obzir uvjete u kojima se rad smatra izvršenim. Pouzdanost nekog stroja temelji se na njegovoj dotrajalosti i degradaciji kroz korištenje, a može poprimiti vrijednosti između 0 i 1.

Prema konceptu pouzdanosti (Vukomanović, 2017.), strojevi i tehnološka oprema u nekom sustavu mogu biti povezani serijski, paralelno ili kombinacijom tih dvaju načina. Osnovna karakteristika serijske povezanosti je da otkazom jednog od elemenata sustava cijeli sustav nužno prestaje djelovati, dok kod paralelne povezanosti u slučaju otkaza jednog od elemenata sustav nastavlja djelovati sa smanjenim učinkom. Pouzdanost nekog postrojenja, odnosno sustava sastavljenog od 2 ili više stroja možemo izračunati na sljedeći način:

Redna (serijska) povezanost:

$$P_{e,sustava} = P_{e1} \times P_{e2} \times \dots \times P_{en}$$

Paralelna povezanost:

$$P_{e,sustava} = 1 - [(1 - P_{e1}) \times (1 - P_{e2}) \times \dots \times (1 - P_{en})]$$

pri čemu je P_e pouzdanost pojedinog stroja u sustavu.

Slijedom dvaju prethodno navedenih izraza možemo izračunati pouzdanost svakog od definiranih strojnih sustava, odnosno varijanti. Dobiveni rezultati dani su sljedećom tablicom 3.

Iako su glavni parametri za odabir identificirani kao učinak strojnog sustava, odnosno ukupno trajanje strojnog rada, zatim cijena radnog sata stroja, odnosno ukupna cijena strojnog rada te pouzdanost strojnog sustava, konačni odabir vrši se na temelju jednog podatka koji obuhvaća sve navedene, a to je omjer troškova i pouzdanosti strojnog sustava (varijante). Primarno, ukupni trošak po varijanti strojnog rada sveden je na jedinični pa zatim podijeljen s pouzdanošću varijante. Konačni rezultat je omjer troška i pouzdanosti koji predstavlja cijenu izgradnje jednog kubičnog metra nasipa, a koja preko pouzdanosti u obzir uzima i mogućnost kvara stroja te popravke istog, odgode i zastoje u radu. Na kraju, najpovoljnijom se pokazala druga varijanta čija je cijena 83,41 kn/m^3, kako je prikazano u tablici 4.

Tablica 3. *Pouzdanost strojeva i strojnih sustava*

Varijanta	Aktivnost	Stroj	Broj strojeva	Pouzdanost stroja	Pouzdanost aktivnosti	Pouzdanost varijante
1	Nabava materijala	Bager	3	0,91	0,999	0,585
		Kamion kiper	6	1		
		Postrojenje za obradu	1	1		
	Prirpema tla	Dozer	1	0,8	0,768	
		Utovarivač	2	0,8		
		Zglobni damper	5	0,8		
	Transport	Utovarivač	2	0,8	0,96	
		Zglobni damper	6	0,8		
	Ugradnja	Dozer	1	0,8	0,794	
		Grejder	2	1		
		Valjak	2	0,91		
2	Nabava materijala	Bager	3	0,91	0,999	0,76
		Kamion kiper	6	1		
		Postrojenje za obradu	1	1		
	Prirpema tla	Skrejper	4	0,8	0,998	
	Transport	Utovarivač	2	0,8	0,96	
		Kamion kiper	7	1		
	Ugradnja	Dozer	1	0,8	0,794	
		Grejder	2	1		
		Valjak	2	0,91		
3	Nabava materijala	Bager	3	0,91	0,999	0,761
		Zglobni damper	5	0,8		
		Postrojenje za obradu	1	1		
	Prirpema tla	Bager	3	0,91	0,999	
		Zglobni damper	7	0,8		
	Transport	Utovarivač	2	0,8	0,96	
		Zglobni damper	6	0,8		
	Ugradnja	Dozer	1	0,8	0,794	
		Grejder	2	1		
		Valjak	2	0,91		

Tablica 4. *Konačni odabir strojnog sustava*

Varijanta	Jedinična cijena [kn/h]	Jedinična cijena [kn/m3]	Ukupna cijena [kn]	Pouzdanost	Jedinična cijena / pouzdanost [kn/m3]
1	10.257,20	76,38	57.346.700,87	0,585	130,56
2	7.774,45	63,39	49.743.748,33	0,760	83,41
3	9.049,49	77,31	58.812.075,31	0,761	101,59

U ovoj situaciji odabir najpovoljnije varijante bio je relativno očigledan već na temelju prethodnih parametara, ponajviše na temelju cijene koštanja strojnog sustava, međutim može se reći da se radi o slučajnosti. Naime, ako usporedimo cijenu koštanja prve i treće varijante možemo vidjeti da je razlika mala, a čak ide i u korist prve varijante dok pouzdanost ide u korist treće te bi tek na temelju omjera troška i pouzdanosti mogli donijeti odluku o odabiru. Može se dakle zaključiti da taj omjer može biti odlučujući kod konačnog odabira strojnog sustava u slučaju kada su od dvije ili više varijanti troškovno slične.

4. Nepouzdanost projektantskih procijenjenih cijena

Kao što je rečeno, analizirat će se utjecaj koeficijenata kojima se uzima u obzir organizacija gradilišta, iskorištenje radnog vremena i ograničenja u prostoru rada stroja na ukupne troškove strojnog rada, odnosno na cijenu koštanja strojnog rada. To su koeficijenti koji uglavnom ne ovise o vrsti stoja već o organizaciji i planiranju strojnog rada, što znači da se na njih u jednom dijelu može utjecati. Oscilacije u troškovima pokazat će se na primjerima bagera, dozera i utovarivača.

Učinci i cijene ovih strojeva s odabranim srednjim vrijednostima tih koeficijenata prikazani su u tablici 5.

Tablica 5. *Učinci strojeva i cijene s srednjim vrijednostima koeficijenata ispravke*

Stroj	**Operacija**	**Učinak [m3/h]**	**Trajanje [h]**	**Jedinična cijena [kn/h]**	**Ukupni troškovi [kn]**
Bager	Iskop	138,24	7.167,58	857,07	6.143.117,79
Dozer	Iskop guranjem	366,39	776,56	1.538,85	1.195.009,36
Utovarivač	Utovar	200,22	4.948,79	983,30	4.866.145,21

Kako bi se prikazao raspon u kojem ovi parametri mogu poprimati vrijednosti, odabrat će se i najmanje i najveće vrijednosti navedenih koeficijenata, a rezultati prikazati tablično. U tablici 6 prikazani su rasponi koeficijenata ispravke vezani uz organizaciju građenja, dok tablica 7 prikazuje aproksimacije koeficijenta radnog vremena koji se koriste u vidu koeficijenta ispravke za radno vrijeme.

Tablica 6. *Aproksimacija koeficijenta organizacije gradilišta*

Uvjeti strojnog rada	**Vrsta stroja**				
	Dozer	Utovarivač	Bager (utovar)	Bager (iskop)	Damper
Dobri	0,83	0,83	0,83	0,83	0,8
Prosječni	0,8	0,8	0,8	0,75	0,7
Loši	0,75	0,75	0,75	0,67	0,6
Nezadovoljavajući	0,7	0,7	0,7	0,58	0,5

Tablica 7. *Aproksimacija koeficijenta radnog vremena*

Odlično korištenje radnog vremena	k_{rv} = 0,92 (efektivni rad od 55 minuta na sat)
Dobro korištenje radnog vremena	k_{rv} = 0,84 (efektivni rad od 50 minuta na sat)
Slabo korištenje radnog vremena	k_{rv} = 0,75 (efektivni rad od 45 minuta na sat)

Koeficijent radnog prostora krp može se pretpostaviti da kod radova u slobodnom preglednom širokom prostoru iznosi oko 1, dok u slučaju ograničenja slobode kretanja stroja u prostoru iznosi oko 0,95.

Nakon uvrštavanja vrijednosti ovih koeficijenata u izraze, dobivene su najveće i najmanje moguće vrijednosti učinaka ovih triju strojeva. Analogno tome izračunata su i trajanja rada te troškovi rada. Dobiveni rezultati su prikazani u tablici 8 i tablici 9.

Tablica 8. *Vrijednosti s najvećim vrijednostima koeficijenata*

Stroj	**Operacija**	**Učinak [m3/h]**	**Trajanje [h]**	**Jedinična cijena [kn/h]**	**Ukupni troškovi [kn]**
Bager	Iskop	169,92	5.831,25	857,07	4.997.791,05
Dozer	Iskop guranjem	417,68	681,20	1.538,85	1.048.267,14
Utovarivač	Utovar	226,34	4.377,69	983,30	4.304.582,43

Tablica 9. *Vrijednosti s najmanjim vrijednostima koeficijenata*

Stroj	**Operacija**	**Učinak [m3/h]**	**Trajanje [h]**	**Jedinična cijena [kn/h]**	**Ukupni troškovi [kn]**
Bager	Iskop	92,16	10.751,37	857,07	9.214.677,25
Dozer	Iskop guranjem	271,12	1.049,44	1.538,85	1.614.931,47
Utovarivač	Utovar	147,99	6.695,36	983,30	6.583.547,45

Vidljivo je da učinak stroja značajno ovisi o odabiru ovih koeficijenata. Raspon u kojem učinci mogu poprimiti vrijednosti iznosi čak preko 80% minimalne vrijednosti za bager. Analogno tome se i ukupni troškovi pojavljuju u tom rasponu – rad jednog bagera u tom slučaju košta preko 4 milijuna kuna više u odnosu na dobro isplaniran i organiziran rad. Jasno je dakle kolika može biti nepreciznost u procjeni ukupnih troškova u nekom projektu.

5. Zaključak

Primijenjena metodologija izračuna parametara na temelju kojih se provodi odabir optimalnog strojnog sustava bila je primjenjiva za analizu ovog projekta. Ona koristi veliku i sveobuhvatnu bazu ulaznih podataka relevantnih za izračune, čime se može dobiti velika preciznost rezultata. Također je moguće znatno manipulirati rezultatima retroaktivnim unosom ulaznih podataka koji kao takvi mogu oscilirati, a također u vidu oscilacija konačnih rezultata, što u određenim situacijama istraživaču može biti korisno. Ono što može predstavljati problem ove metodologije je prikupljanje, dostupnost i točnost ulaznih podataka, koji ukoliko nisu precizni vrlo brzo akumuliraju ukupnu nepreciznost i to u značajnoj veličini, što za posljedicu opet može imati značajnu oscilaciju krajnjeg rezultata.

Izbor strojeva za izvođenje radova, kao što se moglo vidjeti, ovisi o velikom broju i vrstama ulaznih podataka, od kojih najčešće nisu svi dostupni, a i ako jesu, ne znači da su nužno točni i dovoljno precizni, što predstavlja svojevrsno ograničenje u istraživanju. Tehničke specifikacije strojeva, karakteristike tla, karakteristike gradilišta, dostupnost resursa, mogućnosti nabave i način kreditiranja nabave strojeva neki su od podataka na koje se ne može utjecati, a utječu na ukupne troškove strojnog rada. Što se tiče prikazanih triju varijanti strojnog sustava, njihove točnosti rezultata mogu biti upitne s obzirom na takvo ograničenje u dostupnosti ulaznih podataka, no, kako su za sve varijante korišteni isti ulazni podaci, tako one imaju i odstupanja u istoj ili vrlo sličnoj mjeri, što daje istraživaču legitimno pravo na međusobnu usporedbu varijanti, a budući da je zadatak ovog rada upravo odabir optimalnog strojnog sustava između više potencijalnih, može se još jednom reći da je metodologija primjenjiva za traženi cilj.

Literatura

Bezak, S., Linarić, Z.: Metodološki pristup proračuna troškova strojnog rada pri građenju, GRAĐEVINAR, 61, (2009), 1, pp. 23-27.

Zdravko Linarić - Leksikon strojeva i opreme za proizvodnju građevinskih materijala, Učinci za strojeve i vozila pri zemljanim radovima, biblioteka Mineral, Busines Media Croatia, Zagreb, 2007.

Mladen Vukomanović – Građevinski strojevi: Učinkovitost i pouzdanost tehničkih sustava - predavanja

Building Information Modeling

Korištenje BIM-a i drugih naprednih tehnologija za mjerenje količina izvedenih radova i praćenje procesa gradnje

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Sažetak:

Ovaj članak prikazuje izazove s kojima se susreću nadzorni inženjeri u okviru njihovih obaveza propisanih regulativom i ugovornim odnosima u području kontrole količina izvedenih radova i praćenja napretka radova te načine prevladavanja tih izazova. Trenutne metode kontrole količina, iako su dokazane u praksi i dovoljno točne u primjeni, polako postaju nedovoljno učinkovite obzirom na moderne zahtjeve građevinske industrije. Potreba za modernizacijom povećava se proporcionalno s porastom složenosti građevinskih projekata i sve većim zahtjevima za učinkovitosti. Određen broj novih tehnologija koje su primarno razvijene za druge svrhe mogu se prilagoditi upotrebi u građevinarstvu kako bi se ubrzao i automatizirao proces kontrole količina izvedenih radova i praćenju izvršenja. Prednosti modernizacije ne uključuju samo povećanje brzine obavljanja tih zadataka već i povećanja točnosti budući da se ljudski faktor u procesu može barem djelomično poboljšati moderniziranim tehnikama prikupljanja podataka. Tehnologije obrađene u članku prezentirat će se skupa sa svojim prednostima i nedostacima u kontekstu mjerenja količina izvedenih radova. Poseban naglasak bit će stavljen na Building Information Modelling (BIM) kao platformu za mjerenje i izvještavanje o napretku izvršavanja građevinskih radova kroz integraciju s navedenim tehnologijama.

Ključne riječi: *BIM; Praćenje i kontrola gradnje; Stručni nadzor; Mjerenje i kontrola količina izvedenih radova; moderne tehnologije*

1. Uvod

Building Information Modelling (BIM) tehnologija se sve više i više upotrebljava u građevinskoj industriji, ali ponajviše u fazi projektiranja i koriste ju uglavnom projektanti. No, BIM tehnologija, ali i ostale napredne tehnologije koje će biti navedene u članku, mogu se koristiti i u fazi izvođenja i biti od koristi i ostalim sudionicima u gradnji, posebice izvođačima i nadzornim inženjerima. Ovaj rad fokusira se upravo na mogućnosti primjene takvih tehnologija u okviru djelatnosti koje obavlja nadzorni inženjer, točnije na poslove praćenja i kontrole gradnje.

U radu se istražuje na koji se način BIM tehnologija koristi u praćenju i kontroli gradnje, istražuju se kvalitete naprednih metoda koje se tek razvijaju te njihova implementacija u BIM tehnologiju i nadzor gradnje kroz kontrolu količina, kvalitete i vremena. Cilj je produbiti znanje o praćenju i kontroli gradnje te istražiti napredne tehnologije koje olakšavaju taj posao, ubrzavaju ga i podižu njegovu kvalitetu. Kroz rad su opisane metode, njihovi nedostaci,

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područje primjene te mjere koje je još potrebno poduzeti da bi se implementirale u praćenje i kontrolu gradnje.

Članak ukratko pojašnjava i sudionike u gradnji i njihove ugovorne odnose kroz različite faze građenja. Opisani su ugovorni odnosi i ugovorni modeli u kojima se regulira način plaćanja, a što direktno utječe na način provedbe kontrole i stručnog nadzora. Opisan je rad nadzornog inženjera te njegove dužnosti i ovlasti. Kroz literaturu, prospekte i prezentacije tvrtki napravljen je presjek kroz napredne tehnologije za praćenje gradnje, njihove mogućnosti, mane i područje primjene. Definirana je sama BIM tehnologija, njezina svrha te integracija prezentiranih naprednih metoda za praćenje s BIM tehnologijom.

2. Regulativa i ugovorni odnosi

Građevinska industrija je izrazito regulirana brojnim zakonima i pravilnicima. Iz tog razloga potrebno je dati kratak uvid u pravnu okolinu u koju je smještena obrađivana problematika, posebice stoga što se direktno dotiče nekih aspekata koji su izrijekom propisani regulativom. Stoga će ovo poglavlje dati kratki uvod u regulativu koja je vezana uz praćenje i kontrolu gradnje, s posebnim naglaskom na nadzornog inženjera i njegove dužnosti, i uz ugovorne oblike koji reguliraju odnose među sudionicima u gradnji, a posebice na one ugovorne odredbe koje određuju načine obračuna izvedenih radova.

2.1 Sudionici u gradnji

Zakonom o gradnji (2014) definirani su sudionici u procesu gradnje: investitor, projektant, izvođač, nadzorni inženjer i revident. Članak je fokusiran na korištenje naprednih tehnologija u fazi gradnje te je samim time fokusiran i na one sudionike koji su prisutni u projektu u fazi izvođenja. Prvenstveno se odnosi na nadzornog inženjera koji provodi postupke praćenja i kontrole prema propisanim mu obavezama, ali se isto tako može primjenjivati i na izvođača ako provodi svoje interne procese kontrole, mjerenja učinka, utroška materijala i radnih sredstava i slično. Investitor također ima posljedičnu korist od primjene naprednih tehnologija jer je on krajnji korisnik za kojeg rade i izvođač i nadzorni inženjer te se sve prednosti koje oni ostvaruju u nekom obliku (primjerice uštedama, većom kvalitetom radova,…) prenose i na njega.

U cilju razumijevanja konteksta problematike kojom se članak bavi, ovo podpoglavlje će ukratko opisati ulogu i dužnosti nadzornog inženjera. Uloga nadzornog inženjera propisana je Zakonom o gradnji (2014), Zakonom o poslovima i djelatnostima prostornog uređenja i gradnje (2015d), Zakonom o komori arhitekata i komorama inženjera u graditeljstvu i prostornom uređenju (2015b), te Pravilnikom o načinu provedbe stručnog nadzora građenja, obrascu, uvjetima i načinu vođenja građevinskog dnevnika te o sadržaju završnog izvješća nadzornog inženjera (2015a). Ta regulativa navodi kako je nadzorni inženjer fizička osoba koja prema posebnom zakonu ima pravo uporabe strukovnog naziva ovlašteni arhitekt ili ovlašteni inženjer i provodi u ime investitora stručni nadzor građenja i propisuje njegove obaveze koje uključuju: kontrolu da se radovi izvode u skladu s aktom kojim se odobrava građenje; provjeru da li osobe koje izvode radove i koje su izvele iskolčenje zadovoljavaju propisane uvjete; provedbu kontrolnih ispitivanja kvalitete; upoznavanje investitora sa svim nedostacima; i sastavljanje završnog izvješća.

Osim provedbe aktivnosti stručnog nadzora prema Zakonu o gradnji i prostornom uređenju i pratećim propisima, nadzorni inženjer smije obavljati poslove i koje mu ugovorom povjeri investitor, kao primjerice: poslove tehničkog savjetovanja, kontrole ispunjavanja ugovornih obveza izvođača radova prema naručitelju i poduzimanja odgovarajućih mjera za realizaciju tih obveza, poslove obračunavanja izvedenih radova i slično. No, te poslove nadzorni inženjer ne smije obavljati na način koji bi ugrozio njegovu neovisnost i nepristranost u ispunjavanju obveza koje ima prema regulativi ili koji bi na bilo koji drugi način ugrozio ili onemogućio ispunjavanje tih obveza.

Tema članka se fokusira ponajviše na kontrolu da li se radovi izvode u skladu s projektom, koja je propisana regulativom, i na kontrolu i obračun izvedenih radova koja je izrazito često predmet ugovora između investitora i nadzornog inženjera.

2.2 Ugovorni odnosi i načini obračuna izvedenih radova

Ugovorni odnosi izvođača i investitora određeni su ugovorom o građenju. Ugovorom o građenju izvođač se obvezuje prema određenom projektu izgraditi u ugovorenom roku određenu građevinu na određenom zemljištu, ili na takvom zemljištu, odnosno na postojećoj građevini izvesti kakve druge građevinske radove, a naručitelj se obvezuje isplatiti mu za to određenu cijenu (2015c). O obliku ugovora o građenju (posebice o ugovorenom načinu obračuna izvedenih radova) ovisi i način obračuna i plaćanja izvedenih radova.

Oni tipovi ugovora kod kojih nisu apsolutno fiksno definirani troškovi građenja, odnosno kod kojih nije poznat maksimum i/ili minimum vrijednosti ugovora već samo okvirna procijenjena vrijednost zahtijevaju detaljnu i što točniju kontrolu izvedenih količina budući da se temeljem izvedenih radova vrši plaćanje. O tipu ugovora ovisi i tko snosi rizik pojave veće ili manje količine radova (više/manje radnje).

Kod ostalih tipova ugovora također je moguća (i poželjna) kontrola količina, zbog praćenja izvršenja, buduće točnije procjene vrijednosti radova na sličnim projektima i izvođačeve vlastite evidencije troškova. Design & Build ugovori su u ovom kontekstu specifični jer se kod njih dodatno mora specificirati način obračuna radova. Najčešće sadržavaju odredbu ključ u ruke, no moguće su situacije obračuna i po stvarno izvedenim količinama. Tipovi ugovora i njihove karakteristike obzirom na navedene načine obračuna radova prikazani su pregledno u Tablici 1.

Uz tipove ugovora navedene u Tablici 1, postoji još nekoliko tipova prema načinu obračuna izvedenih radova koji se uglavnom koriste ili rijetko ili za manje radove i objekte te kao takvi nisu predmet istraživanja ovog članka. To su primjerice: paušalno plaćanje, plaćanje po izvršenim fazama ili etažama i plaćanje fiksnog mjesečnog iznosa. Za takve tipove obračuna metode provjere količine radova navedene u ovom članku nisu prikladne.

Tablica 1. Tipovi ugovora po načinu obračuna radova

Tip ugovora	Poznata maksimalna vrijednost radova prije okončanog obračuna	Poznata minimalna vrijednost radova prije okončanog obračuna	Potrebna kontrola količina izvedenih radova	Rizik viših/manjih radnji snosi
Ugovor s jediničnim cijenama i stvarno izvedenim količinama	Ne	Ne	Da	Investitor
Ključ u ruke	Da	Da	Ne	Izvođač

Ugovor s fiksnom cijenom	Da	Da	Ne	Izvođač
Guaranteed maximum price	Da	Ne	Da	Izvođač
Design & Build	Da/Ne	Da/Ne	Da/Ne	Izvođač/Investitor

2.3 Dokumentacija na gradilištu i građevinska knjiga

Na gradilištu se u svakom trenutku mora nalaziti dokumentacija propisana Zakonom o gradnji, ali i ona propisana drugim propisima ili definirana ugovornim odnosima. Ukoliko ugovorni odnosi definiraju obračun po stvarno izvedenim količinama, obavezna dokumentacija je i građevinska knjiga.

Građevinska knjiga je osnovni dokument temeljem kojeg se izrađuje obračun izvršenih radova. U građevinsku knjigu upisuju se točni podaci o izmjerama i količinama stvarno izvedenih radova po odgovarajućim stavkama iz troškovnika i služi kao dokaz (dokument) za obračun i naplatu radova. Podaci o mjerama i količinama izvršenih radova klasificirani su po pojedinim vrstama i pozicijama radova, po nazivu i redoslijedu, kao u predmjeru projekta odnosno ugovornom predračunu radova. Po potrebi, u građevinsku knjigu ucrtavaju se i odgovarajuće skice.

Voditelj građenja (ili radova) i nadzorni inženjer dužni su izrađivati potrebne obračunske nacrte koji se smatraju sastavnim dijelom građevinske knjige. Obračunski nacrti vode se u jednom primjerku na kopiji izvedbenog projekta. Stranice građevinske knjige i obračunske nacrte potpisuju i ovjeravaju pečatom nadzorni inženjer i voditelj građenja (ili radova). Građevinska knjiga vodi se u jednom primjerku na način da svaka stavka iz troškovnika ima svoj zasebni list. Po završnom obračunu svi listovi građevinske knjige uvezuju se i predaju naručitelju. Podatke za građevinsku knjigu prikuplja rukovoditelj radova, koji krajem mjeseca upisuje količine radova izvršene u tom mjesecu sa računskom dokaznicom tih količina te izrađuje privremenu situaciju za taj mjesec. Obveza nadzornog inženjera je pregledati i građevinsku knjigu i privremenu situaciju te obje ovjeriti svojim žigom i potpisom, kojima pod materijalnom i kaznenom odgovornosti jamči točnost tih podataka.

3. Tradicionalne i napredne metode mjerenja izvršenja građevinskih radova

3.1 Tradicionalne metode mjerenja izvršenja

Mjerenje količina izvršenih građevinskih radova se obavlja u skladu s ugovorom, tj. mjeri se neto stvarna količina svake pozicije radova. Izmjereni podaci, kao što je objašnjeno u prethodnom poglavlju, unose se u građevinsku knjigu u obliku količina i dokaznice i ovjeravaju se od strane izvođača i nadzornog inženjera. Svaka od pojedinačnih aktivnosti prilikom klasičnog načina mjerenja i priređivanja snimaka trenutnog stanja ovisi o preciznosti osobe koja provodi mjerenje, a ograničena je i uporabom korištenih analognih mjernih instrumenata kao primjerice krutih metara, mjernih letvi, mjernih traka i klasičnih libela i visaka. Svi ti tradicionalni instrumenti osiguravaju zadovoljavajuću točnost rezultata uz uvjet da je vremenski rok takav da je iste u njemu moguće realizirati, uz sve nužne korektivne procedure (provjere i ponovne izmjere) (Arbutina, 2011).

Prvotni napredak na polju mjerenja izvršenja ostvaren je uporabom suvremenih digitalnih i posebice laserskih naprava, koje su u vidu laserskih mjerača udaljenosti ili digitalnih kutomjera, laserskih libela ili nivelira uvelike olakšali i ubrzali mjerenje, no i povećali njegovu preciznost. Primjena laserskih daljinomjera integrirana je uz primjenu laserskih nivelira, ali i računala koja imaju mogućnost direktne veze s mjernim uređajem, tako da se uporabom određenih računalnih programa gotovo istovremeno može integrirati uzimanje podataka na građevini s digitalnim unosom istih u računalne alate (Arbutina, 2011). Ovime je ubrzan proces mjerenja i povećana točnost, no sam postupak se provodi na funkcionalno identičan način te stoga još uvijek pripada u tradicionalne metode mjerenja izvršenja.

3.2 Mjerenje geodetskim instrumentima

Primjena geodetskih instrumenata najprikladnija je za mjerenje količine zemljanih radova (ceste, tuneli, građevne jame, iskopi), količine iskopa temeljnog tla, količine slojeva posteljice, količine asfalta i kontrolna mjerenja nadzornog inženjera tijekom izgradnje. Instrumenti koji se najčešće koriste su: klasični niveliri, digitalni niveliri, totalna mjerna stanica i GPS sustavi.

Od navedenih instrumenata, najprilagođeniji za napredne tehnologije mjerenja je robotska totalna mjerna stanica. Ona je elektronski teodolit integriran s elektronskim daljinomjerom koji očitava udaljenosti od instrumenta do određene točke. Nakon snimanja totalnom stanicom prikupljeni podaci čine niz prostornih točaka čije su koordinate relativne poziciji samog mjernog instrumenta. Takav niz točaka prebacuje se na računala koja specijalnim računalnim alatima generiraju mapu prikupljenih podataka. Računalni alati pripremaju prikupljene podatke i uz obradu u CAD alatima, gdje je pojedinačno snimljene točke nužno povezati linijama u kostur koji će dati osnovne podatke o mjerenoj stavci (Arbutina, 2011).

Ona može biti povezana s BIM tehnologijom što ubrzava proces kontrole, obilježavanja i prikupljanja točaka sa gradilišta. Ako su u BIM modelu generirane točke pomoću robotske totalne mjerne stanice mogu se prenijeti na gradilište. Nadzor može pregledati komponente zgrade u smislu provjere izgradnje prema projektu i unutar raspona tolerancije (npr. kod montažnih elemenata gdje je geodetsko obilježavanje vrlo bitno). Robotska totalna stanica ima sposobnost automatskog snimanja promjenjivih koordinata točnosti u milimetrima što omogućuje preciznost i od pomoći je pri mjerenju manjih kretnji.

3.3 Fotogrametrija i aerofotogrametrija

Cilj fotogrametrije u okviru kontrole izvršenja je analitički obraditi podatke sadržane u slici gradilišta i pretvoriti ih u 3D gradilišni model. Fotogrametrija počiva na načelima stvaranja 3D slike objekta na principu stereo vida. Promatranjem scene iz dva različita kuta kamere, metodom triangulacije dolazi se do 3D koordinata identičnih točaka iz dviju ili više snimaka (Gajski, 2010).

Fotogrametrija je pogodna za primjerice mjerenje građevinskih elemenata koji se nalaze na nedostupnim i/ili opasnim područjima i za provjeru dimenzija montažnih jedinica na licu mjesta uz kontrolu kvalitete. Fotogrametrijske metode prilikom izrade snimaka stanja na gradilištu danas se sve više koriste kao način integriranja digitalnog fotografiranja i prikupljanja osnovnih tehničkih/prostornih informacija o građevinama.

Računalni alati koji se koriste za obradu fotografija u fotogrametrijske svrhe mogu se svrstati u dvije grupe povezanih, no principijelno različitih programskih struktura. U toj podjeli tako treba definirati slijedeće skupine računalnih alata (Arbutina, 2011):

- računalne alate koji fotografski materijal (raster digitalne fotografije ili digitalni scan analognih fotografija) obrađuju i eksportiraju u dvodimenzionalnom obliku;
- računalne alate koji obrađuju osnovni grafički materijal na način kojim se anuliraju perspektivne distorzije, te se zatim takav prilagođen grafički materijal kao podloga eksportira u neki od CAD računalnih alata na daljnju obradu i tehničku prilagodbu.

Slika 1. Primjer aerofotogrametrijskog snimka gradilišta (AEROmetrex, 2016)

Obje skupine alata uvelike ovise o digitalnoj fotografskoj tehnologiji koja im omogućava manipulaciju slikovnim podlogama izuzetno visoke razlučivosti, tako da su i mogućnosti takvih programa izuzetno velike. U slučaju obje od ovih grupa nužno je napomenuti kako zahtijevaju i značajnu količinu direktne ljudske manipulacije i povezivanja podataka koji se unutar pojedinačnih računalnih alata unose. Tako svaki od tih alata zahtjeva povezivanje slikovnih prikaza pojedinačnih elemenata neke građevine (vrhova, bridova, ploha i sl.) sa njihovim vektoriziranim interpretacijama (točke, linije, točke, plohe i sl.) kako bi se uspješno proveo postupak fotogrametrijske rektifikacije. Navedeni postupak u pravilu je to točniji što je više međusobno povezanih elemenata, sa točno utvrđenim dimenzijama i/ili pozicijama. Uz veliku atraktivnost modela koji se tako dobiju značajna je i ušteda prilikom izrade snimaka zatečenog stanja i optimiziranje na minimum terenskog rada i smanjivanje ekipe koja snima trenutno stanje (Arbutina, 2011). Tako dobiveni snimci zatečenog stanja mogu se u 3D obliku uspoređivati s 3D BIM modelom građevine te se preklopljeni dijelovi mogu smatrati izvršenim radovima, a dijelovi u kojima se modeli razlikuju, radovima koji se tek trebaju izvršiti.

Aerofotogrametrija podrazumijeva primjenu fotogrametrije iz zraka, prilikom kojega se kamera postavlja vertikalno ili približno vertikalno u odnosu na teren najčešće pomoću bespilotnih letjelica, odnosno dronova. Prednosti takve fotogrametrije leže u činjenici da s obzirom na visinu leta, snimak obuhvaća veće područje u odnosu na terestičku fotogrametriju. Da bi se ostvarilo potpuno prekrivanje određenog područja fotogrametrijske izmjere, snimanje je potrebno izvršiti s određenim uzdužnim i poprečnim preklapanjem snimki. Uzdužni preklop se planira u iznosu od 60%, a poprečni u iznosu od 30% (Gajski, 2010).

3.4 3D lasersko skeniranje

3D lasersko skeniranje je postupak detaljne izmjere velike gustoće, odnosno snimanja objekata i terena korištenjem posebnog preciznog uređaja - 3D terestričkog laserskog skenera, koji velikom brzinom šalje lasersku zraku prema objektu, te mjeri njihovu refleksiju od objekta. Skeniranjem se dobiva veliki broj precizno određenih prostornih točaka koje čine takozvani "oblak točaka" (point cloud). Digitalnom obradom "oblaka točaka" mogu se dobiti različiti proizvodi, kao što su jednostavnije ili složenije animacije, vektorski 3D modeli objekata, digitalni ortofoto prikazi fasada, 2D nacrti fasada, tlocrti, presjeci i slično. Kombinacijom više snimanja u odgovarajućim vremenskim razmacima mogu se odrediti količine iskopa i nasipanja, slijeganje terena i objekata, odstupanje od projekta i slično. 3D lasersko skeniranje primjenjuje se i za snimanje trenutnog stanja kod projekata rekonstrukcije (Zavod za fotogrametriju, 2016, Geodata, 2016).

LADAR (Laser distance and ranging) skeniranjem dobivamo podatke u obliku 3D točaka koji se pretvaraju pomoću programske podrške u 3D slike. Tehnologija radi na principu slanja svjetlosnog impulsa na objekt i određivanjem lokacije obzirom na vrijeme povrata zrake. Svaki impuls proizvodi piksel ili točku u obliku „oblaka“ i impulsi predstavljaju niz slika.

Najčešći izazov laserskog skeniranja je diskontinuitet prostornih informacija zbog kojeg laser u procesu skeniranja može zahvatiti samo elemente istaknute ili odvojene od površine objekta ili aktivnosti. Problem kod prikupljanja potrebnih podataka također predstavljaju i privremeni objekti poput skela, opreme, privremenih građevina i sličnih struktura.

Proces prikupljanja podataka potražuje dosta uloženog vremena i iskusne i obučene stručnjake koji upravljaju laserom. Domet laserskog skeniranja je ograničen, a najbitniji faktori kod skeniranja su stupanj površinske refleksije, kut mjerenja i kalibracija senzora jer utječu na točnost prikupljenih informacija. U slučaju lošeg vremena (vjetar, kiša) skeniranje nije izvedivo. Ograničenje laserskog skeniranja je i trajanje skeniranja i visoki troškovi povezani s opremom.

Integracija navedene metode sa BIM tehnologijom moguća je na isti način kao i s metodom fotogrametrije. Nakon obrade podataka u za to specijaliziranom software-u, 3D point cloud model može se uspoređivati s 3D modelom izrađenim u BIM software-u. Preklopom ta dva 3D modela može se steći uvid u to koji elementi građevine su u trenutku snimanja bili izvedeni.

Slika 2. Primjer point cloud snimka izvedenog stanja (Hobs Studio, 2016)

3.5 Integracija 3D laserskog skeniranja i fotogrametrije za praćenje izvršenja

Kao što je u prethodna dva podpoglavlja navedeno, jedna od metoda koja se koristi za prikupljanje podataka o količinama i napretku planiranih radova je 3D lasersko skeniranje, gdje se gradilište skenira u različitim vremenima, a podaci se koriste za procjenu količine izvedenih radova u vremenskom intervalu između dva uzastopna skeniranja. Druga metoda prethodno spomenuta metoda je fotogrametrija koja se koristi za prikupljanje podataka geometrijskih svojstava nekog objekta obradom fotografija snimljenog objekta.

Integracija 3D laser skeniranja i fotogrametrije služi za prevladavanje ograničenja vezanih uz zasebnu uporabu svake od dviju tehnologija. Ograničenja 3D skeniranja uključuju vrijeme potrebno za obavljanje jednog skeniranja i broj skeniranih pozicija za dobivanje točne informacije. Fotogrametrijske metode zahtijevaju postavljanje mnogobrojnih „meta" za generiranje dovoljno informacija o dijelovima objekta.

Metode se koriste za mjerenje količina zemljanih iskopa, napretka lijevanja betona, operacija asfaltiranja i kontrolu količina i kvalitete gradnje. U ovoj objedinjenoj metodi fotogrametrija se koristi za izdvajanje geometrijskih svojstava objekta što uvelike skraćuje ukupno vrijeme skeniranja. Vezanjem digitalnih fotografija visoke razlučivosti sa trodimenzionalnim modelom prilagođenim iz prikupljenog oblaka točaka dobivamo i podatke o boji i teksturi pojedinačnih ploha te se računalnom obradom ti podaci vežu za trodimenzionalne točke modela koje su nastale obradom točaka oblaka. Metoda omogućuje pravovremene informacije u vezi količine obavljenog posla na kraju svakog radnog dana.

3.6 Korištenje RFID tehnologije

RFID (Radio-frequency identification) je tehnologija koja koristi radio frekvenciju za razmjenu informacija između prijenosnih uređaja i računala. RFID sustav obično se sastoji od tag-a (labele) koja sadrži podatke, antene koja komunicira s tag-ovima i kontrolera koji upravlja i nadzire komunikacijom između antene i računala (Babić et al., 2010). Tehnologija se koristi u svrhu kontrole i dohvaćanja podataka na licu mjesta te integraciju podataka u BIM model. Koristeći ovu tehnologiju nadzorni inženjer može automatski dohvatiti podatke i količine primjerice ugrađenih predgotovljenih dijelova ili opreme skeniranjem pomoću pametnog telefona ili tablet računala. Osim u praćenju količina na gradilištu RFID tehnologija može se koristiti i za kontrolu alata (sprječavanje gubitaka i krađe alata), za poboljšavanje sigurnosti i zaštitu na radu i za evidenciju dolazaka na posao.

Ovaj proces omogućuje brzo prikupljanje podataka, može se implementirati u BIM tehnologiju i ne traži posebnu obuku korisnika. No nedostaci su mu to što zahtijeva instalaciju i održavanje RFID oznaka, sama implementacija u dnevnu dinamičku građevinsku okolinu može biti problematična, oštećenje samog tag-a onemogućava postupak, antena tag-a je mala i ima kratki domet, za rad koristi radio frekvenciju koja može dovesti do smetnji sa drugim uređajima i tako smanjiti sposobnost prijenosa podataka, a i cijena primjene tehnologije je visoka.

3.7 Augmented reality

Augmented reality (AR) ili proširena stvarnost jedna je od metoda koja koristi naprednu tehnologiju za automatsko ažuriranje gradilišnih aktivnosti i detektiranje razlika između projektiranog i izvedenog. Definira se kao tehnologija koja se koristi za jednostavno povezivanje digitalnih informacija sa stvarnim objektima i prostorima. AR je okoliš u kojem su virtualni elementi ugrađeni u sliku stvarnog okruženja, odnosno sučelje koje prikazuje digitalne informacije i prezentira ih korisniku, prostorno usklađene i preklopljene s trenutnim fizičkim okruženjem.

Slika 3. Primjer korištenja proširene stvarnosti na gradilištu (Shapetrace, 2016)

U kontekstu građevinske industrije proširena stvarnost može se koristiti na sljedeći način: Voditelj gradilišta i nadzorni inženjer koriste ugrađenu kameru u PDA uređaj ili pametni telefon za fotografiranje trenutnog stanja na gradilištu. Fotografije su pomoću tog uređaja koji je spojen na internet poslane na server koji je spojen i instaliran u uredu. Programska podrška automatski provjerava i uspoređuje gradilišnu sliku s 3D BIM modelom i pronalazi sve razlike. Bilo kakve razlike između stanja konstrukcije na gradilištu i BIM modela sustav šalje kao povratnu informaciju nadzornom inženjeru ili voditelju gradilišta na njegov uređaj.

Za praćenje svih aktivnosti na gradilištu potrebna je izrazito velika količina fotografija, što je značajno ograničenje za uporabu metode. Osim navedenog, problemi se javljaju kod snimanja unutarnjih objekata zbog slabijeg osvjetljenja. Nadalje, dinamična priroda gradilišta onemogućava slikanje samih elementa građevina zbog prisutnosti privremenih objekata, alata, radnika, strojeva i materijala na objektu.

4. Korištenje BIM tehnologije u praćenju izvršenja

4.1 Koncept BIM-a

Building Information Modelling, odnosno Informacijsko modeliranje gradnje u prijevodu na hrvatski, je digitalni prikaz fizičkih i funkcionalnih karakteristika objekta, platforma za razmjenu znanja i informacija o objektu, baza koja omogućava pouzdano donošenje odluka i postupaka u cijelom životnom vijeku građevine od samog projektiranja i gradnje do uklanjanja (NBIMS V.3, 2015). Za sudionike koji su uključeni u projekt, BIM omogućuje virtualni informacijski model na kojem rade svi sudionici uključujući i glavnog izvođača i nadzornog inženjera. Iz BIM modela se lako mogu iščitati količine i svojstva materijala i uspoređivati s izvedenim stanjem na gradilištu pomoću metoda koje su prezentirane u prethodnom poglavlju.

Koncept BIM tehnologije uključuje virtualnu izgradnju objekta prije njegove stvarne fizičke izgradnje, kako bi se smanjili rizici, poboljšala sigurnost, simulirale i analizirale potencijalne opasnosti i smanjio broj prepravki i ponovljenog rada na gradilištu. Njegova primjena je u velikom porastu u svijetu, no i dalje je uglavnom fokusiran na fazu projektiranja. Zbog svih koristi koje primjena BIM-a omogućuje, sve se više koristi i u fazi izvođenja za planiranje izvođenja i tehnologije radova, za zaštitu na radu, a i za svrhu provjere i usporedbe količina izvedenih radova.

4.2 Dimenzije BIM-a

BIM se smatra nadgradnjom na 3D modeliranje na način da implementira dodatne podatke u same 3D elemente modela. Samo 3D modeliranje pruža prednosti nad 2D nacrtima zbog jednostavnije vizualizacije i otkrivanja potencijalnih problema u nacrtima, jednostavnijeg modeliranja i izmjena u projektu itd. Nadgradnje na osnovni 3D model koje omogućuju dodatne brojne prednosti za cijelu građevinsku industriju nazivaju se dimenzijama BIM-a. Tako je primjerice integracija vremenske komponente četvrta dimenzija, a integracija informacija o količinama i troškovima peta dimenzija BIM-a

4D model predstavlja povezivanje 3D modela s vremenom odnosno s rasporedom i redoslijedom aktivnosti – planom gradnje. On omogućuje planiranje, praćenje izvršenja i napretka projekta, osigurava sredstva za verifikaciju gradilišne logistike i operacija na gradilištu, uključujući alate koji vizualno prikazuju iskoristivost prostora tijekom gradnje. Prometni pristup, rute za kamione, dizalice, dizala i druga oprema mogu biti također uključeni u model kao dio logističkog plana.

5D BIM model uključuje troškove. S razvojem 3D BIM tehnologije u kombinaciji s kvalitetom upravljanja informacijama, količine, napredak i troškovi se mogu pratiti i kontrolirati u realnom vremenu s točnošću i transparentno. Odstupanja, manje i više radnje uočljive su ranije i mogu se poduzeti koraci za njihovo otklanjanje ili minimalizaciju posljedica. Ključ je u tome da se količine i troškovi prate na osnovu izvedenih količina koje se mjere u skladu s napretkom i na licu mjesta. Precizna kontrola količina na temelju prethodno obrađenih metoda može osigurati brojne pogodnosti za projekt.

Određivanje cijene projekta i samo praćenje troškova na tradicionalan „ručni“ način proces je pun potencijalnih pogrešaka. Pomoću BIM tehnologije mogu se vrlo lako generirati količine i troškovi, pratiti troškovi i produktivnost u realnom vremenu. Podatak o cijeni se može dodati na svaki element u BIM modelu što omogućava automatsko izračunavanje grube procjene vrijednosti radova. Količine za troškovnik se dobivaju izravno iz BIM modela, a troškovi koji se odnose na promjene u dizajnu mogu biti automatski generirani bez ponovnog mjerenja i ponovnog računanja količina. Ovdje treba napomenuti da predviđanje ukupne cijene projekta još uvijek ipak zahtijeva uključenost osobe kompetentne za procjenu troškova.

4.3 Uloga BIM-a u poslovima nadzornog inženjera

Jedna od zadaća nadzornog inženjera je kontrola količina i procjena kvalitete. Obavljanje tih zadataka je zahtjevno, dugotrajno i sklono pogreškama. Tradicionalnim metodama nadzorni inženjer zadatak izmjere količina obavlja ručnim mjerenjem, crtanjem na papir ili korištenjem softvera za 2D CAD, prenošenjem dimenzija u excel proračunske tablice i ispisa obrasca u obliku građevinske knjige. Pri svakoj izmjeni u projektu ili na gradilištu podaci se moraju ručno ažurirati što pridonosi pogreškama. Te konvencionalne metode su stoga neučinkovite, iziskuju puno vremena i sklone su pogreškama koje negativno utječu na samu uspješnost projekta.

BIM tehnologija pruža potencijalno rješenje i automatizaciju tih zadataka i omogućuje nadzornim inženjerima posvećivanje vremena za druge usluge s dodanom vrijednošću. U samoj praksi nadzora, BIM može ponuditi značajne prednosti u odnosu na konvencionalne metode rada vezane uz uzimanje količina koje se temelji na bazi 2D crteža dokaznice. Unatoč prednostima, nadzorni inženjeri još uvijek zaostaju u BIM tehnologiji u odnosu na ostale ovlaštene inženjere.

Korištenjem BIM-a u građevinskoj praksi mogu se izvući točne količine i mjesta koja se mogu koristiti za provjeru troškova rano u procesu projektiranja i u bilo koje vrijeme projekta. BIM omogućuje nadzoru identifikaciju i komunikaciju odnosa među količinama, troškovima i lokacijama te razlučivanje koliko koje područje i dio zgrade doprinosi ukupnoj cijeni projekta. Ovaj proces omogućuje i projektantima da vide efekt troškova svake izmjene u projektu i omogućuje optimalizaciju troškova gradnje već u fazi projektiranja. Ako se pak BIM model podijeli s izvođačem u fazi izrade ponude, vrijeme za detaljnu procjenu troškova može se smanjiti dramatično i preciznost se može samo povećavati. Na ovaj način nadzorni inženjer ima gotove i precizne količine za građevinsku knjigu i privremene situacije koje se kontroliraju na načine opisane u prethodnim točkama. Automatizirane količine osiguravaju brži, točniji alat za analizu podataka i olakšavaju posao nadzornog inženjera.

4.4 Primjer korištenja BIM-a i 3D laserskog skeniranja

Primjer jedne integracije BIM-a i metode praćenja izvršenja s 3D laserskim skeniranjem iz prakse poduzeća GO2BIM d.o.o. (2016) prikazan je u ovom podpoglavlju. Za praćenje izvođenja na gradilištu pomoću 3D laserskog skeniranja mora postojati 3D BIM projekt projektiran na način da je moguće pratiti izvršenje (npr. da nije izveden jedan zid kroz sve etaže nego da je on podijeljen po etažama) ili se mora objekt skenirati i napraviti projekt postojećeg stanja ako se radi o renovaciji ili prenamjeni. Praćenje se može obavljati na način da se skeniranje vrši nakon svakog radnog dana. Ovisno o veličini gradilišta i obujmu radova potrebno je skenirati gradilište s minimalno 4 do 5 mjesta. Obrada oblaka točaka traje oko sat vremena do dva sata nakon čega se scan ubacuje u BIM software, primjerice u Revit ili Navisworks. Preklopom samoga scan-a i modela vrlo precizno se može pratiti što je izgrađeno tog dana. Ono što je napravljeno prebacuje se u status finish, dok ono što još nije izgrađeno ostaje u fazi nedovršeno.

Kod samog skeniranja gradilišta, ukoliko postoji već gotovi BIM model objekta, utjecaj opreme na gradilištu (skele, strojevi) i vremenski uvjeti nisu toliko bitni jer se iz samog scan-a dovoljno točno može vidjeti napredak u radovima. U slučaju kada na temelju scan-a modeliramo objekt od početka to može biti otežavajuća okolnost. Vremenski uvjeti također mogu biti problem ukoliko se eksterijer skenira u boji i žele se dobiti prave teksture i boje (GO2BIM d.o.o., 2016).

5. Zaključak

Ovaj članak prikazuje izazove s kojima se susreću nadzorni inženjeri u području kontrole količina izvedenih radova i praćenja napretka radova te načine prevladavanja tih izazova. Istraživanje potencijalnih tehnologija koje bi mogle olakšati te poslove prikazalo je na koji se način BIM tehnologija može koristiti u praćenju i kontroli gradnje. Istražen je i potencijal primjene novih tehnologija, koje su primarno razvijene za druge svrhe, u građevinarstvu kako bi se ubrzao i automatizirao proces kontrole količina izvedenih radova i praćenja izvršenja. Trenutne metode kontrole količina, iako su dokazane u praksi i dovoljno točne u primjeni, polako postaju nedovoljno učinkovite obzirom na moderne zahtjeve građevinske industrije. Potreba za modernizacijom povećava se proporcionalno s porastom složenosti građevinskih projekata i sve većim zahtjevima za učinkovitosti.

Istraživanje opisano u ovom članku provedeno je pregledom literature iz područja istraživanja i razgovorom s jednom tvrtkom koja te metode primjenjuje u praksi. Svaka od navedenih metoda je dovoljno opširna da bi se mogla istražiti u opsegu zasebnih članaka. Također, detaljnija analiza mogućnosti primjene i razine primjene pojedinih metoda u praksi bi također bila moguća nadgradnja na istraživanje prikazano ovim člankom.

Razina implementacije BIM-a u građevinskoj industriji je u porastu. Trenutno je primjena fokusirana uglavnom na fazu projektiranja, no prednosti primjene u fazi gradnje su također mnogobrojne i očekuje se porast implementacije BIM-a kod ostalih sudionika u procesu gradnje. BIM bi primjerice u kombinaciji s drugim modernim tehnologijama, kako je opisano u ovom članku, nadzornim inženjerima omogućio jednostavnije prikupljanje podataka o količinama izvedenih radova, o napretku i statusu radova te omogućio bržu i točniju analizu podataka. Time bi se olakšao manualni posao nadzornih inženjera i omogućilo bi im se fokusiranje na složeniju problematiku njihovog posla.

6. Reference

2014. Zakon o gradnji. Republika Hrvatska: NN 153/13.

2015a. Pravilnik o načinu provedbe stručnog nadzora građenja, obrascu, uvjetima i načinu vođenja građevinskog dnevnika te o sadržaju završnog izvješća nadzornog inženjera. Republika Hrvatska: NN 78/15, 107/15.

2015b. Zakon o komori arhitekata i komorama inženjera u graditeljstvu i prostornom uređenju. Republika Hrvatska: NN 78/15.

2015c. Zakon o obveznim odnosima. Republika Hrvatska: Narodne novine.

2015d. Zakon o poslovima i djelatnostima prostornog uređenja i gradnje. Republika Hrvatska: NN 75/15.

AEROMETREX. 2016. *Aerial photogrametry of a construction site* [Online]. Available: http://aerometrex.com.au/index.html [Accessed 15.05. 2016].

ARBUTINA, D. 2011. Suvremene metode izrade snimaka zatečenog stanja. Zagreb: Program stručnog usavršavanja ovlaštenih artihekata i inženjera.

BABIĆ, D., LAJIĆ, B. & JUREČIĆ, D. 2010. Predavanja Katedre za ambalažu, knjigoveštvo i projektiranje. Zagreb: Grafički fakultet, Sveučilište u Zagrebu.

GAJSKI, D. 2010. Predavanja iz kolegija fotogrametrija. Zagreb: Geodetski fakultet, Sveučilište u Zagrebu.

GEODATA. 2016. *Lasersko skeniranje* [Online]. Geodata Projekt d.o.o.,. Available: http://geodata.com.hr/odjeli/inzenjerska-geodezija/lasersko-skeniranje/ [Accessed 18.06. 2016].
GO2BIM D.O.O. 2016. *RE: Primjer integracije BIM-a i praćenja izvršenja s 3D laserskim skeniranjem* Type to BARULEK, K.
HOBS STUDIO. 2016. *3D laser scanning* [Online]. Available: https://hobsstudio.com/primary-services/3d-laser-scanning/ [Accessed 15.05. 2016].
NBIMS V.3 2015. National BIM Standard - United States Version 3. National Institute of Building Sciences buildingSMART alliance.
SHAPETRACE. 2016. *Augmented Reality for Construction* [Online]. Available: https://www.shapetrace.co/ [Accessed 15.05. 2016].
ZAVOD ZA FOTOGRAMETRIJU. 2016. *3D terestričko lasersko skeniranje* [Online]. 3D terestričko lasersko skeniranje d.d.,. Available: http://www.zzf.hr/index.php/usluge/3d-terestricko-lasersko-skeniranje [Accessed 18.06. 2016].

Construction and Project Management Issues

Rekonstrukcija Radićeve ulice u Zagrebu

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Abstract:

Na primjeru Radićeve ulice u Zagrebu prikazan je cijeli proces, koji je potreban da bi se rekonstruirala cesta u Gradu Zagrebu, kao zaštićeno kulturno dobro Republike Hrvatske.

Opisan je tijek od prijedloga plana i programa, postupak ishođenja građevinske dozvole, ugovaranje sa sudionicima građenja putem javne nabave, investicijsko praćenje projekta i samo izvođenje radova.

Prikazana je problematika prilikom izrade projekta, financiranje izrade projektne dokumentacije i izvođenja radova (više investitora, preinake glavnog projekta, ishođenje građevinskih i uporabnih dozvola), te tekući problemi na gradilištu s obzirom odvijanja radova u najužem središtu grada Zagreba.

U sklopu rekonstrukcije gradske ulice obuhvaćena je izgradnju novog javnog kanala, vodoopskrbnog cjevovoda i plinovoda sa svim kućnim priključcima, kompletna EEN mrežu sa priključcima i održavanje EKI mreže, te izvedba kolničke konstrukcije (ugradnja kocke u kolnik i nogostup) s oborinskom odvodnjom, spajanjem krovnih voda i obnovom javne rasvjete.

Na osnovu obrađenog zahvata rekonstrukcije Radićeve ulice, zaključak je da je cjelokupni proces od početka do kraja bio vrlo zahtjevan, kompliciran i dugotrajan. Potvrđena je važnost sustavnog vođenje projekta, jer veliki broj čimbenika s više razina odlučuje o kvaliteti graditeljskog postupka od projektnog zadatka pa do uporabne dozvole.

Keywords: *rekonstrukcija gradske ceste, zaštićeno kulturno dobro, gradnja u centru grada ;*

1. Uvod

Radićeva ulica smještena je u samom središtu grada Zagreba, počinje od glavnog zagrebačkog trga, trga Bana Josipa Jelačića i pruža se sjeverno prema Ilirskom trgu. Ulica pripada najstarijem dijelu „*Povijesne urbane cjeline Grad Zagreb*“, evidentirana kao zaštićeno kulturno dobro Republike Hrvatske [1].

Kolnik Radićeve ulice prije rekonstrukcije bio je popločen granitnim prizmama dimenzije 18x12x16-20 cm i 28x18x16-20 cm (četverostranim i peterostranim), te kockama dimenzije 8x8x8 cm, a površine nogostupa bile su asfaltirane. Zbog dotrajalosti kolnika i nogostupa u obliku izražajnih uleknuća, mnoštvo pukotina (slika 1), pristupilo se rekonstrukciji kompletnog gornjeg ustroja prometnice.

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Rekonstrukcijom je zadržan postojeći profil ulice, uz minimalnu korekciju kota nivelete kolnika i nogostupa. Postojeće granitne kocke i prizme su pažljivo uklanjane jer su ponovno ugrađivane, te su tijekom rekonstrukcije odvezene na deponij izvan gradilišta, a koji je osiguravao izvođač radova. Dio kamenih kocki i prizmi uz uvjet ujednačene kvalitete i dimenzija sa postojećim, su nabavljeni od strane izvođača. Uklonjeni kameni rubnjaci su smješteni na gradilišnoj deponiji. Oštećeni dijelovi su izrezani, a dio rubnjaka je zamijenjen novima, koji su dopremljeni sa deponije Investitora.

Figure 1. Radićeva ulica prije rekonstrukcije

Nogostupi su izvedeni od stare, granitne kocke koju je osigurao Investitor, dimenzija približno 17-25x15-17x18 cm, tako da se rezanjem dobila kocka okvirnih dimenzija 17-25x15-17x9 cm. Završna obrada kamenih prizmi za nogostupe je paljenjem odrezane površine radi hvatljivosti.

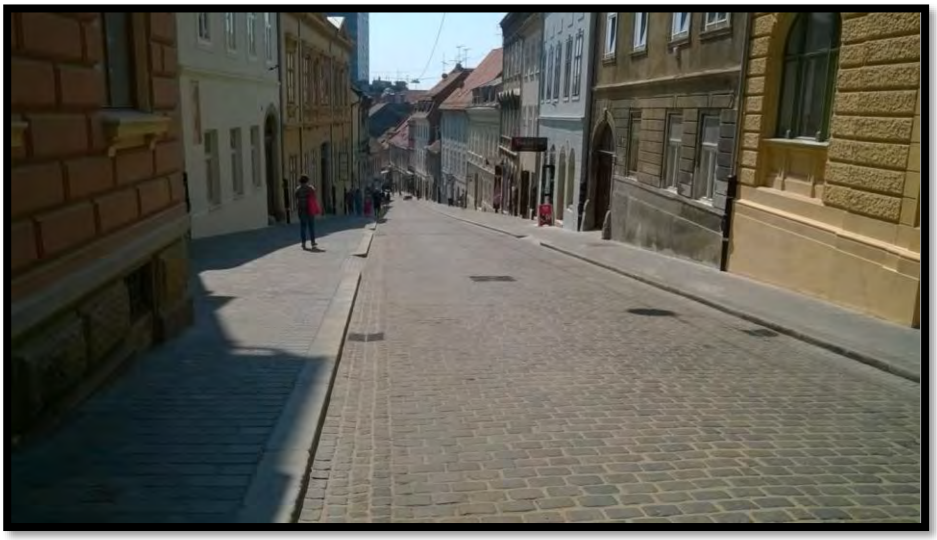

Figure 2. Radićeva ulica nakon rekonstrukcije

2. Priprema i provedba rekonstrukcije

Grad Zagreb, Gradski ured za prostorno uređenje, izgradnju grada, graditeljstvo, komunalne poslove i promet 10.7.2014. godine pokreće postupak rekonstrukcije Radićeve ulice u Zagrebu. Prvotni plan je bio, rekonstrukcija i sanacija prometnih površina, koja ne obuhvaćaju komunalnu infrastrukturu, već samo rekonstrukciju prometnih površina do dubine od cca 60 cm, te su obaviještena sva komunalna poduzeća, HEP i gradska plinara o planiranom zahvatu i zatraženi su podaci o stanju njihovih instalacija [2].

Važnost sustavnog vođenje projekta od strane investitora, bila je od ključna da bi se postigla dobra koordinacija između mnogobrojnih izvođača/podizvođača i ostalih čimbenika uključenih direktno ili indirektno u rekonstrukciju gradske ulice.

2.1 Pripremne aktivnosti

Prije svake rekonstrukcije ili izgradnje prometnice u gradu Zagrebu potrebno je zatražiti projektni zadatak od Sektora za promet, koji daje smjernice za izradu projektne dokumentacije. Isto tako se od komunalnih poduzeća, HEP-a i gradske plinare traže informacije o položaju njihovih instalacija.

Sektor za promet na zahtjev Sektora za ceste dostavlja prijedlog projektnog zadatka:
I. Potrebno je uz suglasnost Gradskog zavoda za zaštitu spomenika kulture i prirode sagledati mogućnost popločivanja ili asfaltiranja nogostupa i kolnika te moguću nivelaciju nogostupa u visini kolnika.
II. Na predmetnom dijelu Radićeve ulice, koja je pješačka zona, prometuje autobus javnog gradskog prijevoza te je u slučaju niveliranog nogostupa u visini kolnika potrebno pješačku stazu vidljivo odvojiti od vozne kolne površine.
III. Autobusno stajalište na početku Radićeve ulice planirati u skladu s pravilnikom o autobusnim stajalištima (NN 119/07) uz nužnu konzultaciju projektanta sa stručnim službama Zagrebačkog holdinga d.o.o. Podružnica Zagrebački Električni tramvaj.
IV. Stupove javne rasvjete i nadzemne hidrante potrebno je smjestiti tako da ne ometaju promet.
V. Potrebno je pridržavati se pravilnika o osiguranju pristupačnosti građevina osobama s invaliditetom i smanjene pokretljivosti (NN 78/13). Upuštanje rubnjaka u zoni pješačkih prijelaza planirati u širini od minimalno 1,20 m (rampu izvesti u asfaltu i postaviti taktilno polje upozorenja čepaste strukture)
VI. Pri izradi projekta trebaju biti zadovoljeni svi propisi i važeće norme za izgradnju prometnica i ostalih prometnih površina. Prometnu signalizaciju te sve prometne površine potrebno je planirati u skladu s Pravilnikom o prometnim znakovima, opremi i signalizaciji na cesti (NN33/05 i 155/05) i odgovarajućim normama u skladu s Zakonom o normizaciji (NN 80/13).

Projektant je izradio dvije varijante idejnog rješenja završne obrade prometnice prema projektnom zadatku Sektora za promet i smjernicama Zavoda za zaštitu spomenika kulture i prirode [3].

Varijanta 1 – uvažava postojeće stanje i smjernice Zavoda za zaštitu spomenika kulture i prirode, zadržana je visinska razlika između nogostupa i kolnika, na kolniku je zadržana kamena kocka, a na nogostupu asfalt kao povijesni materijal koji se počeo ugrađivati još krajem 18. stoljeća (slika 3).

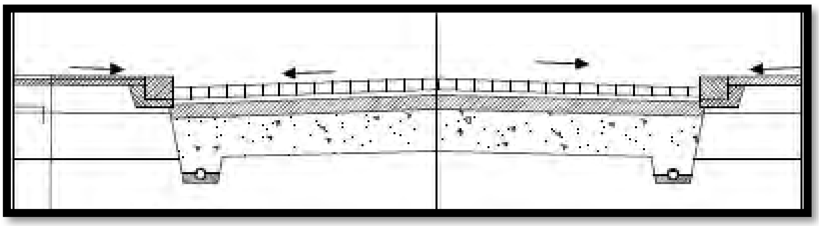

Figure 3. Varijanta 1 normalnog poprečnog profila

Varijanta 2 – sadrži rješenje gdje bi nogostup i kolnik bili u istoj razini, kolnik ostaje u kamenoj kocki, a nogostup bi također bio popločan kamenim kockama (slika 4).

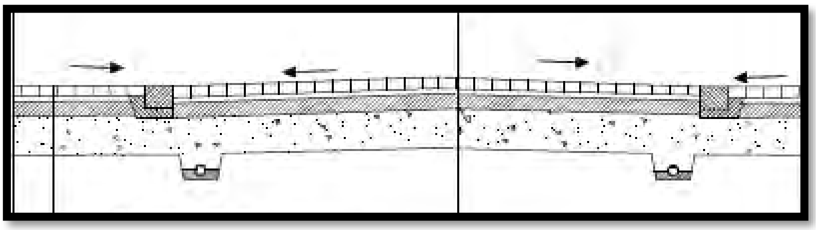

Figure 4. Varijanta 2 normalnog poprečnog profila

Zatraženo je pismeno mišljenje Sektora za promet i Zavoda za zaštitu spomenika kulture i prirode o konačnom očitovanju o predloženim rješenjima. Stručno mišljenje Sektora za promet i Zavoda za zaštitu spomenika kulture i prirode bio je da se odabire Varijanta 1. kojemu se zadržava postojeći povijesni izgled ulice s visinskom razlikom između kolnika i nogostupa.
Na temelju odluke o izvedbi Varijante 1, projektna dokumentacija za izdavanje građevinske dozvole je zatražena i izvedena od Središnjeg odsjeka za prostorno uređenje.
Javno pravna tijela od kojih je potrebno zatražiti potrebne uvjete su:

- Gradski zavod za zaštitu spomenika i kulture,
- Hrvatske vode,
- Sektor za građenje i održavanje komunalne infrastrukture; Odsjek za građenje i održavanje javne rasvjete,
- Zagrebački holding d.o.o. Vodoopskrba i odvodnja Sektor razvoja odvodnje,
- Zagrebački holding d.o.o. Vodoopskrba i odvodnja Sektor vodoopskrbe,
- HEP – ODS d.o.o. D.P. Elektra Zagreb,
- Hrvatska agencija za poštu elektroničke komunikacije (HAKOM),
- Gradska plinara Zagreb,
- MUP – PUZ Sektor upravnih i inspekcijskih poslova,
- Sektor za promet,
- Ministarstvo zdravlja Uprava za sanitarnu inspekciju,
- T – Hrvatski Telekom d.d. Odjel za energetiku i mrežnu infrastrukturu.

U sklopu izdavanja građevinske dozvole, prema nalogu gradonačelnika Grada Zagreba, dolazi do izmjene projekta da se postave kamene kocke i na nogostupu umjesto asfalta (slika 5). Zbog izmjene projekta potrebno je bilo niz radnji da sve izmjene budu sukladne zakonima. Potrebno je bilo pismenim nalogom obavijestiti tvrtku koja je izradila projekte i ugovoriti naknadne radove za izmjenu projekta. Pošto se mijenja bitna stavka samog projekta (traži se kamena kocka umjesto asfalta na nogostupima) potrebno je bilo izmijeniti kompletne nacrte, troškovnike i cijeli projekt. Prije izmjene projekta potrebno je bilo prikupiti nove suglasnosti te potvrde na glavni projekt nakon izrade. Povećana je stavku rebalansa i produžen rok izvođenja samih radova zbog zahtjevnosti izvedbe u uskoj ulici.

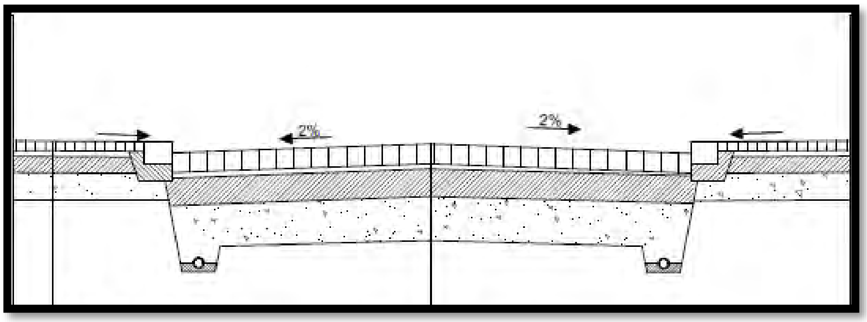

Figure 5. Konačna varijanta normalnog poprečnog profila

U tijeku pripremnih radova za uređenje Radićeve ulice (od Trga bana Josipa Jelačića do Kamenitih vrata) potrebno je bilo izraditi elaborat o stanju objekata prije bilo kakvih radova. Uređenje obuhvaća radove na rekonstrukciji, komunalnih instalacija (vodovod, javni kanal, javna rasvjeta), te donji i gornji ustroj ceste s oborinskom odvodnjom. S obzirom na starost postojeće infrastrukture, dubinu, i položaj te mnoštvo priključaka, veliki nagib ulice i malu širinu, predviđeni radovi odvijati će sa znatno smanjenim prostorom za manipulaciju. Stoga je bilo potrebno, prije početka radova, snimiti zatečeno stanje građevinskih objekata te o tome izraditi elaborat ovjeren od strane sudskog vještaka, a čime će se osigurati dokazi prilikom eventualnih zahtjeva za nadoknadu nastale štete.

Zbog predviđenog iskopa rovova, starosti podzemnih instalacija i samih objekata, bilo je potrebno snimiti stanje svih susjednih objekata na lokaciji na čiju bi stabilnost i stanje mogli djelovati radovi. U zoni obuhvata nalazi se 46 objekata koje je bilo potrebno snimiti kompletno iznutra i izvana.

Elaboratom je potrebno dokumentirati:

- stanje fasade sa ulične i dvorišne strane,
- stanje stolarije (prozori i vrata) sa vanjske strane,
- površine oko prozora i vrata,
- prisutnost vlage u podrumskim prostorima,
- postojeća oštećenja unutar podrumskih prostorija,
- ostale vidljive nedostatke i oštećenja.

Grad Zagreb je bio investitor prometnice sa oborinskom odvodnjom te je ishođena građevinska dozvola. Vodoopskrba i Odvodnja je investitor javnog kanala – kolektora i vodoopskrbnog cjevovoda te je ishođena građevinska dozvola za javni kanal i za vodoopskrbni cjevovod. Gradska plinara Zagreb je investitor rekonstrukcije, sanacije i održavanje plinovoda prema zasebnoj građevinskoj dozvoli. T- Hrvatski Telekom d.d. sam izvodi svoje radove na zamjeni dotrajalih cijevi prema građevinskoj dozvoli. HEP Elektra Zagreb je investitor svoje mreže i izvode radove sa svojim izvođačima i nadzorom za radove na EEN mreži. Niskonaponska mreža u Radićevoj ulici postojala je prije 1968. i njena izgradnja nije podlijegala ishođenju građevinske dozvole.

2.2 Izvođenje

Ukupni rok izvođenja radova na rekonstrukciji Radićeve ulice, sa svim instalacijama, kolničkom konstrukcijom i završnim opločenjem bio je 6 mjeseci i stoga su radovi na vodoopskrbnom cjevovodu, plinskim i ostalim instalacijama morali pratiti radove na kanalizaciji [4].

Granica obuhvata je iznosila 3500m^2. Rekonstrukcija je obuhvatila i zamjenu postojećih komunalnih instalacija: javni kanal, vodoopskrbni cjevovod, plinovod, EEN, javnu rasvjetu sa

svim priključcima koji su bili predmet posebnih nadmetanja, te je navedene radove bilo potrebno međusobno uskladiti i koordinirati s radovima na samoj prometnici.
Udio pojedinih radova rekonstrukcije:

- cesta s oborinskom odvodnjom (56%)
- javni kanal s priključcima (16%)
- plinovod s priključcima (10%)
- vodoopskrbni cjevovod s priključcima (9%)
- EKI mreža (8%)
- EEN mreža s priključcima (1%)

Na počeku izvođenja radova postavljana je zaštitna ograde i krenula je demontaža kocke prve dionice s deponiranjem na privremenu deponiju.

Radovi na **kanalizaciji** započeli su od Trga bana Josipa Jelačića prema Kamenitim vratima. Odvodnja ulice i stambenih objekata riješena je novo predviđenim kanalom od poliesterskih cijevi mješovitim sustavom odvodnje. Cijevi su vodonepropusne, sa ugrađenim spojnicama od gumenih brtvi, a pojedinačne su duljine 6,0 m i profila Ø 80cm, prema uvjetima „Vodoopskrbe i odvodnje“ sva priključenja vrše se u šahtovima, kanal se izvodi vodonepropusno [5]. Otpadne vode odvode se putem novog kanala do spoja na postojeći javni kanal na Trg bana Josipa Jelačića. Projektom je predviđena kompletna zamjena svih 38 kućnih priključaka na kanalizaciju. Prilikom izvođenja moralo se voditi računa o kontinuiranom dotoku fekalnih voda, jer okolne kuće i sve što gravitira odvodnom kanalu bilo je u funkciji. Prema terminskom planu rok za izvođenja kanalizacije je bio 60 dana. Na početka radova naišlo se na problem, postojeće vodovodna komora nalazila se je na trasi kanala, a prema projektu nije predviđena za rušenje. Radi smetnje na trasi neophodno je bilo ukloniti postojeće vodomjerno okno.
Na slici 6 je oplate „krings“ pomoću koje se štitilo urušavanje tla u iskopanom rovu prilikom polaganja poliesterskih kanalizacijskih cijevi.

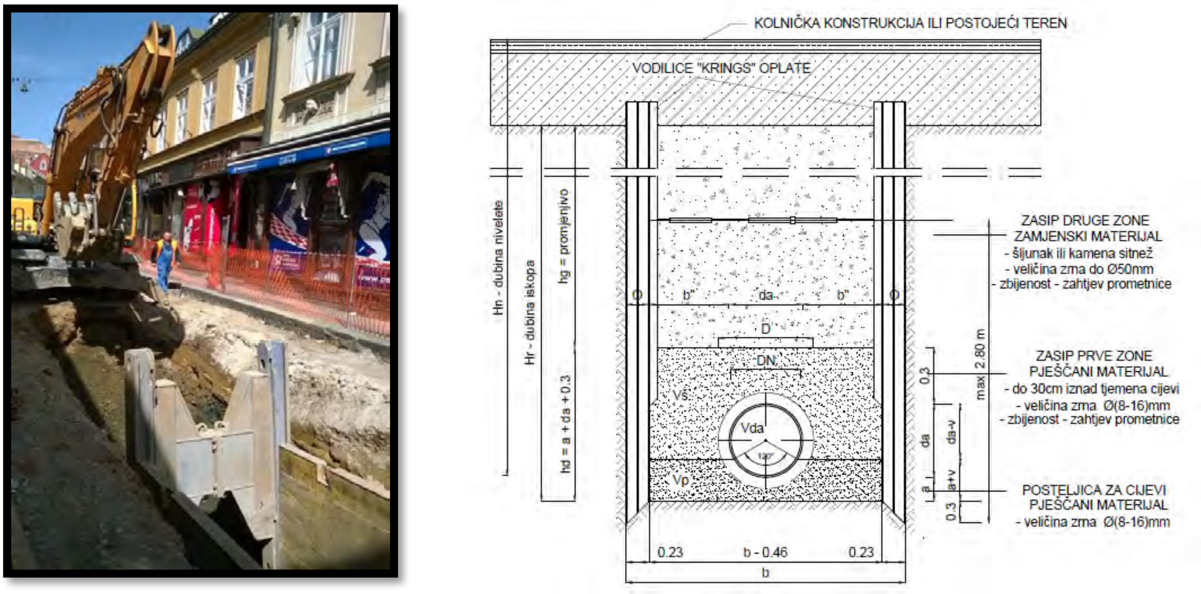

Figure 6. Oplata „Krings“ za zaštitu polaganja kanalizacije u rovu

Početak rada na **vodovodu** bio je moguć tek nakon završetka radova na kanalizaciji na dionicama do Krvavog mosta i to radi ne mogućnosti prilaska gradilištu sa dviju strana. Spoj na vodovodnu mrežu predviđen je na postojeći cjevovod SL Ø=200 u komori 374 na Trgu bana J. Jelačića. U komori je izveden T komad Ø=200/150 sa zasunima na sva tri kraka, na koji će se spojiti novo projektirani vodovod te se proteže uzduž ulice u predviđenoj dužini od 298 m kako bi omogućio opskrbu vodom objekata Radićeve ulice [6]. Nova trasa cjevovoda predviđena je na zapadnoj strani prometnice, na mjestu postojećeg vodovoda uz minimalne korekcije, a tlocrtno je usklađena sa drugim postojećim i budućim komunalnim instalacijama. Niveleta cjevovoda rađena je na dubini određenoj dubinom postojećih cjevovoda. Prema uputama RH MUP PU Zagrebačka, sektor upravnih, inspekcijskih i poslova civilne zaštite svi hidranti trebaju biti nadzemni Ø=100 mm osim kada to nije moguće, kao u ovom slučaju, s obzirom da je pločnik uzak, te bi nadzemni hidranti smetali prometu, te su prema uputama iz projektnog zadatka predviđeni podzemni hidranti. Na slici 7 je postupak zbijanja dna rova prije polaganja vodovodne cijevi.

Figure 7. Zbijanje dna rova prije polaganja vodovodne cijevi

Problematika kod rekonstrukcije **plinovoda** je to što prema zakonu potrošači ne smiju biti više od 3 tjedna bez opskrbe plina. Plin je odsijecan u 3 dionice sukladno radovima na terenu. Radovi su započeli tek nakon završetka radova na kanalizaciji i izvodili se od trga bana Josipa Jelačića prema Krvavom mostu na istočnoj strani ulice.

Radovi na postavljanju **kablovima DTK-a i HEP-a** su izvođeni u dogovoru s drugim izvođačima. Problem prilikom izvođenja radova je manjak prostora i visinska razlika samih kablova koji nisu postavljeni na pravoj dubini.
Prilikom skidanja nogostupa sa istočne i zapadne strane od Krvavog mosta do Kamenitih vrata postavljeni su EEN i EKI kablovi u nogostup.

Dužina **trase** je 306,98 m, dok je dio prema Kamenitim vratima u dužini 49,25 m. Horizontalni tok trase ima tri horizontalne krivine (R1=200 m; R2=190,06 m i R3=614,65 m) s pripadajućim međupravcima. Vertikalni tok trase čine vertikalna kružna zaobljenja (konveksna i konkavna) u rasponu od R=200 m do R=2233,90 m. Minimalni uzdužni nagib je 0,949% na dužini 17,14 m, a maksimalni je 11.66% na dužini 25,36 m. Širina nogostupa po poprečnim profilima kreće se od 1 m do 4 m, u potpunosti se pridržavajući postojećeg stanja, te nagibima prilagođenima postojećim ulazima u objekte te dvorišta. Kod izvođenja poprečnih nagiba postojećim ulazima strogo se pridržavalo pravila minimalnog nagiba od 1% zbog odvodnje.

Kolnik:

- granitne prizme (16-20 cm), završna fuga u visini 3 cm od vrha kocki/prizmi sa materijalom *CDS-FUGENMORTEL 0-3P ST* (dvokomponentni epoksidni mort sa dodatkom kvarcnog pijeska veličine zrna 0,1–0,3 mm, omjer mješavine 96% komponente A + 4% komponente B + kvarcni pijesak do 25%, ostatak fuge ispunjen smjesom cementa i eruptivnog pijeska u omjeru 1:4),
- sloj cementa i eruptivnog pijeska u omjeru 1:4 (5cm),
- cementna stabilizacija nosivi sloj (CNS=25 cm),
- donji nosivi sloj mehanički zbijenog kamenog materijala Ms> 80 MN/m^2 (40cm)
- nasipni materijal, Ms> 35 MN/m^2,
- temeljno tlo Ms>20 MN/m^2.

Nogostup:

- rezane granitne prizme obrađene paljenjem (9 cm), završna fuga u visini 3 cm od vrha kocki sa materijalom *CDS-FUGENMORTEL 0-3P ST* (dvokomponentni epoksidni mort sa dodatkom kvarcnog pijeska veličine zrna 0,1–0,3 mm, omjer mješavine 96% komponente A + 4% komponente B + kvarcni pijesak do 25%, ostatak fuge ispunjen smjesom cementa i eruptivnog pijeska u omjeru 1:4),
- sloj cementa i eruptivnog pijeska u omjeru 1:4 (5cm),
- cementna stabilizacija nosivi sloj (CNS=15 cm),
- donji nosivi sloj mehanički zbijenog kamenog materijala Ms> 60 MN/m^2 (20cm)
- nasipni materijal, Ms> 35 MN/m^2,
- temeljno tlo Ms>20 MN/m^2.

Radovima na **gornjem i donjem ustroju ceste** se moglo pristupiti nakon što su završili svi radovi na komunalnim instalacijama. Izvođenje radova iziskivalo je vrlo dobru organizaciju građenja, radi velikog broja tvrtki izvođača/podizvođača, a koji su izvodili radove na relativno malom manipulativnom prostoru. Kontrola kvalitete materijala i radova provedena je tijekom pojedinih faza odnosno izvedenih slojeva donjeg i gornjeg ustroja ceste [7].
Problematika pri samom izvođenju su bile instalacije na nepropisnim dubinama koje su smetale za pravilno izvođenje oborinske odvodnje sa krovnih ploha (slika 8).

Figure 8. Spajanje krovnih voda

Prema terminskom planu prvo je završen sa slaganjem kamene kocke istočni nogostup od Trga do Krvavog mosta, te nakon toga zapadni nogostup. Problemi koje su nastali zbog visinskih razlika između projekta i postojećeg stanja pa samim time su detalji ulaza rješavani svaki za sebe. Na slici 9 prikazan su postavljeni rubnjaci i kocke na zapadnom nogostupu.

Figure 9. Izvedeni rubnjaci i kocka na nogostupu

Kako su dionice postepeno završavane tako je rađeno je završno fugiranje, a koje se je radi temperature i vlažnosti zraka izvodilo u noćnim satima [8]. Na slici 10 je rekonstruirana Radićeva ulica u Zagrebu.

Figure 10. Rekonstruirana Radićeva ulica u Zagrebu

3. Zaključak

Kao posljedica izuzetno dugog perioda pripremnih aktivnosti, rok završetka radova prema ugovoru sklopljen sa izvođačem smanjen je za dva mjeseca i to na samom otvaranju radova. Dopisom je dostavljena obavijest prema svim javno pravnim tijelima, izvođačima i ostalim sudionicima u gradnji, da svi radovi moraju biti organizirani u dvije smjene (minimalno do 18h) svaki radni dan uključujući i subotu, a terminski planovi su morali biti revidirani.

Grad Zagreb je svim turističkim zajednicama, udrugama vodiča, informativnom centru i građanima Grada Zagreba dostavio obavijest o radovima koji se odvijaju na samom gradilištu. Gradilište je bilo propisno označeno, a zone neposrednih iskopa dodatno su bile ograđene. Uz zonu radova ostavljeni su uski prolazi na nogostupima kao nužni prolazi sa stanare. Zbog velikog broja turista koji su se kretali tim prolazima, izvođač je bio prisiljen zaustavljati radove, a što utjecalo na sigurnost i dinamiku radova. Traženo je da se turistički vodiči kao i turisti koji se nađu na gradilištu obavijeste da nije dozvoljeno kretanje ni zadržavanje u zoni gradilišta iz sigurnosnih razloga, te da se u zoni gradilišta kreću na vlastitu odgovornost, u protivnom postojala je jedina mogućnost da se ulicu u potpunosti zatvoriti za prolaz.

Cjelokupni proces od početka do kraja rekonstrukcija gradske ceste u užem području centra Zagreba, pokazao se vrlo zahtjevan, jer se radi o kompliciranom i dugotrajnom postupku, od projektnog zadatka do okončanog obračuna trajao je gotovo 28 mjeseci. Potvrđena je važnost sustavnog vođenje projekta od strane investitora, jer veliki broj čimbenika s više razina odlučuje o kvaliteti graditeljskog postupka od samog projektnog zadatka pa do uporabne dozvole.

References

[1] Registar kulturnih dobara RH pod brojem Z – 1525 (Narodne novine br. 92/11).

[2] Odluka o izmjenama i dopunama Odluke o nerazvrstanim cestama, Službeni glasnik Grada Zagreba br. 6 od 4.7.2014.

[3] Glavni projekt prometnice; TD1016/15; EKO PLAN d.o.o.; Zagreb; rujan 2015.

[4] www.zagreb.hr,

[5] Glavni projekt Javni kanal u Radićevoj ulici I. faza; EKO PLAN d.o.o.; Zagreb; lipanj 2016.

[6] Glavni projekt rekonstrukcije vodoopskrbnog kanala u Radićevoj ulici I. faza; EKO PLAN d.o.o.; Zagreb; lipanj 2016.

[7] Završno izvješće o provedenim kontrolnim postupcima utvrđivanja kvalitete posteljice, donjeg nosivog sloja od zrnatog kamenog materijala i nosivog sloja stabiliziranog cementom; Institut IGH d.d.; Zagreb; kolovoz 2016.

[8] Završno izvješće o ispitivanju sukladnosti mase za fugiranje sa uvjetima projekta konstrukcije; Institut IGH d.d.; kolovoz 2016.

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