A Survey on Application of Building Information Modelling in Road Construction

Amirkasra Honarpisheh

Submitted to the
Institute of Graduate Studies and Research
in partial fulfillment of the requirements for the Degree of

Master of Science
in
Civil Engineering

Eastern Mediterranean University
July 2014
Gazimağusa, North Cyprus

Approval of the Institute of Graduate Studies and Research

Prof. Dr. Elvan Yılmaz
Director

I certify that this thesis satisfies the requirements as a thesis for the degree of Master of Science in Civil Engineering.

Prof. Dr. Özgür Eren
Chair, Department of Civil Engineering

We certify that we have read this thesis and that in our opinion it is fully adequate in scope and quality as a thesis for the degree of Master of Science in Civil Engineering.

Assist. Prof. Dr. Alireza Rezaei
Supervisor

Examining Committee

1. Asst. Prof. Dr. Tülin Akçaoğlu
2. Asst. Prof. Dr. Mürüde Çelikağ
3. Asst. Prof. Dr. Alireza Rezaei

ABSTRACT

Project management success is mainly evaluated by assessing the capability of managing time, cost, quality and nowadays, health and safety. Time and cost overruns can arise by various reasons in different projects especially roads and highways. These project types can also benefit from using Building Information Modelling (BIM) from the inception till the operation. Although the implication of BIM in building industry has been noticed theoretically and practically, its application in road and highway design and construction seems to be comparatively slower than building design and construction especially in developing countries such as Iran. Moreover, construction firms are still reluctant to admit changes even by facing delay and cost escalation in almost 100% of their roadway projects.

To understand better about the deviation in project constraints, a questionnaire was administered among 20 construction firms and they were asked to rate the given causes of delay, cost overrun and quality deviation in road projects and also to evaluate BIM efficiency in preventing the causes considering the basic definitions. Furthermore, a case project was studied to assess the reliability of findings and to determine how BIM can be applied to road and highway design and construction.

As the case study implied, by using Navisworks Manage clash detection feature, the change orders in some sections would have not probably happened which would have resulted in a cost reduction of approximately equal to 1.8% of the total project cost. Considering the project finishing date, case study showed a 12% more accuracy in time estimations with BIM.

Keywords: Project Management, Road and Highway Construction, Building Information Modelling

ÖZ

Proje yönetimindeki başarı, zaman yönetimi, maliyet, kalite ve son zamanlerde eklenen sağlık ve güvenliğin değerlendirilmesiyle belirlenmektedir. Özellikle yol ve otoyol projelerinde, zaman ve maliyet aşımları çeşitli sebeplerden dolayı ortaya çıkabilmektedir. Bu tür projelerde, projenin başlangıcından yapımına kadar Yapı Bilgi Modellemesi'ni kullanmak yararlı olabilmektedir. Genelde Yapı Bilgi Modellemesi'nin kullanımı kabul gorse de, özellikle İran gibi gelişmekte olan ülkelerde, yol ve otoyol yapımındaki uygulaması, bina tasarım ve yapımındaki kullanımına kıyasla oldukça yavaş ilerlemektedir. Buna ek olarak inşaat firmaları, yol yapımı projelerinin %100'ünde zaman ve maliyet aşımıyla karşılaşmalarına rağmen, değişimleri kabullenmekte isteksiz bir tavır sergilemektedirler.

Proje kısıtlamalarındaki değişimler konusunda bilgilenmek adına, 20 inşaat firmasına bir anket dağıtılmıştır ve onlara yol projelerindeki gecikme, fazla maliyet, kalite yetersizliğine neden olan etkenleri değerlendirmeleri istenmiştir. Ayrıca genel tanımları bağlamında, bu etkenleri önlemek adına BIM'in etkililiğini değerlendirmeleri de istenmiştir. Bunlara ek olarak, bulguların güvenilirliğini ve BIM'nin yol ve otoban tasarımı ve yapımlarındaki uygulanmasını belirleyebilmek adına bir vaka projesi üzerinde de çalışılmıştır.

Navisworks Manage sorun bulma uygulamasıyla vaka çalışmasından çıkan sonuçlara göre, bazı bölümlerde değişiklik talimatları yaşanmayarak, tüm projede toplamte %1.8'i kadar maliyette bir azalma olabilir. Projenin sonlandırma tarihi göz önünde bulundurulduğunda, vaka çalışması BIM’in belirlediği sürenin %12’lik bir oranla daha doğru olduğu tespit edilmiştir.

Anahtar Kelimeler: Proje Yönetimi, Yol ve Otoyol Yapımı, Yapı Bilgi Modellemesi

To my beloved wife

ACKNOWLEDGEMENT

I would like to appreciate my dear supervisor Dr. Alireza Rezaei for his masterly supports and guides on my master thesis research. His companionship helped me in all aspects of this research. I owe him for the many lessons I learned in construction management field, research methods and many more.

Besides, I would like to value Prof. Dr. Tahir Çelik who taught me the basics of project management. He made the opportunity for me to raise my academic knowledge.

Also I would like to thank my dear friend Mohammadnima Tazehzadeh for helping me a lot in this path.

At last, I would like to thank my dear family for their supports through my life and my lovely wife for her kindness and patience.

TABLE OF CONTENT

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

BIM	Building Information Modeling
AEC	Architectural, Engineering and Construction
COBIE	Construction Operation Building information Exchange
AVS	Audio Visual Software
FGI	Focused Group Interview
GIS	Geographic Information System
KSU	Kent State University
UF	University of Florida

Chapter 1

INTRODUCTION

1.1 Background

Project management success is mainly evaluated by measuring time and cost (also known as schedule and cost). Summation of these two criteria and scope are recognized as project management triangle which is illustrated in Figure 1. However, quality and health and safety are known as fourth and fifth criteria considered in project management (Çelik, 2010).

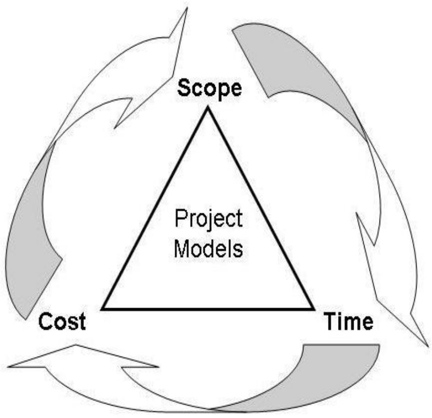


Figure 1: Project management triple constraints

As these criteria are relatively connected to each other, deflection in one item might result in a change in others. For instance, change in project scope might affect the project time and probably the project cost. Time and cost overruns might arouse by various reasons and causes in different projects especially roads and highways which are larger in size. Causes such as change order in drawings and specifications, material shortage, improper planning and management etc. affect road and highway projects more due to their size and complexity. These types of projects can also benefit from Building Information Modeling (BIM) as a design and management tool from inception till operation. Genesis of Building Information Modeling returns to mid-2005 when the US General Services Administration (GSA) made its decision to build a new courthouse in Jackson, Mississippi with the total area of 410,000 square feet (Robert L. R., 2011). Since that time, 2D and 3D software were used for design, documentation and planning during all construction phases in building industry. This differs a bit in road and highway construction while it has been just a few years that application of BIM in road construction is proposed. By this technology, visualization and communication of design and construction process can be supported somehow. This might be so efficient due to pre-evaluating design choices and choosing the best through the inception phase. Moreover, more accurate cost estimation and better planning in construction and waste management will be resulted by applying BIM workflow.

Though the benefits of applying BIM in building design and construction have been noticed theoretically and practically, its application in road and highway design and construction seems to be comparatively slower than building industry especially in developing countries such as Iran. Moreover, construction firms are still reluctant to admit changes even by facing delay and cost escalation in almost 100% of their roadway projects. Besides, the various advantages of adoption of BIM in horizontal constructions are not evident.

In this survey, two methods have been applied to collect the needed data in order to reach the goals. First, a questionnaire survey was done to address and evaluate major causes of delay and cost escalation in road construction projects from the contractors and consultants' points of view. It was also tried to observe the extent of familiarity with BIM among Iranian construction firms and the degree they thought BIM will be efficient to prevent mentioned causes of time and cost overrun. After completing the results of the questionnaire survey, a case study was analyzed to find out how real the results of the questionnaire were. In this case study, a completed road project in Iran was modeled and scheduled by BIM-based software programs.

The questionnaire results presented a ranking for the detected causes and factors of time, cost and quality deflection in road construction projects. Also a very low degree of knowledge on BIM was found among respondents. Therewith the case study implied that change orders applied to project would probably not have happened by using BIM during design phase. Furthermore by having an accurate cost estimations and scheduling, gaps and ceases in the execution phase during the last two years could have possibly be avoided in most cases.

1.2 Research Question

For those practitioners who work with designers and structural engineers every day, BIM is probably a routine; however within the field of road and highway design and construction, BIM expresses a modern concept during whole life cycle. BIM is not just about 3D modeling (though design is one of the main features). One of the efficiencies of BIM workflow in road construction is the capability of integrating topography plans and existing infrastructure such as waste water, communication cables, electrical and other underground infrastructure which make road projects more complicated. Furthermore, BIM files are interoperable with Geographic Information System (GIS) which might be so useful in the developed countries who have their own satellites with the ability to prepare high quality images of the ground. The last to be mention here is the connection and uniformity between the design, detailed design and documentation steps in BIM process. In contrast with the traditional 2D drafting-centric design in which each step should be finished in order to start next step, within BIM workflow, these steps can be followed simultaneously. This will lead to more collaboration, less time consumption and also less risk of human error in case of updating any needed change. Figure 2 demonstrates the difference in level of effort, cost and effect during the life cycle of project by using BIM or 2D drafting-centric workflow.

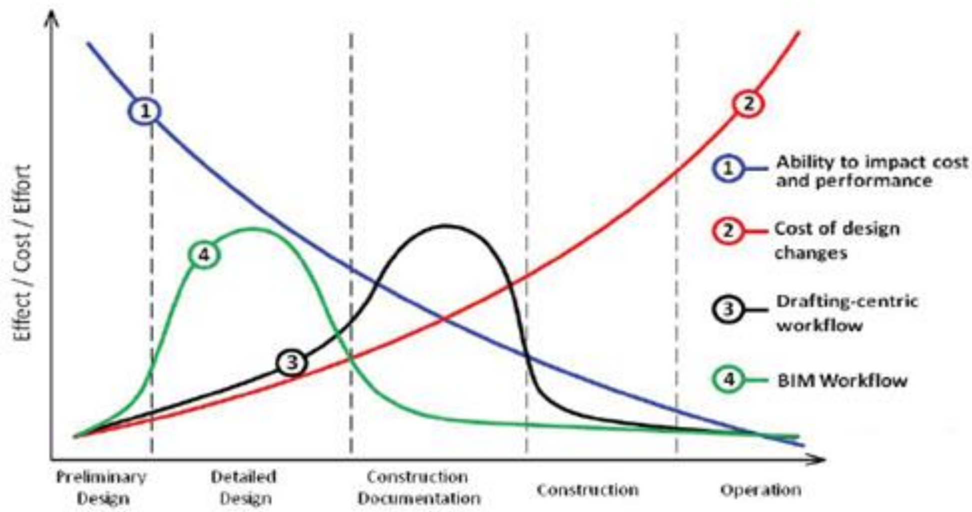


Figure 2: Level of effort, cost and effect in project life cycle

Considering these theoretical details, the usefulness of applying BIM in road and highway construction is not yet assured. Due to this ambiguity, this research was done with the aim of answering this question: “To what extent BIM application is useful in road and highway construction design and execution in real life?”

1.3 Aims and Objectives of the Study

In order to answer the research question as the aim of this study, a number of objectives were determined as listed below:

1. To inquire the level of knowledge on BIM among road and highway consultants and contractors.
2. To specify the percentage of road projects in Iran which face delay and cost escalation.
3. To evaluate the list of factors which affect time and cost overrun in road and highway projects in Iran from construction firms point of view.
4. To investigate the level of efficiency of BIM in preventing deflection factors.
5. To find out the financial benefits of using BIM in road and highway projects.
6. To estimate the amount of time which can be saved by using BIM.

1.4 Works Carried Out

In order to study the effects of BIM on road and highway construction and management, two methods of survey were done simultaneously. By means of a questionnaire survey, first of all the abundance of time and cost overrun in road projects were determined. Moreover, the causes of deflection were ranked from the respondents points of view. Furthermore, respondents expressed their assessment on the influence of BIM on mentioned causes considering BIM definitions and features. The case study almost verified the results of questionnaire survey and approximately indicated the effect of applying BIM workflow on preventing identified causes of deflection in project triple constraints.

1.5 Achievements

As stated by the survey contributors, BIM could be very useful in controlling causes of delay, cost overrun and quality deflection in projects. Although the traditional 2D drafting-centric methods seem to be no longer beneficial in the current design-tender-build system in Iranian road construction society, still there is reluctance toward implementing new concepts due to wide range of causes such as high preliminary costs, lack of expert staff etc. Also in the path of importing new technology, a strong supervision and legislative governmental institution is needed.

Case study shows a various percentage between 7 to 40% more accuracy in cost estimations between considered items. Furthermore change orders imparted in some sections of the project, added about 1.8% of the total project cost mentioned in the contract which might have not been occurred by using BIM.

1.6 Guide to Thesis

After the introduction, chapter 2 focuses on basic definitions of Building Information Modeling (BIM) and the related literature. Further studies on BIM abilities, applications, benefits and limitations all over the world are the scope of this chapter.

In chapter 3, the main challenges and obstacles in road construction will be discussed considering their consequences. Furthermore, the causes will be brought up and finally the cures will be presented which is one of the main aims of this survey.

Chapter 4 contains selected methods which have been used in this study. Preparation and finalizing the questionnaire will be detailed. A brief explanation about the respondents will be provided thereafter and finally an explanation on the case study will be presented.

Chapter 5 presents the results and outputs generated by the questionnaire survey. Respondents include two groups of Iranian contractors and consultants although the results are integrated. The chapter includes the main topics asked from the respondents.

In order to prevent disorder, all data related to the case study project were brought in chapter 6 separately. The first part of this chapter contains general specifications and details of the case project. After that in the second part, BIM modeling procedure done in this survey are explained.

In the first part of chapter 7, relevant discussions around the findings of questionnaire survey will be presented. Results of each part of the questionnaire will be checked separately in order to find out the advantages of the positive points. The second part of this chapter contains a case study including modeling a constructed road project in Iran in order to evaluate the usage of BIM workflow in road and highway construction field.

Chapter 8 answers the questions aroused by the research and offers recommendations for further studies in the field of BIM application in heavy construction industry especially road and highway construction from the construction managers' view and finally a few suggestions are offered for further studies in this field.

Chapter 2

BUILDING INFORMATION MODELING (BIM)

2.1 Introduction

The concept of BIM has existed since 1970s. Although the appearance of the term Building Information Modeling, the popularity of BIM started after releasing a paper entitled "Building Information Modeling" by Autodesk company in about 2002. Genesis of Building Information Modeling returns to mid-2005 when the US General Services Administration (GSA) made its decision to build a new courthouse in Jackson, Mississippi with the total area of 410,000 square feet. Since that time, 2D software were used for designing and documentation during all construction phases while GSA inquired its staff to shift from familiar 2D to the three dimensional approach (Robert L. R., 2011).

Building information modeling (BIM) has been defined diversely by various authors. Considerably these definitions are based on process or product.

Generally BIM is described as "a digital representation of physical and functional characteristics of a facility. As such it serves a shared knowledge resource for information about a facility forming a reliable basis for decisions during its life-cycle from inception onward" (United States National BIM Standard, 2008). By this new technology, visualization and communication of building design and construction process can be supported to some extent.

Further studies on BIM abilities, applications, benefits and limitations all over the world are the scope of this chapter.

2.2 What is BIM?

Building Information Modeling (BIM) perhaps is one of the most emphasized concepts in the Architecture, Engineering and Construction (AEC) industries nowadays. AEC industry has continued informing its association segments, members and stakeholders about BIM adoption in various paths.

Unlike other digital technologies affiliated by the building industry, BIM has altered the way buildings are designed, built, assembled, commissioned, operated and maintained (Sharag-Eldi and Nawari, 2010). By the definition, Building Information Modeling (BIM) workflow is able to create live and intelligent three-dimensional parametric models. These models can become a 4D model by being linked to time and also a 5D considering financial data links. Contemplating all project contributors (architect, engineer, contractor, subcontractor), BIM is aimed to resemble all physical and functional characteristics of the structure true to scale.

As the software is capable to detect conflicts between different parts included, these models are known as "live" models. Moreover, BIM uses a pre-considered database including all contributed structure's elements. For example, if the designer chose to add a wall to the model as a component, the best suited wall considering the necessary characteristics can be chosen from the list of pre-programmed walls.

On the other hand, BIM models are brought to discussions as "intelligent" because when a change is accomplished through the design, the software has the capability to redact other related elements through the design in order to compensate for the change. Furthermore, BIM is able to attach the input data to the model and information is produced automatically by using a centralized mechanism for the project information (Monterio and Martins, 2013).

In order to go through these innovations in BIM, each feature will be explained more with its benefits:

1. 3D Design: By the help of this type of design, customers will get the chance to visualize the project and see the project site with respect to the project construction (GSA BIM Guide, p.14).
2. 4D Design (Time): Integrating project construction phases and sequences to the 3D model, 4D model is resulted with the ability of visualizing the sequence of the construction. This 4D model can contain various level of details in order to be used in different phases of the construction by owners, subcontractors, etc. (GSA BIM Guide, p.2, 3).
3. 5D Design (Cost): By adding the project costs to the mentioned model, BIM mode will be able to print out the Quantity Take-Offs (QTO) and cost estimations including the relationships between quantities, costs and locations.
4. Collision Detection: BIM software is planned to examine the model in order to find spatial and sequential conflicts. In case of finding any clashes, automated notifications will be sounded.
5. Construction Operations Building Information Exchange (COBIE): COBIE is an information exchange format to capture the information created during different phases of the project from the early designing till the commissioning. This information would be available to the building operator even after the project is finished.

6. Energy analysis: By this capability, BIM will provide the user with a detailed accurate energy modeling.

What can be seen is that BIM is adopted more and more every day among contractors, engineering firms and architects. According to McGraw-Hill (2010), approximately 23% of contractors had used BIM in at least 60% of their projects in 2008 in the USA while this amount had risen to 38% in 2009. Referring to Infocomm BIM brochure (2010), two major facts are involved:

1. Building industry consumes a massive percentage of our resources each year. As a limited amount of these resources are recycled materials, stakeholders hope that BIM will be a solution for this problem in early future.
2. Comparing to the manufacturing industries, large portion of the money allocated to the construction industry is wasted. What Construction Industry Institute stated in 2004, shows that 57% of expenses in construction are non-value-added which is wasted. Considering the estimation of US$1.288 trillion in 2008 for US construction market at 57% waste, this would be equal to $600 billion per year. Figure 3 illustrates the portion of waste of money in construction industry.

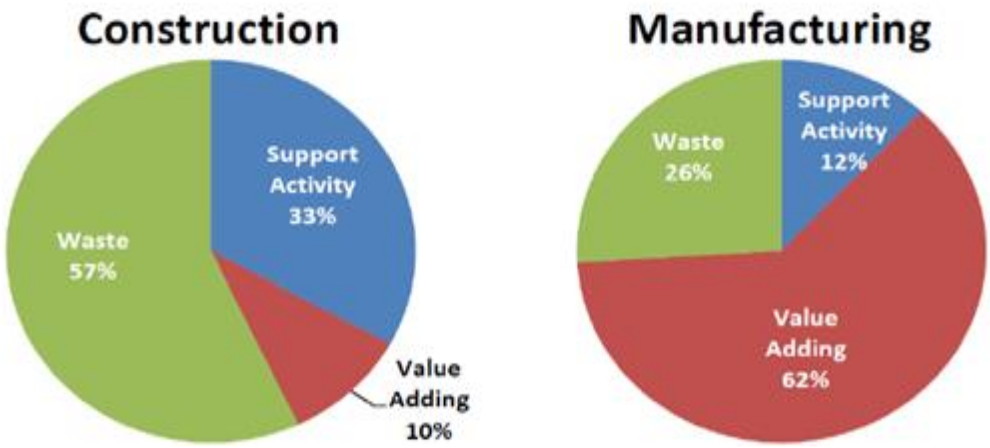


Figure 3: The portion of waste of money in construction industry (Infocomm BIM Brochure 2010)

Furthermore, BIM is not only limited to drawings. It is a combination of design, construction and maintenance information and data reservoir as a model which can be shared with all involved members. In order to propagate project success using BIM, it is better for these members to use a combination of BIM and Integrated Project Delivery (IPD). IPD is an alternative for the traditional contract methods like design-bid-build and design-build. As far as all stakeholders share the risk in design and build process and also the profit of growth in productivity in IPD, a precise BIM integration will help the system to work well. This is why the term "drawing" is being replaced with the buzzword "modeling" gradually.

The prevailing BIM platform for AEC contributors is Autodesk Revit these days. But Revit is not the only choice of architects and building owners. In United States Bentley BIM also has been used frequently by the AEC counterparts while Graphisoft, Tekla structure, Solibri model checker, Nemetschek etc. are in the next seats for the users worldwide (JBIM, Fall 2012).

2.3 Benefits of BIM

Theoretically speaking, BIM has expressed to be advantageous in both geometrical modeling of a building's performance and management of construction projects (Bryde, 2012). BIM has a separate usage in all phases of the project life-cycle: it is used by the client in order to find out the project needs; by the design team to analyze, design and develop the project; by the contractor in the way of project management and late in the operation phase by the facility manager (Grilo and Jardim-Goncalves, 2010). One of the most important issues caused by BIM is the collaboration between the different members of the construction team. This collaboration will eventuate in:

1. Decrease of the hazy shades between design drafts and constructability.
2. Speeding up the production which will lead to earlier completion of the project.
3. Giving the construction manager a better chance in quality control considering the incorporation of design, engineering and construction.
4. As the quantities resulted from BIM are more accurate, there would be a better chance for the members in order to prepare cost estimations.

Another strength of BIM is the ability to check and compare the cost of design alternatives which can lead to cost savings in the projects. Most of the times this occurs when the contractor has a vivid image of project and tries to prevent mechanical, electrical and plumbing (MEP) conflicts and finally result in the reduction of change orders.

Some other advantages that have been delivered by BIM include but not limited to the availability of the plans, elevations and sections which are produced as "views" by generating a single design model. On the other hand, BIM is capable of modifying the changes in the model. As an example, if a change happens in one of the details, all the related details will be updated automatically to be correspondent with the changes.

As it is expressed in the technical report of the Stanford University Center for Integrated Facilities Engineering (CIFE), five important benefits resulted by using BIM in 32 major projects include (CIFE, 2007):

- Up to 40% elimination of unbudgeted change.
- Cost estimation accuracy within 3%.
- Up to 80% reduction in time taken to generate a cost estimate.
- A saving up to 10% of the contract value through clash detection.
- Up to 7% reduction in project time.

As a brief, these five benefits are the result of a set of critical information within each major phase of the construction lifecycle including design, construction and management. By using BIM, this information will be available classified as follows (Autodesk, 2003):

- In the design phase these information include the design, schedule, and budget information.
- In the construction phase there are quality, schedule and cost information.

- And finally in the management phase, performance, utilization, and financial information are offered.

2.4 BIM Limitations and Risks

A great modification in communication amongst AEC team members and stakeholders can obviously be seen by using BIM. While BIM is one of the most desirable assets in construction industry, there are some essential considerations and limitations that should be observed in order to have a successful use. A list of these inherent limitations is given below (Infocomm BIM brochure, 2010):

1. Cost of software and hardware: Currently most AEC companies have applied a version of Audio Visusl (AV) software including 2D or 3D CAD drafting. It is obvious that the cost of procurement, maintenance and renewing the software must be taken into account. However, BIM packages seem to be more costly than ordinary CAD software. Furthermore, unlike CAD software which can be even operated simply by a laptop, in respect to the basic introduction of BIM, more equipped workstations are needed. Usually the exact needs for BIM software are recognized in the "Getting Started section".
2. Cost of training: Regardless of how expert are the staff in using current software, there should be a quick and efficient training for all related members of a company which desire to use new software. This should be done simultaneously while current activities are in progress in the company.
3. Transition from drafting to modeling: Transferring from a simple CAD drafting to BIM modeling might impose a large deal of alteration in performing current tasks in a company. After the transition, a BIM operator with a wider view and knowledge about the project would be needed instead of a draftsman.

4. Compatibility between software platforms: The inter-product compatibility is probably the most important problem with the BIM adaptors. It should be mentioned that all team members within the project should use a compatible version of software with the others in order to increase the interoperability. An easy solution for a company is that to manage all members to use a single format.
5. Innovation: As far as BIM is aimed to allocate parameters to intelligent objects in order to progress the output, there is a potential to interdict innovation which would probably occur without the automated processes that BIM now provides otherwise.

In order to reduce the limitations discussed above, it is serious to take some situations into account before the project starts and make a few agreement within the company to evaluate the risks and control them in case of happening. These agreements include:

1. Liability: One of the most important things in AEC projects is cooperation. The responsibilities of project participants should be defined prior to the project start while the limitations for contributing the model by different members must be determined. To decrease the liability risks, contractual relationships should be considered and level of liability should be defined for all members.
2. Intellectual property: As BIM has given all members the ability to simply share information, all related members and stakeholders have the accessibility to other individual project participants' intellectual properties.

Also confidential issues should be addressed at the beginning of the project. "Regarding the number of project participants, it is required to determine if it is even possible to assert confidentiality or ownership".

3. Data transfer: Nowadays a variable set of BIM programs is available for applicants. Since it is scarce that all project participants use the same software, some problems might occur in data transfer. There is a question still left here that considering this problem, is the data yet precise?
4. Software malfunction: Unexpected misdeed risks always exist in all technologies which can cause the data irremediable or inaccessible. That is why it is so important to have always a backup of the software and data since the software company is not always liable for the software malfunctions.

   Moreover, as the system is intelligent, it can make some changes to the model in case of finding clashes and it may cause some problems in real life construction if the changes do not have the sufficient accuracy.

The recommendation to the companies in construction industry which have chosen BIM is that consider the challenges of using building information modeling and do the necessary arrangements within the company before starting the projects with BIM so that they can minimize these potential risks of BIM.

Succeeding in using BIM within a company begins with the firm determination and shared vision of change among all employees of the organization and of course the support and knowledge of senior leadership. It should be known that early difficulties must be endured to reach future rewards.

2.5 Literature Related to BIM

Since the beginning of the theories on building information modeling, there have been a lot of researches and surveys done by many people trying to find out capabilities, risks, benefits etc. of BIM. Still after 8 years, there have been many questions left without answer because of the wide domain of the field and the relations between BIM and other related issues. This section goes through a limited up to date surveys being conducted worldwide.

Given the benefits to project documented in the case studies, it is a questionable point why there has not been a greater take up of BIM on construction projects (Bryde et al., 2012). Bryde et al. (2012) made a survey in order to explore the limit of usage of BIM lead to reported benefits in construction project. By gathering the secondary data of finished construction projects that have used BIM in their projects, it is concluded that a precise cost/benefit analysis is required ensuring the practitioners about investing on BIM. Although the price of common BIM software is somehow the same as analogous software in CAD platform, still the maintenance and initial costs of BIM is significant especially for new established and smaller companies. But for sure it can be said that by succeeding in BIM usage and increasing the productivity, Return on Investment (ROI) is something inevitable.

While in academia BIM has been mostly focused as a modeling and audiovisual tool, Allison (2010) introduced BIM as a Project Management (PM) tool. The potential benefits of using BIM for project managers from Allison's point of view are listed in the Table 1.

Table 1: Potential benefit of using BIM for project managers (Allison, 2012)

Potential benefits for PMs	**Why?**
Organize the project schedule and budget	An integrated 5D model immediately updates both the schedule and budget when any design change occurs
Work well with the design team	By using the integrated 5D BIM model to visualize and explore the impact of changes, s/he can keep project scope in check and become a trustworthy liaison between the designer and owner
Hiring and controlling the subcontractors	Having a handle on clash detection and coordination plays a key role in keeping sub-contractors' work predictable
Requests for information and change orders	Utilizing coordination resolution in preconstruction, these numbers can be brought to near zero
Optimize the owner experience and satisfaction	Owner received a big injection of confidence in the GC when the PM showed him/her design decisions impacted cost and schedule
Project closeout	PM to present a 6D BIM- a facility resource with information on warranties, specifications, maintenance schedules, and other valuable information
Profit margin	By thoroughly understanding the project in 5D, the PM has more tools at his disposal to keep tight reins and more reports to monitor progress
Progressive owners are mandating BIM on their projects	Becoming the BIM expert, in both preconstruction and out in the field, makes the PM invaluable and key player.
PM firm growth	Project's success with 5D means the opportunity to grow the firm's reputation and helps the corporate team win new business.

"Building performance and predictability of outcomes are greatly improved by adopting BIM" (Azhar et al., 2011). Azhar et al (2011) found the return of investment for BIM as 94.86% which can obviously highlight the economic benefits. On the other hand, as BIM provides a trustful sharing of data which can be imported by other users easily, from Azhar’s point of view, this might cause an elimination of the critical checking phases.

Eadie et al. (2013) tried to measure BIM implementation throughout UK construction project life cycle. They found the collaboration aspects as the most important impact. Considering 92 responses from BIM users, they mentioned collaboration (ranked first), management aspects (ranked second), reduction of waste (ranked third), accuracy (ranked forth) and less significant than those visualization as the impacts of BIM in construction lifecycle. "Finally the research indicated that the main reason for not adopting BIM on current projects relates to the lack of expertise within the project team and external organizations". Akcamete et al. (2011) demonstrated that facility managers' duty in operation and maintenance of construction projects is about 60% of the total costs of the project. Khanzode et al. (2008) states a 1% to 2% reduction in costs of Mechanical, Electrical and Plumbing engineering (MEP) systems in a large-scale healthcare project due to contractors' specialist expressions.

Gu and London (2010) analyzed the readiness of industry in adopting BIM regarding people, product and processes as the main criteria. They found both technical and non-technical subjects that needed to be noticed. By using the Focus Group Interviews (FGI) method, they derived that due to the development of construction industry and the need for collaboration, the broader adoption of BIM in the AEC industry is very promising.

"It is still underexplored how BIM model respond when quantity takeoff is its primary use" (Monterio and Martins, 2013). In the survey on modeling guidelines for quantity takeoff-oriented BIM-based design, Monterio and Martins (2013) enumerated automatic quantity takeoff as a product of BIM tools although the process is not upstanding and direct and also strict rules need to be pursued to have an accurate result.

From a different point of view, benefits of presenting BIM in AEC education have been discussed in the USA. "The main objective of this studio is to provide students with means through which integrative pedagogical objectives are achieved through BIM" (Sharag-Eldin and Nawari, 2010). The introduction of BIM at Kent State University (KSU) and University of Florida (UF) eventuated that BIM can deliver educational build environment which will lead to an interoperable format that integrates design and construction comprehension.

The main purpose of this study is to identify the efficiency of BIM on challenges and to a lesser degree their causes in Iran. In order to do so, the first step is to address the problems and challenges in road and highway construction in Iran. However, there is a wide range of challenges considering the source and it is not the subject of this study to discuss all; related literature on some amendable nonmonetary parts were brought up in the next chapter.

Chapter 3

ROAD CONSTRUCTION PROJECTS: PROBLEMS, CAUSES, CURES

3.1 Introduction

It has been years that construction industry is been used by different societies as a tool in order to develop their urban and rural spaces (Enshassi et al., 2006). This is more obvious in developing countries and probably leads to development of economy.

There are three main parameters being considered in project success measurement: cost, time and quality (Mahamid et al., 2012). According to Ahmed et al. (2003), construction projects have been accompanied by delay in most cases all over the world which results in cost overruns. These delays are more likely to occur in infrastructure projects such as roads and highways, railways etc. as they are larger and more costly. These are what make this type of project more risky especially when they have to be planned precisely for long horizons. Due to KMPG (2005) one of the latest surveys among 25 of the largest construction firms in the world expressed that they see managing and pricing risk as one of their biggest challenges and mentioned poor forecasting, cost escalation and also poor risk identification as the main issues leading to profit margin reduction.

In this chapter, first the main challenges and obstacles in road construction will be discussed considering their consequences. Furthermore the causes will be brought up and finally the cures will be presented which is the main aim of this survey.

3.2 Challenges, Obstacles and Their Causes in Road Construction

The main purpose of this study is to identify which factors are considered as challenges and to a lesser degree the causes behind them. The first step is to address the problems, challenges and opportunities. However, there is a wide range of challenges considering the source and it is not the subject of this study to discuss all; just some amendable related parts have been brought up.

It is obvious that all researchers and specialists have divided the main obstacles in large construction and infrastructure projects into main categories of time overruns and cost escalation and tried to study the issue from different points of view including contractor side, consultant side and owner's side. In all findings, a root of poor managing can be seen, which is a subsequent of many reasons.

According to KMPG (2005), 25 of the largest construction firms worldwide mentioned poor forecasting, poor risk identification and cost escalation as the main challenges in road construction. Cost escalation is the increase of financial needs for completing a project above the forecasted budget amount. In the USA, Government Accountability Office expressed that 77% of highway projects face cost escalation as a matter of inaccuracies in cost estimates (GAO/RCED, 1997). Adams (1997) provided a list of problems facing contractors in Nigeria including inappropriate contract conditions, meeting contract deadlines, design changes, incomplete contract documents, communicating with client, lack of project planning and site management, providing quality workmanship etc. Flyvbjerg (2007) found inadequate risk assessment factor as the most important problem in Denmark infrastructure projects like Copenhagen Metro which resulted in financial risks. Kaliba et al. (2008) found cost overruns, schedule delays and the need to improve management of projects as the most important issues in road construction in their country Zambia. Odeh and Battaineh (2002) also considered improper planning and slow decision making among the top 10 main problems of contractors in large size projects which might result in construction delay in Jordan. Al-Momani (2000) conducted a survey between 130 public projects in Jordan and found also the designer role and user changes important in the causes of delay. In Saudi Arabia, Assaf and Al-Hejji (2006) identified 73 causes of delay and concluded the most common problem recognized by the consultants, contractors and the owners as "change orders". Mezher et al. (2006) studied the subject from the viewpoints of contractors, consultants and owners separately. According to their findings, owners are mostly faced to financial issues while contractors voted for contractual relationships as the most important problem and consultants mentioned management issues. Moreover Abd-Majid and McCaffer (1998) conducted a survey on the causes of contractors' performance delay in the United Kingdom. Their findings indicated materials, equipment and labor-related delays as the major causes by that time.

Flyvbjerg (2005) studied among 167 cases distributed between 20 nations and 5 continents. The striking results showed the average cost overrun of 20.4% between these 167 road projects. Also the high amount of 29.9 for standard deviation expressed that the uncertainty and risk on cost overruns are large indeed (N=167, SD=30). Considering the length of implementation phase as the period of time between decision to start a project till the finish of construction, Flyvbjerg et al.

(2004) concluded that projects with longer implementation phases seem to have a larger cost escalation and sluggish projects are usually more expensive.

Therefore, it is so overt that all the ability should get to work in order to make a proper preparation and to conduct an explicit planning and authorization before the owner makes his/her decision to start the project. Strong and solid risk assessment, documentation and forecasting would be necessary to be on budget and on time.

The question is how to reduce inaccuracy and risk in forecasting?

In order to have a better understanding on what is presented below, it would be useful to take a look at the procedure which has been used for design and constructing of road and highway projects for the past 10 to 20 years first called 2D drafting centering design workflow. The method starts with the preliminary design. Completing this step, detailed design takes place and then on to construction documentation. Each step has to be completed before the start of the next step. Regardless of the separation between the steps, this process will play the role properly until the usual unavoidable design change should be done. This is where the time-consuming and error-prone process of manual drafting process is needed to be made. Figure 4 demonstrates the level of cost, effect and effort in 2D drafting-centric workflow. Strafaci (2008) has tried to compare the Building Information Modeling with the traditional method in road and highway design and construction and to check the extent it would be found helpful.

Regardless of the name, the benefits of BIM are not limited to building industry and architecture anymore. For the past few years, BIM has been proposed as a tool to speed up all phases of life cycle in public sector transportation and infrastructure projects. Thanks to technology development, companies like Autodesk or Bentley have provided us with software to perform BIM workflow in road and highway project. Software products like Autodesk Infrastructure Design Suite or Bentley MXROAD Suite are solutions for planning, designing, building and managing heavy construction projects. But still construction firms are using the traditional methods instead of BIM regardless of the many benefits of it.

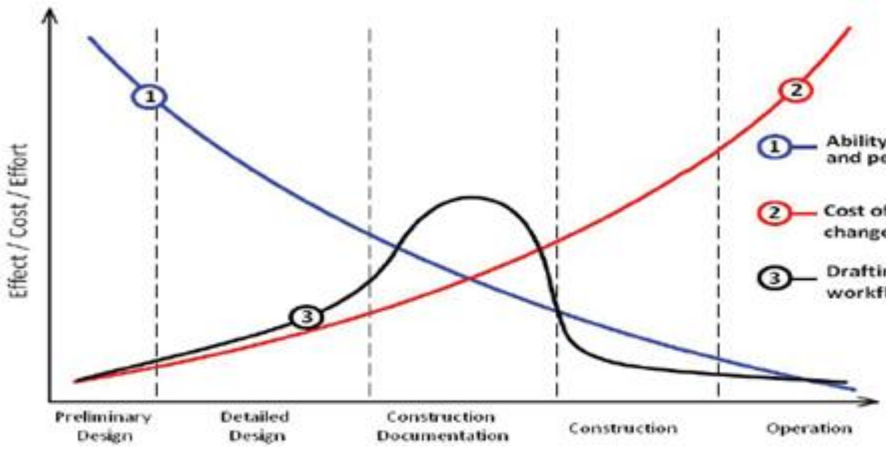


Figure 4: Level of cost, effect and effort in 2D drafting-centric workflow (Strafaci, 2008)

3.3 How BIM Acts in Road and Highway Projects

Today, BIM is one of the hottest subjects in the infrastructure both for governmental projects and private sector. Practically speaking, utilization of BIM workflow in road and highway projects starts with creation of an intelligent 3D model of the highway in which the components are linked to each other dynamically; this means a set of coordinated, reliable design information of the project together in a single file. This model-based design method gives the opportunity to take different design alternatives into consideration in order to reach the optimal one. Regardless of drawings including lines, arcs, etc., the chance of easier designing of complicated road and highway features like junctions and curves is given. Another advantage of this wizard-based design tools is the ability to implement the late stage design changes in a short time and benefit from the automatic update system in all documentations such as bills of quantities, schedules etc. incorporating all the edits. Moreover, the clash detection technology used in Building Information Modeling in buildings to meet the interferences between water, structural, HVAC and other subsystems can be used effectively in road design and construction to prevent clashes with underground infrastructures water and sewerage systems, electric and telecommunication cables etc.

But unlike the vertical structures, BIM is much more than intelligent 3D model for horizontal constructions such as roadways. It can be used in simulating lighting, lines of sight, drainage, signage and many things more and of course at the center of attention, in construction planning and scheduling which the whole thing might lead to prevention of costly errors before a project even goes to site. Another advantage of using BIM in horizontal construction is the more complicated situation of this type of projects than building structures because of the correlation with ground topography and existing infrastructure unless in tall buildings, regardless of one or two ground level floors and foundation, other floors are usually typical and identical. This makes believe that roads can even benefit more than buildings from BIM as a matter of this complexity.

London’s M25 motorway widening project can be looked as a successful case of using BIM, completed without any time overrun in summer 2012; the joint venture of Atkins, Skanska and Balfour Beatty through design coordination and construction planning in three years. This means about half the time needed for completion of projects of this scope. As the existing road needed to be active throughout the three years of construction period, planning played an acute role in this project (Skanska, 2011).

The benefits of BIM in road construction projects can be summarized as:

- Evaluation of design alternatives is much easier with BIM.
- Design for the objectives such as constructability, sustainability and road safety can be optimized by using the simulation and the information model.
- Design deliverables such as 2D plans and documentations, quantity take offs, as-built drawings and comparisons, operations, construction sequencing and also operations and maintenance can be achieved directly by using a BIM workflow.

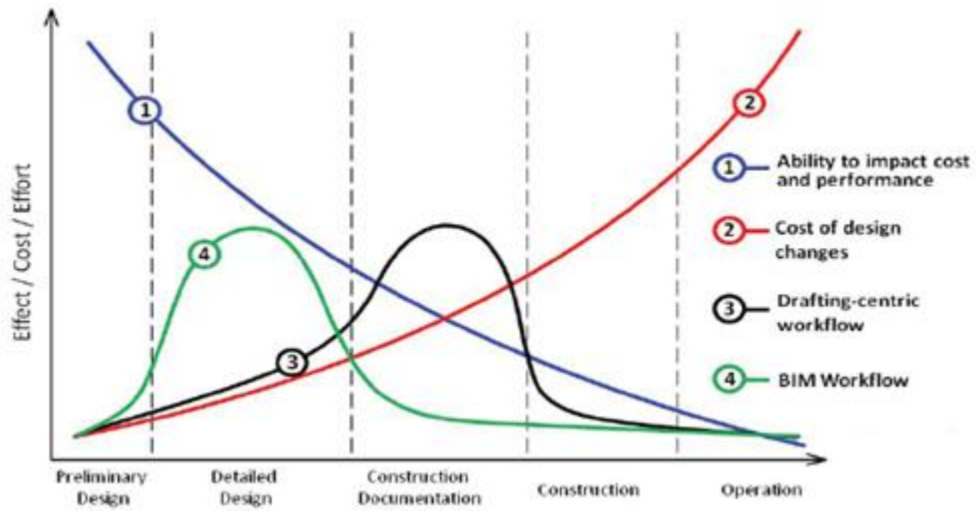


Figure 5: Level of cost, effect and effort using BIM workflow (Strafaci, 2008)

As presented in Figure 5, design for the objectives such as constructability, sustainability, road safety etc. can be optimized by using the simulation and the information model. For instance, two of these criteria are described more:

Road Safety – There are many factors in driving design such as sight distance, safe speed, longitudinal and latitudinal slopes etc.; traditional analysis in these fields are based on mathematical equations which include vertical curvatures and slopes, however there are some inefficiencies in this method like visual obstructions. This is the point which integration of 3D model visualization and simulation helps civil engineers to recognize the barriers before the inception phase.

Constructability – Most often civil engineers and designers do not consider constructability in design phase and just focus on code compliance. This might occur as false explanations on design content because of poor documentation and probably might end in change orders and extra cost and time.

3.4 Related Software

Although the method of Building Information Modeling has been used since the previous decades, still the application in road and highway design and construction has been rather gradual comparing to building construction.

Today all members involved in construction industry face tight timelines and budgets especially considering the competitive and tough economy. In order to be accurate in specifications, on budget and around the clock, some computer software with the content of BIM have been offered by reputed companies such as Autodesk and Bentley. Here it has been decided to take a quick look at these new products' functions.

3.4.1 Autodesk Infrastructure Design Suite

The 2014 Autodesk Infrastructure Design Suite has provided users product for use in BIM modeling for roads and highways. By checking the list of programs of

Infrastructure Design Suite, variable application will be found for different stages of the project lifecycle. In order to move forward through the purpose of this study, three main areas have been considered.

1. Planning and early design
2. Documentation and detailed design
3. Construction simulation and management

Autodesk Infraworks can be used for obviating the first area and to create a reliable 3D model of a planned development. This program is completely compatible with Geographic Information System (GIS) and other Autodesk software such as Civil 3D, Revit etc. After the preliminary design is done, the file can be exported to Autodesk Civil 3D to add any civil engineering information which can be used in BIM process in upcoming stages. So this is where the second mentioned area is proceeding. Analysis will be done while cut plans, sections, quantity take-offs, earthwork and material volume calculations are provided. After finalizing the design it is time to move to the third mentioned area of our BIM workflow. The completed model will be imported to Autodesk Infraworks to prepare the visualization of the final design and finally by Naviswork Manage, construction management and sequencing will be done. Using a Timeliner tool like Microsoft Project or Primavera simultaneously within Navisworks Manage, 4D or 5D final product of the BIM workflow is ready. Also by using the “Clash Detection” technology of Navisworks Manage, there would be a chance of saving time and money by early detection of clashes between components instead of facing costly redesign and change orders during the construction.

3.4.2 Bentley MXROAD Suite

Bentley MXROAD is an advanced modeling tool which provides the user with fast and precise design for any type of roadway regarding of possible design alternatives in order to achieve the ideal road system. Same as Autodesk Infrastructure Suite, it begins with a powerful 3D modeling technology with an interoperable database which helps the designer to create the best possible 3D model in a popular CAD platform. Digital Terrain Model (DTM) creation and analysis, full alignment, road and junction design capability, 2D and 3D drainage design, volume and quantity extraction, 2D and 3D PDF creation, integration with Google Earth, and automated production of contract drawings complete a tool set that allows MXROAD users to feel confident tackling the design of any type of road, large or small.

Chapter 4

METHODOLOGY

4.1 Introduction

In all surveys and researches, methodology is a need in order to answer two main questions:

- How the surveyor has created or collected the needed data?
- How the surveyor has analyzed the collected data?

Methodology is the discussion of analysis of method applied to the survey. By means of good methodology, the researcher will succeed in providing the relative data with the minimal time and cost expenditure.

Coming up after introduction, selected methods being used in this survey will be explained. Preparation and finalizing the questionnaire will be detailed. A brief about the respondents will be given after and finally an explanation on the case study being held in this survey will be presented.

4.2 Questionnaire Survey

Questionnaire is a compilation of preplanned and written questions which can be responded with or without presence of the surveyor. Due to research objectives, this research is based on a questionnaire survey in order to collect the needed information in a useful way.

4.2.1 Questionnaire Design

A set of closed ended questions including multiple choices and matrix form were defined in order to have more accurate results. The questionnaire was divided into two main parts. In the first part, general information of both respondents and company were asked. All respondents were requested to state their experience in road and highway construction, grade of the company and some other basic information. The second part mainly included the discussion on 13 factors such as change order in design, poor design, poor management etc. which had been found effective on time and cost overruns and the assessment on preventing them. The whole 13 mentioned factor are brought in chapter 5 through the next chapter. These 13 factors were chosen from a list of detected factors through the existing literature on road and highway construction. For the effect of each factor the severity was categorized on a five range scales as follows: least important, less important, important, more important and most important on a 0 to 100 point scale. Also for the efficiency of BIM in preventing mentioned factors, the same categorization was used.

As the target people of the study were located in Iran, e-postal questionnaire method was used. By mean of this method, the questionnaire was emailed to the respondents and the results were emailed back to the surveyor. Furthermore, the web-based questionnaire was easier to standardize and more reliable as the questions are sent straightly to the responder and filled up online. Figure 6 shows the workflow of deigning the questionnaire form in this survey. Appendix A includes a sample of the questionnaire used in this survey.

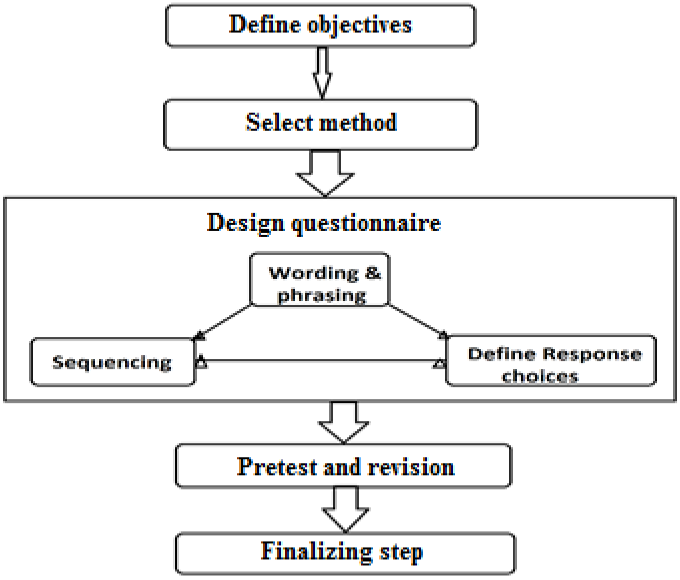


Figure 6: Questionnaire design workflow

4.2.2 Pretest and Revision

It is so important to assure that the respondents understand the questionnaire contents completely. As a result, before emailing the questionnaire to the main target population, 3 postgraduate students of the Construction Management group of the Eastern Mediterranean University were provided with the first copies of the questionnaire to find out if there are any problems and defects understanding the main idea. In this stage, respondents were interviewed one by one to discuss on the fluency and clearness of the questions. The revision of the first draft was finalized and prepared to be sent to the main target population.

4.2.3 Respondents

186 companies were membered in the Iran Road Construction Association at the survey period. The questionnaires were emailed to approximately 11% of these members (equal to 20 road construction firms) as the target population of this study. 66.67% of the respondents had a grade 1 company while 16.67% had grade 3 and the same percentage had grade 4. Table 2 demonstrates the general authorities and

capabilities of different grades of construction firms in Iran including maximum allowed costs and maximum allowed number of projects per year. Figure 7 shows the percentage of the respondents in terms of companies' grading for both contractors and consultants.

Table 3: General authorities and specifications of Iranian construction firms

Construction company's grade	Number of projects allowed per year	Maximum cost allowed per year ($)
1	4	12,500,000
2	3	7,812,500
3	2	3,125,000
4	2	1,562,500
5	2	468,750

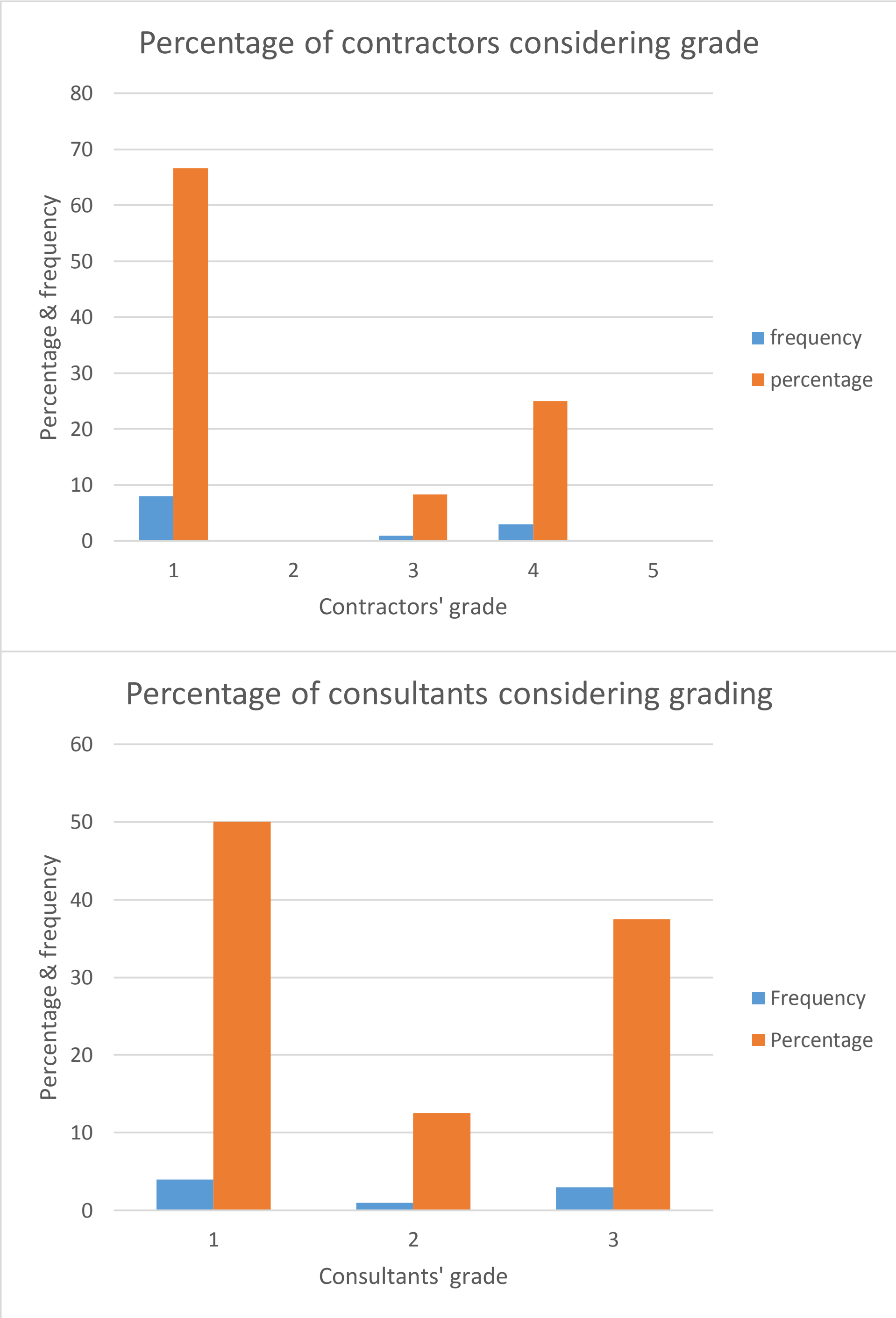


Figure 7: Percentage of the respondents in terms of companies' grading

4.3 Case Study

In order to validate the results of the questionnaire survey, it was decided to conduct BIM workflow on a constructed road project in Iran as a case study. Generally, case study research method is used to diagnose the accuracy of presumed or resulted data in real-life situation. According to Schell (1992), case study is the best research pattern to accredit the specs of an empirical event in real-life.

Because of the multiplicity of standard road projects, the case study of this survey contains a road segment considering all construction details like cut and fills, compactions, bridges, culverts etc.

Chapter 5

DATA COLLECTION

5.1 Introduction

This chapter will present the results and outputs generated by the questionnaire survey. Respondents included two groups of Iranian contractors and consultants; however, the results are integrated. The chapter is based on seven subheadings which are the main topics asked from the respondents. Totally twenty responses were gathered from twelve contractors and eight consultants related to the field.

Sureveymonkey website was used in order to provide the respondents with easy access to the questionnaires in Iran and finally the responses were analyzed and validated by IBM SPSS Statistics Data Editor Version 22.

5.2 General Characteristics of Respondents

The questionnaire results showed that the majority of the respondents (60%), had the master degree; while less than 10% had bachelor degree and around 35% had PHD. Most of the contractor and consultant companies contributed in the survey had grade one in construction. The details of the grading of the construction companies have been brought in Table 2 in methodology chapter. 60% of the participants were contractors while 40% were consultants. It can also be mentioned that all participant companies were private companies. More detailed data on companies and respondents' characteristics are shown in Table 3 and Figure 8.

Table 4: Main characteristics of the respondents

Main Characteristics of the respondents		Frequency (#)	Percentage (%)
Companies' line of business	Contractor	12	60
	Consultant	8	40
Contractors' grade	One	8	66.67
	Two	0	0
	three	1	8.3
	Four	3	25
	Five	0	0
Consultants' grade	One	4	50
	Two	1	12.5
	three	3	25
Company's working experience	Less than 10 years	7	35
	10 to 20 years	2	10
	20 to 30 years	6	30
	More than 30 years	5	25
Respondents' education degree	Bachelor degree	1	5
	Master degree	12	60
	PHD	7	35

5.3 Respondents Idea about the Detected Deflection Factors

In the second part of the questionnaire, participants were asked to express their idea about the 13 detected deflection factors in this listed as:

1. Change order in drawings
2. Change order in specifications
3. Poor design
4. Poor documentation
5. Improper planning
6. Poor management
7. Construction mistakes
8. Inaccurate estimations

9. Poor risk identification

10. Late clash detection

11. Poor coordination on site

12. Shortage of material

13. Slow decision making

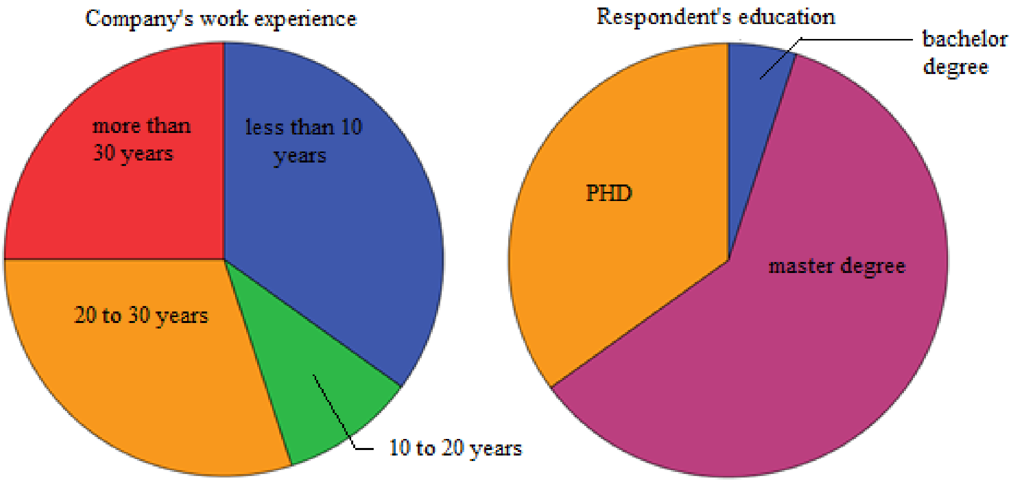


Figure 8: Companies' working experience and respondents' level of education

Excluding financial issues, a list of 13 main causes of time and cost overrun in the highway projects had been presented for the respondents and they were asked to represent their assessment on the extent of controllability of these factors. Furthermore, the frequency of facing time and cost overruns and quality deflection was questioned which the results are shown in Table 4 and Figure 9.

Table 5: Respondents' idea about the detected deflection factors frequency of deflection in projects

Respondents idea about the detected deflection factors		**Frequency (#)**	**Percentage (%)**
Assessment on the factors	Controllable	10	10
	Uncontrollable	50	50
Frequency of facing time & cost overruns in the projects	Usually	13	65
	Always	7	35

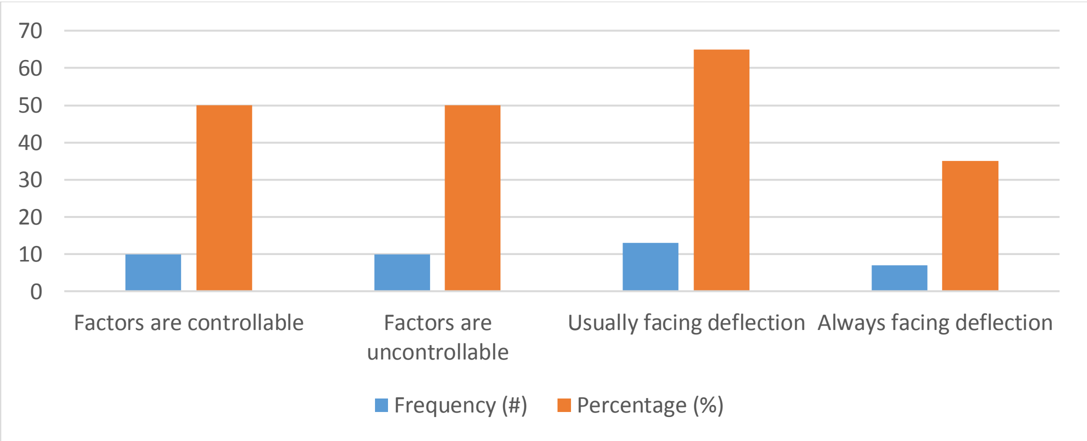


Figure 9: Respondents' assessment of deflection factors and frequency of facing time & cost overruns

5.4 Effect of Factors on Project Constraints

In the next step, participants were requested to score the influence of the detected factors on project constraints including time, cost, quality and health and safety between the ranges of 1 to 5 with 1 as the minimum amount (0-20%) and 5 as the maximum (80-100%). Figures 10, 11, 12 and 13 demonstrate the allocated scores by the respondents.

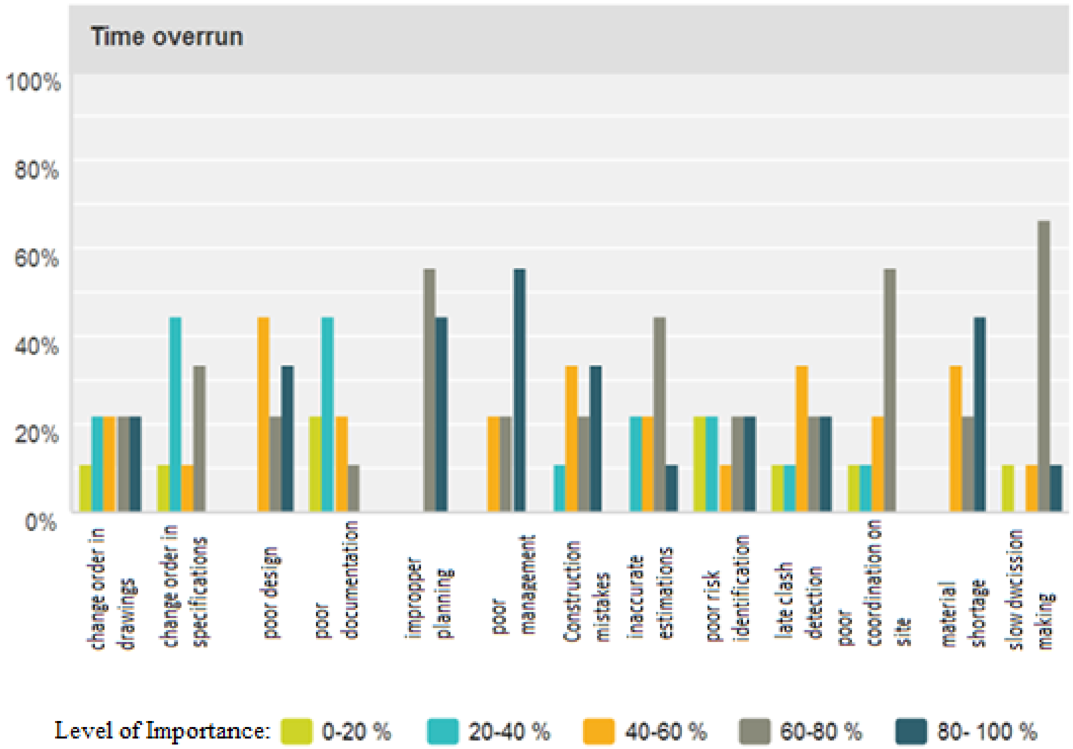


Figure 10: Influence of detected factors on time overrun

As it can be seen, around 70% of the participants selected the level of importance of 4 of 5 for slow decision making on time overrun while about 50% found change order in specifications and poor documentation in the level of importance of 2 of 5.

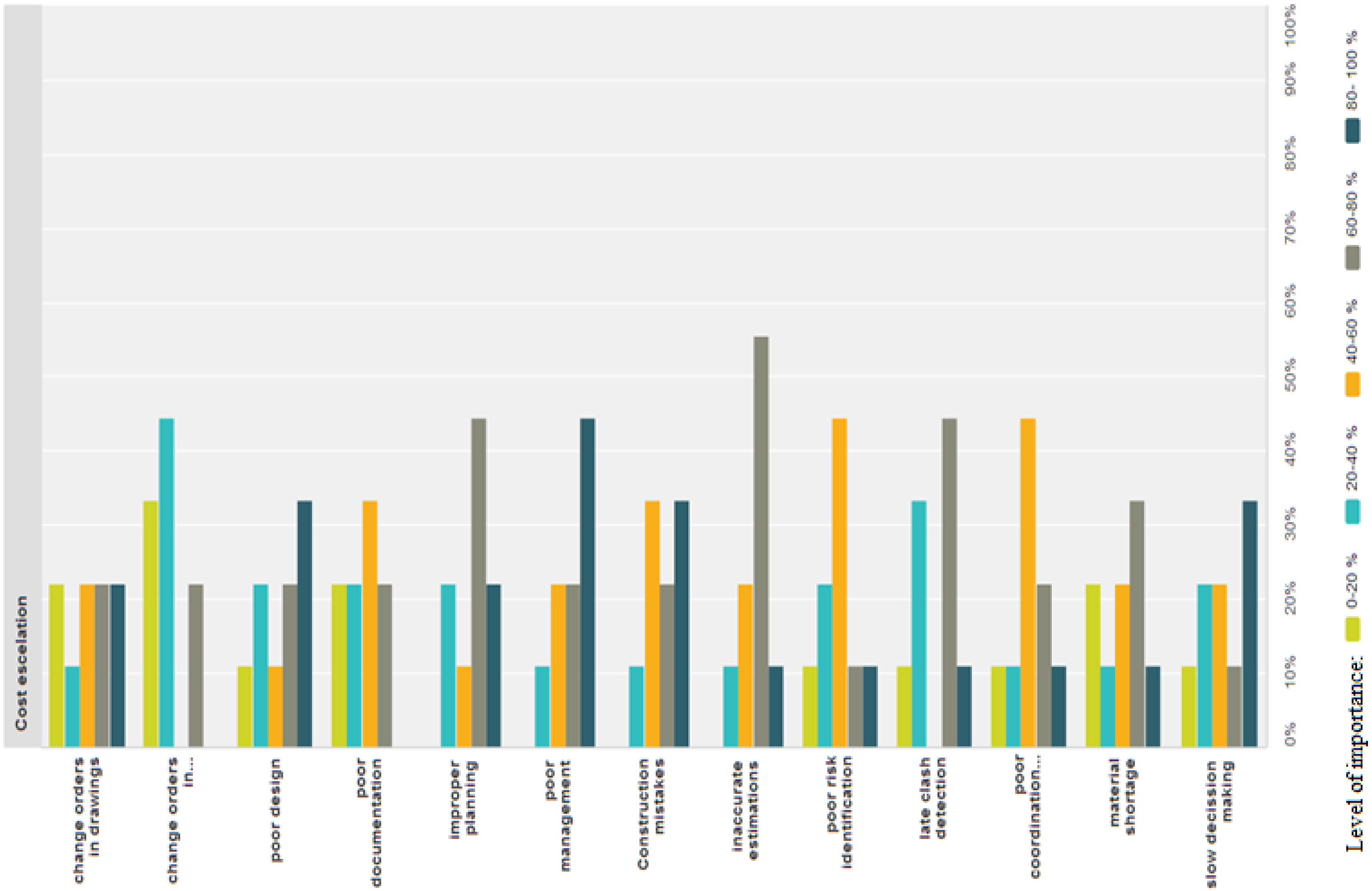


Figure 11: Influence of detected factors on cost escalation

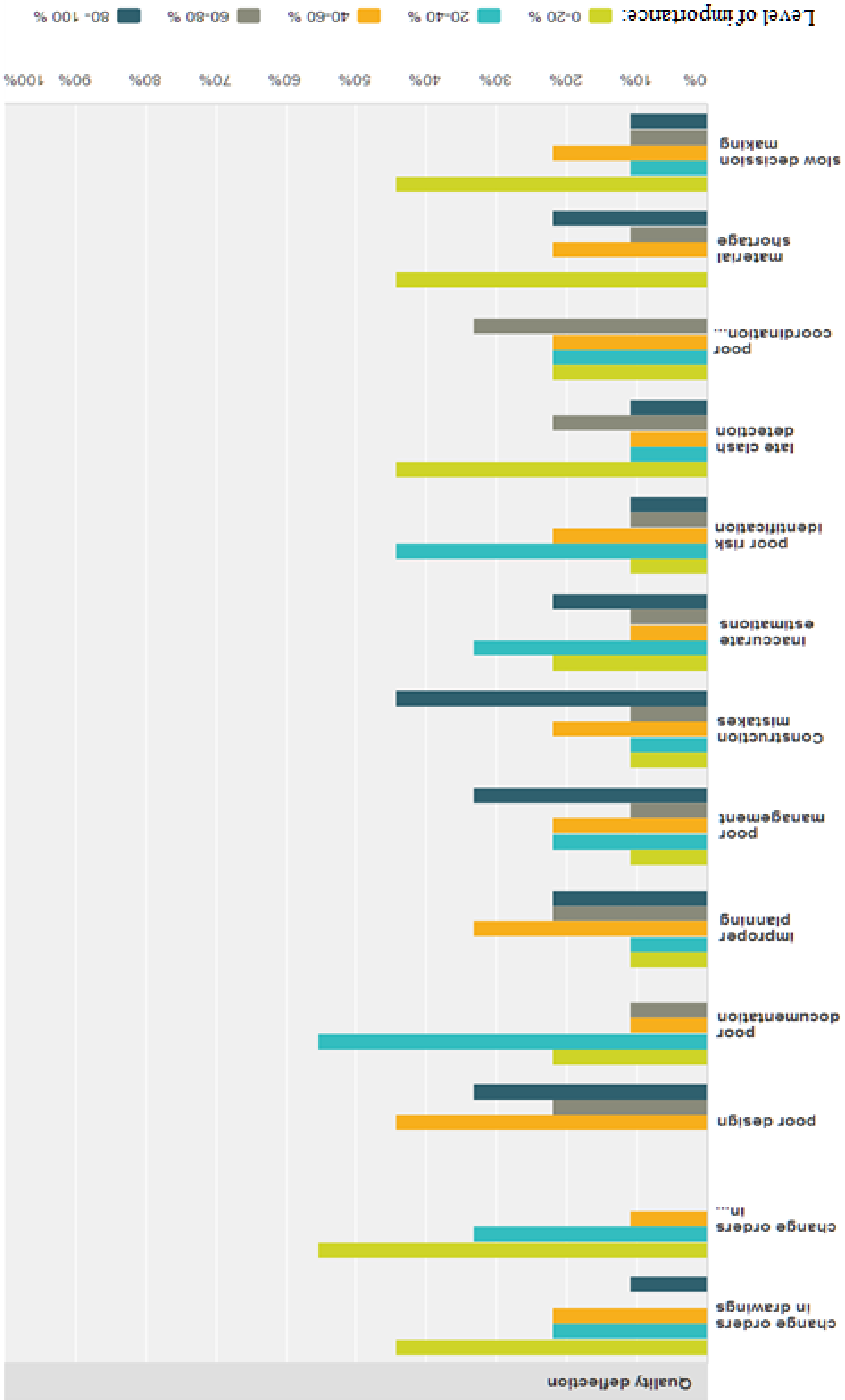


Figure 13: Influence of detected factors on quality deflection

Figure 15: Influence of detected factors on health & safety

5.5 Respondents' Knowledge, Familiarity and Usage of BIM in Projects

In the subsequent questions, it was aimed to check the respondents' familiarity with BIM as a secondary tool in project management. Unfortunately, the results showed an undesirable file. Among the participants, only 20% expressed that they have very good knowledge on the issue while almost 35% had hardly heard about Building Information Modeling before. The worst case is that around 85% had rarely used BIM before. Table 5 represents the results in this step.

Table 6: Respondents' knowledge, familiarity and usage of BIM in projects

Respondents knowledge and familiarity with BIM		**Frequency (#)**	**Percentage (%)**
Extent of familiarity with BIM	Fair	7	35
	Good	9	45
	Very good	4	20
	Excellent	0	0
Extent of using BIM in projects	Hardly ever	17	85
	Occasionally	3	15

5.6 BIM and Its' Ability to Integrate Drawings

In the next question, target group were provided with a brief about the ability of BIM workflow and software products to integrate the drawings of the conducting project with the drawings of the existing infrastructure. As it is one of the main causes of cessations during the implementation phase, contributors should have expressed their assessment on the level of efficiency of BIM in this issue and choose a choice in range of 1 and 4 with 1 representing not at all useful as the least importance, and 4 representing the most important as very useful. Results showed an approximate equality in this case where 57.14% found BIM workflow very useful while 42.86% assessed as somewhat useful.

5.7 Efficiency of BIM in Preventing Deflection Factors

The last part of the questionnaire included a matrix question to investigate the efficiency of BIM in preventing deflection factors. The ability of integrating the 3D model with time and cost as the 4th and 5th dimensions was explained. After mentioning a few advantages of 4D and 5D models, respondents were requested to evaluate the efficiency of using BIM procedure in preventing reflected factors. Table 6 contains the detailed results of the final case.

Table 7: Efficiency of BIM in preventing deflection factors

Efficiency of BIM in preventing deflection factors			
Factor	**score**	**Frequency (#)**	**Percentage (%)**
Change order in drawings	0-25%	0	0
	25-50%	0	0
	50-75%	8	40
	75-100%	12	60
Change order in specifications	0-25%	0	0
	25-50%	3	15
	50-75%	14	70
	75-100%	3	15
Poor design	0-25%	2	10
	25-50%	0	0
	50-75%	11	55
	75-100%	7	35
Poor documentation	0-25%	2	10
	25-50%	3	15
	50-75%	5	25
	75-100%	10	50
Improper planning	0-25%	0	0
	25-50%	6	30
	50-75%	9	45
	75-100%	5	25

Table 6 continued:

Efficiency of BIM in preventing deflection factors			
Factor	**score**	**Frequency (#)**	**Percentage (%)**
Poor management	0-25%	0	0
	25-50%	4	20
	50-75%	13	65
	75-100%	3	15
Construction mistakes	0-25%	2	10
	25-50%	2	10
	50-75%	11	55
	75-100%	5	25
Inaccurate estimations	0-25%	0	0
	25-50%	2	10
	50-75%	10	50
	75-100%	8	40
Poor risk identification	0-25%	0	0
	25-50%	6	30
	50-75%	13	65
	75-100%	1	5
Late clash detection	0-25%	4	20
	25-50%	5	25
	50-75%	5	25
	75-100%	6	30
Poor coordination on site	0-25%	4	20
	25-50%	6	30
	50-75%	5	25
	75-100%	5	25
Shortage of materials	0-25%	2	10
	25-50%	6	30
	50-75%	6	30
	75-100%	6	30
Slow decision making	0-25%	3	15
	25-50%	5	25
	50-75%	11	55
	75-100%	1	5

Chapter 6

CASE STUDY

6.1 Introduction

In order to prevent disorder, all data related to the case study project were brought in this chapter separately.

After introduction, the first part of this chapter contains general specifications and details of the case project. After that in the second part, BIM modeling procedure done in this survey are explained.

6.2 General specifications and details of the project

The project started in July 2002 with the estimated cost of 60,325,299,000 Rials (approximately 1,856,163$). Although the project was supposed to be finished by February 2006, it finished in December 2007 with the total cost of 75,323,927,745 Rials (approximately equal to 2,317,659 $) which shows a 14,998,628,745 Rials (461,496$) cost overrun equal to 24.8% of the estimated cost and also a 23 months period delay in time which is equal to 55% of the total estimated project time.

Table 7 contains the general details and specifications of the case project. In order to prevent disorder and mess, project drawings are inserted in Appendix B. The basic technical specifications of the studied road segment, bridges etc. are included in Table 8.

Table 8: General details of case study project

Project name	Tehran – Pardis Highway, third segment
Client	Iranian Ministry of Roads and Transportation
Consultant	Iran Oston Consulting Engineering Co.
Contractor	Iranian Highway Development Organization

Table 9: General specifications of the project

Project Estimated Duration	42 Months
Project Estimated Cost	60,325,299,000 Rials (approximately 1,856,163$)
Starting Date	Jul-02
Finishing Date	Dec-07
Project Final Duration	65 Months
Project Final Cost	75,323,927,745 Rials (approximately 2,317,659$)
Cost Overrun	14,998,628,745 Rials (approximately 461,496$)
Delay	23 Months (Equal to 55% of project estimated duration)
Terms of Contract	6.4 kilometers highway from kilometer 8+700 to 15+100 with all related construction activities
Other Included Structures	Twin tunnels with the length of 450 and 400 meters and two bridges in kilometers 10+100 & 14+020

6.3 BIM modeling

As the project was designed and planned in Iran, the traditional 2D drafting-centric method was used like all other road and highway projects in Iran. It worth to mention that still there is not any sign of conducting BIM workflow in road construction projects in Iran. This lack of BIM adoption in road construction industry highlights the need

In order to implement BIM workflow for the considered project, three software products were used which will be introduced briefly:

6.3.1 Autodesk Infraworks

This product is the best for easy and quickly preliminary design. It can speed up the design process and help the designer to make a better decision due to better understanding of the project.

6.3.2 AutoCAD Civil 3D

Performing BIM process in roads and highway construction projects starts within the design phase. In this stage, an intelligent 3D model of roadway was generated by means of BIM oriented software product, AutoCAD Civil3D. This software is the key for civil engineering design and documentation. Some features of this software include faster design replication, preparing documentation and sharing and updating information as a collaboration tool; however, these features are not exhaustive.

6.3.3 Autodesk Navisworks Manage

Generally this software has 3 different versions of Naviswork Manage, Naviswork Simulate and Naviswork Freedom. Although there are little differences in the features, the whole software is used to generate a 4D model by integrating 3D model with the 4th dimension which is time. Some features of Navisworks are mentioned and not limited to the list below:

- Planning and sequencing the project;
- Detecting clashes and interference checking;
- Model reviewing options by creating walk-throughs;and
- Creating 5D scheduling, considering cost etc.

In this study, Autodesk Navisworks Manage version 2015 has been used.

Chapter 7

RESULTS AND DISCUSSIONS

7.1 Introduction

In the first part of this chapter, relevant discussions about the findings of the questionnaire survey will be presented. Results of each part of the questionnaire will be checked separately in order to find out the advantages of the positive points. Moreover, cures and recommendations will be proposed for the negative points and disadvantages.

The second part includes an analysis of a case study including modeling a constructed road project in Iran in order to evaluate the usage of BIM workflow in road and highway construction field. The workflow will usually begin with preliminary modeling the project in Autodesk Infraworks, detailed modeling in AutoCAD Civil 3D and finalizing by importing the completed model in Navisworks. As this case study contains a finished project and there is not any need for preliminary design, case study had started with modeling the project with AutoCAD Civil 3D.

7.2 Lack of Familiarity with BIM among Iranian Construction Firms

It is so unreasonable to find out only 20% of the target population know a little about BIM or heard about it before and almost 80% not even have heard the term before. Although 40% chose agree and 60% chose strongly agree on the topic of "efficiency of BIM in preventing time and cost overrun" considering the definitions and a need of change is perceptible in construction management methods, still construction firms prefer to work with the traditional systems as before. There are a number of obstacles which prevent companies to go through a change while almost all of them suffer from excessing time and cost. These obstacles and the extent that BIM can play the role in this issue, especially in developing countries like Iran, are the subjects of next sections.

7.2.1 Advantages of using BIM in road and highway construction

Skanska BIM brochure (2011) mentioned M25 highway widening project around London as a successful sample of implementing BIM workflow in highway projects by using the capabilities in order to finish the project on time. Highway 78 Brawley Bypass project in California is another example of this kind. The latter would be more impressive when it is known that 77% of the projects of that size in the US have faced time overrun due to previous reports (McGraw hill, 2012).

Advantages of applying BIM workflow in projects can be observed from the inception and tendering phase till the operation and maintenance. However, surveys on applying BIM in road construction projects can hardly be found and just a few companies are now working with this procedure in their horizontal construction projects. The numeral benefits can be guesstimated from the previous studies on vertical construction.

Early estimations and tendering stage will be discussed first. As an accurate quantity takeoff is the main requirement of the preliminary cost estimations, it would be wise to take a look at preparing BIM oriented quantity takeoff. Till now, all quantity takeoff processes have been done manually. According to Monteiro (2013), there are four deficiencies in the traditional system which can be eliminated by using BIM-based method. First of all, it is more error prone as a matter of human error. Moreover, measurements are done due to human interpretation and it is on the estimator to define the correspondence of the project and specifications. Other deficiency is the differences that might occur because of the stakeholders' different points of view and the last deficiency relates to the qualification of the quantity surveyor as they are less qualified than the designers. Taking these four points into consideration, more accurate quantity takeoffs will be resulted in the beginning which might result into more valid cost estimations. Figure 14 illustrates BIM workflow in traditional Design-Tender-Build contracts which is still the most commonly applied method for the road construction projects in Iran.

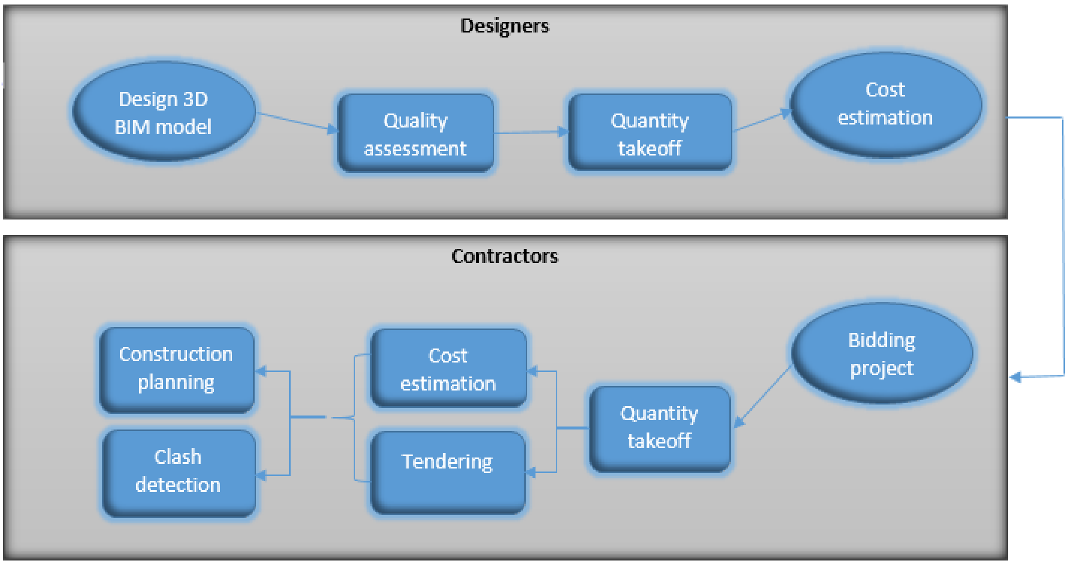


Figure 14: BIM workflow in Design-Tender-Build contracts

Table 9 shows the comparison of the quantities and costs in the bidding and contract documents with the amounts resulted from BIM model. Major measurable items were taken into consideration. Due to the detailed information and subgroups for each item, just the headings were considered. For example, demolition item includes 9 separate subheadings by itself such as removing trees with the diameter up to 60cm, removing trees with the diameter up to 90cm, demolishing buildings, demolishing reinforced concrete etc.; therefore, the units and amounts were not been brought in the table.

Table 10: Costs of activities in contract documents and BIM model

Item	Preliminary cost estimation (Rials)	BIM cost estimations (Rials)	Final costs (Rials)
Demolition	18,942,000	50,000,000	92,318,780
Earthwork	12,434,251,000	13,500,000,000	17,378,123,378
Tunnel excavation	2,598,622,020	2,600,000,000	4,189,092,000
Formwork	2,130,492,120	2,150,000,000	4,056,802,900
Steel-bars activities	2,565,995,920	3,100,000,000	6,469,069,300
Steel work	851,814,100	1,450,578,000	2,780,459,400
Concrete work	7,631,963,600	7,500,000,000	6,011,321,902
Sub-base & base	849,495,800	850,000,000	846,165,170
Asphalt	948,797,630	1,450,000,000	1,277,641,500

As the table implies, cost estimations done in BIM procedure in the case study resulted in more accurate estimations in most items; however various accuracy percentages were obtained. In demolition item for instance, BIM estimation is about 40% closer to final cost whereas in formwork item, BIM estimation is only about 7% more than preliminary cost estimations.

Moving forward with BIM, contractors may have the chance to detect the clashes and conflicts early before the construction launch by using the 3D visualization of BIM models. This might help to generate an appropriate planning for the construction phase. Consequently, clashes during the construction might be prevented in offices instead of construction site and less time overrun, risk reduction and saving in costs might be resulted. Figure 15 illustrates the 3D model in AutoCAD Civil 3D. As the case study implies, by using Navisworks Manage's clash detection feature, the change orders applied in kilometers 11+225 and 13+060 probably would have not happened which would have resulted in a reduction equal to approximate 1,100,000,000 Rials equal to 1.8% of the total project cost. Considering the project finishing date, case study shows 4.7% more accuracy (4.7% closer to reality) in time estimations with BIM.

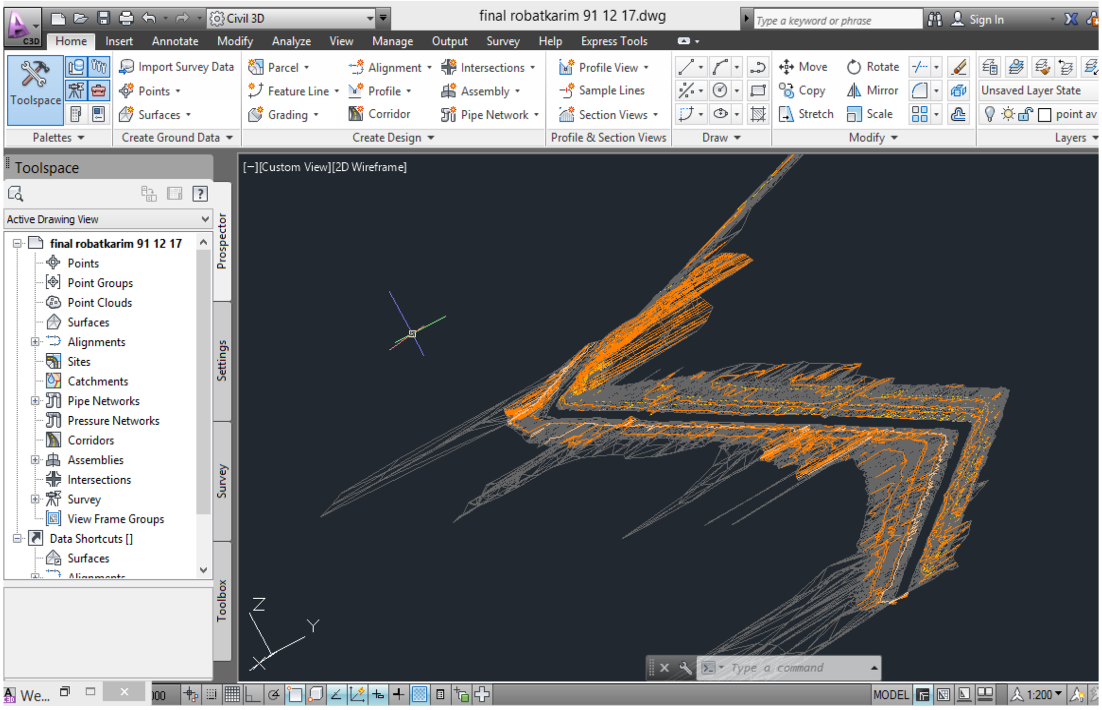


Figure 15: Highway modelling in AutoCAD Civil3D

But this is not all about the benefits of using BIM models in road and highway construction. As a matter of strong and up to date documentation, there would be less effort needed in the closing phase of the projects and a great deal of time will be saved. Also, an up to date database of the project will be available in case of any need during the operation phase. Unfortunately in this case study, there was not any report available on the delays through the final documentation in the closing phase to be considered.

7.2.2 Obstacles toward BIM adoption in road and highway construction

Based on the existing literature, by using Focused Group Interview (FGI) method, Gu (2010) listed the challenges of applying BIM as the absence of knowledge and training, the separated character of AEC (Architecture, Engineering and Construction) industry, the existing disaffection between stakeholders to adopt new concepts and the lack of appropriate segmentation in roles and responsibilities between stakeholders. Alternatively in this survey, questionnaire method was used and the results mostly expressed that in Iran, the main cause of not adopting BIM is the lack of knowledge about the new concepts being used in the world. The trend to adopt a new technology is different in various countries. In accordance to the classification defined by Rogers (1995) for new technology adoption, Iran should be considered as laggard applying BIM as a new concept in road construction while questionnaire results demonstrate a rate of almost 100% of projects facing time and cost overrun.

On the other hand, those 20% of the respondents which stated to be more familiar with the term BIM, did not also show willingness to apply it in projects for reasons such as fears of low success and failure, wide initial investment costs, high level of practice needed and insufficient expert staff. In order to quantitatively illustrate the BIM return on investment for those who have fear of investing on it, Azhar et al. (2011) conducted a study on Hilton Aquarium project in Atlanta. As mentioned in their study, mean BIM return on investment is about the strange amount of 9486% which obviously expresses the economic advantage. However, their survey is different from the case study being done in this study in two main criteria. The first main difference is that it had been done in the field of vertical construction. Second main difference is that the focus in this survey is on the efficiency of BIM in constructing road and highway within the confined time, budget and desired quality.

7.2.3 Recommendations toward BIM adoption in road construction

In order to eliminate the problem of unfamiliarity with BIM as a new concept among road construction society in Iran, a few recommendations are offered below:

- Presenting BIM in construction education as a must: By inserting the trainings of Building Information Modeling in construction pedagogical objectives, in a few years a wide number of fresh experts will be educated to service the construction industry. In some developed countries, the term has been started to be trained during the past few years as an optional course in master degree courses. However, in developing countries like Iran with a very high need of construction after the revolution of 1979, this should be started in the earliest point as a must for the students. Sharag-eldin et al. (2010) assessed the implementation of BIM in AEC education successful in his case study done on Kent State University (KSU) and University of Florida (UF).
- Making BIM a compulsory mandate for road construction sector: After preparing the fundaments of BIM adoption, as the road and highway projects are mainly public and the clients of the field are mostly governmental, it is recommended that clients consider BIM workflow as a mandatory contract document for new road projects. Although this needs a strong leadership and support, especially in its' commence, a good fortune would emerge most probably. In contrast with Porwal (2013) who claimed that even for the unfinished and half-worked projects a supplement should be added to the contract, in case of road and highway projects, the issue might consume a great deal of time as a matter of project size and scope.

- Related institution establishment: In order to start such fundamental change, an organized move and framework is required for progression. The literature review implies that adopting BIM will not lead to any considerable change within project delivery method. As the main focus is still on the traditional Design-Tender-Build method for road and highway projects, just a liable organization is needed to specify new responsibilities caused by the adoption of new technology.

7.3 Controllability of Deflection in Project Triangle since the Early Beginning of the Project

Causes of duration overrun, cost escalation and end product quality deflection are mainly divided into two groups, controllable and uncontrollable. In this survey, the controllable causes were at the center of attention. Controllable causes are those which can be prevented in advance. As discussed in previous chapter, the questionnaire analysis results imply that the whole target population of this study agreed on the controllability of the deflection causes early at the beginning. Based on empirical findings of visiting a number of road project sites in Iran, land acquisition, delay in accessibility of design details in site, improper planning for construction and material and also change orders in design are the main current controllable causes of deflection in the road projects. Taking BIM capabilities into consideration, the cure for all these mentioned causes will be found immediately.

The first issue to be discussed is land acquisition. As mentioned before, by using the ability of integrating the BIM model with the existing infrastructure or/and the map of project area and location, further problems caused by interference of the project with public or private land properties can be solved peacefully early in the offices instead of complaints during the construction phase.

In order to confront the problem of accessibility of design details in road construction sites, easy share property of BIM models is one of the most effective cures. All details are prepared in a database and the last updated versions are accessible for all staff as easy as possible. Just a simple tablet is the key considering the availability of wireless internet connections nowadays.

One of the main advantages of BIM concept is its managerial and sequencing capabilities. Although Building Information Modelling is mostly used to be a tool for designers, it is now a strong instrument to plan properly for the construction phase not only for execution part but for managing supply and waste. Case study showed ten relative long term ceases during the construction time with a total duration of 115 days equal to almost 9% of the project duration. Three of them were related to material and supply shortage during the asphalting operation. Even if the shortages were a matter of financial issues, there would be more chance of prevention by a more powerful forecasting and time management which is one of the BIM workflow's features. One month of the remaining 19 months delay was due to the workers sit-in due to wage postponement.

The rest of construction delay was mostly a matter of difference in client's, consultant's and contractor's points of view in estimating project duration and the real pace of project progress. As shown in Figure 14, BIM workflow will help in uniformity of estimations from the stakeholders' points of view.

The last thing to be discussed in this part is the change orders in design. Although change orders in road construction are not as common as building industry, they are still the causes of time overrun in the field. The case study conducted in this survey simply demonstrated how effective BIM could be in preventing change orders in the studied project. In the studied case for instance, the interference of the constructing road and the electricity pylons in kilometers of 11+225 And 13+060 could be determined before starting the construction phase by integrating the drawings in BIM software products. The same thing can be mentioned about the main water pipe in kilometer 9+900 next to one of the two bridges of the project mentioned in Table 8. Considering the delays relating to preparing new documents and drawings and also notifying the change orders and implementation of new documents, approximate delay equal to 20 days have been reported in the reports which is equal to 2.9 % of the project time overrun. These delays are most likely the causes of cost overrun mentioned at the end of the project.

7.4 3D, 4D or 5D BIM Models in Road and Highway Construction

In the latter part of the questionnaire, the ability of integrating the 3D model with time and cost and also the benefits of applying this features in road construction projects were declared; benefits such as better coordination and collaboration on site, faster drafting and applying changes and more accurate time and cost estimations. Results showed that more than 50% of respondents assessed the efficiency of BIM as 75 – 100% in preventing inaccurate estimations, poor documentation, changes in drawings and poor planning.

As a principle, it is known that severity and difficulty of projects are functions of size. Therefore, the more wide and extensive the project, stronger and more rigid management, documentation and design skills are needed. That is why the concept is theoretically accepted by most of the respondents of the survey. Due to larger scale and the variety of activities, BIM workflow can be even more helpful in road projects than buildings.

The case study results also showed that by implementing BIM in the studied project from the beginning and using the clash detection technology, the changes in 11+225 and 13+060 might probably have not been occurred. Moreover case study results showed that by having accurate cost estimations and scheduling, at least gaps and ceases equal to 1.8% of the project duration in the execution phase could have possibly been avoided.

Unlike what was expected, case study did not show any significant difference between the preliminary time estimation in project contract and the duration estimated in the survey as the unexpected events still cannot be well forecasted. It seems considering the normal situation and routines, the estimation would be equal to almost 43 to 45 months as mentioned in the contract. Indeed, some few further clashes might be discovered earlier.

Chapter 8

CONCLUSSIONS AND RECOMENDATIONS

8.1 Introduction

This chapter aims to conclude the study, answer the questions aroused by the research and also offers recommendations for further studies in the field of BIM application in heavy construction industry especially road and highway construction from the construction managers' points of view. Finally, a few suggestions will be offered for further studies for those who are interested.

8.2 Conclusions

In order to conduct this survey with the subject of applying BIM in road and highway construction industry in Iran, a questionnaire was sent to 20 roadway construction companies including 12 contractors and 8 consultants. According to what respondents stated, almost 100% of the road projects in Iran face time and cost overrun; however, they all admitted that causes of delay and excess in time are controllable issues. The respondents not only believed that BIM adoption in heavy construction can be helpful in reducing time overrun and cost escalation, but also believed that it could be efficient in obtaining better end product quality and safety in projects.

Although it seems that all respondents were theoretically attracted to BIM, there are still some barriers such as fear of failure, investment costs, lack of expert staff and also lack of knowledge which prevents firms from adopting BIM as a new concept.

As far as questionnaire results showed, most of respondents had not heard the term BIM or just had a little knowledge about it.

As to be compared with the traditional 2D drafting centric method, case study shows a 7 to 40% more accuracy in cost estimations through different items. Furthermore, change orders imparted in kilometers 11+225 and 13+060, added a cost of about 1,100,000,000 Rials equal to 1.8% of the total project cost mentioned in the contract which might have not been occurred by using BIM. The case study also stated that BIM workflow let the contractor schedule the whole executing phase more precisely in order to minimize the time overrun of 23 months occurred in the end of project which equals to 54.7% of the total project duration.

8.3 Recommendations

Results and findings of this survey propose a few topics for further study for researchers and BIM practitioners in road construction in Iran as follows:

8.3.1 Recommendations for future research

First of all, as the financial issues has not been considered in any part of this study as one of the causes of delay and cost overrun in road projects in Iran, it is recommended to those who are interested in this subject to over check the results considering financial issues, inflation, interest rate etc. in a separate new case study. The results might most probably be more accurate in comparison with the results of this study.

Moreover in this thesis, due to requirement of comparing the results with the end results of a finished project, the case study has been started by modeling the project within AutoCAD Civil3D. However, a case study can be conducted in further researches by implementing BIM workflow from the design phase. This will necessitate the application of Autodesk Infraworks in the early design phase to consider different design alternatives and compare with the real drafts of the project.

8.3.2 Recommendations for practitioners

In order to apply BIM in road construction as a fundamental change, some essential infrastructures should be performed as mentioned previously in the discussion chapter such as presenting BIM in civil engineering education as a must, making BIM a compulsory mandate for road construction sector, establishing the related institution for legislation and supervision by the government and related ministries, and also insisting on establishment of BIM association in eligible construction firms.

REFERENCES

Abd Majid, M. Z., & McCaffer, R. (1998). “Factors of non-excusable delays that influence contractors’ performance.” *Journal of Management in Engineering*, 14(3), 42–49.

Adams, O. (1997) Contractor development in Nigeria: perceptions of contractors and professionals, *Construction Management and Economics*, 15(1), 95-108.

Ahmed, S., Azhar, S., Kappagantula, P., and Gollapudi, D. (2003). “Delays in construction: A brief study of the Florida construction industry.” Proc., 39th Annual Conf. of the Associated Schools of Construction, Clemson Univ., Clemson, SC.

Akcamete A., Akinci B., Garrett J., "Potential Utilization of Building Information Models for Planning Maintenance Activities", Nottingham University Press, Nottingham, UK, 2011.

Allison H., 2010. 10 Reasons Why Project Managers should Champion 5D BIM software. VICO Software. [online] Available at: http://www.vicosoftware.com/vico-blogs/guest-blogger/tabid/88454/bid/27701/10-Reasons-Why-Project-Managers-Should-Champion-5D-BIM-Software.aspx (Retrieved 13Dec 2013).

Al-Momani, A. H. (2000). “Construction delay: A quantitative analysis.” Int. J. Proj. Manage., 18(1), 51–59.

Assaf, S. A., & Al-Hejji, S. (2006). “Causes of delay in large construction projects.” Int. J. Proj. Manage., 24(4), 349–357.

Azhar S., Hein M., Sketo B., (2011), "Building Information Modeling (BIM): Benefits, Risks and Challenges", *Leadership and Management in Engineering*, Vol. 11, Issue 3 (July 2011).

Autodesk, White-Paper, 2003. www.autodesk.com/buildinginformation , Retrieved on January 2014.

BIM in civil projects (2011). “BIM-Building Quality” Skanska BIM brochure 2011, [online] Available at: http://group.skanska.com/Global/sustainability/BIM/Skanska-BIM-2011-brochure.pdf (Retrieved May 20th 2014)

Bryde D., Broquetas M., Volm J. M., (2012). "The project benefits of Building Information Modelling (BIM)", *International Journal of Project Management*. Vol. 31, pp. 971–980.

Celik, T. (2010). Construction management in practice. Magusa: Middle East Technical University.

CIFE, (November 22, 2007), CIFE Technical Reports, [www document] http://cife.stanford.edu/Publications/index.html. Retrieved on December 2013.

David M. Lick, Allison Kahrnoff (2009). "BIM: A Great Resource with Risk as the 6th Dimension",http://www.fosterswift.com/publications-BIM-Great-Resource-WithRisk.html. Retrieved on March 2014.

Eadie R. and Browne M., et al., Odeyinka H., Mckeown C., Mcniff S., (2013), "BIM implementation throughout the UK construction project lifecycle: An analysis", *Automation in Construction*, 36 (2013) 145–151.

Enshassi A., Al-Hallaq K., and Mohamed S. (2006). "Causes of contractor's business failure in developing countries: The case of Palestine." J. Constr. Dev. Countries, 11(2), 1–14.

Flyvbjerg B., Mette K. Skarmis and Soren L. Buhl (2004). "What causes cost overrun in transport infrastructure projects?". *Transport Reviews*, vol. 24, no. 1, January 2004, pp. 3-18.

Flyvbjerg B. (2005). "Policy and planning for large infrastructure projects: problems, causes, cures." World Bank Policy Research Paper 3781, December 2005.

Flyvbjerg B. (2007). "Cost overruns and demand shortfalls in urban rail and other infrastructure" *Transportation Planning and Technology*, vol. 30, no. 1, February 2007, pp. 9-30.

GAO/RCED. Transportation infrastructure managing the costs of large-dollar highway projects, Washington, DC; 1997.

Grilo A., Jardim-Goncalves R. (2010). "Value proposition on interoperability of BIM and collaborative working environments", *Automation in Construction*. Vol. 19, pp. 522–530.

GSA BIM Guide, Series 3, [online] Available at: www.gsa.gov/bim , p. 14.

GSA BIM Guide, Series 4, [online] Available at: www.gsa.gov/bim , p. 2, 3.

Gu N., London K., (2010). "Understanding and facilitating BIM adoption in the AEC industry", *Automation in construction.* Vol. 19, pp. 988-999.

Infocomm International, "BIM Brochure", (2010), Retrieved on March 2014. Available at: http://www.flipdocs.com/scripts/showbook.aspx?ID=10001172_975708

JBIM, "Journal of Building Information Modeling", (Fall 2012)

Kaliba, C., Muya, M. and Mumba, K. (2008). "Cost escalation and schedule delays in road construction projects in Zambia" *International Journal of Project Management* 27 (2009) 522-531.

Khanzode A., Fischer M., Reed D., "Benefits and lessons learned of implementing building virtual design and construction (VDC) technologies for coordination of mechanical, electrical, and plumbing (MEP) systems on a large healthcare project", J. Inf. Technol. Constr. (ITcon) 13 (2008) 324–342(Special Issue Case studies of BIM use).

KPMG (2005), Global Construction Survey 2005: Risk Taker, Profit Maker? (London: KPMG Building and Construction).

McGraw Hill, Smart Market Report 2012: "BIM Usage on Infrastructure Compared to All Projects", Retrieved on April 2014, Available at: http://download.autodesk.com/us/bim_infra/Business_Value_of_BIM_for_Infrastructure_SMR_2012.pdf

Mahamid I., Bruland S., Dmaidi N. (2012). "Causes of delay in road construction projects" *Journal of Management in Engineering*. Vol. 28, pp. 300-310

Mezher, T. M., and Tawil,W. (2006). "Causes of delays in the construction industry in Lebanon." *Engineering and Construction Architectural Management*, 5(3), 252–260.

Monteiro A., Martins J., (2013). "A survey on modeling guidelines for quantity takeoff oriented BIM-based design", *Automation in construction*. Vol. 35, pp. 238-253.

Odeh A. M., and Battaineh H. T. (2002). "Causes of construction delay: Traditional contracts." *International Journal of Project Management*, vol. 20, Issue 1, pp. 67–73.

Porwal A., Hewage K. N. (2013). "Building Information Modeling (BIM) partnering framework for public construction projects", *Automation in Construction*. Vol.31, pp. 204-214

Robert L. R., March 2011, "Judging BIM", *Civil Engineering Magazine*, Vol.81, 0885-7024/03-0011-0066.

Rogers E. M., (1995). “Diffusion of innovations”, 4th edition. The free press, New York.

Sharag-Eldi A., Nawari O. N., (2010). "BIM in AEC Education", 2010 Structures Congress, 2010 ASCE.

Schell, C. (1992). “The value of the case study as a research strategy” Manchester Business School.

Skanska, “BIM-Building Quality”, BIM Brochure (2011).

Strafaci A. (2008). “What does BIM mean for civil engineers?” Transportation, CE News, October 2008, [online] Available at: http://www.cenews.com/article/6098/ (Retrieved march 14th 2014)

United States National BIM Standards V1, P1, Jan 2008.

APPENDICES

Appendix A: Questionnaire sample

Dear sir/madam

You are kindly invited to participate in a "Project Management" survey. In this survey, a few questions on the application of "Building Information Modelling" (BIM) in road and highway construction will be asked. Completion of this survey will take approximately 5-10 minutes.

Your participation in this study is completely voluntary. There are no foreseeable risks associated with this survey. However, if you feel uncomfortable answering any questions, you can withdraw from the survey at any point. It is very important for us to learn your opinions.

Your survey responses will be strictly confidential and data from this research will be reported only in the aggregate. Your information will be coded and will remain confidential. If you have questions at any time about the survey or the procedures, you may contact Mr. Amirkasra Honarpisheh by email at the e-mail address specified below:

Ouss_kasra@yahoo.com

Thank you very much for your time and support.

1. What is your company's business type?

- Sole proprietorship
- Partnership (general / limited)
- Governmental
- Non-profit entity

Diğer (lütfen belirtin)

Q2 | Edit Question | ▼ | Add Question Logic | Move | Delete

2. What is our company's field of work?

- Architecture
- Construction
- Infrastructure engineering

Diğer (lütfen belirtin)

Q3 | Edit Question | ▼ | Add Question Logic | Move | Delete

3. What is your company's line of business?

- Designer
- Consultant
- Contractor

Diğer (lütfen belirtin)

Q4 | Edit Question | ▼ | Add Question Logic | Move | Delete

4. What is your company grade (only for contractors)?

- 1
- 2
- 3
- 4
- 5

Q5 | Edit Question | ▼ | Add Question Logic | Move | Delete

5. What is your company grade (only for consultants)?

- 1
- 2
- 3

Q6 Edit Question ▼ Move Delete

6. What is your company's average number of projects per year and annual turnover (million Rials)?

Q7 Edit Question ▼ Add Question Logic Move Delete

7. Please specify your company's working experience?

- Less than 10 years
- 10 - 20 years
- 20 - 30 years
- More than 30 years

Q8 Edit Question ▼ Add Question Logic Move Delete

8. How long have you been working with this company?

- 1 - 5 years
- 6 - 10 years
- 10 - 20 years
- More than 20 years

Q9 Edit Question ▼ Add Question Logic Move Delete

9. Your education:

- Diploma
- Bachelor's degree
- Master degree
- P.H.D

Diğer (lütfen belirtin)

Q10 Edit Question ▼ Add Question Logic Move Delete

10. Regardless of financial issues, what is your idea about reasons and factors that lead to time and cost overruns or quality deflections?

- Mostly controllable
- Somehow Controllable
- Somehow Uncontrollable
- Mostly uncontrollable

Q11 Edit Question ▼ Add Question Logic Move Delete

11. How often do you meet time and cost overrun in your projects?

- Hardly ever
- Occasionally
- Usually
- Always

Q12 Edit Question ▼ Move Delete

12. Regardless of financial issues, how do you assess the effect of factors mentioned below on project parameters? (0-20 implies least important, 20-40 less important, 40-60 implies important, 60-80 implies more important, 80-100 implies most important)

	Time overruns	Cost overruns	Quality	Health & safety
Change orders in drawings	▼	▼	▼	▼
Change orders in specifications	▼	▼	▼	▼
Poor design	▼	▼	▼	▼
Poor documentation	▼	▼	▼	▼
Improper planning	▼	▼	▼	▼
Poor management	▼	▼	▼	▼
Construction mistakes	▼	▼	▼	▼
Inaccurate estimations	▼	▼	▼	▼
Poor risk identification	▼	▼	▼	▼
Late clash detection	▼	▼	▼	▼
Poor coordination on site	▼	▼	▼	▼
Shortage of materials	▼	▼	▼	▼
Slow decision making	▼	▼	▼	▼

Q13 Edit Question ▼ Add Question Logic Move Delete

13. Time and cost overruns could highly be prevented from the pre-planning and inception phases. What is your idea?

- Strongly agree
- Agree
- Disagree
- Strongly disagree

Q14 Edit Question ▼ Add Question Logic Move Delete

14. How much are you familiar with Building Information Modelling (BIM)?

- Poor
- Fair
- Good
- Very good
- Excellent

Q15 Edit Question ▼ Add Question Logic Move Delete

15. How often do you use BIM in your projects?

- Hardly ever
- Occasionally
- Usually
- Always

Q16 Edit Question ▼ Add Question Logic Move Delete

16. How useful have you found using BIM in your projects (in case of using)?

- Very useful
- Somewhat useful
- Not very useful
- Not at all useful

Q17 Edit Question ▼ Add Question Logic Move Delete

17. By having the chance of integrating the project drawings with the drawings of existing infrastructures in road and highway construction projects, to what extent do you find it useful to apply BIM tools in the beginning phases?

- Very useful
- Somewhat useful
- Not very useful
- Not at all useful

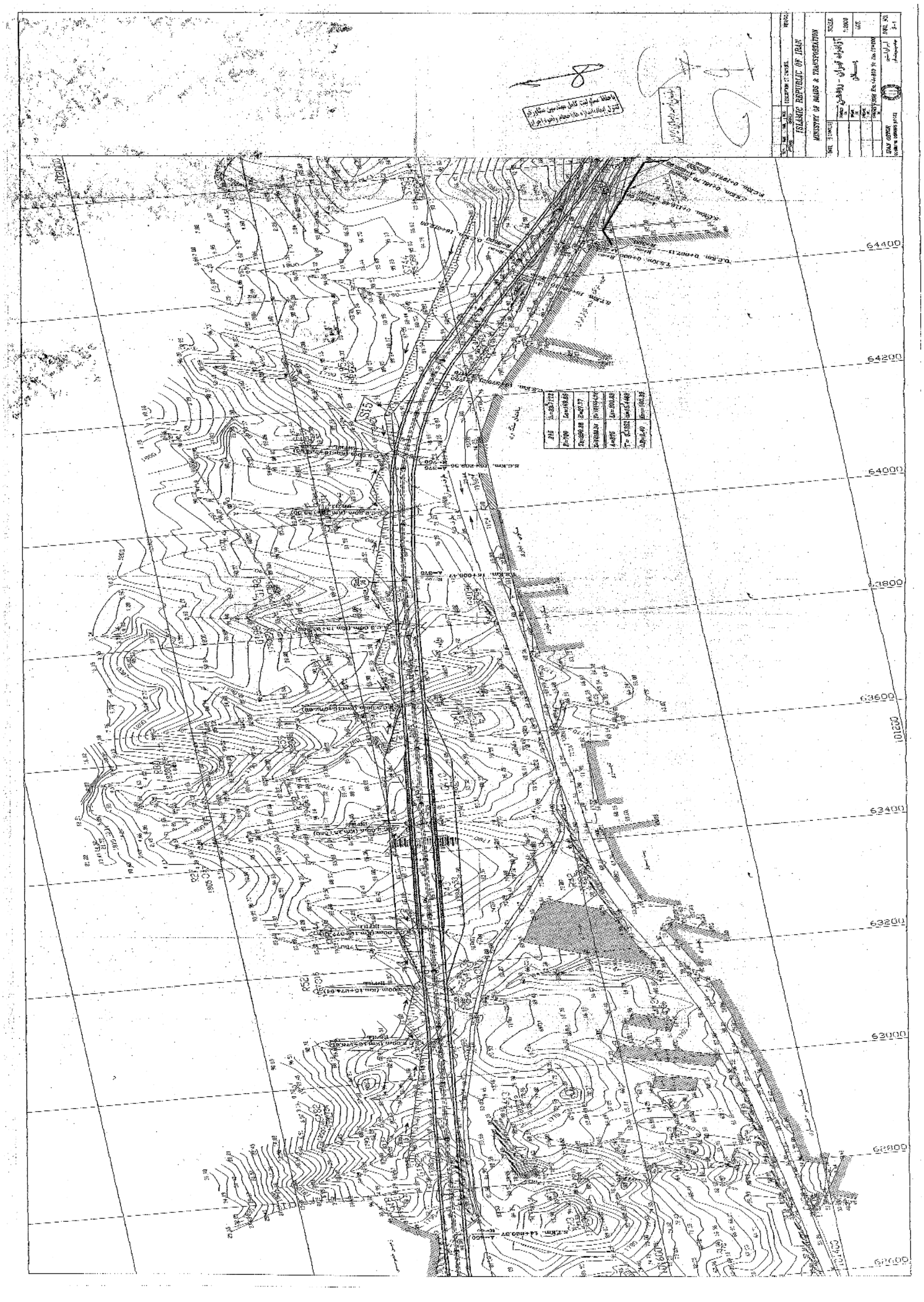
Q18 Edit Question ▼ Move Delete

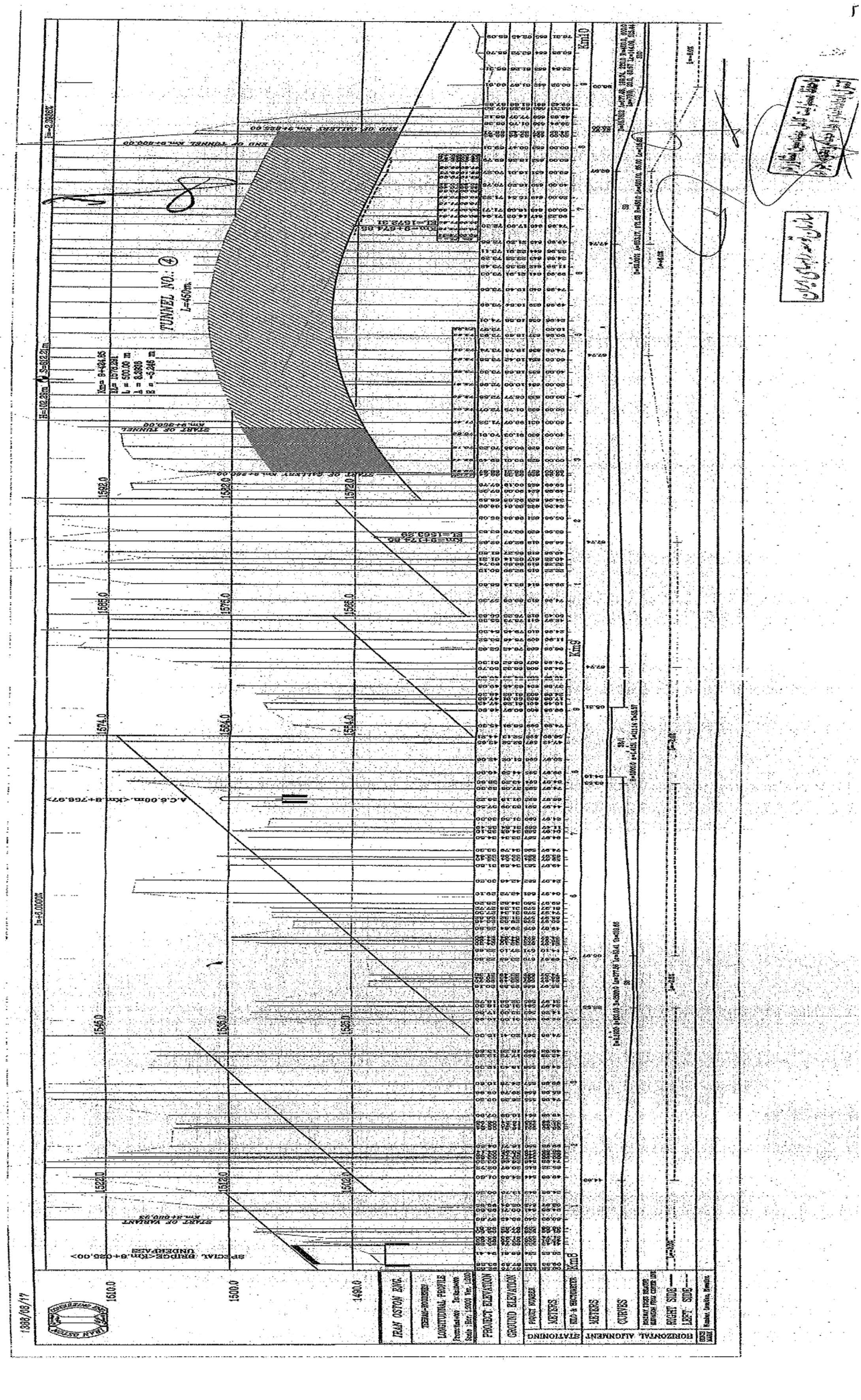
18. As you might know Building Information Modeling (BIM) is a method of creating live and intelligent three-dimensional parametric models. These models can become a 4D model by being linked to time and also a 5D considering financial data link. Using integrated details system, BIM offers some benefits including coordination and collaboration, faster drafting and early detection of conflicts in construction. Considering these definitions, to what extent do you evaluate BIM efficient in preventing factors mentioned below? (0-20 implies least important, 20-40 less important, 40-60 implies important, 60-80 implies more important, 80-100 implies most important)

	0-20 %	20-40 %	40-60 %	60-80 %	80-100 %
Change orders in drawings					
Change orders in specifications					
Poor design					
Poor documentation					
Improper planning					
Poor management					
Construction mistakes					
Inaccurate estimations					
Poor risk identification					
Late clash detection					
Poor coordination on site					
Shortage of materials					
Slow decision making					

Thank you very much for taking the time to complete this survey. Your feedback is valued and very much appreciated!

Appendix B: Case study project related plans and drawings




1388/03/17
IRAN OSTON ENG.
LONGITUDINAL PROFILE
PROJECT ELEVATION
GROUND ELEVATION
CURVES
RIGHT SIDE
LEFT SIDE
TUNNEL NO.: 4
L=450m.
START OF TUNNEL
END OF TUNNEL
Km8
Km9
Km10