Cost Planning Strategy in Bidding Stage Using 5D BIM

Yazan Alsharqawi

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

Masters of Science
in
Civil Engineering

Eastern Mediterranean University
February 2016
Gazimağusa, North Cyprus

Approval of the Institute of Graduate Studies and Research

Prof. Dr. Cem Tanova
Acting 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.

Assoc. Prof. Dr. İbrahim Yitmen
Supervisor

Examining Committee

1. Assoc. Prof. Dr. Serhan Şensoy
2. Assoc. Prof. Dr. İbrahim Yitmen
3. Dr. Tolga Çelik

ABSTRACT

Construction bidding is the process of submitting a tender to undertake, or manage the undertaking of a construction project. Increases in completed project cost compared to bid price is often observed in construction industry. This defect is a result of poor planning for cost, time and scope. These elements are considered as the main three important constraints of bidding phase for every project.

A relative new technology that is progressively getting accepted in the construction industry is Building Information Modeling (BIM), which plays a major role on improving construction management background. BIM is based on a 3D model which is complemented by fourth dimension (time) and fifth dimension (cost). The 5D BIM technique can be incorporated into the cost planning process. A 3D model of the construction project is developed and then imported into suitable 5D BIM tool. Thereupon, the project costs are estimated on the basis of generated quantities and unit costs.

A case study is presented to illustrate the cost planning and simulation processes in 5D BIM more appropriately during bidding stage, based on a BIM model of a reinforced concrete structure. RIB iTWO is one of the BIM softwares which were used in this study. It provides opportunities to import 3D BIM models, and then carry out cost planning and simulations.

Results from the case study suggests that 5D BIM cost planning provides advantages during bidding process by better visualization of the building model, earlier risk identification, producing schedules of quantities for cost planning purposes, more accurate and fast cost estimation, simulated project in the 5D BIM environment and collaborative group working amongst the project team.

This study intends to provide novel information process for cost planning experts, as well as it may serve as the basis for further research in the 5D BIM based construction project management field. Furthermore, it contributes to the projects to be completed on time without leading to extra costs.

Keywords: Cost Planning, Bidding Process, Building Information Modeling, 5D BIM, RIB iTWO

ÖZ

İnşaat ihalesi bir inşaat projesinin taahhüdünü üstlenmek ya da yönetmek için bir fiyat teklifi teslim işlemidir. Teklif fiyatına kıyasla tamamlanan projelerdeki maliyet artışları genellikle inşaat sektöründe görülmektedir. Bu kusur maliyet, zaman ve kapsam gibi unsurların kötü planlanması sonucunda ortaya çıkar. Bu unsurlar her proje için ihale aşamasında üç ana önemli kısıtlama olarak kabul edilmektedir.

inşaat sektöründe giderek kabul gören ve nispeten yeni bir teknoloji olan Yapı Bilgi Modellemesi (YBM) inşaat yöneti bilgi alanını geliştirmede önemli bir rol oyn amaktadır. YBM, 3B modele dayanan dördüncü boyut (zaman) ve beşinci boyut (maliyet) ile tamamlanmaktadır. 5B YBM tekniği maliyet planlama sürecine dahil edilebilir. İnşaat projesinin bir 3B modeli geliştirilir ve daha sonra uygun 5B YBIM aracına iaktarılır. Bunun üzerine, proje maliyetleri üretilen miktarlar ve birim maliyetler esas alınarak tahmin edilmektedir.

Bir vaka çalışması, bir betonarme yapının BM modeline dayalı, ihale aşamasında daha uygun 5B YBM maliyet planlama ve simülasyon işlemlerini göstermek için sunulmuştur. RIB iTWO bu tezde kullanılan YBM yazılımları dan biridir. Daha sonra, 3B YBM modellerine aktarım, i maliyet planlama ve simülasyonu gerçekleştirmek için fırsatlar sunar.

Vaka çalışmasın sonuçları, 5B YBM maliyet planlamasının ihale sürecinde bina modelini daha iyi görselleştirme, erken risk tanımlama, metrajları üretme, daha doğru

ve hızlı maliyet tahmini, 5B ortamında proje simulasyonu ve proje ekibi arasınfa işbirlikli grup çalışması avantajları sağladığını göstermektedir.

Bu çalışma, 5B YBM tabanlı inşaat proje yönetimi alanında daha ileri araştırmalar için temel olarak hizmet verebilmesinin yanı sıra, planlama uzmanları için yeni değerli bilgiler sunmayı amaçlamaktadır. Ayrıca, ekstra maliyetlere yol açmaksızın zamanında tamamlanmasına katkıda bulunmaktadır.

Anahtar Kelimeler: Maliyet Planlama, İhale Süreci, Yapı Bilgi Modellemesi, 5B YBM, RIB iTWO

ACKNOWLEDGEMENT

First of all, thank God who was with me and who gave me the power and strength to hold on against this great work. Then, special thanks to the man who gave me the opportunity to expand my knowledge about BIM, who supported me in each step and gave me a lot of advises which I find them life lasting treasure Assoc. Prof. Dr. İbrahim Yitmen. Moreover, I would like to thank and apologies to him for giving me much of his precious time.

Secondly, I would like to thank my family and in particular my parents who didn’t only support me financially but also morally with is much worth than money. To thank the people helped reach here by giving me part of their knowledge about BIM and RIB iTWO software: engineers (Williams, Nitesh, Selmi, Nawras) about BIM and RIB iTWO software.

Tiredly, parts of the credit go to my friends (Ahmed Khalifa, Hussain, Lara, Lieth and Omar) who helped as much as they can and who was always there for me whenever I needed them, even if I didn’t ask them to.

Finally, most of the credit goes to RIB ITWO Company the leading company in the construction industry sector for its great upholding me by proving precious information and data about their product.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

CAD	Computer Aided Design
BIM	Building Information Modelling
AEC	Architectural Engineering Construction
IFC	Industrial Foundation Classes
BoQ	Bill of Quantity
RICS	Royal Institution of Chartered Surveyors
NBIMS	National BIM Standard
DBB	Design Bid Build
FM	Facilities management
QTO	Quantity Takeoff
NRM	New Rule of Measurement
RFI	Request For Information
GC	General Contractor
SMM	Standard Method of Measurement for Building Works
BCIS	Building Cost Information Service
SFCA	Standard Form of Cost Analysis
GC	General Contractor
Subs	Subcontractors
Qs	Quantity surveyor

Chapter 1

INTRODUCTION

1.1 Background

Cost planning in construction projects is the process of looking into the future and trying to predict project costs and resource requirements (Haque, 2011). The cost planning process arose as a result of the need to plan effectively the cost of a construction project, through investment appraisal, life cycle costing and value analysis, bidding process, evaluation of tenders and cash-flow forecasting (Hendrickson,2010).

Cost planning cannot succeed without competent cost estimating. Estimation is a subset of the cost planning methodology providing only one cost structure of the project. Estimates are needed from the inception of a project, through all the design stages, up to the receipt of tenders. Which should confirm the accuracy of the estimating on the project (Shen,2010).

On the other hand, the current cost planning process has been found to be inconsistent, inaccurate and providing a poor cost management service before, during and after construction projects to the architecture, engineering, construction and facilities management (AEC/FM) industry. This leads to significant financial losses or a decrease in the profit (RICS, 2012).

The constraints associated with traditional cost planning and estimating the determination of the amount of resources needed for the construction project. This is also known as quantity takeoff. Quantity takeoff is a very long and error-prone process that is performed manually. Missing or duplicating work items are among the errors that can occur during the quantity takeoff process (Shrestha, 2012). Similarly, the time spent by the estimator on quantification varies by project around 50% to 80% of the time needed to create a cost estimate spent on quantification (Rundel, 2008).

Bidding process in construction industry is a stage of the building/construction the project. The first stage of a bidding process is that the client produces tender documents that include general arrangement drawings, bills of quantities and work specifications (Estman et al., 2011). In order to select the most suitable price, the client invite competing contractors to estimate a price based on the tender documents. When the contractors present their prices the client choose one of them based on price and fulfilment of requirements (Estman et al., 2011). The selected contractor then gets to sign a contract with the client.

According to Touran (2009), increasement of the finished project price comparing to bid price is often observed in construction industry. This happens due to changes applied on the project which are based on client's wish or design mistakes. Unforeseen additional materials and works still appear and increase total cost and duration of the project. This defect, considered as a result of poor planning for Cost, time and scope. Which are considered the main three important constraints of bidding phase for every project.

Construction cost estimation is a cumbersome process. It takes a long time for an estimator to complete an accurate estimate. Therefore the construction contractors must prepare cost estimates quite often in order to prepare bids for new projects. This presents a challenge to an estimator who has to prepare several estimates in a short period of time (Zhiliang, et al., 2010).

A relative new technology that is progressively getting accepted in the construction industry which is Building Information Modeling (BIM). It is playing a major role on improving construction management background. There are several factors that have made the use of BIM technology popular in the construction industry. First, its popularity may be attributed to the availability of both software and hardware applications that are likely to minimize errors. Similarly, BIM technology has created very competitive markets for the modern construction (Aranda-Mena et. al, 2009).

On the other hand an emerging approach in the construction industry is the use of 5D-BIM, by combining the traditional three dimension of BIM with the schedule as the fourth dimension and cost estimates as the fifth dimension. This approach allows the contractors to better predict the cost of the project and the time-line of the project of when these expenses are anticipated to occur (Mouflard, 2013).

5D-model task provide detailed and accurate 5D estimates and living cost plans. This assistance is provided to projects at any phase from concept design through to construction and completion (Becerik, 2012). Certain software providers are now publicizing that it is possible to develop Cost planning through linking a ‘5D Cost Library’ to BIM model,which performs the function of an estimating database (Thurairajah, 2013).

According to McCuen (2008) Estimators with an adequate BIM understanding can benefit from the 5D BIM function and automatic quantification, by creating quicker estimates.

In this thesis, benefits of 5D BIM were explained through RIB iTWO which is used as 5D BIM software. That provides opportunities to import 3D BIM models then cost planning will be carried forward. Moreover the ability to link a 3D BIM with schedule and cost provides a 5D BIM model and simulation. RIBiTWO offers fast and accurate quantity take off extraction for cost planning purpose, visualization, simulation, etc.

1.2 Research Scope and Objectives

The scope of this research illustrates the cost planning and simulation processes in 5D BIM more appropriately during bidding stage.

Therefore, the major objectives of the research are as follows:

1. To determine the perceived benefits of 5D BIM implementation in cost planning process during bidding stage.
2. To examine possibilities for usage of BIM technology. By linking 3D model with time schedule and cost plan, generating 5D BIM model.

1.3 Research Methodology

The research includes an extensive literature study, conducting a case study of the Europe Outsourcing Center (EOC) Building project which was built in China. The applications of 5D BIM for the work flow of bidding process is presented , then a BIM model of a completed project was provided from RIB iTWO company.

The 3D BIM model of the construction project was imported into a suitable 5D BIM tool (RIB iTWO), thereupon the model elements costs were estimated on the basis of generated quantities and unit costs. The project activities that were defined depending on the 3D model elements were also imported to the 5D BIM tool, to link the 3D model element’s costs with time schedule which results in generating 5D BIM model and 5D simulation.

1.4 Thesis Guideline

The entire thesis consists of 5 chapters. Chapter 1 covers the introduction about the study. Chapter 2 represents the literature review that includes an extensive literature study for traditional cost planning in bidding stage, construction bidding process, Building Information Modeling technology, 4D BIM and 5D BIM definition and New Rule of Measurements, cost planning in 5D BIM and its requirement’s. Chapter 3 provides a description of the methodologies followed in this research. While, chapter 4 include results and discussions about the case study and literature . Finally chapter 5 concludes overall summary from the study as well as important findings.

Chapter 2

LITERATURE REVIEW

In this chapter a review of literature is presented. It includes description of cost planning in bidding stage, Building Information Modelling (BIM) technology, different dimensions of BIM models and cost planning process using 5D BIM.

2.1 Cost Planning in Bidding Process

2.1.1 Cost planning

Cost planning is a system that requires total coordination of the project form. It involves a systematic framework procedure and demand high commitment to ensure that the objectives in terms of costs, time and quality are achieved (Kuprenas, 2007). Effective cost planning will help to ensure that, once a realistic estimate is agreed between the parties, everything that follows is in accordance with it, from the successful contractor's tender to the final project cost (Hendrickson, 2010). According to Jackson (2011) the cost planning process consist of essentially three phases:

1- First involvement of the establishment of the realistic estimate (Preliminary Approximate Estimate).

2- The second stage plans how this estimate should be spent among the various elements of the project (Cost Plan).

3- The final stage is checking process to ensure that the actual design details for the various elements can be constructed within the cost plan.

As shown in Figure 1, the cost planning process starts with the preparation of an approximate estimate, The approximate quantities cost plan is a first attempt to measure a defined quantities from drawings. It presents a more accurate picture of where costs are distributed then setting of costs which is based upon elements. The elemental cost plan in which the cost of elements is broken down from the overall construction cost is based on the experience of the cost consultant and known as costs of similar completed projects.. The value of each element's costs can be a subject to be changed during various validation stages in the delivery process of a project. Then actual prices are provided by specialist contractors and suppliers. The Tender Cost analysis takes place in tender evaluation stage based on the preferred tenderer's price, to enable the comparison of the detailed tender costs. The Analysis of Outturn Costs takes place as a part of the post-project review when the project has been completed, to compare the actual costs of the project with the budget as set out in the Tender Cost Analysis.

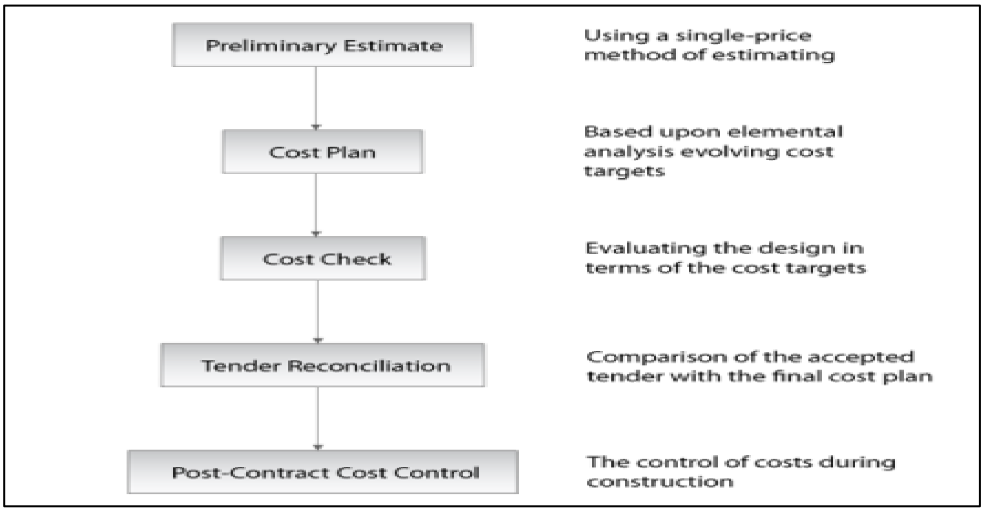


Figure 1: The various stages of Cost Planning (Jackson,2011)

The largest problem in the cost planning is the incorrect visualization of the project information. If it is not fully visualized, understood, and communicated, it cannot be represented correctly in the contract documents and may consequently create problems during construction (Matipa, 2010). Moreover, it requires a lot of preparation at the early stage of the project. The estimator need to be equipped with the experience and knowledge about the factors influencing the cost (Haque, 2011).

2.1.1.1 Standard Form of cost analysis (BCIS)

Building Cost Information Service (BCIS) is the source of the Standard Form of Cost Analysis (SFCA) which is a document that explains how a project's cost may be broken down into elements on the basis of the process of procurement (BCIS, 2009). SFCA is regarded as being an accepted standard for the construction industry as it provides a framework for presenting the cost of planning and advice that would help project managers avoid a number of misappropriations in the construction process. (Cartlidge, 2011).

SFCA provides an outline of the all the project's elements in terms of their functions. Moreover, it provides a framework for analysis, storage, distribution and capturing the project's data over a historical period of time. Through such an analysis it is easy for the project manager to come up with a cost plan which helps in the provision of cost advice regarding a project (BCIS, 2009).

Kymmell (2011), argues that SFCA has been used for a fairly long time now bearing in mind that it has been effective since 1961 when BoQ was a widely accepted and used standard. Notably, policy makers in the construction industry have not made any changes to its format four decades later since it gained entry into the construction industry. Hence, it was insufficient to address the modern business needs without further improvements. The elemental cost data captured could not be readily used in the new construction procurement processes.

2.1.1.2 The Standard Method of Measurement for Building Works (SMM)

SMM has been in use since 1922 to provide quantity surveyors a uniform set of rules and guidelines for measuring and pricing building works (Hendrickson, 2010). It has been revised several times over the years and SMM7 is its latest version.

The SMM7 regulations are ideal for categorizing and organizing the measurements of various works in terms of the systematic structure, content, layout, details and phraseology for BoQ (Nunnally, 2011). uses the Common Arrangements of Works Sections to classify and code various items in three different levels. This enhances consistency and information distribution (Kymmell, 2008).

According to Kymmell (2008), there are various regulations that maintain BoQs constituency, has resulted to an improvement in the understanding of the project's details among participants. Therefore, they can form a uniform standard for evaluation of a tender. SMM7's framework has a close correlation to BoQ's preparation. However, it is not ideal for estimating the cost of the entire project. Hence, SMM7 cannot help quantity surveyors provide cost advice as it cannot suit the modern day cost planning approach especially when there is a need to come up with cost information due to its failure to suit the new approach of cost planning, particularly when capturing cost information (Nunnally, 201).

2.1.2 Bidding Process

2.1.2.1 Design-Bid-Build (DBB)

According to Estman (2011) there are different contract methods used in construction industry. Most common is traditional Design Bid-Build method. In the first stage of DBB model client chooses an architect who sets requirements for the building and objectives. The architect makes schematic design, develops it and makes contract documents. Structural and building service engineers then are involved to assist in design of structural, HVAC, piping and plumbing components. The end product of this stage is set of drawings and specifications which must be sufficient enough to go to construction bidding phase.

In bidding stage general contractor for the project is being determined. Owner and architect usually decide who will participate in the competition. Competing contractors, after they receive set of drawings and specifications, make their own quantity survey. Based on those quantities bids are received from subcontractors and cost estimation of the project is determined. The winning contractor is usually determined by lowest bid price as shown Figure 2.

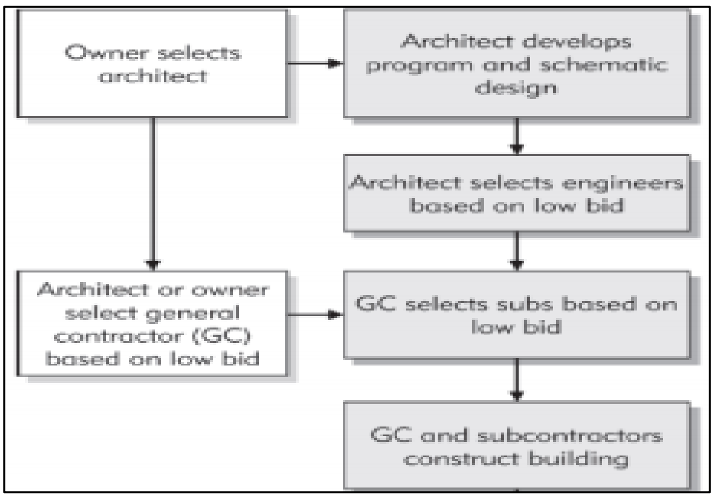


Figure 2: Schematic diagram of Design-Bid-Build(Eastman et al., 2011)

Before construction takes place contractors usually need to redraw drawings so they are sufficient for construction process. Those drawings are called “general arrangement drawings”. Furthermore, subcontractors make their own “shop drawings” which are ready for production of items like precast walls, steel connections, piping runs, etc. Shop drawings are very precise and detailed. If they are based on drawings which already contain errors there might be conflicts on the site. And costs associated with this issue might be significant. To produce building elements offsite when detailed drawings may not reflect real situation onsite is not rational solution. Therefore, most of the fabrication has to take place onsite where all conditions are known. This, however, is more costly and time consuming; quality control of produced elements is not as good as it is in factory.

During construction phase there are often changes made in the project. They might be related with mistakes made in the design, unanticipated site conditions, changes in material availabilities, new client requirements, and new technologies. The problem with that is, that often contractors bid below the estimated cost in order to win the project and when changes appear they abuse the changes process in order to recoup losses from too low bid price. This way project may become even more expensive.

2.1.2.2 Description of bidding process within Construction Company

Bidding process in construction industry is a stage of the building/construction project where competition for the best suitable contractor for the project erection is held. In the bidding stage, the main aim for the contractor is to establish a competitive bid price in order to get the job. Winner of the competition is usually defined by proper fulfillment of requirements set by client/consultant, lowest bid price and/or best solution proposed (Iossa, 2008). Tender documentation is main form of communication in bidding process. There are various stages in preparing a tender and the action needed with successful tenders' .The model of proposal preparation process is shown in Figure 3.

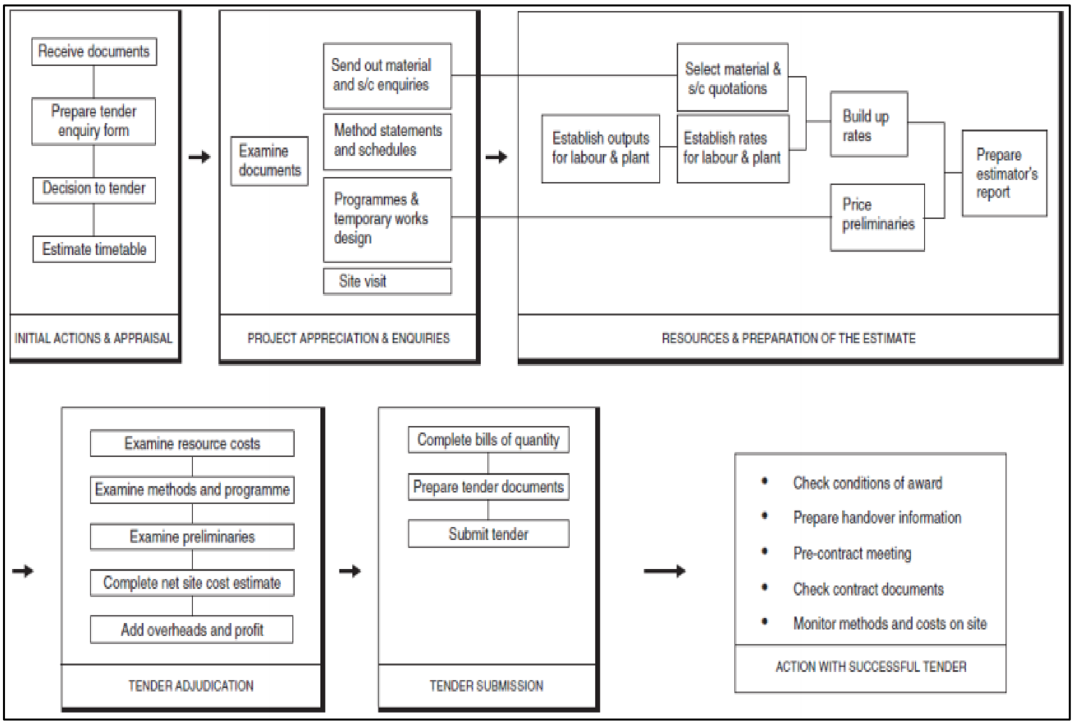


Figure 3: Estimating and tendering flowchart (Iossa, 2008)

2.1.2.3 Negotiated Contract

There is another project delivery method that does not involve the bidding process and instead involves a direct relationship between the owner and the general contractor company. That method is called the negotiated contract. There are many types of negotiated contracts ranging from cost-plus-fee to a lump sum. In a cost plus fee contract the payment to the general contractor is determined by the cost of the work and the contractor's fees. The owner will be able to see the changes in cost per phase of the project based on the estimates provided by the estimating group. Any savings that might occur throughout the duration of the project is generally shared by the owner and the contractor. In a lump sum contract, the owner just sees the final value of the project and any savings that might be gained throughout the project goes to the contractor. This type of contract is beneficial to both parties because if the project is estimated correctly, then the contractor could see a large profit margin while the owner will have a level of certainty as to the cost of the project (Rossi et al., 2014).

2.1.3 Cost planning in Bidding Stage

Detailed Cost estimating is an essential task for bid preparation for any construction project. It is vital for a construction contractor to make realistic project cost estimations during the bidding stage. In order to make the estimation as realistic as possible, the estimator needs to have a good understanding of the project and good knowledge of production costs (Bengtsson and Jauernig, 2008). The basis for cost estimation is set of Tender documents consisting of general arrangement drawings, bills of quantities and work specifications (Ohrn and Rogers, 2008).

According to Halpin (2006), estimators generally take certain steps in developing a bid estimate :

1. Divided the project into elements (WBS)

2. Estimate the quantities required for elements.

3. Pricing out the individual quantities determined in step 2 using historical data.

4. Calculate the total price for each element by multiplying the required quantity by the unit price.

The estimator divides the project into individual elements. These elements are especially useful in projects that are more complex because on such projects, the need for such a control and information structure is much greater. After the elements has been selected for cost estimating The next step in developing an estimate is the estimation of the required quantities for elements (quantity takeoff). Quantity Takeoff is a process of determination of the amount of materials for elements used in a particular construction project. It is a base for formulating a bid/estimate as part of the bidding process. When estimators complete the count, they start on pricing out the quantities using the cost data collection regarding on historical data. Historical data can be collected from previously executed projects or obtained from third parties: manufacturers, subcontractors or database references (e.g. RS Means in North America). Cost data regarding project resources are organized in Excel sheets. The design of spreadsheets involved the setup of several data lists and establishe the relationships among them. Finally, a calculation to produce the cost estimate is performed. The estimate worksheet can then be printed for bidding documents or future reference.

All these methods introduce the potential human error and propagate any inaccuracies that may be in the original drawings. As observed, detailed cost estimating is a time-consuming process and a cumbersome process that involves a lot of data and calculations. It is prone to mistakes when done manually. In general, it depends on simple mathematics (Halpin,2006).

According to Haque (2011), during the process of construction cost estimating, the estimator must learn about the design and conditions of the project. A lot of data are needed to prepare an estimate which involves reviewing drawings, extracting information for quantity takeoff and looking up the latest cost information from the cost databases. Construction cost estimating requires a lot of manual work.

2.2 Building Information Modeling

2.2.1 BIM Definition

BIM is the development of a model to simulate the different stages on the project and it is based on a computer and software technology. This model is an information storage from which, any user is allowed to extract and incorporate information increasing the reach of the model in terms of information (Azhar et al. 2012).

BIM has often been used in the management of modern models that have 3D elements as their parametric elements. They fall into the following categories and subcategories (Family: Windows; Category: Wooden windows; Type: Wooden window). The wooden window has two layers. 2D/3D CAD refers to the graphical illustration of geometrically compatible elements. Many of these elements do not have a defined construction procedure. Similarly, they are devoid of additional information. Hence, one can only comprehend their design through the use of an external data (Estman, 2011).

2.2.2 General Advantages of BIM

BIM has numerous advantages. According to Becerik et al. (2013); positive attributes of BIM incudes the ease in which the user can single out the relevant material and leave the non-relevant ones. This reduces wastage of time and resources, facilitates communication and easy management of the group. Lastly, the quality of the product is also improved. Kymmell et al (2008) believes that BIM is advantageous as its tools minimize the prevalence of mistakes besides loss of data in the projects. Lastly, it has more advanced geometrical and visual features that are easy to manage. They are also ideal when there is a need to detect collisions and conflicts in the structure (Azhar, 2012).

According to Azhar et al (2012), BIM is more reliable when there is a need to obtain candid financial data, marketing deals alongside accessing data regarding the project with ease. Designers argue that they obtain a better visual structure of the model to aid them incorporate the virtual features when examining some of the features. This phase is also desired as it is possible to produce documents in a faster and more effective way. Therefore, construction managers can access a wide range of data in the earlier phases at a friendly cost. The profits are also desirable.

2.2.3 Maturity Levels of BIM

The four maturity levels of BIM determine the technical features besides other approaches that are critical for evolution. This approach is transparent as it indicates the services that clients expect to receive. The construction industry has evolved over the recent years. The rise and development of such organizations has also increased significantly (Government Construction Client Group 2011). The 0-3 levels explain this evolution as shown in (figure 5).

Level 0: In level 0, communications is mainly done through writing or electronically.

Level 1: CAD 2D and 3D work in tandem and receives orders from BS1192:2007. There is no tool that shows the exact cost of the process at this stage.

Level 2: at this level, it is utterly critical to adopt various BIM's disciplines as they are important for the management of 3D elite models through ERP. Both 4D and 5D disciplines may be integrated in the system to help in the management of cost and time. The government of the United Kingdom demands that all firms should have adopted this model by 2016 (BIM Task Group, 2014).

Level 3: at this level, the implantation of a network takes place. It is important to note that the BIM being used should have a level that accommodates information from various disciplines. The virtual service may be used to integrate both IFD and IFC. The BIM technology is ideal in implementing the whole cycle of the project.

Each of the levels has various dictates about the expected standards and technical approaches that should be used. This draft explains the procedures used by the standard B/555 for purposes of modeling, design and data exchange in the United Kingdom (BSI Standards Development n. d). The main aim of this is to reduce the risks involved, minimize pollution and do away with the delay in the delivery of the completed projects. In other words, the model is on the look-out for better ways of minimizing the charges imposed (Government Construction Client Group 2011).

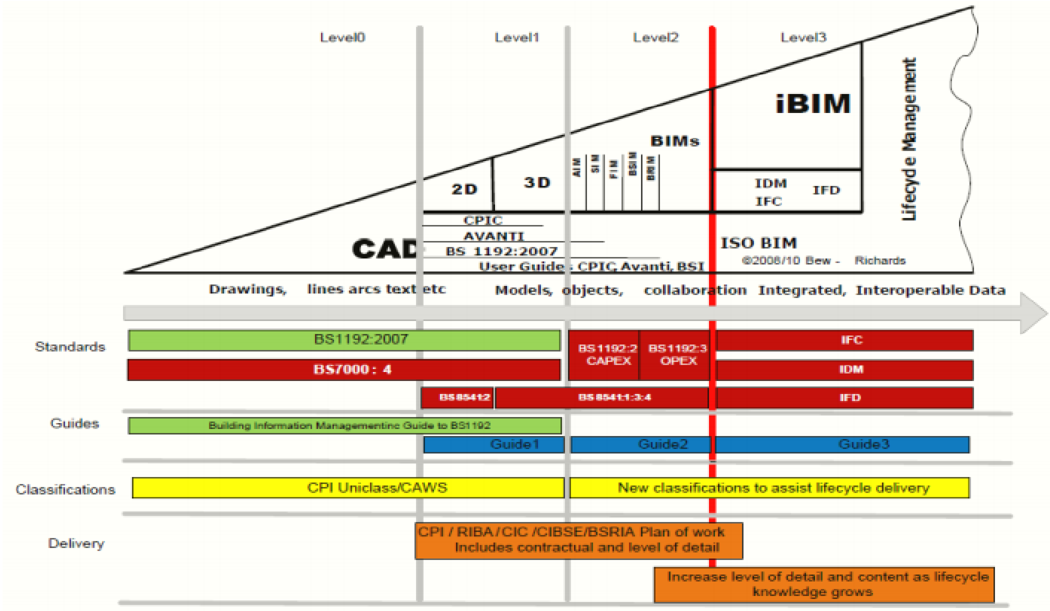


Figure 4: Scheme of levels of maturity on BIM (Government Construction Client Group, 2011).

United Kingdom is dedicated towards being a market leader in BIM in the shortest time possible. Hence, it is utterly critical to examine the levels of maturity. In this case, level 2 should be fully functional before 2016. According to Zhiliang (2013), there are various improvements that should be implemented in this level. Some of them include:

- State of the art digital imaging: the stakeholders have a chance to check and visualize the 3D model before the commencement of any construction project. This allows the stake holders to make suggestions and come up with more viable solutions to some of the problems that confront them.
- Detection of any inferences: ability to detect any clashes between various disciplines helps minimize many of the mistakes in the initial phase. This is mainly the case if the solution is less costly than the construction field.
- Constructability: this should be determined to come up with the exact technical needs shortly after the design stage is complete.

- Scanning: using laser makes it possible to scan a building to obtain accurate data. The data available in this model help in the enhancement of the maintenance of the operations.

2.2.4 Interoperability between Different Software

Azhar et al. (2012) brands interoperability as being the software's capacity to interchange data. It is important to improve software's interoperability to beef up the co-operation among different entities in the construction industry. This is mainly done through the standardization of the file formats of the available applications. Standardization of the file formats makes it easy to use, change, move and interchange data in various applications.

2.3 4D BIM

BIM's fourth dimension links the 3D model to the time dimension (construction schedule activities). This creates virtual simulation to understand various sequences of construction. (Eastman et al., 2011). Simulations aid communication in a work sequence to avoid repetition of tasks in the construction industry. Moreover, it helps in identifying other congested locations (Kymmell, 2008).

According to Thurairajah (2013) through the simulation of the construction sequences, 4D-BIM helps optimize the process and minimize any changes and re-work. Through the use of 4D-BIM technology; construction contractors may be able to optimize material movement, people and equipment at a construction site.

2.4 5D BIM

2.4.1 Introduction

The fifth dimension added to the 4D-BIM model is 'cost'. A 3D-BIM model has all the geometrical information needed to perform a take-off of material quantities. A

4D-BIM model has all the activities needed to complete the project. By attaching a cost database to the 4D-BIM model and by assigning actual costs to materials, equipment and personnel, a 5D-BIM model can be created to provide the construction team with a useful tool (Eastman et. Al., 2011). According to Smith, (2014), 5D in BIM ought to include schedules, quantities and prices during the process of cost planning.

Mitchell (2013) define that the most important advantages offered by BIM on 5D are the automatic extraction of data from the model, which increases the productivity and eliminates a large number of mistakes. The better visualization of the model, the 3D view optimizes its understanding and provides more accurate details and finally, the possibility for linking the 3D model with specific tools offers the chance of making an endless number of estimations when the model suffers modifications.

The resulting 5D-BIM model can be used by construction professionals to give faster feedback about the cost of a project, allowing the designer to adjust the project design to fit the budget. The 5D-BIM model can provide the owner and the design team with greater transparency in seeing the contractor's budget, building confidence within the various stakeholders of a project. Projects using 5DBIM would also mean there would be a less of a need for a large contingency on behalf of the owner (Smith ,2014).

Integrating 4D (time) and 5D(cost) would deliver significant value at all levels of development and would help overcome various challenges that BIM implementation faces; such as a collaboration, liability and protection of intellectual property, know-how and technology (Mitchell, 2012).

According to McCuen (2008) estimators with an adequate BIM understanding can benefit from the 5D BIM function and automatic quantification, by creating quicker estimates.

2.4.2 Cost Planning in 5D BIM

Cost planning is one of the critical stages of construction management. However, with 5D BIM, it is possible to automate it (Sattineni, 2011). Certain software providers are now publicizing that it is possible to develop detailed cost planning through linking a '5D Cost Library' to BIM, which performs the function of an estimating database A'master' library can be formed, in addition to several project specific variation libraries, making the process highly productive and easily repeatable (Thurairajah, 2013).

According to Estman (2011) has defined three types of linking the model in order to transfer the information into the cost estimation´s tool.

- <u>Transferring the data from the model into estimation tools</u>

  This process encloses the tasks of extracting the data from the 3D model and Exporting it to any spreadsheet like Microsoft Excel is. In this case, the disadvantage is that at any time the model changes information needs to be exported and structured again. This fact limits the number of cost simulations.

- <u>Using a specific quantity takeoff tool.</u>

  The second case is the use of specific tools to takeoff the quantities from the model. It reduces the possibility of missing information and also offers special features to modify the data. After extracting all data from the model it is exported as an output into an Excel spreadsheet where is managed and linked with any cost database.

- Linking the 3D BIM model with 5D BIM tools

  Initially, construction specialists would develop a 3D model through adequate modeling. Later on, linked BIM model directly to an 5D BIM tool in the plug-in or third-party tool. 3D model linked to price lists for different materials in the 5D BIM tool. The price lists are mainly based on volume cost of materials, but can also include labourer and equipment costs for more detailed cost estimates. This enables 5D BIM users to generate accurate and reliable cost by automatic quantity take off from the building model, A major opportunity of this system is that different design options can be compared and then act as a supporting base for decision-making. Materials and construction solutions can therefore be evaluated from an economical perspective.

Mithcel (2012) argues that there are a number of modern techniques for 5D QS which may be used alongside many traditional frameworks to setting up a 5D cost plan and cost strategies. These techniques can be blended within the traditional design and construction phases as illustrated below:

- Concept Design

  5D QS can potentially generate a concept estimate that one may present through an elemental format. Similarly, it is possible to identify the rate of each unit and its quantity. 5D QS depends on experience to make sure that the entire project is within the set estimate. Therefore, the concept estimate serves as the basis of compiling and re-compiling the estimates to help in the examination of other alternative designs identified at the concept design's proving phase.

- Detailed Design

  The aim of the 5DQS at the design stage is to come up with a systematic design of the approximate dynamic links that are useful in forming the foundation of a plan of the living cost. It may also be used for processes such as bidding and developing a design. The plan of the living cost forms the basis of updating the cost estimates in an instance where there is a change of the model's information during exercises such as budget variances, final cost of the forecast, finance, value management, funding, negotiation with the contractor and final investment decisions.

- Schematic Design

  The 5D QS is useful in the preparation of a sketch of a cost plan's design that is mainly presented as an elemental format of the generic materials used for construction, service and finish specifications.

  The 5D QS checks the model and includes an elemental pricing code to fine tune the available information to suit the intended purpose. Later on, one may create a dynamic link between structural elements and generic architecture.

- Developed Design

  5D QS is used to design a cost plan. The plans are them presented to illustrate the service specifications, and construction materials. The last estimates identify sub-elements such as quantity and rate of a unit. During this stage, one may include additional cost details to the model's information.

- Quantity Take-off and Bidding

  A bill of quantities that is easily interrogated by contractors and subcontractors because the dynamic links allow each quantity to be viewed in the model. The file is also recompiled in a trade format so that the quantities reflect the scope for each subcontract.

- Contractors Priced Bill of Quantities

  5D QS includes a contractor's prices and rates. They may then present a priced quantity bills to a zone and trade base. It also includes item description on features such as finishes, specific materials used in construction and service specifications besides the rate of the quantities.

- Change Orders, Variations and Payments

  A dynamic link refers to any change or variation in orders that may be easily, quickly and reliably computed for in case of any change in the model information. It is also possible to compute for the progress payments in the executable file through isolating all the completed zones. It may also be done through re-compiling the quantity of the produce to come up with a payment value that is not only transparent but also easy to interrogate.

- Cost Integrated Construction Model

  The 5D QS is also well suited to make significant changes in the cost data. The changes may be made to include the actual cost of the contract, and any other adjustment and payments that may mushroom during the construction process. All the information is mainly stored in the 5D BIM authoring tool.

- As-Built Cost Data & Facilities Management

  The 5D QS has various parameters that consolidate the cost data. The as-built cost data packet contains various fragments of information. Such information includes the cost of replacement, the expected period of replacement by the manufacturer, expected depreciation life and the approximate cost of running the budget.

2.4.3 New Rules of Measurement (NRM)

Upon reviewing the SFCA and SMM7, there was a growing intention within the RICS working group to bridge the gap in the existing standards. Accordingly, a new set of rules known as the New Rules of Measurement (NRM) was drawn up in three separate volumes in 2010 to be applied at various stages of the construction process from early feasibility to building occupation through completion and handover (Cartlidge, 2011). The three volumes are named as follows.

NRM 1: Order of cost estimating and cost planning for capital building works

NRM 1 is the major ‘cornerstone’ of appropriate cost management in various construction projects. It breeds reliable cost advice to project team members, and clients. Interestingly, it facilitates appropriate cost control. It helps in the preparation of the cost estimates although it is primarily created for cost plans. It regulations greatly aid in obtaining historical cost data in the most appropriate form. Therefore, it completes the cycle of cost management.

The volume provides state of the art guidance on how to quantify building projects with an aim of creating a cost plan and a cost estimate. Information on how to quantify various items included in a construction project that did not appear in the in the measurable building work items. Some such projects include overheads, preliminaries, profits, risk allowance, fees for the design team, inflation and any other project cost.

NRM 2: Detailed measurement for building works

This volume has been extensively used by project managers as it provides them with insightful guidance on how to measure and describe construction projects with an aim of coming up with a reasonable tender price. The rules of building includes all the aspects of BQ (Bill of Quantities) such as production and setting. Moreover, it is the source of information for the employers and construction consultants. Such information helps them create a bill of quantities and quantify any non-measurable items, risks and works. The content should also include guidance on the format, structure and content of the bill of quantities. In many case, the bill of quantities is written to enable the project contractor create a work schedule and determine the rates of the items contained in the bill of quantities. It also provides information over the advantages of the bill of quantities for those who wish to comprehend its use, benefits and purpose.

NRM 3: Order of cost estimating and cost planning for building maintenanceworks

This volume serves as a guidance on the quantification exercise. In addition, it has been proved to be quite effective in the maintenance of building works to aid in the preparation of the cost estimates of the initial order, the cost of preparing a building project, and the cost of all other stages involved in a building project. The guidance aids in cost control and procurement of various maintenance works.

2.4.4 Location-Based Management Systems

Location-Based Management Systems (LBMS) is a construction scheduling and production control methodology that achieves a fully 3D, 4D, and 5D integrated workflow (Seppänen, 2010). The underpinning theory of LBMS is the result of Critical Path Method (CPM) calculations that have been adapted for modern day construction needs (Seppänen, 2010). Seppänen (2010) define the objectives of LBMS as focusing on providing continuous workflow, completing locations in sequence, and promoting balanced and optimal production for work crews by using quantities and productivity data to add certainty in schedule creation. Thus, the focus is not simply on a chain of critical path activities, but rather the resulting task of multiple like locations. Resource usage and flow are defined by the 5D cost estimate, 4D productivity data, and the project location sequence.

2.4.5 Key Requirements of Cost Planning in 5D BIM Environment

Through the literature search, Zhe (2009) suggested a comprehensive list of requirements, of cost planning in the 5D BIM environment, those were adapted in this research (table 1).

Table 1: Key Requirements of Cost planning in 5D BIM Environment

No	Key Requirements	Description
1	**Automatically import design result**	This feature allows estimators to design an IFC data automatically. The user does not have to identify the drawing manually. It is an ideal feature that helps in the elimination of manual reworks, improves productivity and boosts speed.
2	**Interactive 3D visualization**	This feature allows users to use the 3D model to examine the elements of a building. It enhances the performance and creates a highly interactive environment for data modification.
3	**Intelligent match**	All the elements of a building should be directly proportional to the cost items. This is mainly done through intelligence judgment of the properties. It is one of the most desirable features as it reduces much of the work done by the estimators.

4	**Intelligent change management**	This feature allows the user to change the design. It has cost estimation software that displays the changes made at every stage. It is even easier to adjust.
5	**Ability to export the standard cost estimating data**	This feature allows the user to export IFC data during the construction process. Hence, it is easier for other software's to use the data with ease.

Chapter 3

METHODOLOGY

3.1 Introduction

In the previous chapter, the study was initiated to collect information on the 5D BIM, as well as perform a literature review on the traditional cost planning process in bidding stage. In order to achieve research objectives, a BIM model of a completed project was provided from RIB ITWO Company as a case study in this section to demonstrate the process of cost planning and simulation in 5D BIM more appropriately during bidding stage. The Europe Outsourcing Center (EOC) Building project which was built in China. The project is 2250 meter square along with reinforced concrete structure composed from the foundation concrete slab, retaining external walls, the internal walls, the internal columns and the roof slab as shown in Figure 6 below.

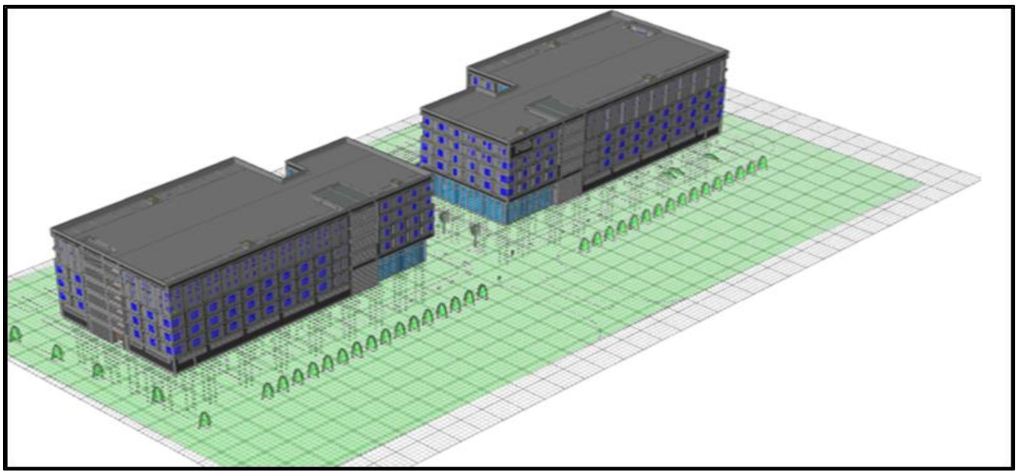


Figure 5: Europe out sourcing center model in China
(Source: model provided RIB iTWO)

The project delivery method (Design-Bid Build) was used with Lump Sum contract type. The cost of the project was (43,826,621.37 RMB), while the goal has been achieved in 439 days.

3.2 Case Study Software Tools Selected

3.2.1 Primavera

Primavera is published by Oracle Corporation as software concentrations in the construction management fields to create the construction planning. This software was involved in this case study to create the suitable schedule for the 3D model elements, which include description of the activities, the duration related to them and the relationship between those activities. This time schedule was imported to the RIB iTWO to help in transforming the 3D BIM model to 5D BIM model and to simulate construction sequences.

3.2.2 RIB iTWO

RIB iTWO is a cost estimating model, based on the concept of Target Cost Planning .

The software provides possibilities to visualize analyze and optimize the construction project. The main features of this application is Automation that can count buildings elements and can measure areas itself, create an integrated costing with the quantities that automatically taken and compare various cost estimates and provides highly accurate estimations. Moreover, this software integrates the 3D with 4D and 5D BIM and can also perform advanced level of simulation. In this case study RIB iTWO was used to utilize the cost planning and simulation, because it contains all the required advantages. To implement and reuse 3D model for cost planning the 3D model is transferred into the program and then the required work in program was carried out.

3.3 Framework of the Case Study Work Flow

5D BIM based cost planning and simulation of the construction project can be performed through several steps using RIB iTWO software (as shown in figure 3.2). The main step is to use this building model to create the QTO list of the building elements as well as level the price data base on the list to estimate the project costs. The next step is to link the building element's costs with the defined project schedule to generate the 5D BIM model and to simulate the project process in the 5D environment.

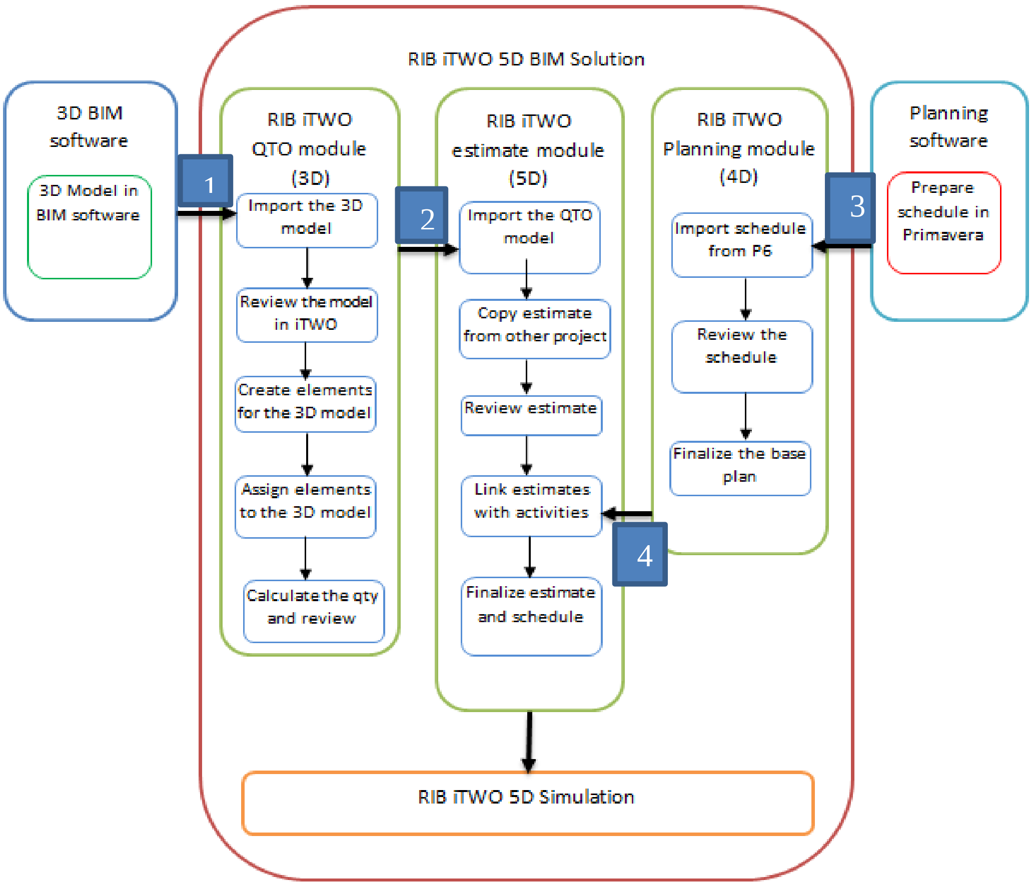


Figure 6: Framework of the case study

The 3D model was drawn correctly with no clashes and errors so that the measurements and quantities of the elements in the model are reliable. Also a QTO list is generated by the help of building model and as well as the project cost is also been calculated by balancing the data cost.

It`s important to mention that the quality of the figures related to any of the software's in this research was brought as a snapshots which consider the best way available to bring a software view into document papers.

3.4 5D BIM Cost Planning in Bidding Stage

When the BIM model of the construction project was formed during bidding stage, the cost planning was implemented in RIB iTWO by employing the 5D BIM cost planning approach through the following steps:

1- Import the 3D model into RIB iTWO.

2- Determining elements of cost plan for the building model.

3- Assigning elements to the building model then generate the QTO list

4- Linking quantified elements of the building model with price data base.

1- Import the 3D Model into RIB iTWO

The 3D BIM model was developed using an adequate modeling application. In the first step, the 3D model of the construction project and the 3D model objects that were extracted from the BIM authoring tool was imported into the element planning document in RIB iTWO software. This is then activated and colored automatically as yellow icons in the Structure Tree in RIB iTWO as shown in figure 8.

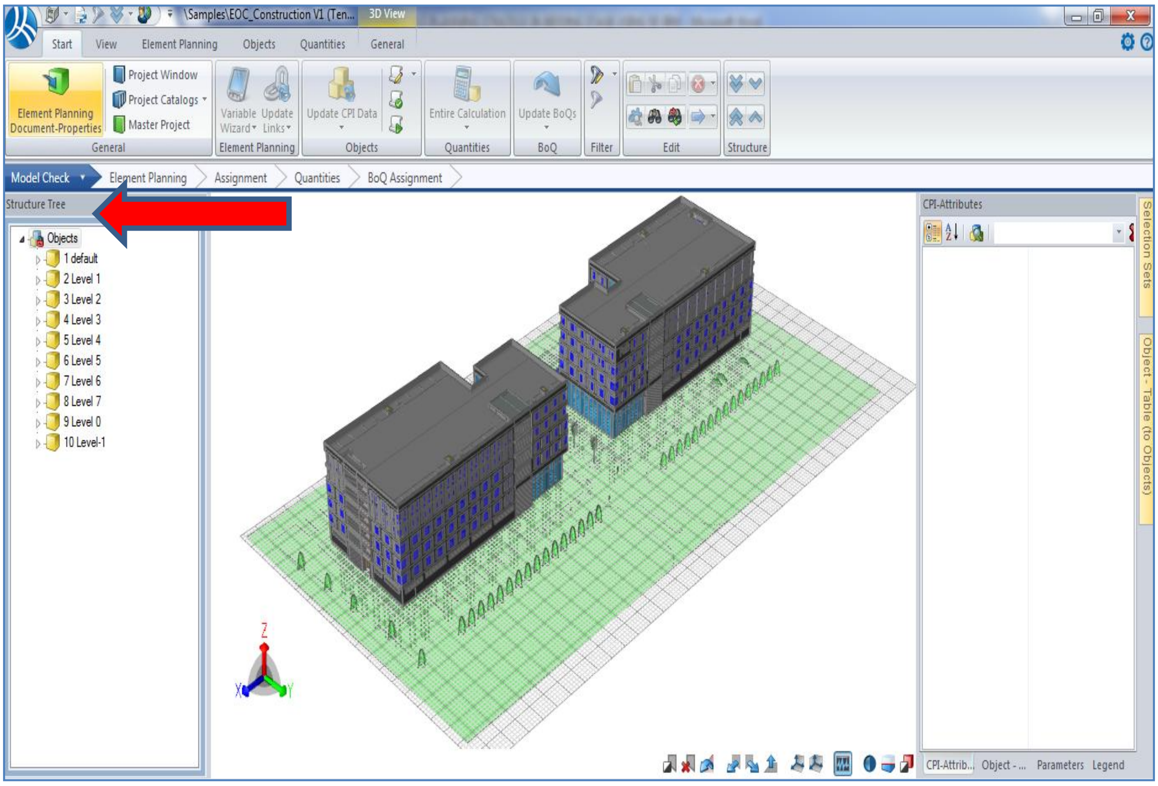


Figure 7: 3D BIM model imported into RIB iTWO

The element planning document allows user to synchronize and review 3D model in multiple interfaces such as the 3D view, the elevation view, the floor plan views, *etc*. Furthermore, it can carry out interrogation of the model and check clash detection.

In the view options panel of the Element Planning document, there are the 'orbit', 'look around', 'walk-through' and 'clipping' tools. Each of these tools preforms different functions. For example, as seen in figure 9, the Clipping tool allows clipping the view of the model in the X, Y or Z directions to visualize and partition (make section) the model.

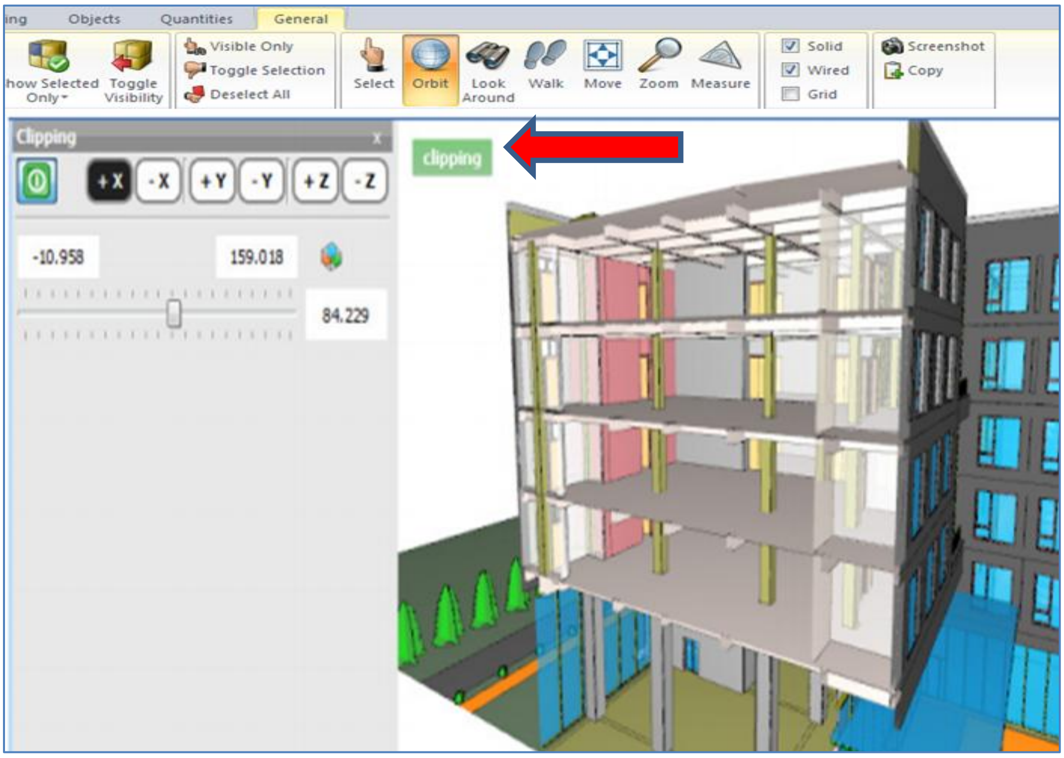


Figure 8: Cross section for the 3D model in RIB iTWO

In RIB iTWO it is possible to isolate various components in the model by clicking on Component Type in the Object Filter Tab. This attribute gives a faster and efficient way to determine the class of object – for example: Walls, Slabs, Foundation, etc. As shown in figure 10 the model was filtered to Foundation from component type in object filter tab.

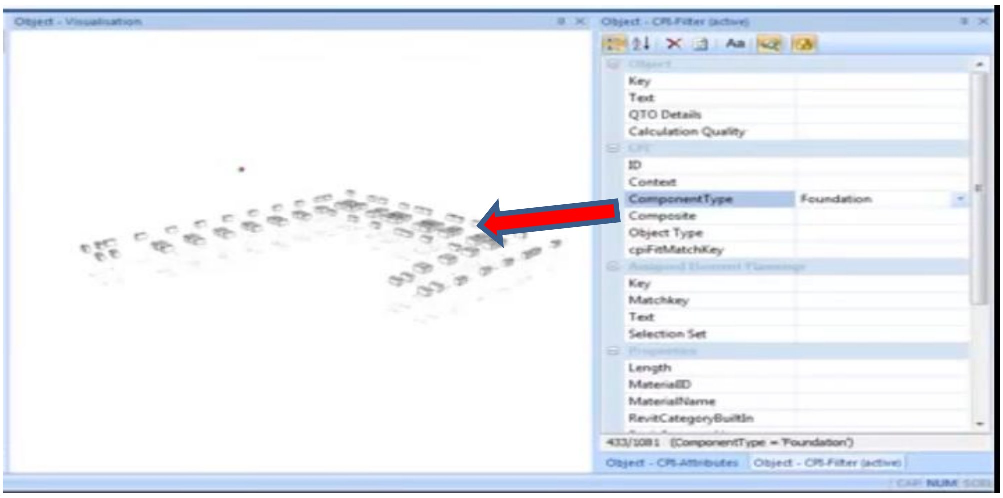


Figure 9: 3D model of Foundation

2- Determining Elements of Cost Plan for the Building Model from NRM

Afterwards, one of the most necessary processes is defining elements related to the 3D model. Figure 11 shows, elements of cost plan for the 3D model that was determined from New Rules of Measurement (NRM) library directly in RIB iTWO and each element has its measurement queries. These elements are used in measuring quantities of the building model. In addition to its employment as source quantities for further cost and time of the project and providing a more useful means of navigating and classifying the model in the Element Planning Tree.

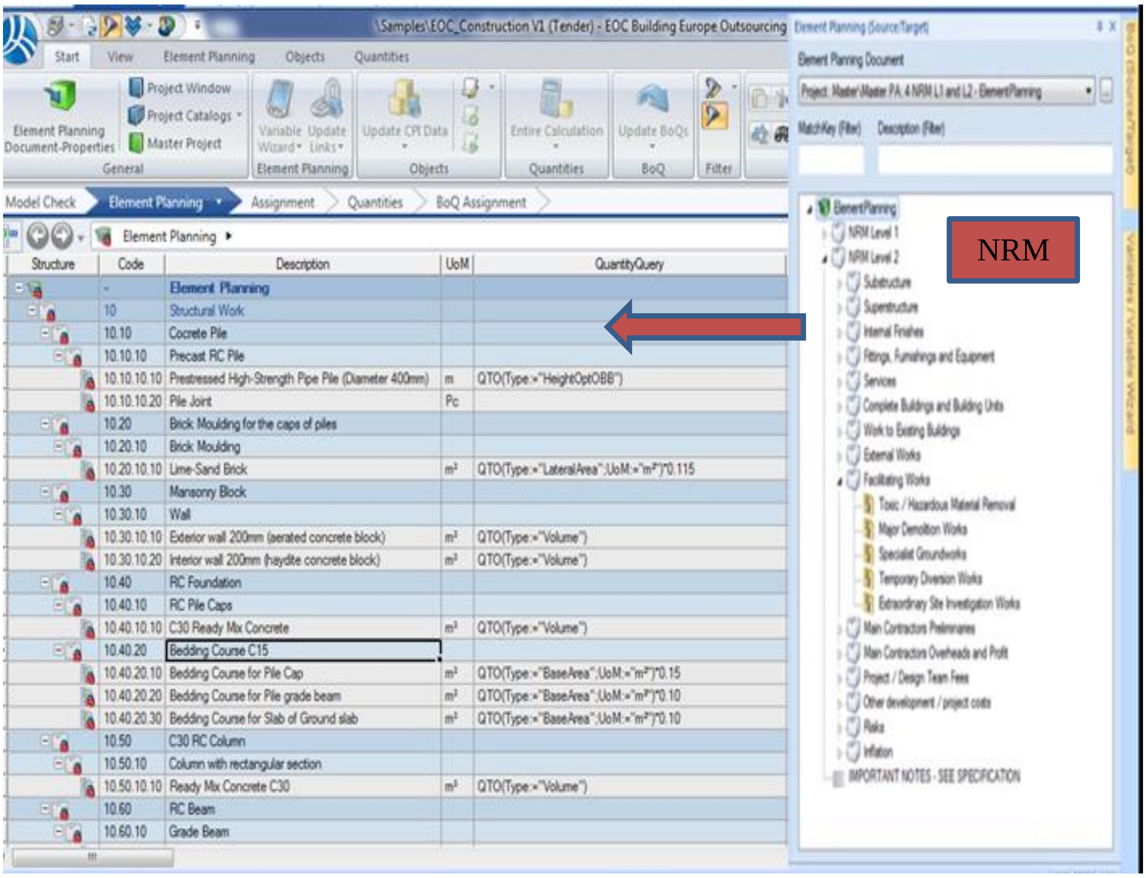


Figure 10: Elements of cost plan determined from NRM library in iTWO

3- Assigning Elements to the Building Model then Generate the QTO list

Elements of the building model were correctly determined in the element planning tree structure and categorized into different groups. Afterwards, the next task was to assign these elements to the building model in order to measure the quantity in more accurate way. Assigning can be done at any level of the cost plan. For example: as shown in figure 12 below, the model was filtered up to Concret Beam Slab by clicking on Component Type in Object Filter Tab. Then the element of RC Beam Slab in the Element Planning Tree Structure was dragged to the model to assign the element in this section to all of Beam Slab model. Each element of cost plan in Element Planning Tree has been assigned to the 3D BIM model. Which then allow to measure quantity.

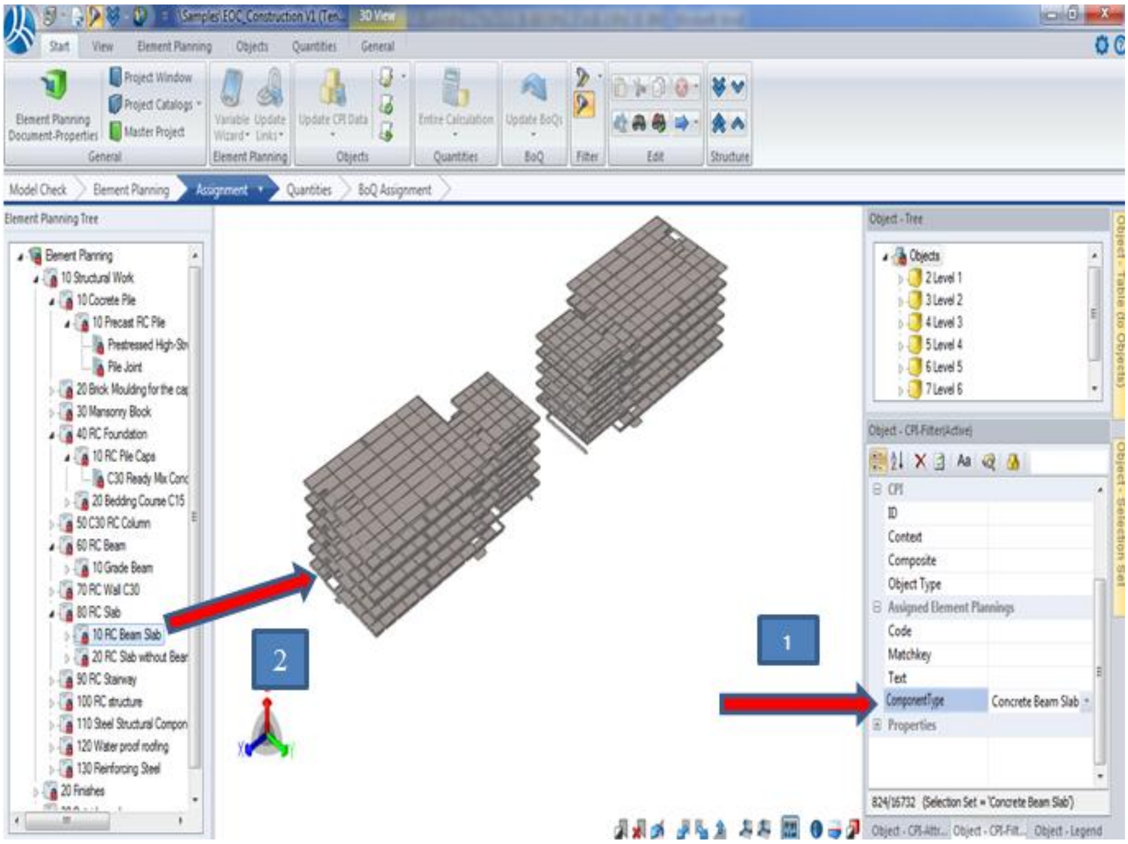


Figure 11: RC Beam slab element assigned to the 3D model of Concert Beam Slab

RIB iTWO takes few minutes to generate the QTO list of the entire building without the need of counting them one by one and each generated Quantity of element cost plan will be visualized in the a model-based takeoff. In this case study the entire process was finished only within 17 minutes. Figure 13 showes that the quantity of Pre-Stressed High Strength Pipe Pile is 3699.10 meter which can be read directly from the QTO list in element planning table, and the quantity is visualized in the 3D Viewer then the Quantity Derivation viewed to check quantity accuracy. Moreover, Due to practicability of the software, unit types of each element such as area and volume which were needed for takeoff were also displayed.

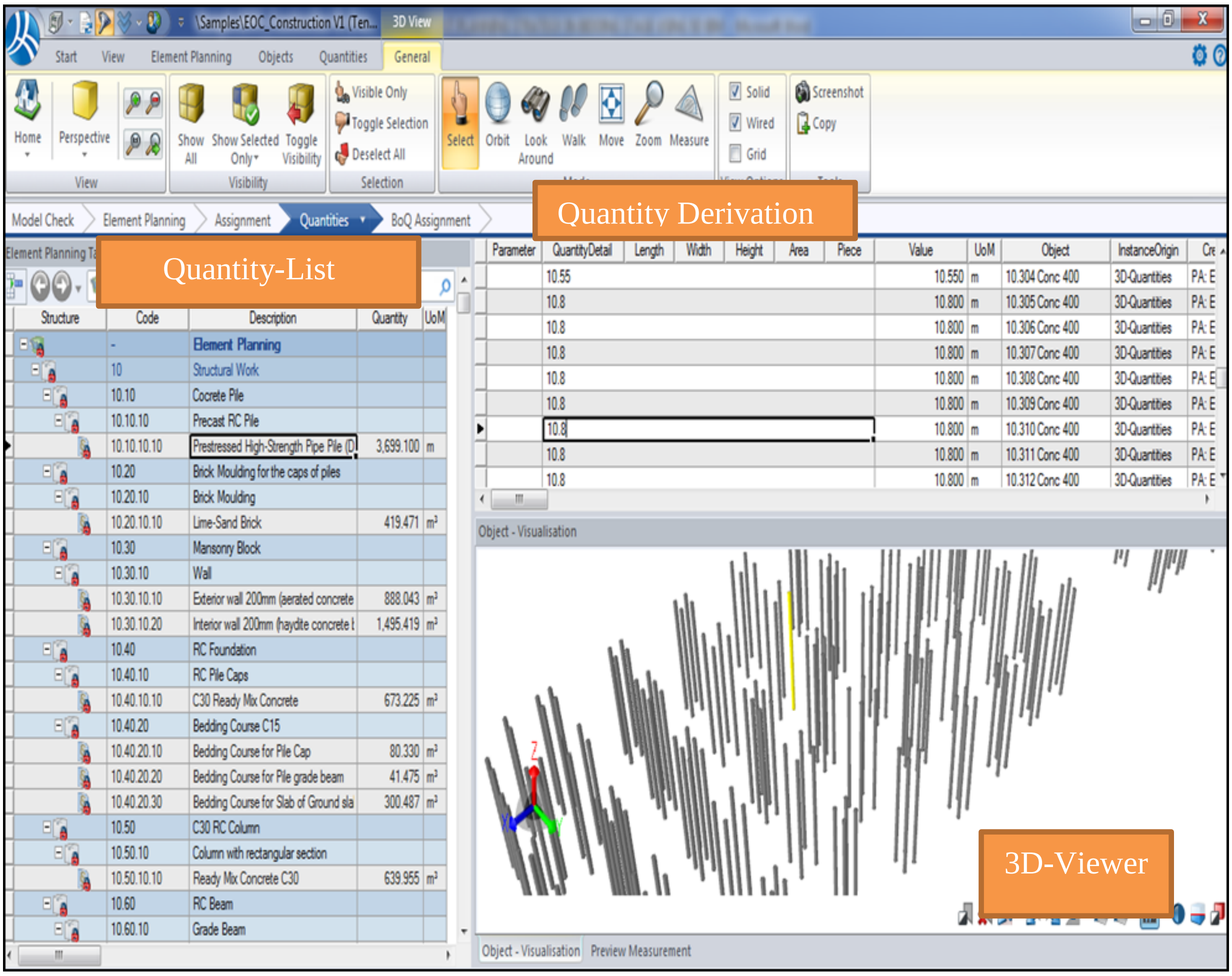


Figure 12: Sample of quantity takeoff list of elements and the 3D view of Piles

In RIB iTWO there is also possibility to do a manual quantity takeoff, user can measure surface Area, the length or number of the individual elements depending on the type of the measurement which is selected in the category of the measurement queries. It is also possible to view the model in any other RIB iTWO document that contains a reference to the location of the cost plan items This can be useful when some specific costs will be developed at a later stage.

4 - Linking Quantified Elements of the Building model with Price Data Base

Building element's quantities were counted and measured in the previous step. The following work is to only map the Price Data Base with the QTO list to generate a more accurate project cost. RIB iTWO can calculate the cost for each quantified element of the building by adding the unit costs into the model. On the other hand, the RIB iTWO library restores unit rate prices from previous historical projects, this library is able to apply this rate prices on projects and update them as required through importing the data information. as shown in figure 14.

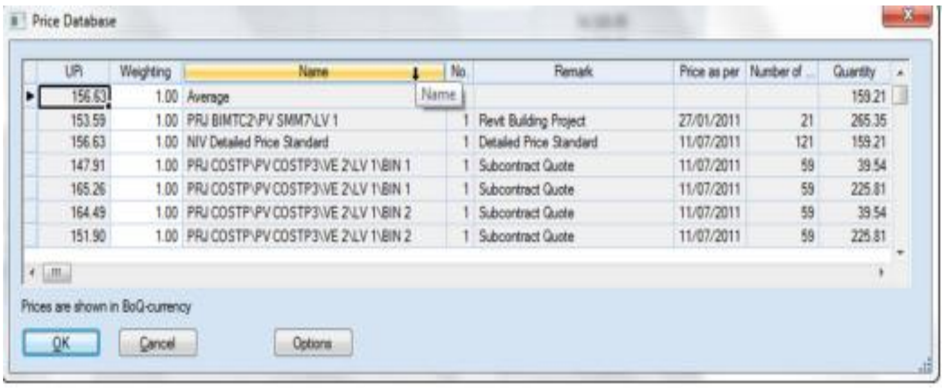


Figure 13: unite rates prices from a reference projects in library of RIB iTWO

In addition the Unite Rate price can be looked up manually in RIB iTWO, estimators use their own knowledge in pricing or ask sub-contractors for unit pricing.

In this case study, the unit pricing from the Price Standard in RIB iTWO library was mapped to the each quantified element of the building model, for the pricing of each line item to define a realistic estimate. As shown in figure 15 the elements were matched to thier assembly from the cost estimating database for pricing.

Structure	RN	Short-Info	Outline Spec	Quantity	UoM	Unit Rate	Total Amoun
	4.		D - Groundworks				397,228
	4. 1.		Concrete Pile Caps				11,795.
	4. 1.D20.		D20 Excavating and filling				11,795.
	4. 1.D20. 2.		Excavating				2,325.
	4. 1.D20. 2. 7.		For pile caps and ground beams between piles				2,325.
§	4. 1.D20. 2. 7.2.	FxP	Maximum depth <=1.0m	223.579	m3	10.40	2,325.
	4. 1.D20. 7.		Earthworks support				7,442.
	4. 1.D20. 7. 1.		Maximum depth <=1.0m				7,442.
§	4. 1.D20. 7. 1.1.	FxP	Distance between opposing faces <=2.0m	305.884	m2	15.76	4,820.
§	4. 1.D20. 7. 1.2.	FxP	Distance between opposing faces 2.0m to 4.0m	116.868	m2	22.43	2,621.
	4. 1.D20. 8.		Disposal				507.
	4. 1.D20. 8. 3.		Excavated material				507.
§	4. 1.D20. 8. 3.2.	FxP	On site	422.752	m3	1.20	507.
	4. 1.D20.10.		Filling to make up levels				1,521.
	4. 1.D20.10. 1.		Average thickness <=0.25m				1,521.
§	4. 1.D20.10. 1.1.	FxP	Arising from the excavations	135.108	m3	11.26	1,521.
	4. 2.		Concrete Floor Slab				25,354.
	4. 2.D20.		D20 Excavating and filling				25,354.
	4. 2.D20. 2.		Excavating				2,202.
	4. 2.D20. 2. 2.		To reduce levels				2,202.
§	4. 2.D20. 2. 2.2.	FxP	Maximum depth <=1.0m	1,429.904	m3	1.54	2,202.
	4. 2.D20. 6.		Working space allowance to excavations				8,029.
	4. 2.D20. 6. 1.		Reduce levels, basements and the like				8,029.
§	4. 2.D20. 6. 1.0.	FxP	Reduce levels, basements and the like	814.300	m2	9.86	8,029.
	4. 2.D20. 7.		Earthworks support				14,146.
	4. 2.D20. 7. 1.		Maximum depth <=1.0m				14,146.
§	4. 2.D20. 7. 1.1.	FxP	Distance between opposing faces <=2.0m	91.700	m2	15.76	1,445.
§	4. 2.D20. 7. 1.2.	FxP	Distance between opposing faces 2.0m to 4.0m	196.800	m2	22.43	4,414.
§	4. 2.D20. 7. 1.3.	FxP	Distance between opposing faces >4.0m	525.800	m2	15.76	8,286.
	4. 2.D20. 8.		Disposal				977.
	4. 2.D20. 8. 3.		Excavated material				977.

Figure 14: The coupling of geometric quantities to the recipes of cost

After all model elements have been estimated, the estimator can review the estimate by using the Review Cost plan Model in the RIB iTWO. Figure 16 below shows some elements of the building model in cost plan which are hierarchically arranged containing a list of all work items in the project. Also, it describes the elements containing a (outline) description, unit of measurement, a quantity, a unit rate, and cost. As well as the quantities visualization for each element and resources build up the unite rate. This allows the user to see the derivation of quantities in the cost plan.

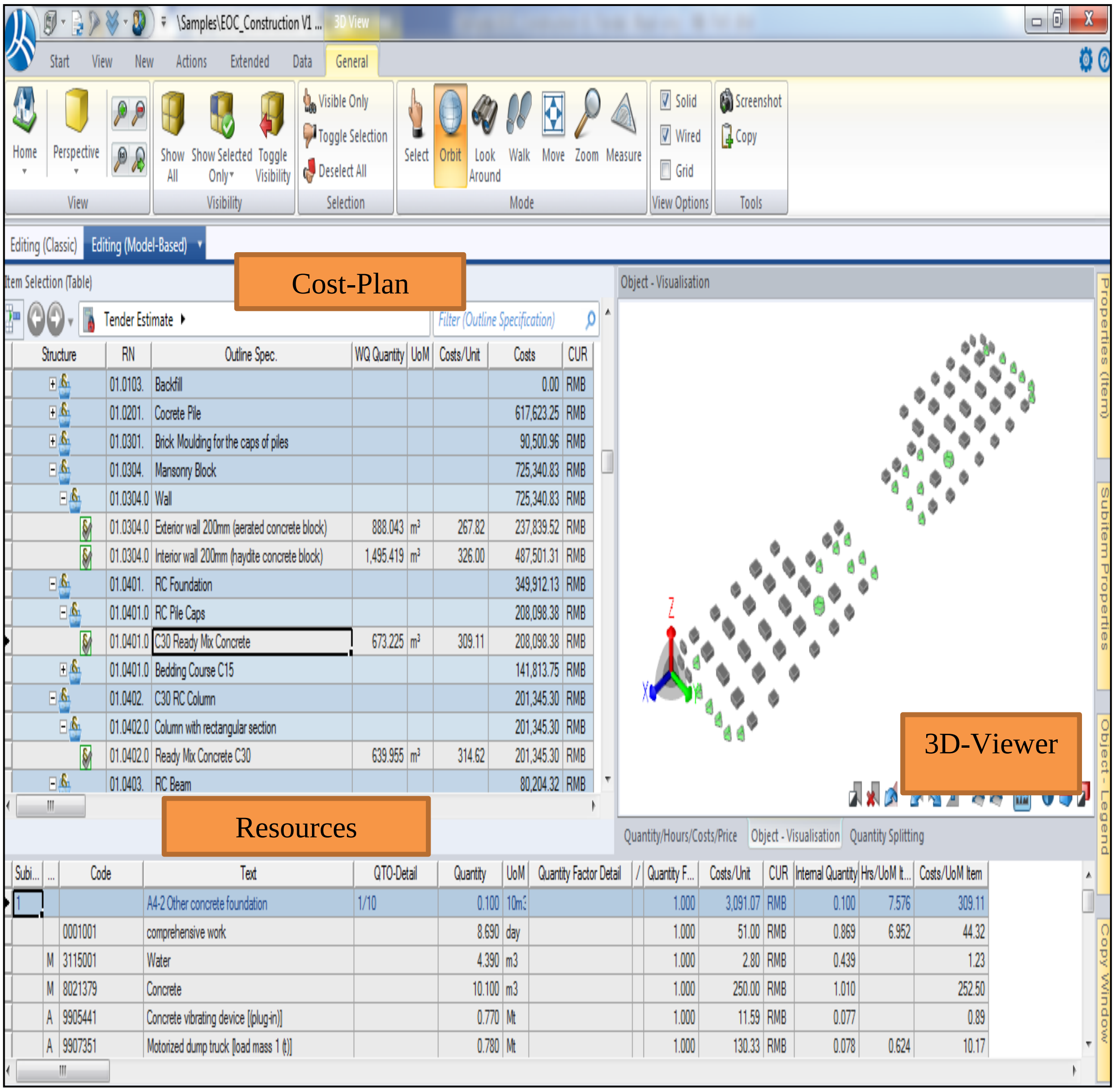


Figure 15: model based cost plan in iTWO

Furthermore, in RIB iTWO the cost plan can be rolled up or expanded to proper level of details. It is then possible to see the total cost of the project and detailed costs. These costs represent the principle details for various building elements and have been used to build the recipes in case study. The total estimated cost of the project is (43,826,621.37 RMB) as shown in figure 17.

Description	Costs
EOC Project (Parallel)	43,826,621.37
Preliminary Work	2,317,756.00
Foundation	1,296,906.70
Superstructure (Carcassing&MEP)	21,217,907.69
Ground Floor	3,529,536.12
First Floor	3,435,889.38
Second Floor	3,448,247.78
Third Floor	3,450,633.30
Fourth Floor	3,441,856.25
Fifth Floor	3,911,744.86
Superstructure (Finishes Work)	11,742,373.74
Ground Floor	1,544,673.59
First Floor	1,686,114.59
Second Floor	2,024,512.14
Third Floor	2,080,938.45
Fourth Floor	2,091,395.88
Fifth Floor	2,264,739.08
Lightning Protection	50,000.00
Outside Work	22,852.85
Measure for Construction	2,607,103.00
Power and Electrical	4,621,721.40
Intelligent System	2,262,036.40
High Voltage for Building	2,359,685.00

Figure 16: Items Cost Estimating Summary

Finally, RIB iTWO software allows the quantities and costs to be exported to a number of different file types such as Microsoft Excel, Microsoft Word or PDFs. This allows the estimator to extract whatever data they need and input it into their own estimate format easily.

3.5 5D BIM Model and 5D Simulation

In this section the procedures described were used in the case study in order to generate the 5D BIM model of the project, and to simulate the project in 5D BIM environment. To generate a 5D BIM model using RIB iTWO with a better simulation, the following steps are required :

1- Defining the schedule related to the 3D BIM model.

2- Linking the 3D model elements costs with defined time schedule.

3- View simulation in 5D BIM environment.

1- Defining the Schedule Related to the 3D BIM Model

In order to generate the 5D BIM model , defining schedules related to the elements of 3D BIM model is needed. A various theories can be adopted in order to add/incorporate the schedule into the 3D model: (1) The construction schedule can be generated in RIB iTWO, which allows users to define activites directly in the software tool itself like any planning software using the feature of “Built-in” or (2) Importing Primavera or MS Project schedule in RIB iTWO.

For this case study, the second approach was used to develop a certain construction schedule. RIB iTWO can import construction schedule from Primavera. There is a direct link between RIB iTWO and Primavera which allows importing WBS, activities, calendars and Primavera resources. Also it can be send back to Primavera to update the schedule information for cost and quantity resources. RIB iTWO can also verify durations of schedule based on the estimate then send revised schedule of selected activity or each activity back to primavera for allowances of re-schedule.

During the process of project scheduling, The project activities are defined and the sequences between them are in easy and clear way in Primavera, based on the the construction works that should be executed. A suitable duration is added to each activity and their relationship, thereupon the project duration automatically determined. The time frame used in this case study started from Aug 2010 to May 2012 as shown in figure 18 below:

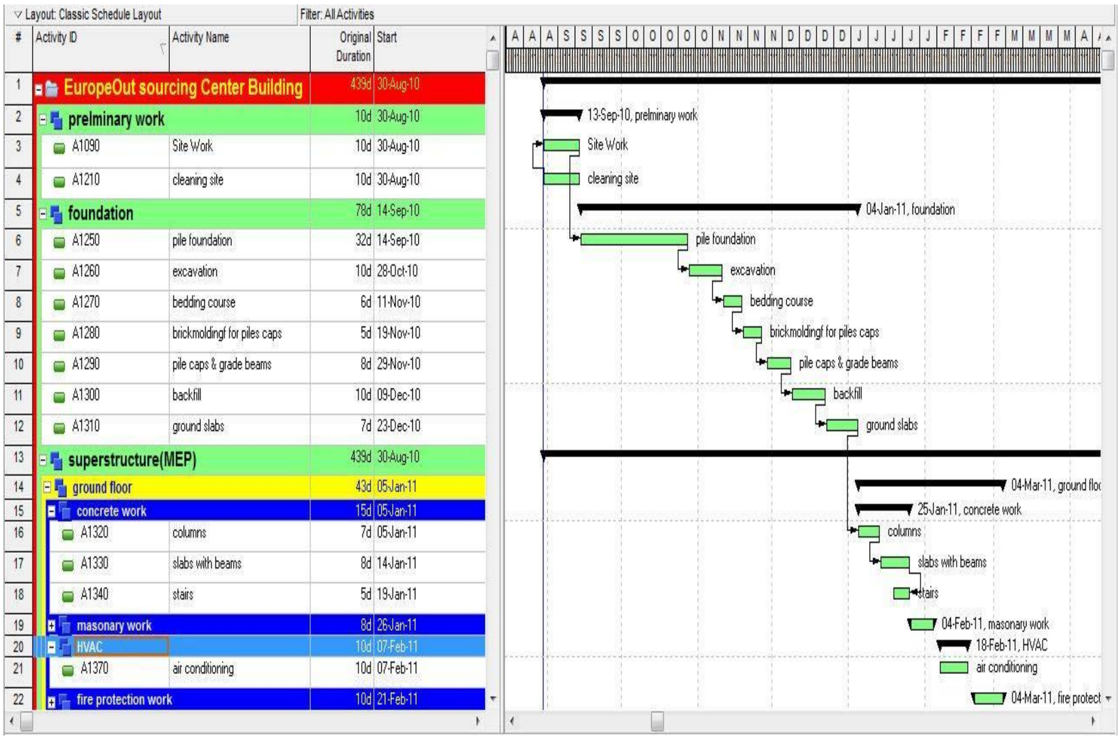


Figure 17: The Generated Construction schedule in primavera

The defined links between construction activities also enable the planner to obtain an appropriate Gantt Chart view which provides a graphical representation of the project schedule based on the activities defined. Figure 19 illustrates the created WBS in Primavera.

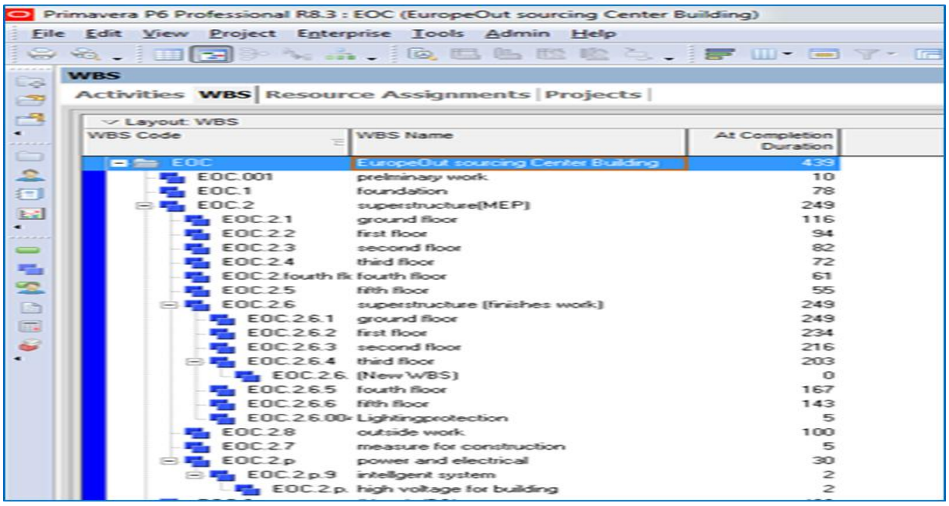
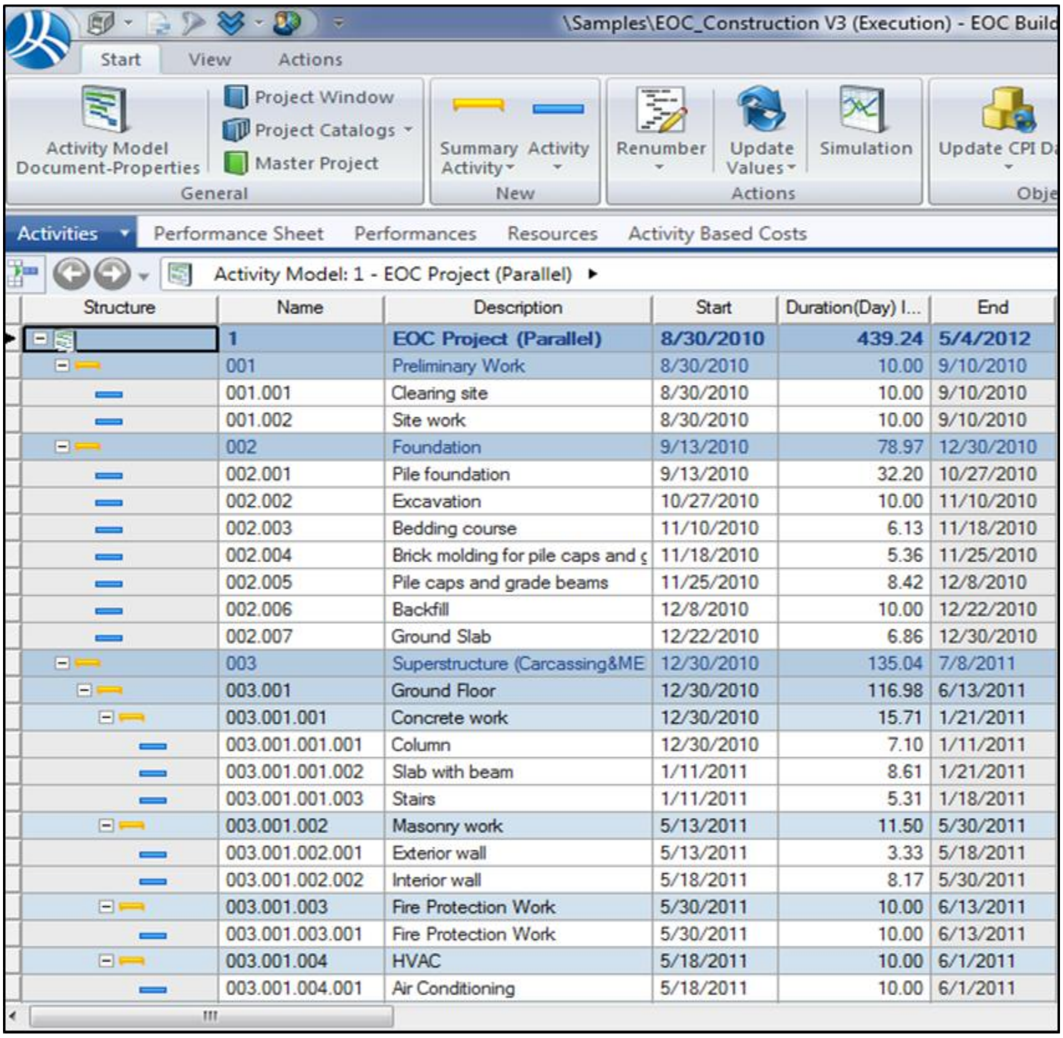


Figure 18: Model Plan WBS Names, ID`s and Durations

When the process of creating the construction schedule in Primavera was finished, a transfer of the created construction schedule from planning software (Primavera) needed and then imported it in RIB iTWO to generate the 5D BIM model. Several methods can be used to import the created construction schedule from any planning software to RIB iTWO. In this case study the RIB iTWO allows the capability to transfer the schedule next to RIB iTWO which can be done easily and also gives the chance to import all the activities. Figure 20 shows, the project activities that were imported and activated directly in the RIB iTWO in easy and clear way.



Structure	Name	Description	Start	Duration(Day) I...	End
	1	EOC Project (Parallel)	8/30/2010	439.24	5/4/2012
	001	Preliminary Work	8/30/2010	10.00	9/10/2010
	001.001	Clearing site	8/30/2010	10.00	9/10/2010
	001.002	Site work	8/30/2010	10.00	9/10/2010
	002	Foundation	9/13/2010	78.97	12/30/2010
	002.001	Pile foundation	9/13/2010	32.20	10/27/2010
	002.002	Excavation	10/27/2010	10.00	11/10/2010
	002.003	Bedding course	11/10/2010	6.13	11/18/2010
	002.004	Brick molding for pile caps and g	11/18/2010	5.36	11/25/2010
	002.005	Pile caps and grade beams	11/25/2010	8.42	12/8/2010
	002.006	Backfill	12/8/2010	10.00	12/22/2010
	002.007	Ground Slab	12/22/2010	6.86	12/30/2010
	003	Superstructure (Carcassing&ME	12/30/2010	135.04	7/8/2011
	003.001	Ground Floor	12/30/2010	116.98	6/13/2011
	003.001.001	Concrete work	12/30/2010	15.71	1/21/2011
	003.001.001.001	Column	12/30/2010	7.10	1/11/2011
	003.001.001.002	Slab with beam	1/11/2011	8.61	1/21/2011
	003.001.001.003	Stairs	1/11/2011	5.31	1/18/2011
	003.001.002	Masonry work	5/13/2011	11.50	5/30/2011
	003.001.002.001	Exterior wall	5/13/2011	3.33	5/18/2011
	003.001.002.002	Interior wall	5/18/2011	8.17	5/30/2011
	003.001.003	Fire Protection Work	5/30/2011	10.00	6/13/2011
	003.001.003.001	Fire Protection Work	5/30/2011	10.00	6/13/2011
	003.001.004	HVAC	5/18/2011	10.00	6/1/2011
	003.001.004.001	Air Conditioning	5/18/2011	10.00	6/1/2011

Figure 19: Activities are activated in RIB iTWO

2- Linking the 3D model elements costs with defined time schedule

This process is considered as a fundamental process, to represent the bond between the element's costs of the 3D model and the activities after importing the construction schedule. One of the advantages 5D BIM simulation , is the capability of RIB iTWO to link the construction elements of the 3D model with the quantities that were determined during cost planning process, and the calculated cost elements with the project activities related to the construction schedule created in Primavera. To generate the required 5D BIM model and to simulate construction process in 5D environment. This connection has been completed separately for each element with its related activity.

As an example of figure 21, Activity Model in RIB ITWO contains the schedule activities with dates and durations "in the left hand side", the Viewer shows 3D model "in the bottom right", and the cost plan\BoQ "in the middle". The Column element of cost plan was assigned to the activity column in the schedule . From the moment of connecting an element with an activity, all the data "in the bottom left" appears. Quantity of each estimate areas are being allocated to the schedule which divides the estimate among schedule activities. This is in order to identify and isolate the different quantities and costs incurred.

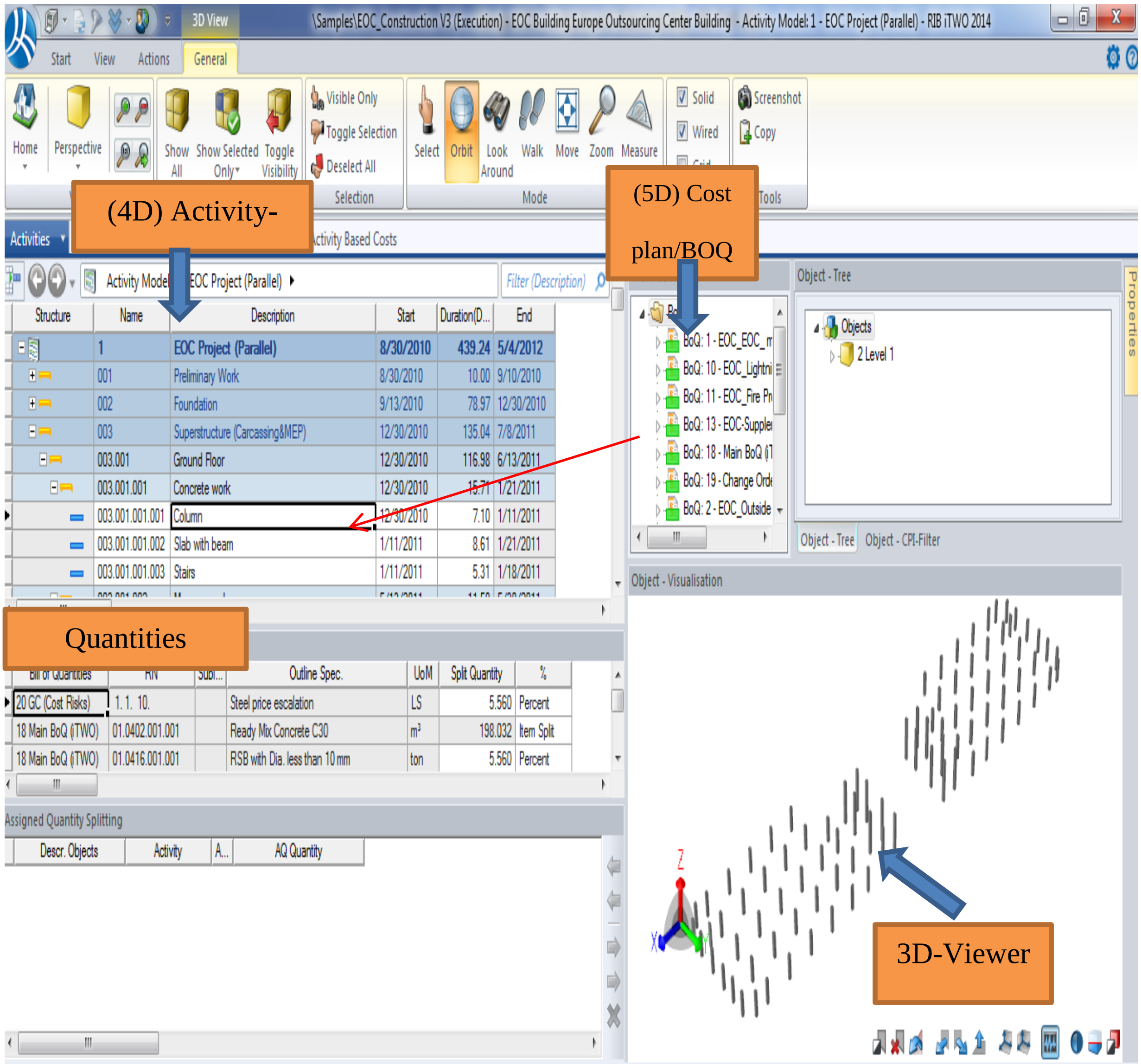
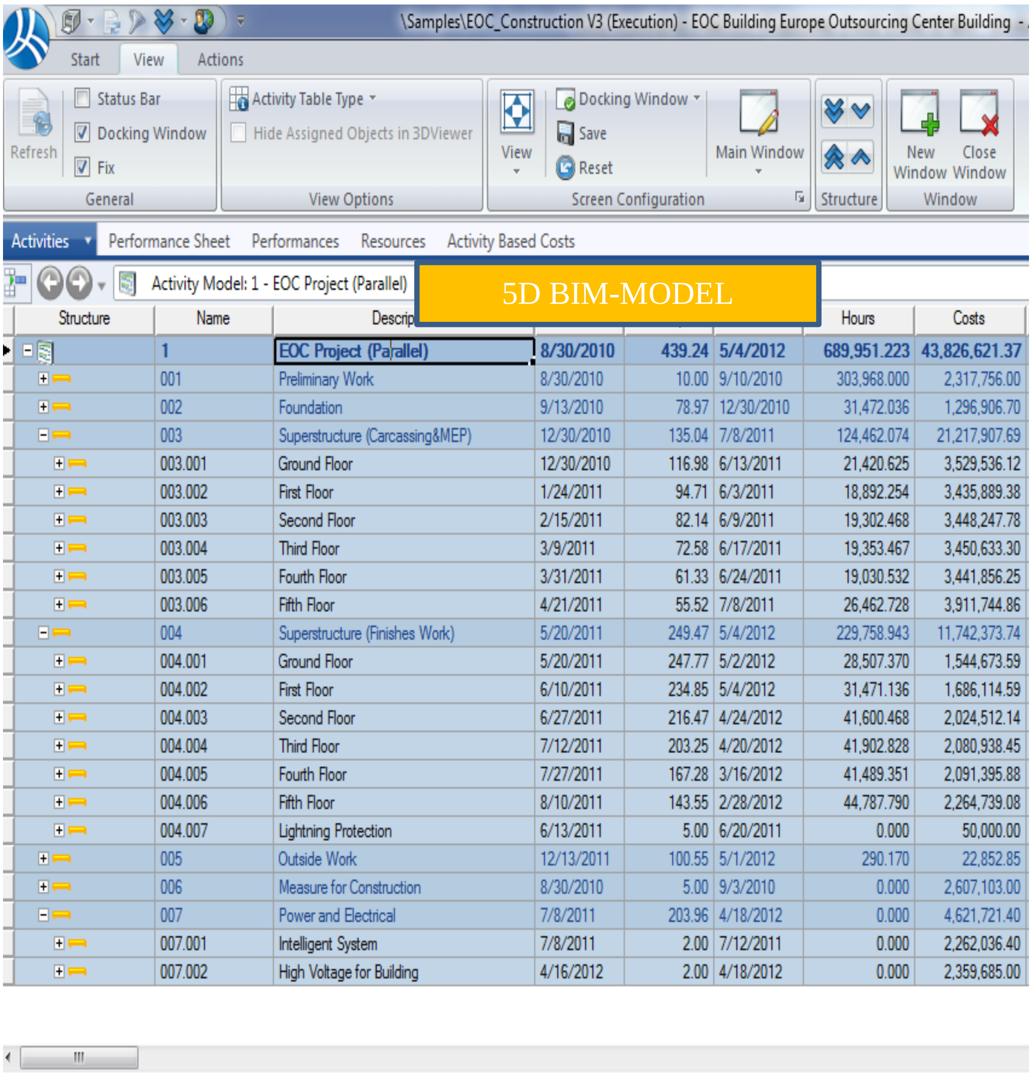


Figure 20: The column assigned to the column activity

Once, the schedule activity and element’s costs was linked. The project time and cost planning process is completed and the 5D BIM model of the construction project is developed as shown in figure 22.



Structure	Name	Descrip				Hours	Costs
	1	EOC Project (Parallel)	8/30/2010	439.24	5/4/2012	689,951.223	43,826,621.37
	001	Preliminary Work	8/30/2010	10.00	9/10/2010	303,968.000	2,317,756.00
	002	Foundation	9/13/2010	78.97	12/30/2010	31,472.036	1,296,906.70
	003	Superstructure (Carcassing&MEP)	12/30/2010	135.04	7/8/2011	124,462.074	21,217,907.69
	003.001	Ground Floor	12/30/2010	116.98	6/13/2011	21,420.625	3,529,536.12
	003.002	First Floor	1/24/2011	94.71	6/3/2011	18,892.254	3,435,889.38
	003.003	Second Floor	2/15/2011	82.14	6/9/2011	19,302.468	3,448,247.78
	003.004	Third Floor	3/9/2011	72.58	6/17/2011	19,353.467	3,450,633.30
	003.005	Fouth Floor	3/31/2011	61.33	6/24/2011	19,030.532	3,441,856.25
	003.006	Fifth Floor	4/21/2011	55.52	7/8/2011	26,462.728	3,911,744.86
	004	Superstructure (Finishes Work)	5/20/2011	249.47	5/4/2012	229,758.943	11,742,373.74
	004.001	Ground Floor	5/20/2011	247.77	5/2/2012	28,507.370	1,544,673.59
	004.002	First Floor	6/10/2011	234.85	5/4/2012	31,471.136	1,686,114.59
	004.003	Second Floor	6/27/2011	216.47	4/24/2012	41,600.468	2,024,512.14
	004.004	Third Floor	7/12/2011	203.25	4/20/2012	41,902.828	2,080,938.45
	004.005	Fourth Floor	7/27/2011	167.28	3/16/2012	41,489.351	2,091,395.88
	004.006	Fifth Floor	8/10/2011	143.55	2/28/2012	44,787.790	2,264,739.08
	004.007	Lightning Protection	6/13/2011	5.00	6/20/2011	0.000	50,000.00
	005	Outside Work	12/13/2011	100.55	5/1/2012	290.170	22,852.85
	006	Measure for Construction	8/30/2010	5.00	9/3/2010	0.000	2,607,103.00
	007	Power and Electrical	7/8/2011	203.96	4/18/2012	0.000	4,621,721.40
	007.001	Intelligent System	7/8/2011	2.00	7/12/2011	0.000	2,262,036.40
	007.002	High Voltage for Building	4/16/2012	2.00	4/18/2012	0.000	2,359,685.00

Figure 21: 5D model of the construction project (EOC)

3- The Simulation View in 5D environment

After creating the 5D BIM model with a suitable method , the final step was in the case study to simulate the project phases in the 5D environment using RIB iTWO with a better simulation and an easier way. This simulation will provide a clear picture of the construction process for the construction building which was made. As shown in figure 23 below the simulation of the project progress is shown on 15 monthly based interfaces form a video simulation done by Simulation Module (a part of RIB iTWO). On the upper left side of simulation interfaces, the date and on-going project sequence are shown. Different colors were selected manually was defined within the 5D Simulation module and used for animation to achieve better visualization of single building elements. The Red color indicates elements under construction and the Gray color indicates elements which have already been built. Simulating the progress can analyze every point of progress in the project, and jump to a specific date. Each activity is carried out on a specific location of the building.

Figure 22: The different time frameworks that consist of the 5D simulation the construction

Chapter 4

RESULTS AND DISCUSSIONS

4.1 Introduction

This chapter describes the analysis of the case study results, consistent with that indicated in the literature about benefits of using 5D BIM. Depending on the outcomes of the research analysis, the most essential benefits of using RIB iTWO software will be discussed. In addition to a comparison between 5D BIM cost planning and the traditional cost planning method. Concluding this, managerial implications of the usage of 5D BIM models are presented.

4.2 Results of Case Study

4.2.1 Enhanced Visualization

Visualization technology changes the plane lines into three-dimensional graphs. In the studied case, visualization has been considered a field of benefits when its about the 5D modeling. For instance as shown in figures (3.3 and 3.4) in chapter 3. 5D BIM provides a clear understanding of the building elements and its ability to review each part of the model. Which ultimately improves the decision making, reduces the chance of misplacement or misinterpreting vital elements and also reduces the assumptions that contractor needs during cost planning in bidding stage. These findings seem consistent with Thurairajah (2013), who describes QSs as being better able to understand the project they are involved in, as they can see and interact with the 3D model The results also suggests that the 5D BIM offers earlier risk identification e.g. potential clash detection is improved at bidding stage than with the traditional approaches. The use of 5D BIM to reduce risk is supported by Boon (2009) where contractors are able to analyze risk earlier and derive other construction options. By finding problems early, it may be possible to save both time and money. In this case, 5D BIM can be an effective alternative method to minimize these problems.

In short, it can be concluded that a clear understanding of a project is one of the essential parts of the cost planning and bidding process. The implementation of 5D BIM, and particularly the Model Checking function, can improve the effectiveness of the process through streamlining, simplifying and making the evaluation as objective as possible. Thus, it can reduce time of the project by avoiding delays resulted from RFIs.

4.2.2 Automatic Quantification

Automatic quantification means auto generation of quantities from BIM model elements. A careful review of the case study shows that the 5D BIM increases the accuracy and fast extraction of quantity takeoff in cost planning process. This leads the project to cost reduction and less human error.

RIB iTWO software is one of the 5D BIM tools that is used to extract quantities from a model. This software was used to extract quantities from the 3D model by exporting model into RIB iTWO. A list of QTO of the all building elements was generated automatically in 17 minutes. The QTO process was desirable as it was reliable. This produces a visual and numerical representation to check QTO accuracy as shown in figure 24 below. A quantitative study found that even when detailed estimates are produced by relatively inexperienced estimators, 5D was more effective than that of the traditional 2D estimating methods, especially in reducting errors and time taken (Shen and Issa 2010).

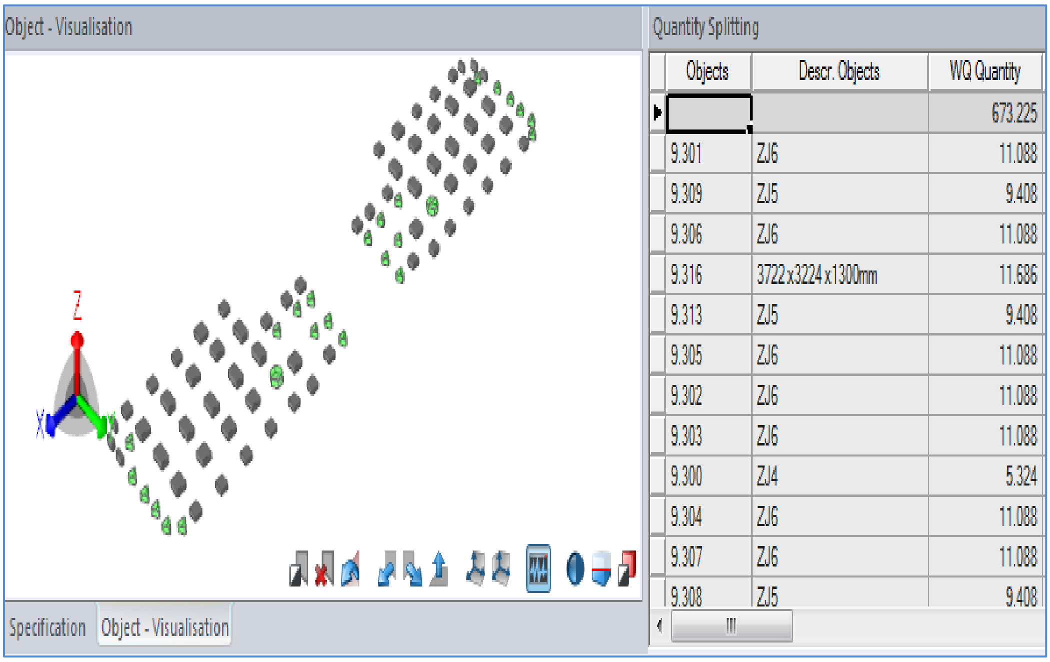


Figure 23: C30 Ready Mix Concret Splitting

On the other hand, the change of the design in the building model can be updated and reflected in the QTO list in minutes. This means that the owner and contracts can get a faster cost feedback on changes in design using 5D BIM technology.

It can be concluded that there is no possibility of doing mathematical errors in quantities by using 5D BIM tool in cost planning because it directly gives the quantities of the building elements. Thus the estimator productivity and accuracy increases during bidding process. The 5D BIM software capability in reporting numbers of components, area and volume of spaces, and quantities of materials can help contractor during bidding process. Using 5D BIM also decreases the bid cost by reducing the uncertainty materials quantities.

4.2.3 Detailed cost planning

Considering review of literature, 5D BIM can provide a high level of cost detail which can be useful in the early stages, and certain software providers are now making it possible to develop detailed cost planning by live linking the model to a 5D cost library (Thurairajah, 2013).

Similarly, in the studied case, the generated quantities of the building model elements and price data base were mapped together in RIB iTWO as shown in figure 3.8. in chapter 3. Mapping the QTO list with cost database in 5D BIM enviroument. Allows estimators to generate a more accurate and reliable cost estimate of the building with minimal effort and stremline their work during bidding process. The implementation of 5D BIM can reduce the effort in the cost estimation and reduce the economic loss of the bidders (COBIM, 2012).

The project was executed in China and element's prices were determined in local currency. It was estimated that the total cost of the project was (43,826,621.37.RMB). As was shown in (Figure 3.8 in chapter 3) the results also proves that 5D BIM provides an accurate geometric and detailed elements of project and enables more efficient detailed elemental cost plans for certain building elements.

On the other hand, a close review of the case study also indicated that when cost planning was based on information including quantities and placement from a 5D BIM model, estimators was able to use this 5D model cost plan to present quantities and cost variances graphically, which helps quick identification as long as the elements are available in the model. Figure 25 below shows a sample of cost plan list which is corresponding elements of the building model, were used in providing proposed tender cost. All components and subcomponents are hierarchically structured for the purpose of providing the level of cost estimation. The risk of later claims will be reduced, which avoids ambiguity and conflicts between the information in the tender documents (Saxon, 2013).

Ref No	Description	Work Qty	Unit	Unit Rate	Total
NRM	**Cost Plan Level 2**				
1.	**Substructure**				
1.4.	**Ground Floor Construction**				
1.4.0.	Element Unit Quantity				
1.4.0.......40.	Ground Floor Construction	255.300	m2GFA	200.00	[illegible],060.00
2.	**Superstructure**				
2.3.	**Roof**				
2.3.0.	Element Unit Quantity				
2.3.0.......30.	Roof	294.814	m2	392.476	[illegible],707.42
2.5.	**External Works**				
2.5.0.	Element Unit Quantity				
2.5.0.......50.	External Works	279.487	m2	280.34	[illegible],351.39
2.7.	**Internal Walls and Partitions**				
2.7.0.	Element Unit Quantity				
2.7.0.......70.	Internal Walls and Partitions	59.729	m2	134.563	[illegible],037.31
2.8.	**Internal Doors**				
2.8.0.	Element Unit Quantity				
2.8.0.......80.	Internal Doors	1.000	Nr	1,345.631	[illegible],345.63
3.	**Internal Finishes**				
3.1.	**Wall Finishes**				
3.1.0.	Element Unit Quantity				
3.2.0.	Element Unit Quantity				
3.2.0.......20.	Floor Finishes	233.626	m2	34.762	[illegible],121.31
3.3.	**Ceiling Finishes**				
3.3.0.	Element Unit Quantity				
3.3.0.......30.	Ceiling Finishes	233.626	m2	50.461	[illegible],789.00
4.	**Fittings, Furnishings and Equipment**				
4.1.	**General Fittings, Furnishings and**				
4.1.0.	Element Unit Quantity				
4.1.0.......10.	General Fittings, Furnishings and Equipment	233.626	m2GIFA	56.068	[illegible],098.94
5.	**Services**				
5.1.	**Sanitary Appliances**				
5.1.0.	Element Unit Quantity				
5.1.0.......10.	Sanitary Appliances	2.000	Nr	1,121.359	[illegible],242.72
5.1.0.	Element Unit Quantity				
5.1.0.......10.	Sanitary Appliances	2.000	Nr	1,121.359	[illegible],242.72
5.3.	**Disposal Installations**				
5.3.0.	Element Unit Quantity				
5.3.0.......30.	Disposal Installations	2.000	Nr	600.00	[illegible],200.00
5.4.	**Water Installations**				
5.4.0.	Element Unit Quantity				
5.4.0.......40.	Water Installations	2.000	Nr	2,000.00	[illegible],000.00
9.	**Facilitating Works**				
9.1.	**Toxic / Hazardous Material Removal**				
9.1.0.	Element Unit Quantity				
9.1.0.......10.	Toxic / Hazardous Material Removal	233.626	m2SA	200.00	[illegible],725.20
10.	**Main Contractors Preliminaries**				
10.1.	**Employer's Requirements**				
10.1.1.	Site Accomodation				
10.1.1.1.	Site accomodation				
10.1.1.1.......10.	A test item	1.000	LS		[illegible],000.00

Figure 24: some elements of cost plan for the 3D model

To sum up, implementing 5D BIM contractors can track a more accurate cost of the project at the bidding stage. For this reason, the final offers will be more reliable and the gap between the tender price and the final one will be reduced. 5D BIM-assisted estimation will not take the job from the estimator; it will instead release them to focus on more valuable work than calculation. This will provide higher value for the project.

4.2.4 Improved Simulations

In the case study, RIB iTWO was linked the building element's costs with activities to simulate the building in 5D environment. This integration will allow contractors to see the cost distribution based on project schedule, which helps contractors to arrange financing activities in a more effective way, and assist contractors to make faster adjustments to the financial plan according to the design change.

The simulation process for the building model was run easily in RIB iTWO. This allows seeing the costs incurred in each stage of construction. This is used to monitor the Construction Progress. The simulation shows the construction of the building and serves more as a visual representation of the sequence.

It is also convenient for the project contractor to provide the owner with a virtual and intuitive view of the project progress. Boon (2009) added "the 5D BIM simulation is used at the tendering stage of projects for showing customers footage of the construction process".

At the end, 5D BIM has obtained an improvement in the cost monitoring throughout entire bidding process. It shows how financial situation is going through time while building and compares available finances as well as outflow of financial resources.

Therefore, it can make prediction of when and where it might run out of funds. This will help contractors and investors to address the problem before it arrives and so well settled prematurely and enable a continuous workflow.

4.3.5 Collaborative Working

From the case study, it is evident that 5D BIM has a collaborative approach as it uses a centralized model. Through the model, it is possible for the planner, estimator, and designers to collude and come up with the milestone of a project among other construction plans. The findings are in line with the findings of Popov (2008). He believes that using 5D is useful in cost modeling to encourage collaboration.

4.3 Benefits of RIB iTWO Software

This section will focus on the RIB iTWO software that was used in the case study for the different dimensions of BIM a variety benefits that can be included in, as listed below:

- The development of the application was based on the activities of the human brain. It is based on activities such as processing information by the human brain. Hence, it is effective in minimizing the estimator's load on the long term memory as they prepare an estimate.
- RIB iTWO can easily enable the latest model version. The contractor can easily see what changed in the model and on schedule and cost calculation. Increasing the efficiency in construction and minimize disruptions to construction process.
- RIB iTWO demonstrated has the characteristics required for the 5D BIM technique. It is possible to reduce confusion as all information about the model with its quantities, calculations and recipes are available on the same

location. This contributes to the contractors can cooperate better and create high-quality documents.

- RIB ITWO gives a clear vision to the 3D model which is essentially to extract quantities from the 3D model, which significantly reduces the potential error compared to manual input.
- RIB iTWO supports the idea of developing cost planning where the estimate becomes more detailed and more accurate through the construction process at all stages.
- RIB ITWO optimizes schedules, costs and risks. And uses visual displays to display tasks that have bigger priorities to minimize delays during construction.
- RIB iTWO is ideal when the estimator wishes to visualize BIM excellently. The model can perform quick and reliable tests to identify whether there are any objects that have not been measured and whether there are is any duplication.
- RIB iTWO is a broad and comprehensive program containing several features is included in the study. The program is primarily intended for construction planning and cost optimization. In its entirety, RIB iTWO calculation platform is a powerful and highly functional tool.

4.4 Comparing the 5D BIM Cost Planning with the Traditional Cost Planning Methods and their procedures

In this section a comparison between the 5D modeling method and the traditional cost planning methods was covered in (Table 2). Then a plan for trational cost planning process (Figure 26) and 5D cost planning process (Figure 27) is given. The aim is to understand the advantages and the process of the 5D BIM modeling.

Table 2: Comparison between the 5D BIM cost planning Method and the Traditional Cost Planing Method

Traditional Cost Planing	5D BIM Cost Planning
Autonomous Documents : One estimate created per page, the difficulty there is no connection between versions. Binding two variance is difficult process	**Gradually developed Cost Information :** Cost planning developed gradually replacing each item one by one
Limited Number : Amount of work in creating traditional estimate is limited because there is no enough time	**Infinite Releases :** Cost information can be replaced gradually so that the results can be viewed at any time and creates infinite number of releases cost plan
Traditional Estimation drawing and Manual Takeoff: The quantity takeoff performed manually or semi manually which makes it a diffculte process	**Model based and Automated input:** Automated input and construction quantity derived from the 3D model
Paper and Disconnection : Paper based on cost estimating. The input disconnected and doesn't have any relation with results and 2D plane or design	**Model and Integration :** Model in 5D cost planning gives visual feed back for any selected cost item ,thus the integration with the design to understand from where the cost raised
Comparison between budget versions needed : The last comparison point comparing versions to other versions is not an easy task, any description changed make it hard to find matches between two versions	**Immediate Feedback :** 5D cost planning gives immediate feedback on each design decision, it easy way to keep budget on track and much more dynamic.
Visualizing the model from different views	**Two dimension view**
Cost Feedback on design traditional estimate typically performed after the design completed	**Participation in decision making** The cost planning in 5d BIM become part in the design process because provide cost feedback on each design decision immidetly
Work successfully with complicated projects	**Not recommended in the complicated projects**
Create connections between the project stakeholders	**No connections between the project Stakeholders. Project participants working individually**
Create connections between the project stakeholders	**No connections between the project Stakeholders. Project participants working individually**
Gives immediate and regular cost feed backs, to keep budget on track	**Difficult process hard to find the matches between two version**

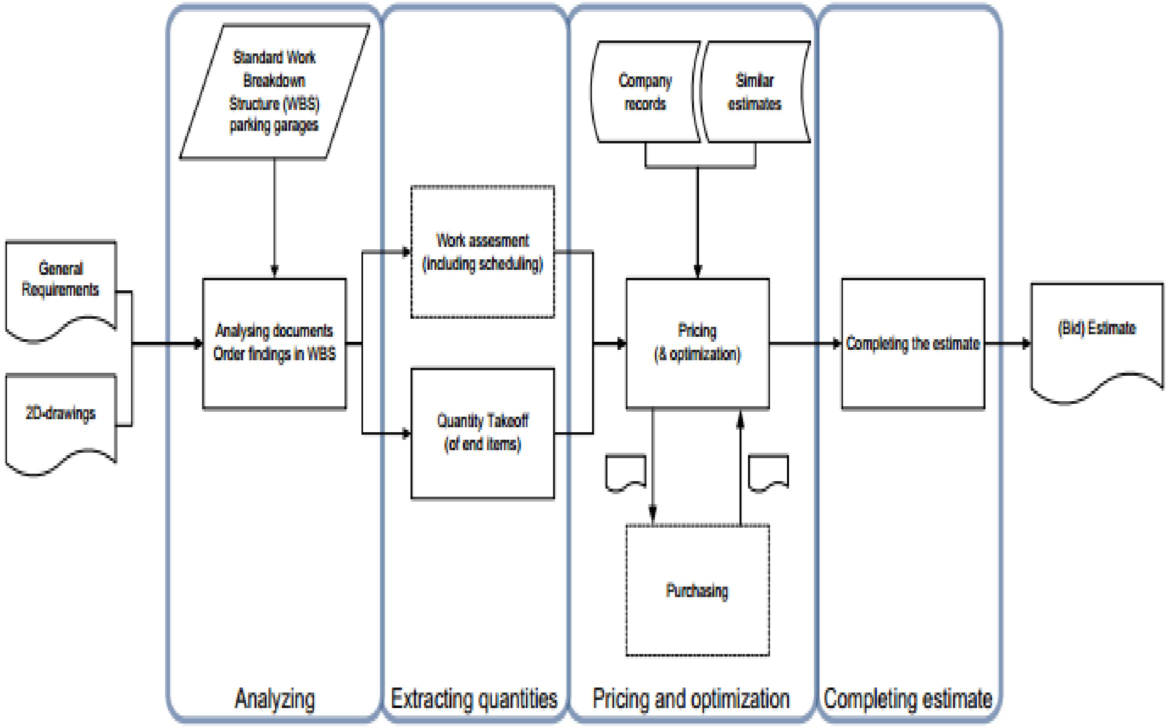


Figure 25: Traditonal cost planning process (Jakson, 2010)

Traditional cost planning process steps: first of all, analyzing the project by dividing the project into elements. Secondly, extracting quantities of the elements. Thirdly, pricing the quantities by using company's old records or similar estimates. Finally, completing the estimate by printing the estimated prices on the worksheet.

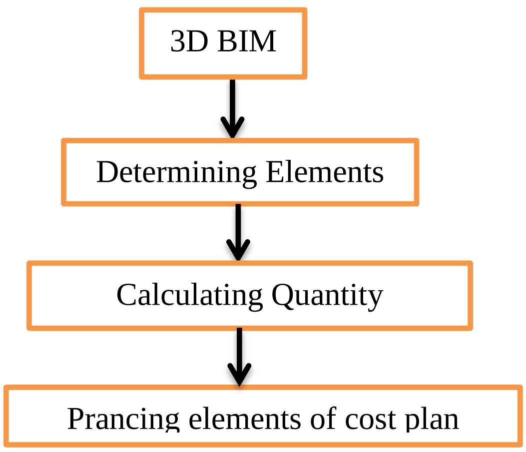


Figure 26: 5D BIM cost planning process

The 5D BIM cost planning process is: First of all, importing the 3D BIM model to 5D BIM tool. Secondly, determining elements of cost planning for the 3D BIM model. Thirdly, calculating the quantities for the determined element. Finally, pricing the quantity for the 3D elements using the data base of pricing.

4.5 Managerial Implications of the Usage of 5D BIM models

5D BIM models have the potential to be the catalyst for Managerial to reengineer their tasks in order to ensure if the project is completed on time or to better integrate the different stakeholders involved in modern construction projects. The list of Managerial Implications of the Usage of 5D BIM models is a useful at the starting point (Table 3).

Table 3: List of Managerial Implication of the Utilization 5D BIM Models

Tasks	Implications of 5D BIM Models
Establish a proper plan and follow the plan	An integrated 5D BIM models optimizing the plan and planning. Through enabling visual evaluation and comparing different alternative schedules. By applying location management techniques to the problem, these schedule interference points can be averted and the schedule kept on track.
Establish and follow the budget	In 5D BIM, the managerial has more tools at his disposal to keep tight reins, and more reports to monitor progresses such as: cash flow reports, work in place reports, look ahead schedules, and even earned value analysis. thoroughly understanding the project in 5D. On the other hand, when the schedule is on track, the budget is on track.

Review any changes in project	By using the integrated 5D BIM model to visualize and explore the impact of changes, the managerial can keep eye on project. Therefore, a trustworthy liaison between the designers and Owner is formed. However , it is the managerial responsibility to optimize the Owner's experience and satisfaction. Moreover, there is no greater influence on satisfaction than a project delivered on time and budget. In addition, the Owner receives a high dose of confidence in the GC when the managerial showed owners how design decisions impacted cost and schedules.
Develop an appropriate plan for resources and review	By using 5D models, managerial gets a two week look-ahead schedule that give alarms when a crew late start or delay, facilities resource with information on warranties, specifications, maintenance schedules and other valuable information automatically. So having a handle on clash detection and coordination plays a key role in keeping Subs' work predictable. And utilizing location management techniques (these schedule interference points can be averted and the schedule is kept on track). Quantities and crew productivity rates helps ensure the Subs that there would not be any stops and starts. This all adds up to getting the best pricing from Subs.

Chapter 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

As the purpose of this research was to find out the benefits gained from using the concept of 5D BIM cost planning in construction bidding stage. For this purpose, the steps of the cost planning of the construction project employing 5D BIM were introduced. Moreover, in this thesis, a case study was presented to illustrate the cost planning and simulation processes in 5D BIM, based on the BIM model of the Europe Outsourcing Center Building (EOC) located in China.

The advantages of construction cost planning using of 5D BIM may significantly improve the project management, especially in cases of large and complex construction projects in which the project goals are usually related to the quality of the building, the short construction time and the cost effective realization of the project. The main perceived benefits of 5D BIM were found in the studied case:

1- Enhanced Visualization

Contractors can have a clear understanding of the project due to visualization ability of 5D BIM to show the inside building with sections. This simplifies and facilitates the cost planning during bidding process, and it's opportunity to carry out collision checks.

2- Automatic Quantification

Procedure of QTO was economical on time at the bidding stage. This includes the potential time improvements through automatic processes and the possibility to access additional information, which helps to decrease the amount of time consumed. The ability to visualize quantities creates trust and is relied upon. Also the ability to update and change quantities quickly can be a major benefit for contractors in terms of cost planning due to dynamic link.

3- Detailed cost planning

The cost estimation becomes more detailed and more accurate. That it enables contractor to add more specific costs to the project. Cost planning process in 5D BIM also includes evaluating conditions of the project which has an impact on costs and provides detailed 5D estimates and living cost plans, such as unique technical details and places with difficult access. On the other hand, Cost databases in 5D BIM provides the foundation for the quality, value of the services and a significant competitive advantage.

4 - Improved Simulations

5D BIM simulation is dynamic and convenient when the project contractor gives the owner feedback regarding the progress of the project. Contractor then can make faster adjustments to the financial plan based on the changes in cost and schedule. This integration between cost and time elements can ensure that the contractor has enough financial resources even when there is a change in the design.

5- Collaborative Working

The full implementation of 5D BIM in bidding stage projects involves the sharing of information amongst project participants. The advantage of the use of 5D BIM is that several participations can work with the model by a common database.

Competitive tendering and bidding with 5D BIM models can reduce the risky gap that exists between project members due to the transparency and accessibility to project information and documentation.

The RIB iTWO software has worked very well to achieve the purpose of the study. It is unique software which delivers an integrated 5D BIM solution for construction industry. It supports modeling, coordination, quantity extractions, costing, scheduling, and controlling production and progress of construction projects Moreover, it is a very effective tool when it comes to estimating.

Hence, the use of modern software that integrated 5D BIM -system that provides benefits in both time and cost should be an important part of business practices. As a result it contributes a better management of construction process.

The importance for the managerial professional to embrace the 5^{th} dimension of BIM is being able to simulate and explore various design and construction scenarios in real time through having their cost data and quantities integrally linked in the live BIM model.

This thesis contributes to provide new valuable information for construction management experts as well as it will serve it may serve as the basis for further research in the 5D BIM based construction project management field. Furthermore, it contributes to the projects to be finished on time without leading to extra cost.

5.2 Recommendations

After long research and driven results of this study, the helpful recommendations that obtained is listed below:

- The contractors must adapt the 5D BIM technology in their practices. As this application helps not only in cost estimation but it's also user friendly and provide accurate results. It can be easily integrated with other systems, as it is more compatible. Contractors should take advantage of it to avoid future problems and delays in project completion. It is also feasible for maintaining the standards of the project.
- Managers and engineers should take an intensive course on how to use the 5D BIM software and to learn more about how will this technology can offer them from advantages and disadvantages over their project. Moreover, companies just have to be more determined to explore all the advantages of this technology and step into the modern future.

5.3 Recommendations for Further Research

Due to various aspects and limitation, suggestions for further research into this subject could include:

- To examine more closely why 5D BIM technology is not used, it may be good to take out the risks that clients, designers and architects will find in this system, and if there are no major fundamental cause that it is not implemented.
- It can also be useful to examine the benefits of RIB iTWO on several construction projects. This provides a more credible result of the program's benefits.

REFERENCES

Aranda-Mena, G., Crawford, J., Chevez, A., & Froese, T. (2009). Building information modelling demystified: does it make business sense to adopt BIM?. *International Journal of Managing Projects in Business*, 2(3), pp. 419 - 434.

Azhar, S., Khalfan, M., & Maqsood, T. (2012). Building Information Modeling (BIM): Now and Beyond. Australasian Journal of Construction Economics and Building.

Becerik-Gerber, B., & Kensek, K. (2012). Building Information Modeling in Architecture, Engineering, and Construction: Emerging Research Directions and Trends. *Journal of Professional Issues in Engineering Education and Practice,* 136(3), pp. 139-147.

BIM Task Group, (2014). BIM Task Group. Available at: www.bimtaskgroup.org.

Bryde, D., Broquetas, M., & Volm, J. M. (2013). The project benefits of Building Information Modelling (BIM). International Journal of Project Management, 31(7), pp.971–980.

BSI Standards Development (2014). B/555 Construction design, modeling and data exchange. Available at: http://www.csinet.org/. [Accessed: 22-Feb-2014].

Eastman, C., Teicholz, P., Sacks, R., & Liston, K. (2011). BIM handbook: A guide to building information modeling for owners, managers, designers, engineers and contractors, 2nd Ed., John Wiley & Sons, New Jersey.

Government Construction Client Group (2011). BIM Management for value, cost & carbon improvement. Department of Business, Innovation and Skills, (March).

Haque, M. E. & Mishra, R. (2011). 5D virtual constructions: Designer/constructor's perspective. In: 10th international conference on Computer and information technology, 27-29 Dec. 2007 2007 Dhaka, Bangladesh. 1-4.

Hendrickson, C. (2010). *Project Management for Construction: Fundamental Concepts for Owners.* Engineers, Architects and Builders, Prentice Hall, Pitsburgh.

Hwang, S., & Liu, L. Y. (2010). *BIM for integration of automated real-time project control systems.* Paper presented at the Construction Research Congress.

Jackson, B. J. (2011). *Construction Management JumpStart: The Best First Step Toward a Career in Construction Management*: John Wiley and Sons.

Jongeling, R., & Olofsson, T. (2007). A method for planning of work-flow by combined use of location-based scheduling and 4D CAD. Automation in Construction, 16(2), pp.189–198.

Kuprenas, J., & Nasr, E. (2007). Cost Performance Comparison of Two Public Sector Project Procurement Techniques. *Journal of Management in Engineering*, 23(3), pp. 114-121.

Kymmell, W. (2008). *Building Information Modeling: Planning and Managing Construction Projects with 4D CAD and Simulations* (McGraw-Hill 53 Construction Series): Planning and Managing Construction Projects with 4D CAD and Simulations. McGraw Hill Professional.

Lindström, & Adam (2013). Model-based Quantity Takeoff in Production. Göteborg: Chalmers tekniska högskola.

Matipa, W. M., Cunningham, P., & Naik, B. (2010) 'Assessing the impact of new rules of cost planning on building information model (BIM) schema pertinent to quantity surveying.

McCuen, T. L., (2008). Scheduling, Estimating, and BIM : a Profitable Combination. AACE International Transactions, pp.11–18.

Mitchell, D. (2012). 5D BIM : creating cost certainty and better buildings. Mitchell, D., 5D Cost Planning. Available at: http://www.mitbrand.com/.

Nunnally, S. (2012). *Construction Methods and Management.* Pearson Prentice Hall. Seventh edition. ISBN 0-13-171685-9.

Ohrn, G., & Rogers, T. (2008). *Defining Project Delivery Methods for Design, Construction, and Other Construction-Related Services in the United States.* Paper presented at the ASC Conference, Auburn, Alabama.

Rossi. M., & Civitillo. C. (2014), Public Private Partnerships: a general overview in Italy, 2nd World Conference On Business, Economics And Management - WCBEM 2013. Procedia - *Social and Behavioral Sciences 109* (2014) 140 – 149.

Rundell, R. (2008). "BIM and Digital Fabrication (1-2-3 Revit Tutorial)." Cadalyst.

Shen, Z., & Issa, R. R. A. (2010). *Quantitative Evaluation of the BIM-Assisted Construction Detailed Cost Estimates.* Papers in Construction Management.

Smith, D. (2014). An Introduction to Building Information Modeling (BIM). Journal of Building Information Modeling, Fall 2007, pp. 12_16.].

Shrestha, P. P., & Mani, N. (2012). Impact of Design Cost on Design Bid Build Project Performance, *Construction Research Congress 2012*, pp. 1570-1579.

Thurairajah, N. & Goucher, D., (2013). 'Advantages and challenges of using BIM: A cost consultant's perspective', 49th ASC Annual International Conference, viewed 20 November 2013.

Touran, A., Gransberg, D. D., Molenaar, K. R., Ghavamifar, K., Mason, D. J., &Fithian, L. A. (2009). A Guidebook for the Evaluation of Project Delivery

Methods, *Transit Cooperative Research Program*. Washington, D.C, Transportation Research Board.

W. Hu (2008). *Integration of Radio-FrequencyIdentification and 4D CAD in Construction Management*, Tsinghua Sci. Technol., vol. 13, Supplement 1, pp. 151–157.

Zanen, P., & Hartmann, T. (2010). *The Application of Construction Project Management Tools an Overview of Tools for Managing and Controlling Construction Projects.*

Zhiliang, M. (2013). *Framework Design for Bim-Based Construction Cost Estimating Software.* 27th International Conference, Cairo, Egypt, s.n