

THE INFLUENCE OF BUILDING
INFORMATION MODELLING ON THE
QUANTITY SURVEYING
PROFESSION

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**THE INFLUENCE OF BUILDING INFORMATION MODELLING ON
THE QUANTITY SURVEYING PROFESSION**

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Submitted in fulfilment of part of the requirements for the Degree of
BSc (Hons) (Quantity Surveying)

In the faculty of Engineering, Built Environment and Information
Technology

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October 2010

DECLARATION BY STUDENT

I, the undersigned, hereby confirm that the attached treatise is my own work and that any sources are adequately acknowledged in the text and listed in the bibliography

Signature of acceptance and confirmation by student

ABSTRACT

Title of treatise : The influence of Building Information Modelling on the Quantity Surveying Profession

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Date : October 2010

Building Information Modelling (BIM) is the latest technology in the built environment utilising data models. It is a multi-dimensional model that acts as a communication and information resource over the lifecycle of a construction project. It consists of 3-dimensional (3D) design functions, cost estimating functions and programming and scheduling functions. BIM will open up a whole new level of data sharing in the construction industry. This brings forth many advantages but also a list of risks and changes to the traditional structure of the construction industry

The purpose of this research report is to investigate the qualities of BIM and the influence it will have on the quantity surveying profession, through research of the opportunities and barriers that it brings forth, and the changes to be made and measures to be taken by quantity surveyors, in order to successfully incorporate BIM into the quantity surveying profession.

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ABBREVIATIONS

3D	Three-dimensional
AIA	American Institute of Architecture
ASAQS	Association of South African Quantity Surveyors
BIM	Building Information Modelling
FIDIC	International Federation of Consulting Engineers
GCC	General Conditions of Contract for Construction Works
JBCC	Joint Building Contracts Committee
NEC	New Engineering Contract
NIBS	National Institute of Building Science
ROI	Return on investment
SME	Small-medium enterprises
SMM	Standard method of measurement
WBS	Work breakdown structure

CHAPTER 1

INTRODUCTION AND BACKGROUND

1.1 INTRODUCTION AND BRIEF OVERVIEW OF BUILDING INFORMATION MODELLING

The International Network for SMEs defines technology as a human innovation in action that involves the generation of knowledge and processes to develop systems that solve problems and extend human capabilities. Across the world new technology is developed daily which is transforming and revolutionising all from the basic to the intricate functions of life. The construction industry is no exception.

Over the years the need for more cost effective, better quality and environmentally friendlier construction has grown, these factors are the main influences on the development of technology in the construction industry. Building Information Modelling (BIM) is one of the technologies that have been creating a buzz in the construction industry over the last few years. “As defined by the National Institute of Building Sciences: A Building Information Model, or BIM, utilises cutting edge digital technology to establish a computable representation of all the physical and functional characteristics of a facility and its related project/life-cycle information, and is intended to be a repository of information for the facility owner/operator to use and maintain throughout the life-cycle of a facility.” (Ashcraft, 2007) With new technology however, there always comes a list of benefits as well as a certain degree of risk or concern. BIM promises to save time and money, and bring collaboration not just between designers but between the whole professional team as well as the contractor.

As the competition in the industry is growing, professionals will need to constantly evolve and incorporate new technologies in order to stay ahead. The purpose of this research report is to investigate the qualities of BIM and the influence it will have on the industry, with the main focus on how quantity surveyors will need to adjust their way of thinking and responsibilities in order to collaborate with BIM.

1.2 STATEMENT OF THE MAIN PROBLEM

How does Building Information Modelling influence the Quantity Surveying Profession?

As technology evolves, we are forced to evolve with it or run the risk of being left behind. The traditional way of utilising the services of a quantity surveyor has largely been at the stage of costing a design, and the production of procurement and construction documentation (Asworth and Hogg, 2002). With the development of technology like BIM, the responsibilities of professionals are starting to shift. BIM includes a series of cost management functions that could change the processes of cost management of construction projects. This forces the quantity surveyor to focus more on different parts of the cost management process, than what would have previously. Not only will BIM influence the cost management functions and responsibilities of the quantity surveyor, but also the technology and types of software that are currently used in quantity surveying offices.

1.3 HYPOTHESIS OF THE MAIN PROBLEM

The incorporation of BIM into the different professions in the construction

industry will change the way the built environment works forever. This holds a great deal of advantages for the industry. There is however a lot of changes that will need to be made before BIM can be utilised fully. Software and technology used in conventional practices will need to be more advanced; this will have lot of cost implications for businesses. The responsibilities of quantity surveyors will be transformed as some of their traditional roles will be replaced by the functions of multi-dimensional models, so that their focus will shift from bill producers to cost managers, which will shift the design process from costing to a design to designing to a cost.

1.4 STATEMENT OF THE SUB-PROBLEMS AND SUB-PROBLEM HYPOTHESIS

1. What is Building Information Modelling?

BIM is a multi-dimensional model that acts as a communication and information resource over the lifecycle of a construction project. It consists of 3-dimensional (3D) design functions, cost estimating functions and programming and scheduling functions.

2. What is the role of the quantity surveyor in the cost management of a construction project?

The quantity surveyor plays a large role in the cost management of a construction project. Some of the main services that the quantity surveyor provides are:

- Financial advisor – this includes preparing budgets, cost control documents and bills of quantities, recommending contract type and

delivery process to achieve time and budget as well as preparing tax depreciation calculations.

- Construction advisor – this includes advising on the costs of alternative materials and construction methods, and advising on the effect of site conditions on the budget and the feasibility of different sites
 - Contract administrator – this includes advising on all contractual matters between the client and consultants as well as the client and the contractor
- (AIQS, 2003 <http://www.aiqs.com.au/What_is_QS/>)

3. What are the cost management functions of Building Information Modelling?

Some of the main cost management functions of BIM are:

- generating bills of quantities
- generating square metre estimates
- generating cost estimates
- rapid updating of costs as the design or material changes

4. What are the steps to be taken and the challenges to be faced by the quantity surveyor to incorporate Building Information Modelling into the profession?

To incorporate BIM efficiently into the quantity surveying profession, quantity surveyors will need to focus on the following aspects:

- updating software and computer systems in the work place
- undergoing training on the cost management functions of BIM
- adjusting their services and responsibilities to the cost management functions of BIM

- gaining knowledge on the new contractual aspects that is related to BIM on specific construction projects

1.5 DELIMITATIONS OF RESEARCH

This study will apply BIM to projects and functions in the construction industry only. This report will be aimed at professionals in the South African construction industry. BIM in South Africa has not been developed and researched as extensively as in countries such as the USA and the UK. International BIM practices will therefore be applied.

1.6 ASSUMPTIONS

Based on the information available on BIM in South Africa, an assumption is made that BIM has not yet been widely incorporated by professionals and companies in the South African construction industry.

1.7 IMPORTANCE OF THE STUDY

As the world is transforming and developing at a very quick pace, while facing tough economic challenges, needs for quicker, more cost effective and higher quality methods and practices are increasing. BIM promises these advantages to members of the construction industry, and has given a competitive advantage to those who have been utilising it.

BIM has been used on several significant international projects such as the Freedom Tower in New York City, the Bart's and The London Hospital project and the Eureka Tower in Melbourne (Howell and Batcheler, 2005). BIM seems to be a fast adopted trend in first world countries, and the South African

construction industry will need to shift their perceptions in order to keep up. The incorporation of BIM however, leaves a distortion of professional responsibilities and list of changes in order to adjust to these systems.

The purpose of this report is to create awareness under professionals in the South African construction industry, regarding the value that BIM will add to the construction industry as well as the shift in methods and responsibilities that will be caused in the construction industry when BIM is fully incorporated.

1.8 RESEARCH METHODOLOGY

The main type of research that will be used for this report will be applied research.

The following resources will be consulted:

1. Text books

Various text books will be consulted as well as a series of electronic books.

2. Journal articles

Journals articles will be one of the main sources of information. Journals articles are usually more easily obtainable as they are more freely available in electronic form which is easily accessible via the internet. It will also serve as a main source as journals and articles holds the most recent information on the topic.

3. Academic dissertations

A dissertation submitted to the National University of Ireland, Cork (NUIC) by Wilfred Masuwa Matipa on the total cost management at the design stage using a building product model, will be used as background for this report.

4. Electronic resources

Various electronic resources will be consulted, as information is easily accessible through the use of a variety of search engines.

CHAPTER 2

BUILDING INFORMATION MODELLING: DEFINITION, CHARACTERISTICS, ADVANTAGES AND BARRIERS

2.1 INTRODUCTION

The Oxford dictionary (2001) defines the term model as a three-dimensional copy of a person or a thing, typically on a smaller scale and is usually used as an example; it is also described as a simplified mathematical description of a system or a process. The term model can be defined in many other ways, as it is used in different forms in different industries or fields for numerous functions and processes. Models form a large part of information sharing and understanding, it transforms large amounts of data into simplified structures that can be more easily processed by the human mind. “A model provides a means for conceptualisation and communication of ideas in a precise and unambiguous form” (Matipa, 2008).

For the purpose of this report a type of data model will be discussed and will be applied to processes and functions in the construction industry. “A data model is an integrated collection of concepts for describing and manipulating data, relationships between data, and constraints on the data in an organisation” (Matipa, 2008). Building information modelling (BIM) is new technology using data models and has been creating quite a large buzz in the construction industry. The buildingSMART Alliance of the National Institute of Building Sciences provides the following definition for BIM: “A Building Information Model (BIM) is a digital representation of physical and functional characteristics

of a facility. As such, it serves as a shared knowledge resource for information about a facility forming a reliable basis for decisions during its lifecycle from inception onward. A basic premise of BIM is collaboration by different stakeholders.” (Sage Construction and Real Estate Solutions, 2008). It is all the information used in a construction project or a computerised portrayal of this construction project, structured according to some building product data model (Matipa, 2008). BIM will open up a whole new level of data sharing in the construction industry. This brings forth many advantages but also a list of risks and changes to the traditional structure of the construction industry.

This chapter will focus on defining BIM by discussing its characteristics, advantages and disadvantages.

2.2 BUILDING INFORMATION MODELLING

2.2.1 Definition and characteristics

Traditionally, the construction industry has relied on hard copies of 2D drawings to depict the work to be executed. They formed part of the contract documentation that were assessed by building codes and used for facilities management (Eastman, 2007). “But there were two strategic limitations of drawings:

- They require multiple views to depict a 3D object in adequate detail for construction, making them highly redundant and thus open to errors;
- They are stored as lines, arcs and text that are only interpretable by some people; they cannot be interpreted by computers.” (Eastman, 2007)

BIM solves these problems through various characteristics. BIM uses geometric shapes and three spatial dimensions (3D) to create building models through parametric modelling. It goes further and incorporates geographic information, properties of building components and quantities (Wikipedia, 2008) to add fourth and fifth dimensions, such as scheduling and sequencing and cost estimating to the model (Sage construction and real estate solutions, 2008). This is called object-orientated modelling and 4D and 5D simulation (Ashcraft, 2007). These characteristics as well as the interoperability of BIM are discussed in more detail hereunder.

- Parametric modelling

Parametric modelling forms the foundation for BIM processes. It is data based modelling, based on large digital databases containing building information regarding a structure's elements and their relations to other building elements (Ashcraft, 2007). These databases are enriched at the creation of building information models, as data for each model are stored in the database, and will be available for use and reuse at a later stage of the project (Autodesk, 2002).

These building product models will consist of building elements and their spatial and non-spatial relationship with one another, that contains material elements, such as windows and doors, and immaterial spaces that are surrounded by these material elements (Matipa, 2008).

Parametric modelling permits the elements or objects to have fixed or flexible ties between them, to either preserve their form or change as its related element changes. Parametric elements are automatically restructured according to the rules programmed into their databases.

The rules may be as simple as, requiring a window to be wholly within a

wall, or complex such as defining size ranges and detailing (Eastman, 2007).

- Object-orientated modelling

In computer science an object can be defined as an autonomous procedure that is embedded with information about all of its characteristics as well as instructions to perform certain directives, and the programming code necessary to adhere to the commands that it may receive (Ibrahim, Krawczyk, and Schipporiet, 2004). In traditional design packages the objects provided are only a graphical depiction of a shape, in other words, the computer serves as a pencil. This restricts the stakeholders of the project in the sense that numerous sections and elevations are needed to display a 3D object in the correct form including all its detail, and that it is not possible to view different building elements in isolation.

In BIM design, object-orientated modelling or “intelligent objects” are used (Ashcraft, 2007). Intelligent objects are objects, such as a door or a window, which has all its characteristics and rules embedded in them. Traditionally a designer would draw a line to depict the position of a wall or a door or a type of service. These lines can then only be interpreted by certain people, but not by computers. With BIM however, the designer uses a wall or door object that will automatically take on its characteristics, such as window integrating wholly into a wall (Eastman, 2007). These objects then transfer information between one another, and then adjust it accordingly in order to accommodate the new object, such as the new window (Ashcraft, 2007). The rules imbedded in objects allows for software packages to initiate design changes if necessary or

even adjust the objects automatically as changes are made to the model. The model is therefore basically constructed by itself through pre-programmed building objects creating a spatial experience, which enables the stakeholders to make informed decisions based on proper visualisation (Campbell, 2007).

- Interoperability

Interoperability is defined by the National Institute of Standards and Technology as “the ability to manage and communicate electronic product and project data between collaborating firms and within individual companies design, construction, maintenance and business process systems” (Martinez and Scherer, 2006). The building industry is a highly collaborative industry in terms of information and data sharing in the design and execution processes, and will need to become even more collaborative when using systems and functions such as BIM. Without proper interoperability between the different stakeholders of a construction project, BIM will not be able to take flight.

This interoperability barrier can however be overcome, with the right software solutions and the implementation of BIM standards. Various software companies, such as Autodesk’s Revit, Bentley Systems and Graphisoft, are developing software solutions to facilitate interoperability (Howell and Batcheler, 2005). The National Institute of Building Science has undertaken the task to define BIM standards, and has released the first edition of these standards on March 13, 2007 (Ashcraft, 2007). The purpose of these standards are to: “provide the diverse capital facilities industry with a vision of how to support and facilitate communications throughout the facility lifecycle, from project inception through design and

construction, even past demolition for improved operations, maintenance, facility management, and long-term sustainability.” (Ashcraft, 2007)

The purpose of BIM software is to create and operate on digital databases for collaboration (Autodesk, 2002). For the purpose of this report, the main focus will be on Autodesk’s Revit. BIM applications capture multiple facts, figures and information to manage and store in a database instead of in a format (such as a drawing file or spreadsheet) predicted on a presentation format. It then transforms this information into conventional illustrations or in any other appropriate way that is suitable for that particular stakeholder for revision or editing (Autodesk, 2002), so although each professional works on his own, familiar working view, they are all still working on the same information model. One of the main benefits of this is the co-ordination of changes to the model in such a database, meaning that if a revision is made to a model, in whichever view by one of the professionals, the changes will be immediately depicted in the model and will also be reflected in the associated views (Howell and Batcheler, 2005).

BIM ensures interoperability or collaboration by all the stakeholders, whether individual members working in the same company or other members of the building team. This is accomplished through the distributing and sharing of information through computer networks or sharing files through project collaboration tools (Autodesk, 2002).

- 4D and 5D simulation

One of the well-known aspects of BIM is its multi-dimensionality. The first three dimensions are found in the design of the model, the fourth

dimension incorporated into the model is time and space and the fifth dimension is cost.

The time dimension consists of scheduling and sequencing. Scheduling and sequencing methods are usually used by the contractor or construction manager, to plan and monitor the progress of the execution of a construction project as well as manage the logistics and resources required for the execution of the project. 4D models are formed through linking a 3D design model with a construction schedule (Meadati, 2010). This enables the specific stakeholders to graphically visualise the information represented by the construction schedule. To set up a construction schedule the sequence and duration of all the different activities has to be determined. The determination of the duration of these activities is supported by the 4D model, through the selecting of quantities from the model (Tulke and Hanff, 2007). The project can then be constructed electronically before the physical start of construction, which allows for the optimisation of sequencing through the evaluation of different alternatives (Ashcraft, 2007), and effective site utilisation (Meadati, 2010). It can also be used to foresee what the effects of delays in construction or other scenarios will have on the project schedule or to solve space interference and constructability problems. These 4D models can also be used later in the construction process to show the current construction status or the progress of the project. Although 4D simulations shows a lot of a promise and benefits, users are still reluctant to use it in the construction, post-construction and maintenance phases of the project. As these phases are still accomplished by using 2D drawings, a lack of information exists at the end of the construction stages for the production of as-built models, which will facilitate the implementation of BIM to the post design stages of the project (Meadati, 2010).

One of the main functions in the successful management of a construction project lies in the accurate management of project costs. The BIM allows for information concerning project costs to be linked to 3D or 4D models, ultimately creating a 5D model. With the 5D model an automatic analysis of all materials and components are done, to obtain their quantities directly from the BIM model. These bills of quantities are then linked to databases where information regarding material, labour and other costs are stored, to estimate the project costs. Expenses relating to changes in design can be generated automatically at the click of a button, without the need to measure and recalculate quantities (Meadati, 2010). This allows for quick financial analysis of different design or material options and swift estimation of the current financial status of the project.

2.2.2 Advantages

The application of BIM has the result of many advantages, such as:

- Greater speed

The multi-dimensionality of BIM allows various deliverables and documentation to be prepared simultaneously to the design of the building. Furthermore, the use of object-oriented design and the re-use of information accelerate the creation of drawings (Ashcraft, 2007). Changes made to a certain aspect of the model or the design will be automatically updated through the rest of the project, which allows for major time savings.

- Lower costs

With the use of BIM, major cost savings can be made especially in terms of professional fees. BIM reduces the work load on the professionals, so that they can achieve the same amount of productivity with a fewer amount of people (Autodesk, 2002). Administration costs are reduced as document quality is better and costs are saved on preparing and printing 2D drawings. BIM allows cost information to be updated regularly, and cost implications regarding changes to be shown at early stages of the project so that costs can be managed thoroughly and unnecessary expenses avoided.

- Uniform design base

With traditional methods every stakeholder uses the same information but interprets it in a different way and enters it into a different format. As this information is exchanged between different parties, errors might be transferred with it. BIM ensures that all parties work on the same base model, that coordinates building objects created across various disciplines which will quickly expose errors (Howell and Batcheler, 2005).

- Cost estimating

The model is able to produce cost estimates, bills of quantities and bills of materials which will be automatically updated as the model or any linked cost information changes (Ashcraft, 2007). This reduces human errors that could have crept in when producing these manually.

- Conflict resolution

BIM models allow stakeholders to visualise the design in 3D, which creates an opportunity for parties to detect inefficiencies or discrepancies in design. “Intelligent objects” and other specifications gives software the ability to detect clashes between elements, which gives opportunity to evaluate and resolve these conflicts before they turn into major problems. When evaluating these conflicts, alternatives can be assessed to determine the option most beneficial to the project (Ashcraft, 2007).

- Visualisation and constructability review

Design proposals or different design alternatives can be shown to the client without any effort through the visualisation of the structure. This will allow the client to understand the proposal more easily, which will ensure that the professional team and the client are on the same page, and therefore that better client services are provided (Azhar, Hein and Sketo, 2010). Contractors use BIM models to review the constructability of the building or structure, and identify the challenges involved in the erection of this structure. It also helps to solve the contractors sequence and scheduling difficulties through the incorporation of 4D simulation (Ashcraft, 2007).

- Drawing fabrication

All floor plans, sections and elevations will be accurate and consistent with one another, as they are produced directly from the same model (Howell and Batcheler, 2005)

- Facilities management

If the design, construction and operational information in the model are properly maintained throughout the construction process, it can be used by the owner at later stages to manage the facility (Azhar, Hein and Sketo, 2010).

2.2.3 Barriers

Despite the advantages that BIM holds, there are a number of factors that creates barriers to the full implementation of BIM.

- Slow adopting market

People are not always as enthusiastic to learn, adapt to and implement new methods. BIM will require a shift in the way the construction industry works. Traditional ways of operating will not work as BIM requires major collaboration (BIMForum, 2007). The implementation of BIM into a company will require various time, money and human resources. Office systems will have to be adapted, computer software will need to be updated and staff will need to be trained to use BIM technology. Furthermore, employers are reluctant to require BIM in their contracts as they are afraid of limiting the potential tenderers for the project which will affectively increase the contract amount of the project (Eastman et al. 2008).

- Software and technology

Technology has not yet been developed fully for integrated design, but for one or two-disciplined designs only. This limits the integration functions of the model as the performance of the model is decreased through an increase in the scope of the model. Model management and information sharing is another barrier in terms of technology and software. As various stakeholders are working on the same model a network or server will be needed to store all data and information with regards to the model as well as the model itself. A management system will need to be set in place to manage editing and integrating of the model (Eastman et al. 2008).

- Legal barriers

Changes will have to be made on several contractual and legal aspects to facilitate the use of BIM and the extensive collaboration of professionals (Eastman et al. 2008). The collaborative aspects of BIM cause the responsibilities of professionals to blur. This creates a large barrier in the allocation of risk. The professional reliable for errors, omissions or mistakes on the project will not be determined easily if it cannot be determined who contributed to which activities. Solving of indemnification claims will be made virtually impossible and therefore contract documents will have to be thoroughly adjusted to address these challenges. If not insurances can also be affected as risk allocation will be unclear (Rosenberg, 2006). Another issue associated with BIM that needs to be addressed beforehand in the contract documents, is copyright. With collaboration and the contribution of various stakeholders to a single

model, who will have ownership of this model? (Thomson and Miner, 2006).

2.3 CONCLUSION

This chapter defined BIM, identified its main characteristic and weighed the advantages and disadvantages to the implementation of BIM in the construction industry.

BIM is a practical, multi-dimensional technology that promises to add exponential value to construction projects through higher quality and efficiency, reduction in costs, effective construction management, and improved customer services. It manages projects through its innovative characteristics, and enhances collaboration between the members of the professional team. There is however still many barriers that needs to be overcome before the full implementation of BIM. BIM software needs to be developed further to overcome its current shortcomings, while contract documents needs to address legal pitfalls such as responsibility and risk allocation, insurances, and copyright.

2.4 HYPOTHESIS

2.4.1 Hypothesis

BIM is a multi-dimensional model that acts as a communication and information resource over the lifecycle of a construction project. It consists of 3-dimensional (3D) design functions, cost estimating functions and programming and scheduling functions.

2.4.2 Testing of hypothesis

BIM uses uniform design bases and interoperable software to create a platform for information sharing and collaboration between stakeholders in a construction project. Its multi-dimensionality is made up out of its 3D object-oriented design capabilities, 4D sequencing and scheduling and 5D cost estimating simulation. These characteristics provide for effective design, spatial visualisation, project planning, progress monitoring and cost and material calculations. The hypothesis is therefore correct.

CHAPTER 3

THE RESPONSIBILITIES OF THE QUANTITY SURVEYOR IN A CONSTRUCTION PROJECT

3.1 INTRODUCTION

The construction industry consists of a large variety of organisations which aims to erect, alter or refurbish different building or civil engineering structures. Building clients or developers responsible for the developing of these building or civil engineering structures can range from central and local government and housing associations to private organisations. Their policies and procedures may differ substantially, but the need for aesthetically striking, quality, functional buildings that is economical and cost effective, remains the same (Seeley, 1997). Developers usually employ a group of professional consultants, in order to help them achieve these needs. The quantity surveyor is one of these consultants.

The quantity surveying profession has become a rapid developing profession over the last few decades. As building work becomes more complex and employers becomes dissatisfied with the methods used for controlling and settling the cost of work, an urgent need for an independent quantity surveyor has arisen. Quantity surveying is a vital part of the construction process, from the project initiation phases to project close-out. The quantity surveyor today can be defined as professional consultants that “add value primarily to the financial and contractual management of construction projects at the pre-

construction, construction and post-construction stages” (Ashworth and Hogg, 2007).

Quantity surveying is a profession that demands great knowledge and the correct and skilful use and interpretation of this knowledge. It also requires correct interpretation and understanding of designs and the numerical representation of these designs (BIM Journal, 2009). Cost estimation, feasibility studies, tendering, cost planning, value management, and dispute resolution are some of the activities employed by the quantity surveyor. This chapter will focus on the main responsibilities of the quantity surveyor in a construction project.

3.2 THE RESPONSIBILITIES OF THE QUANTITY SURVEYOR IN A CONSTRUCTION PROJECT

3.2.1 Estimating and viability studies

Developers invest their capital in property development projects in order to receive a larger rate of return on their capital investment than on alternative investment opportunities such as investments in money markets, shares, savings accounts, etc (Pienaar, 2008). In order to determine the rate of return to be received by the developer the project cost and viability need to be determined. Cost estimating is a practice analyzing the project scope and foreseeing the cost of developing the scope (Choon et al. 2007). The estimated cost and the viability of the project are calculated in the initial design phase of the project. Cost estimating is a crucial factor in the pre-tender stages of the project. If inaccurate it can lead to contracting and tendering being insignificant, and tenders being unacceptable or causing developers or contractors to lose money. As estimates has the potential to undermine a project it is crucial to ensure that correct standards and accuracy are upheld during the estimating process (Hackett and Hicks, 2007).

The estimation of project costs and calculation of project viability requires expert knowledge of construction methods, construction cost and other qualitative information such as, procurement methods, the economic climate of the construction and property industries. It involves gathering, evaluating and summarising all the data of the construction project (Choon et al. 2007) and combining it with historical information of similar projects and the correct estimating methodology. Various institutions has set up standard guides for estimating project cost such as “The guide to elemental estimating and analysis for building works” compiled by the Association of South African Quantity Surveyors (ASAQS). There are various estimating methods, each structured in a particular manner to serve a particular purpose, some of which are:

- The cost-per-unit method of estimating relies on a use-factor of a building, such as the number of seats in a school or the number of beds in a hospital to estimate the project cost (Pienaar, 2008). The use-factor is multiplied by a monetary value that is based on historical information. This method of estimating is not a very accurate method and only gives a rough indication of project costs.
- The square-metre method multiplies an approximate inclusive building rate with the construction area of the building in order to determine the estimated project costs. These rates are average expected building cost rates and are dependent on a number of assumptions (Davis Langdon, 2010). There are design variables that can influence these rates such as, the building shape, building size, the fullness on plan, the perimeter/floor area ratio, circulation space, floor to ceiling height, height of the building, contractual differences, differences in finishes, site conditions and market conditions (ASAQS, 2010). This method is one of the most convenient

methods of calculating costs and an efficient technique in controlling the influence that the design has on building cost, and is therefore still used regularly (ASAQS, 2010).

- The elemental method of estimating, although more time consuming, are the most accurate and reliable method of estimating (Pienaar, 2008). In this method of estimating, the estimator divides the project into building elements that has similar functions and then calculates the approximate cost for each of these elements (Choon et al. 2007). Prices are obtained from historical information, or are based on various components such as labour, material, equipment and delivery cost. Allowances for contingencies and escalation are usually included in such an estimate.

The estimated cost of the project then forms the budget or cost base-line that tenders will be measured against. It also forms a critical part in the calculation of the viability of the project. Project viability is calculated by determining ratio between the yearly net income earned from the property and the total capital invested in the property (Pienaar, 2008). The economic climate, market demand, location of the development, and the desirability of the project, are other factors that need to be integrated into the project feasibility and so ensuring a more accurate result. These factors are usually determined through market research and analysis. Project viability results are usually presented under conservative, realistic and optimistic conditions whereupon the client will base his decision of whether or not to proceed with the development scheme (Seeley, 1997).

3.2.2 Preparing bills of quantities

The role of the preparation of bills of quantities by the quantity surveyor has reduced unquestionably over the last few decades. The ability to measure and

analyse construction information in an organized and useful manner remains an important service of the quantity surveying profession (Ashworth and Hogg, 2007). “Bills of quantities are documents in which all the labour and materials needed to construct a building, or other facility, are accurately given in prescribed units according to a standard method and in which the circumstances under which it is to be executed are fully described” (Hauptfleisch and Siglé 2004). Bills of quantities are based on detailed drawings and specifications supplied by the architect or engineer and a standard method of measurement. In South Africa the standard method of measurement “The Standard Method of Measuring Building Work” (1999) as compiled by the ASAQS is used. Most countries have their own standard system of measurement such as the “Australian Standard Method of Measurement of Building Works” in Australia (Davis and Baccarini, 2004) and the Standard Method of Measurement 7 (SMM7) in the United Kingdom.

Bills of quantities have two principal functions:

- Pre-contract:

The main purpose of pre-contract bills is for tendering (Davis and Baccarini, 2004). These bills can either be measured completely and accurately or preliminary, depending on the information available and the type of contract. Bills of quantities provide a common basis for tenders to be compared to, as the contractors tender on exactly the same information (Ashworth and Hogg, 2007). Contractors therefore have to apply minimum effort when tendering, which invites a greater amount of contractors to tender, which leads to more competitive tendering (Davis and Baccarini, 2004).

- Post-contract:
Bills of quantities is a post-contract administration tool and provide a valuable aid for cost planning, valuing of variations, valuations for interim certificates and final accounting (Seeley, 1997). It offers a financial structure for contract administration (Davis and Baccharini, 2004).

Although bills of quantities has shown to be very useful tools, it is a time consuming process and with the amount of detail required in a bill of quantities it is prone to errors, omissions and discrepancies between drawings and the bill of quantities (Davis and Baccharini, 2004).

3.2.3 Procurement and contract administration

Quantity surveyors have a wide knowledge on construction law and especially construction contracts. Projects vary considerably and each project requires an individual solution (Seeley, 1997). The quantity surveyor implements his expert knowledge in the procurement process by advising the client on the type of contract to be used and interpreting the contract and the special clauses in the contract (ASAQS, 2010). Various types of standard contracts are available, such as the JBCC Principle Building Agreement, FIDIC, NEC and the GCC.

According to Ashworth and Hogg (2002) procurement deals with the arrangements for acquiring construction goods and facilities by clients either as private individuals or corporate establishments or public institutions. Some form of competition is usually favored in order to secure the most beneficial result (Ashworth and Hogg, 2002) or a tender sum is agreed through negotiation. There are various procurement routes for the client to choose from. The main systems are:

- Traditional: The client assigns an architect, to produce a design and specifications of the works, as well as other consultants to manage and control the costs of the works (Seeley, 1997). A main contractor is selected, usually through a competitive tender, to carry out the construction of the works (Ashworth and Hogg, 2002).
- Design-and-build: In this contract the contractor take on the design and the construction of the works (Seeley, 1997). The contractor submits a bid which includes design and price information (Ashworth and Hogg, 2002).
- Management: The client appoints design and cost consultants for the design and cost management of the project, and a contractor to manage the construction of the works. The works is then constructed by specialist contractors appointed through negotiation or competitive tendering (Seeley, 1997).

After choosing the procurement method and contract to be used, an invitation to tender is sent out to the various contractors to notify them of the opportunity to submit a tender. The invitation document should contain all the necessary information about the project and the scope of the works and services to be constructed to enable the contractor to compile the appropriate pricing and information in order to submit a competitive tender (Ashworth and Hogg, 2002). Tenders should always be submitted at a specific date and time and no late tenders should be accepted.

Once the tenders are received they are evaluated by the quantity surveyor. The quantity surveyor should ensure that all tenders comply with the tender data

requirements and all the terms and conditions of the contract (Potgieter, 2009). The tenders are compared to and should be in line with the cost base-line or budget that was set up by the quantity surveyor in the cost estimating phase. An appointment recommendation is then compiled by the quantity surveyor that makes a recommendation, based on his expert knowledge, of the most competitive tender to be accepted. The most competitive tender does not necessarily mean the lowest tender. Other factors, such as quality and other preferences affirmed by the client beforehand can also have an influence on the tender results (Potgieter, 2009). Once the tender is awarded to the specific contractor the contract documents are signed by the client and the next phases of the construction process can continue.

3.2.4 Monthly status, payments and cost reporting

Cost control aspires at ensuring that resources are utilised in such a way to ensure that the client receives good quality and value for money (Seeley, 1997). The cost control process needs to be performed continually through the entire construction project. The quantity surveyor controls the cost of the project in the post-contract stage by monitoring any changes to the contract, implementing a budgetary control system and reporting on the project status on a monthly basis.

A budget is an estimate of the income and expenditure for a set time (Oxford dictionary, 2002). The budget of a construction project provides a base-line where all costs and variations can be measured against. The base-line consists of the contract sum that is divided between a number of different work packages or trades. Variations to the contract should be monitored regularly and the costing of these variations should, ideally, be done prior to them being issued to the contractor (Ashworth and Hogg, 2002). The bills of quantities provide a sound basis for the costing and monitoring of variations (Davis and Baccarini,

2010). Great consideration should be given to costs relating to provisional and prime cost amounts, the management of the contingency fund, and the careful examination of subcontractors' and suppliers quotations (Seeley, 1997). A monthly cost report is set up by the quantity surveyor to report on the financial status of the construction project. Regular cost reporting is necessary to keep the client updated with the financial progress of the project, to better foresee possible problems that can arise and therefore ensure that proper financial control is exercised. The monthly cost report consists of the initial budget or the cost base-line, the variations to the contract as well as expected variations still to come and the estimated final amount at completion (Seeley, 1997). The quantity surveyor should also report on the income received to date, the amounts already paid to the contractor up to date as well as certified amounts that are still unpaid.

Most construction contracts will contain provisions for the payment of the contractor for the work done by him at regular intervals. Payment of the contractor at regular intervals bridges various problems and ensures an adequate cash-flow to the contractor (Ashworth and Hogg, 2002). The payments to be made to the contractor are calculated by the quantity surveyor by doing a fair valuation of the work done by the contractor up to the date of valuation. The valuation will also include materials on site, subject to the approval of the principal agent and the conditions of the contract, and materials off site under specific conditions, such as the place it must be stored and the insurances to be in place for it (Potgieter, 2009). Furthermore a fair proportion of the preliminaries should be included, and each time related, value related and fixed value should be measured independently (Ashworth and Hogg, 2002). The security provisions should be adjusted according to the contract and be included in the payment certificate. The interim payment amount can also be subject to contract price adjustment provisions (Potgieter, 2009). All of the

above mentioned factors are included in the interim payment certificate set up by the quantity surveyor. The final amount in the interim payment certificate should then be checked, approved and then signed off by the principal agent.

3.2.5 Final account

The majority of construction projects have a different end result in final costs than was initially agreed between the contractor and the employer (Ashworth and Hogg, 2002). This has brought forth the requirement for a document, a final account, which summarises everything that had an influence on the project costs and calculates the final construction cost of the project.

The final account should usually be issued within a specific period, stated in the contract, from the date of practical completion. Late issue of the final account could result in payment of interest to the contractor (Potgieter, 2009). The quantity surveyor should therefore have the correct systems in place and ask the assistance of the contractor to meet the requirements on time. In the preparation of the final account the quantity surveyor re-evaluates all the factors that will impact on the final construction cost of the development. These include:

- Work executed

All the work done by the contractor should be re-measured in order to determine the correct final amount. It is advisable to re-measure the work as the construction advances. Elements such as foundations, storm water or plumbing and drainage are more easily and accurately measured before it is covered up, and thus should be done before completion of the works. All provisional work and provisional sums

included in the original contract value should be omitted and accurately measured as executed (Potgieter, 2009).

- Variations

All the variations that were issued in terms of the contract through a variation order by the principal agent should be recorded and the needed adjustments to the contract value should be made. The quantity surveyor usually, it is good practice to do so, records and measures variations as the construction work progresses, this prevents work from building up when it is time to issue the final account and adds the value of seeing the work in the course of construction (Ashworth and Hogg, 2002).

- Preliminaries

The preliminaries comprise of the contractor's on-site and contract costs, these could amount to 5 to 20 percent of the contract sum (Seeley, 1997). Preliminary items may be a fixed amount, time related or cost related, or a combination of the group. The preliminaries should be adjusted according to the terms stated in the contract data.

- Contract price adjustments

The contractor usually includes for escalation in his tender amount and the contract then comes into place with the prices in the tender remaining fixed. However, if contract price adjustments (CPA) are applicable it should be calculated strictly according to the contract price adjustment provisions and the CPA should be included with the final account (Potgieter, 2009).

All the factors evaluated are then carried to a summary page to calculate the final construction cost. The final account is then send to the client to be verified (Potgieter, 2009).

3.3 CONCLUSION

In response to the depreciation of the traditional measure and value role of the quantity surveyor, quantity surveyors began exploring new potential roles that they can adapt into their services (Ashworth and Hogg, 2002). This has led the quantity surveyor to evolve into a professional individual who holds expert knowledge on the contractual and financial aspects of a construction development and manages the project cost from project initiation to project close-out. The roles and responsibilities that the quantity surveyor performs have put him on the market as an essential to any construction development.

3.4 HYPOTHESIS

3.4.1 Hypothesis

The quantity surveyor plays a large role in the cost management of a construction project. Some of the main services that the quantity surveyor provides are:

- Financial advisor – this includes preparing budgets, cost control documents and bills of quantities, recommending contract type and delivery process to achieve time and budget as well as preparing tax depreciation calculations.
- Construction advisor – this includes advising on the costs of alternative materials and construction methods, and advising on the

effect of site conditions on the budget and the feasibility of different sites

- Contract administrator – this includes advising on all contractual matters between the client and consultants as well as the client and the contractor

(AIQS, 2003 <http://www.aiqs.com.au/What_is_QS/>)

3.4.2 Testing of the hypothesis

The research in this chapter has shown that the quantity surveyor is involved in construction development projects from the initial planning phases of the project, estimating project cost and preparing a budget, through the procurement and post-contract phases and up to the resolution of final accounts. The quantity surveyor therefore serves as a financial advisor, construction advisor and a contract administrator. The hypothesis statement proves to be correct.

CHAPTER 4

THE COST MANAGEMENT FUNCTIONS OF BUILDING INFORMATION MODELLING

4.1 INTRODUCTION

The construction of building projects are sometimes considered as low capital expenditure when compared to the lifecycle or other operational costs that accumulate over the life of the building. However, the changing economic climate is forcing developers to focus more on the building delivery process and its impact on their business (Eastman et al. 2003). Construction projects are almost always accompanied by unanticipated costs or cost overruns which oblige employers to go beyond initial budget, turn to value management, or in the worst case cancel the project. Surveys have shown that up to two-thirds of developers report cost overruns on construction projects (Eastman et al. 2008). In the case of the British National Westminster Bank Headquarters' building in 1987 the project cost increased to five times the initial estimated cost (Akpan and Igwe, 2001), or in the case of the Scottish Parliament building the building was nearly ten times over budget at the completion of the project (Fortune, 2005). The Sidney Opera House where the project cost was estimated just over seven million Australian dollars and was completed at a cost of a hundred and two million Australian dollars (Steyn et al. 2008) is another example of problematic cost overruns. Cost overruns are a global problem.

Various reasons can be attributed to causing cost overruns such as increasing costs due to inflation, inadequate analysis and inadequate information. Another

reason attributing to cost overruns is inadequate costing methods and management (Akpan and Igwe, 2001). Studies indicate clients to be generally dissatisfied by the output of services provided by construction cost consultants (Fortune, 2006).

It is clear that the construction industry worldwide has a pressing need for accurate cost estimating in early stages of the design phase as well as better cost management techniques throughout the construction process. This chapter will examine the costing and cost management functions of BIM and case studies where it has been a useful tool in managing and preventing cost overrun problems.

4.2 THE COST MANAGEMENT FUNCTIONS OF BUILDING INFORMATION MODELLING

4.2.1 Bills of quantities

Bills of quantities are one of the main tools used in the cost management of construction projects. The automatic production of bills of quantities is one of the functions that BIM technology developers pride themselves on as the fifth dimension of BIM. The automation of bills of quantities is one of the functions that enhanced BIM technology to be fully collaborative and integrative.

The primary and core component of the 5D concept is a properly configured 3D model of the building (Popov et al. 2009). As discussed in chapter two, a properly produced BIM uses parametric modelling and object-orientated modelling to assign construction data, such as the physical properties and functional peculiarities, to each building element modelled (BIM Journal, 2009). In order to demonstrate this, consider the following example: A door built into a

wall will merely be shown on the BIM model as a simple door. With parametric modelling and object-orientated modelling however, the door is linked to various elements. The BIM model will know the size of door, that the door must have a frame, that it is to be built into a half brick or a one brick wall, that the door and frame must be painted, and that the door must have a lock and handle. All of this is information needed to compile bills of quantities. "Put simply, the model's in-built intelligence knows what each building element is, where it is located, what it is made of and how much there is of it. In other words, the model can automatically create a bill of quantities" (BIM Journal, 2009).

However, to obtain a bill of quantities that is of any worth, the model has to be produced in such a manner to enable it to generate a bill of quantities that is configured to construction methodology (BIM Journal, 2009). The building model must not just have the ability to quantify the building elements, but must be able to group them according to the correct building trades and construction processes. In order to do this the necessary framework needs to be in place to characterize the design protocols for the model. A work breakdown structure (WBS) and the standard method of measurement (SMM) have proven to create the necessary structure, and once this has been clarified the BIM will be able to produce properly set out and accurate bills of quantities (BIM Journal, 2009).

The automation of the production of bills of quantities therefore eliminates tedious traditional take off methods and at the same time reduces human error.

4.2.2 Cost estimates

BIM technology can extract accurate quantities and spaces that can be used for cost estimating at any period of the design of a project. Different information is applicable to different stages of the design phase, and advantage should be

taken of information available and where not reasonable assumptions should be made (Eastman et al. 2008). In the early stages of the design phase, when the design is still conceptual and limited information is available, cost estimates are typically based on a cost per unit or cost per square metre (Eastman et al. 2008). The BIM model can easily make available design variable information, such as the floor-to-ceiling height of each area, the perimeter/floor area ratio, the height of the building, etc which needs to be taken into account as it can have an impact on the cost per unit or cost per square metre rates.

As the design matures, decisions are made and building elements become more specific, more information becomes available on which the cost estimate can be based. The BIM is updated and becomes more detailed as the design phase progresses. Accurate and more detailed spatial and material quantities or bills of quantities can then be extracted from the BIM and with the easy visualisation of the model it becomes clear which elements have been costed and which elements still requires attention. It also allows estimators to identify and communicate relationships between quantities, costs and locations, and distinguish how areas and components of the building are contributing to the total cost of the project (Vicosoftware, 2010). The realisation and understanding of cost-determinants enrich the competence of cost estimators and along with the accuracy of the quantity take-off produced by the BIM enables the estimator to produce reliable and accurate cost estimates in the early stages of the design phase (Elhag et al. 2004).

4.2.3 Rapid updating of costs

By integrating cost estimation with a BIM design tool it allows designers, estimators and clients to carry out value management throughout the design phase (Eastman et al. 2008). As design changes are made to the BIM the cost

estimate can be automatically updated with quantities extracted from the modified model, without the estimator needing to take-off quantities. The client will be able to consider different design alternatives, while at the same time evaluating the costs related to the alternatives. Incremental value management while the project is being developed allows realistic assessment throughout the design of the project (Eastman et al. 2008), which can result in valuable cost savings and resource utilisation.

This BIM cost management function can be extended beyond the pre-construction stage of the project. Through using the same principles costs of variation orders in the construction phase can be calculated. The BIM facilitates collaboration between the different design disciplines. All the various project participants will therefore have access to the information in the BIM. As variations are implemented into the BIM, and costs are updated automatically, all project participants will be able to extract the cost of the changes they make and therefore always be informed of the cost implications of the variations issued by them. The quick calculation of variation orders will facilitate in speeding up and simplifying the production of information for cost reporting and monthly valuations.

If the BIM is properly upheld during construction, it becomes an instrument that can be used by the owner to manage and operate the structure or facility (Ashcraft, 2007). In order to take advantage of the facility management functions of BIM, owners need to work closely with the project participants to ensure that the BIM provide sufficient scope, level of detail, and information for facility management purposes (Eastman et al. 2008). The BIM can be used for managing renovations, space planning and maintenance operations. By rapid updating of the model and therefore costs of the building, modifications and upgrades can be evaluated for cost effectiveness.

4.3 CASE STUDIES

4.3.1 Hillwood Commercial Project

“This case study demonstrates the potential for building information models to support conceptual estimating early and often in a project and during the conceptual design and development phase” (Eastman et al. 2008).

Project information:

- Developer: Hillwood Development
- Architect: Beck Group
- Project scope: Office-retail facility
- Contract type: Lump-sum
- Size: 12 541.50 m²
- Floors: 6

The Beck Group provides conceptual estimating as part of its standard services for architectural design. They started producing the 3D model as soon as the owner approved the conceptual design and prior to the schematic design phase. A preliminary cost estimate was developed and then used to explore various design options and evaluating the costs associated with each of the design alternatives. The iterative process involved exploration of design alternatives, calculation of cost estimates, and presentation to the client. Since the Beck Group is a design-build firm, they are able to rely on internal design and construction knowledge. (Eastman et al. 2008)

DProfiler, a BIM based solution were utilized by the Beck Group to generate accurate cost estimates from a 3D design model. DProfiler is a 3D BIM tool that develops a parametric building model that are linked to cost items from a

database, and makes real-time cost information available. As the model are updated with more detailed information, the cost estimate updates simultaneously and the latest estimated costs can be viewed and costs can be associated with specific design features. (Eastman et al. 2008)

Various design alternatives and what-if scenarios were evaluated by the design team. If the option were found to be over budget, other cost options were evaluated, such as changing floor-to-floor heights, adding and removing a floor in order to increase or decrease the construction area, relocating the garage component from below to above-grade, changing the building into a potentially more efficient shape. (Eastman et al. 2008)

The following benefits were realised by the owner and the design team:

- Reduction in estimating labour-hours when producing a cost estimate due to automatic quantity take-off and rapid updating of quantities.
- Analysing and evaluating costs associated with design changes, therefore having accurate estimates in real-time
- Eliminating errors and omissions caused by oversight by visual representation of the estimate. (Eastman et al. 2008)

The estimating so early in the design process yielded many significant benefits for the owner and the design team and prevented various potential losses and cost overruns. (Eastman et al. 2008)

4.3.2 Hilton Aquarium

Project information:

- Developer: Holder Construction

- Project scope: Hotel and parking structure
- Contract type: Guaranteed maximum price
- Contract sum: \$46 484 000

Digital models were created, during the design phase, of the architectural, structural and mechanical, electrical and plumbing systems of the planned building, using detail level information from subcontractors based on drawings from the designers. Throughout the project, project coordination sessions were held by the project team to efficiently identify and resolve system conflicts and design coordination and through collaborative viewing detect potential clashes and time delays. Table 1 indicates the cost and time savings as a result of using BIM on this project. (Azhar et al. 2010)

Collision Phase	Collisions	Estimated Cost Avoided	Estimated Crew Hours	Coordination Date
100% Design Development Conflicts	55	\$124,500	N/C	June 30, 2006
Construction (MEP Collisions)				
Basement	41	\$21,211	50 hrs	March 28, 2007
Level 1	51	\$34,714	79 hrs	April 3, 2007
Level 2	49	\$23,250	57 hrs	April 3, 2007
Level 3	72	\$40,187	86 hrs	April 12, 2007
Level 4	28	\$35,276	68 hrs	May 14, 2007
Level 5	42	\$43,351	88 hrs	May 29, 2007
Level 6	70	\$57,735	112 hrs	June 19, 2007
Level 7	83	\$78,898	162 hrs	April 12, 2007
Level 8	29	\$37,397	74 hrs	July 3, 2007
Level 9	30	\$37,397	74 hrs	July 3, 2007
Level 10	31	\$33,546	67 hrs	July 5, 2007
Level 11	30	\$45,144	75 hrs	July 5, 2007
Level 12	28	\$36,589	72 hrs	July 5, 2007
Level 13	34	\$38,557	77 hrs	July 13, 2007
Level 14	1	\$484	1 hrs	July 13, 2007
Level 15	1	\$484	1 hrs	July 13, 2007
Subtotal Construction Labor	590	\$564,220	1143 hrs	
20% MEP Material Value		\$112,844		
Subtotal Cost Avoidance		\$801,565		
Deduct 75% assumed resolved via conventional methods		(\$601,173)		
Net Adjusted Direct Cost Avoidance		\$200,392		

Table 1: An illustration of cost and time savings via BIM in Hilton Aquarium Project (Azhar et al. 2010)

Through proper collaboration of BIM between the project team members and therefore efficient design coordination, clash detection and work sequencing an estimated \$600,000 and 1143 labour hours were saved on the project. (Azhar et al. 2010)

4.3.3 Other US based projects

Table 2 illustrates the savings that occurred in projects where BIM was used, as well as the BIM return on investment (ROI) in ten different US based projects.

Year	Cost (\$M)	Project	BIM Cost (\$)	Direct BIM Savings (\$)	Net BIM savings	BIM ROI (%)
2005	30	Ashley Overlook	5,000	(135,000)	(130,000)	2600
2006	54	Progressive Data Center	120,000	(395,000)	(232,000)	140
2006	47	Raleigh Marriott	4,288	(500,000)	(495,712)	11560
2006	16	GSU Library	10,000	(74,120)	(64,120)	640
2006	88	Mansion on Peachtree	1,440	(15,000)	(6,850)	940
2007	47	Aquarium Hilton	90,000	(800,000)	(710,000)	780
2007	58	1515 Wynkoop	3,800	(200,000)	(196,200)	5160
2007	82	HP Data Center	20,000	(67,500)	(47,500)	240
2007	14	Savannah State	5,000	(2,000,000)	(1,995,000)	39900
2007	32	NAU Sciences Lab	1,000	(330,000)	(329,000)	32900

Table 2: BIM Economics (Azhar et al. 2010)

“The large variance in the BIM ROI for the different projects is due to the large data spread which makes it hard to conclude an exact range for BIM ROI. BIM functions responsible for savings on the projects range from collision detection cost avoidance to planning or value analysis cost avoidance. The data analysed in this table does not include indirect or other second wave cost savings that were recognized as a result of the use of BIM and therefore the actual BIM ROI will be much higher than reported here.” (Azhar et al. 2010)

4.4 CONCLUSION

BIM uses digital modelling to simulate the planning, design, construction and operation of a project (Azhar et al. 2010). The main focus of BIM is therefore the design functions and collaboration between different designers. Although not part of the main functions of BIM the cost management functions of BIM have proven to be an extremely beneficial tool to the construction industry. “The accurate and computable nature of building information models provides a more reliable source for owners to perform quantity take-off and estimating and provides faster cost feedback on design changes” (Eastman et al. 2008). BIM can therefore be used for the production of bills of quantities, cost estimating at various levels of the project, rapid updating of costs due to design changes and costing of maintenance, space planning or renovation alternatives in the post-construction phase of a project.

4.5 HYPOTHESIS

4.4.1 Hypothesis

Some of the main cost management functions of BIM are:

- generating bills of quantities
- generating square metre estimates
- generating cost estimates
- rapid updating of costs as the design or material changes

4.4.2 Testing of the hypothesis

The case studies discussed in 4.3 shows that BIM consists of cost control functions that has the ability to save time and money. Bills of quantities are produced from all of the information embedded in the model. The bills of

quantities are then employed to produce square meter estimates at the conceptual design stage of the project and more accurate cost estimates as the BIM and therefore the bills of quantities are updated with more recent and more comprehensive data. Costs are rapidly updated throughout the project stages by updating the model with the latest design and material changes and then automatically updating the bills of quantities and project cost. The hypothesis statement is therefore true.

CHAPTER 5

INCORPORATION OF BUILDING INFORMATION MODELLING INTO THE QUANTITY SURVEYING PROFESSION

5.1 INTRODUCTION

The quantity surveying profession is, like many other professions, an evolving profession that needs to continue to change to meet the ever changing conditions of the building industry (Ashworth and Hogg, 2007). Information technology has had an impact on various processes and has influenced everyone differently. It has become something we rely on because of its high standards and efficiency. The history of quantity surveying and the way quantity surveying tasks were performed provides enough substantial evidence to show how information technology has changed the way quantity surveyors perform their duties. Computers and information technology has made a much needed improvement, especially in such a fast developing industry, on the speed and efficiency of the professional services of the quantity surveyor (Ashworth and Hogg, 2007).

BIM is another form of information technology that promises to revolutionise the building industry. With the implementation of new technology there usually is a learning curve that needs to be overcome as well as a series of other challenges to resolve. Although the changes that BIM brings to the table could make great improvements to the industry, there are still disadvantages that need to be considered and overcome. This chapter discusses the challenges that the

quantity surveyor faces and actions needed to be taken in order to collaborate and incorporate BIM into the profession.

5.2 THE STEPS TO BE TAKEN AND CHALLENGES TO BE FACED BY THE QUANTITY SURVEYOR WHEN INCORPORATING BUILDING INFORMATION MODELLING INTO THE QUANTITY SURVEYING PROFESSION

5.2.1 Software and computer systems

Regardless of the many limitations of the collaborative capabilities of software supporting the traditional methods for developing construction products, most professionals prefer such system because:

- “The traditional approach to ‘software implementation’ enables the systems to be user-friendly
- They offer a gradual change to using automated systems;
- Most systems present data in traditional paper format such as take-off paper
- Other reasons” (Matipa, 2008)

Current systems seem to be working well, yet they severely impact on the pace at which the quantity surveyor performs his responsibilities at the design stage of the construction project (Matipa, 2008). Cost estimates are prone to contain various inaccuracies as they are usually based on limited information and prepared within a limited time frame (Aibinu and Pasco, 2008). It is shown in figure 1 that cost and staffing levels are low at the commencement of the project and increase towards the end. In order to maximise economic sustainability on the preliminary and operating cost of a construction project, more professional

expertise needs to be employed in the initial design phases of the project, as indicated by the blue curve in figure 1 (Matipa, 2008). As a result, computerised estimating tools and techniques have become an indispensable tool in the estimating process because of their effectiveness, consistency and accuracy in formulating estimation of deliverables and sub-deliverables (Matipa, 2008).

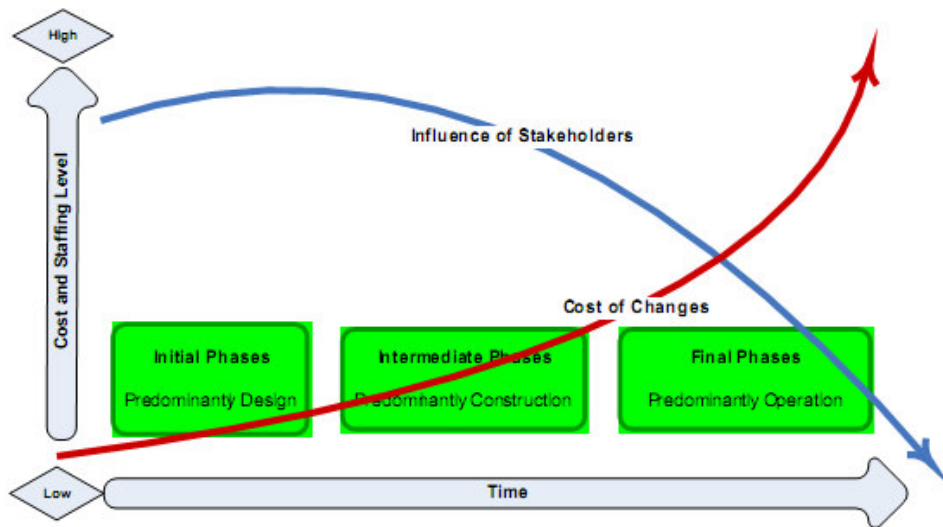


Figure 1: Sample Generic Life Cycle versus Overall Impact on Budget (Cost) on the Project (Matipa, 2008)

As BIM gains more and more importance in the design process of a construction project, the cost control process also has to be integrated into the collaborative model based working environment. In an ideal BIM environment the first step would be the design of a 3D model of the client's proposal, the second will be to automatically generate resource demands, cost calculations or estimates, list of product specifications and bills of quantities (Popov et al. 2008). This requires the extraction of all dimensions and information on building components from the 3D model and then combining it with databases containing unit costs and other data. Data in such data bases will need to be updated on regular intervals, as the economic climate seldom stays the same therefore cost

estimating will seldom be fully automated (Bazjanac, 2010). Traditional methods to sharing project information via file exchange using formats such as .dxf, .dwf, .dwg and .pdf do not transfer the appropriate levels of object intelligence from one model to another (Howell and Batcheler, 2005). According to Bazjanac (2010) “creating a BIM makes sense only if software is available to populate the BIM with data that can be reused by other software, and only if software exists to extract and import data from a BIM.” In an environment where all the project consultants works on an integrated system, quantity surveyors is still faced with data compatibility problems as most software runs proprietary file formats (Matipa, 2008). Traditional computerised estimating and costing tools used by quantity surveyors will need to be adjusted in order to be compatible with the latest BIM software.

BIM uses Industry Foundation Classes (IFC) to create interoperable multi-dimensional technology. “IFCs are data elements that represent the parts of buildings, or elements of the process, and contain the relevant information about those parts. IFCs are used by computer applications to assemble a computer readable model of the facility that contains all the information of the parts and their relationships to be shared among project participants. The project model constitutes an object-oriented database of the information shared among project participants and continues to grow as the project goes through design, construction and operation” (Internet.com, 2010). If the exchange of data in an IFC file is done through “physical file” exchange, the software utilised in the exchange must be compatible with the specific version of IFC in which the BIM was generated. If not, the software will not be able to import the IFC file or write to it (Bazjanac, 2010). Figure 2 depicts the generation of an IFC based BIM and cost and energy performance estimates using data from that BIM. The IFC2x2 file is the component that contains all the data on building components, definitions and quantification for the specific BIM (Bazjanac, 2010).

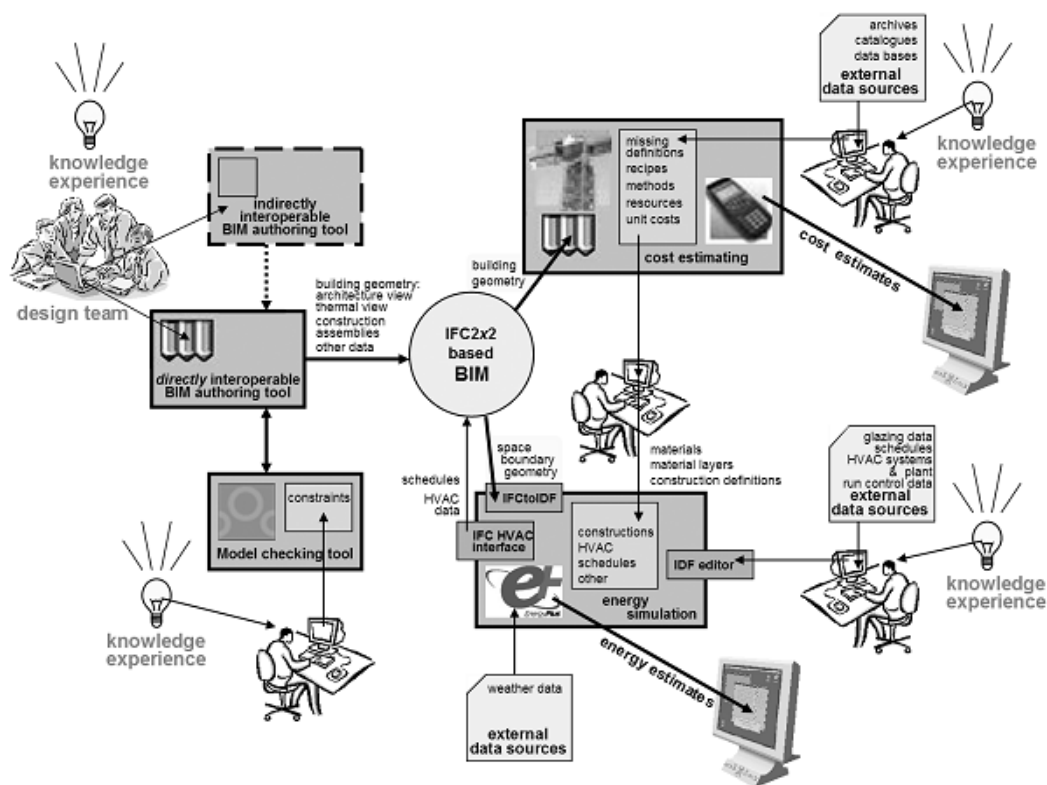


Figure 2: Data generation and flow in current cost and energy performance estimating (Bazjanac, 2010)

The estimator then imports the data from the IFC2x2 file and uses external sources, such as data bases, catalogues, historical information from previous projects and his expert knowledge, to assign unit costs to the imported data and quantities.

It is therefore important to continue in developing software that is compatible to IFC BIM software, and can be used in an interoperable environment where different file formats and data are shared effortlessly between the consultants involved. It must also be able to ensure accurate importing of quantities and as much data from building components as possible into a user-friendly estimating interface that can effortlessly be revised as changes occur, so that further

costing can be done and estimates can be created quicker with prestige accuracy.

5.2.2 Adjusting services and responsibilities

It has been said that quantity surveyors earn their living from the production of bills of quantities and the resolution of final accounts. Traditionally, when the design of the proposed project is at a point where it can almost be frozen, the quantity surveyor starts to prepare bills of quantities and other documentation that can support the procurement process. Estimating in the design phase is usually conceptual and is based on limited project information, with the consequence that quantity surveyors are more involved in the latter part of the design appraisal process (Matipa, 2008). The evolution of the construction industry into a more complex and competitive industry, has forced the quantity surveyor to produce cost information with a limited scope and within a limited timeframe. Adaption to the changing circumstances has become critical to quantity surveyors in order to remain within their leading role as cost managers.

Multiple computer applications have already been developed to automate certain surveying responsibilities in order to alleviate some of the pressures caused by time constraints and competitiveness. Quantity takeoff and bill generation is a very time consuming process that are prone to error (BIM Journal, 2009), and although it is only a small part of the cost management process it takes up a lot of the quantity surveyor's focus and attention. BIM contains 5D simulation which gives it the ability to automatically generate quantities from the model and data captured within the model. In other words, it is able to automate one of the essential traditional tasks of quantity surveying. This leaves the quantity surveyor to adapt some of his tasks or responsibilities.

The use of a BIM model in the early design phases of the project enables the quantity surveyor to produce estimates from accurate quantities obtained from the model. Making available such accurate cost information in such early stages of the project can enable the quantity surveyor to fully participate in the design process (Matipa, 2008). The automation of bills of quantities reduces error and misunderstanding and evolves in step with the design changes (Ashcraft, 2007). It removes some of the tedium and speeds up the process (Ashworth and Hogg, 2007). This leaves more time for analysis, interpretation and organisation of data into a logical, consistent and cognisant format, and shifts the traditional role of costing a design to designing to a cost (Matipa, 2008). Designing to a cost satisfies the demand for 'value for money' and therefore fulfils one of the cardinal responsibilities of the quantity surveyor (Mayer and Petric, 2003).

The automation of bills of quantities unfortunately brings disadvantages to the table as well. Bill production is usually one of the most regular tasks performed by quantity surveyors. The automation of this task will enable them to get more work done with a smaller production team. This will lead to a reduction in staff needed which results in a reduction of size of quantity surveying practices. Quantity surveyors will need to overcome these obstacles by continuing to reinvent themselves and continually adding value and enhancing their professional services (Ashworth and Hogg, 2007).

Complex projects will seldom consist of one BIM only. Different consultants will have different models, for example the architect will have a design model, the structural engineer an analysis model and the contractor a construction model (Ashcraft, 2007). Information between these models needs to be shared in order to avoid inefficiencies and inaccuracies. Interoperability can be defined as "the ability to manage and communicate electronic product and project data between collaborating firms and within individual companies' design,

construction, maintenance and business process systems” (Aranda-Mena and Wakefield, 2010). The continuous data exchange between construction professionals will have to be properly managed in order to prevent inaccuracies of data re-entry and ensure consistency between models. This creates the need for an individual to manage the data exchanged between consultants.

According to Matipa (2008) some of the characteristics of such an individual would be:

- “A team player;
- With vast construction business expertise;
- Not party to construction contract because of inherent conflict of interest;
- Serving the client’s interest;
- Ability to update the repository, with high ICT skills;
- Unbiased to any profession”

The quantity surveyor is responsible for the management of costs through the whole of the project and is involved from the feasibility and design stage up to the completion of the project and can have responsibilities such as calculating replacement cost or estimation for insurance purposes after construction (Matipa, 2008). The production of cost information throughout the project relies on the entire project team members’ work, and therefore data is received by the quantity surveyor from every project team member. The quantity surveyor is a key member in the data exchange of the project and seems to be a front runner to manage the repository with the result of resolving potential problems before they arise (Matipa, 2008)

5.2.3 Training and expenses

The development of new technology and the implementation of new methods and tools usually go hand in hand with multiple expenses and a lack of

knowledge and skill relating to the technology. The transition phase from traditional methods to “new generation” BIM technology will not come without the necessary challenges.

The lack of knowledge and skill relating to sophisticated software and techniques are usually easily overcome through training programmes, seminars, workshops and software tutorials. Software developers are usually prone to provide training programmes to companies implementing their software. Training programmes are usually presented by experts involved with the development and utilisation of software within the construction industry. Staff will not only need training in the use of a new software but also in the changes in responsibility, changes within the organisation itself as well as the change in use of the information that is extracted from the BIM (Rundell, 2005).

The latest technology and keeping a competitive advantage always comes at a cost. Software is in general a large expense and is not something that is replaced without the necessary thought and budgeting. The transition to and implementation of new methods and software usually creates heavy time constraints for companies. As companies cannot afford a standstill in production while implementation and training is undergone, employees need to keep on producing while training is undergone and new systems are learned (Rundell, 2005). The slowdown of production in the transition period and the training undergone also adds substantial costs to a company's expenses.

Another concern shaped by BIM technology is that it could have an impact on professional fee structures. Traditional provisions for professional fees are largely driven by conservative fragmented concepts. New skills will be required by project team in order to use BIM with significant outcomes and fee scales will need to be adjusted in order to commensurate with professional responsibilities (Olatunji and Sher, 2010). The automation of various functions through BIM

means that smaller production teams will be needed and resource input into a project is therefore reduced (Autodesk, 2002). This brings forth the argument that as BIM reduces the resources needed for a construction project and costs are saved on the reduction of resource, professional fees needs to be adjusted downward. However, there are opportunities for the quantity surveyor at the initial design phases of the project. As one of the goals of BIM is to ensure total cost management, it requires the employment of a quantity surveyor as early as possible in the product development, in order to facilitate sustainable construction (Matipa, 2008), as established in the research in 5.2.2. Experts and professionals in the various professional associations will need to take the issue regarding professional fees into serious consideration as it will have an immense impact on the professionals in the construction industry.

5.2.4 Adjusting contractual aspects related to BIM specific projects

Although BIM has changed the industry technologically in so many ways there are still missing links in the legal aspects to fully the support this collaborative environment. The various contributors to a single BIM project cause their responsibilities and work products to become blurry, and as a result the allocation of risk becomes almost impossible (Rosenberg, 2006).

In the event of inaccuracies or mistakes someone needs to be held responsible to the client for the inaccurate data entry. This brings the question to mind: “Should design decisions be tracked to their precise originators in order to assign risk, or does an “open information project” imply equally shared responsibility?” (Bernstein and Pittman, 2004) For example, inaccurate data is entered into the BIM, from this model various information such as bills of quantities are produced. The inaccurate quantities leads to inaccurate cost reporting. Who needs to be held liable for the inaccurate data entry, the

designer, the quantity surveyor, or both? With shared risk, come shared rewards (Bernstein and Pittman, 2004). Not only is shared responsibility and reward an uncertainty but also ownership or shared ownership of the data. As the client are buying the design and the services of the consultants, the owner may feel entitled to own it, but as the consultants are providing proprietary data to the project, they are entitled to ownership as well (Thomson and Miner, 2006).

Current legal frameworks have remained fairly unchanged for long periods. Subsequently, in order to steer future and recent developments in the direction of technological changes, existing legal systems must be re-engineered to achieve the necessary objectives when necessary (Olatunji and Sher, 2010). Lawyers will need to keep up with and familiarise themselves with current technological developments in order to realise the specific legal requirements associated with BIM (Hartman and Fischer, 2007). In order to address these uncertainties the expectations, responsibilities and liabilities of the project will need to be clearly defined; stakeholders will need to agree on a common BIM-based project delivery approach that is supported by a legal structure (Olatunji and Sher, 2010) and the responsibility for the accuracy and coordination of design and cost data will need to be addressed contractually (Olatunji and Sher, 2010). The American Institute of Architects (AIA) and the National Institute of Building Science (NIBS) are part of only a few organisations that have started to address these issues. The AIA has developed and formalised legal regulations relating to digital design technology (Olatunji and Sher, 2010) whereas the NIBS has started documenting and defining standards for BIM (Ashcraft, 2007).

5.3 CONCLUSION

BIM is a development aimed at integrating working systems and adding value to building economics and project delivery (Matipa, 2008). It offers to remove

routine and drudgery from many activities and produce high standard results (Ashworth and Hogg, 2007). Quantity surveyors are still relaying on the production of bills of quantities to feature as their main line of business, this is reducing substantially due to the automation of this task (Matipa, 2008). The changing role of the quantity surveyor lies in the ability to remain key advisors on the financial and contractual decisions on construction developments. Quantity surveyors need to keep reinventing themselves and continually add value and enhance their professional services (Ashworth and Hogg, 2007). Quantity surveyors that are able to overcome these challenges will secure their future in the technologically developing industry.

5.4 HYPOTHESIS

5.4.1 Hypothesis

To incorporate BIM efficiently into the Quantity Surveying profession, Quantity Surveyors will need to focus on the following aspects:

- updating software and computer systems in the work place
- undergoing training on the cost management functions of BIM
- adjusting their services and responsibilities to the cost management functions of BIM
- gaining knowledge on the new contractual aspects that is related to BIM on specific construction projects

5.4.2 Testing of hypothesis

Although correct, the hypothesis statement in 5.4.1 is not sufficient in some of the challenges that will still need to be faced when fully incorporating BIM into

the quantity surveying profession. Not only will software need to be updated, but an enormous focus needs to be placed on the interoperability of software between various consultants. Another factor that the hypothesis does not take into account is the influence that BIM will have on the structure of the profession. The size and structure of firms will be influenced, as well as the professional fee structure, and will need to be re-evaluated in detail to overcome the obstacles presented by these factors.

CHAPTER 6

THE INFLUENCE OF BUILDING INFORMATION MODELLING ON THE QUANTITY SURVEYING PROFESSION

6.1 BACKGROUND

Traditionally quantity surveyors fulfilled the role of measuring and valuing construction works. With the deterioration of this role, quantity surveyors have been evolving and adapting their services that have led them to become professional experts on the contractual and financial aspects of construction developments and the management thereof. Cost estimation, feasibility studies, tendering, cost planning, value management, and dispute resolution are the main activities performed by quantity surveyors that makes them an essential contributor to any construction development.

The purpose of most construction projects is usually to obtain a product that is good quality, great value for money and therefore provides a sufficient return on investment. The need for cost effective, quality, “green” construction has brought new technologies forward in the construction industry. In order to keep up with a competitive industry professionals need to evolve with technology and constantly bring new technology into play. BIM is one of the latest technologies that have been stirring up the construction industry. BIM is a practical, multi-dimensional technology that promises to add exponential value to construction projects through higher quality and efficiency, reduction in costs, effective construction management, and improved customer services. BIM uses digital

modelling to simulate the planning, design, construction and operation of a project (Azhar et al. 2010). The model containing all the physical and functional characteristics of the facility serves as an information resource that is shared between the various parties involved and forces collaboration between the different stakeholders. It manages projects through its innovative characteristics, and is aimed at integrating working systems and adding value to building economics and project delivery (Matipa, 2008). Although its main functions are the design and interoperability of the model and its information, it still holds many other functions that promise to be of great use to professionals other than designers.

BIM does not only provide construction project management and scheduling facilities but it also contains various cost management functions that will come in handy to quantity surveyors. “The accurate and computable nature of building information models provides a more reliable source for owners to perform quantity take-off and estimating and provides faster cost feedback on design changes” (Eastman et al. 2008). The model automatically analyse all materials and components and extracts quantities directly from it. It offers to simplify some of the traditional tasks performed by quantity surveyors and remove routine and drudgery that come with such tasks. BIM can therefore be used to automatically produce bills of quantities and through this also produce cost estimates at various levels of the project, rapidly update costs due to design changes and calculates maintenance costs, and evaluate space planning or renovation alternatives in the post-construction phase of a project. Through the automation of the production of bills of quantities quantity surveyors will be able to produce deliverables much more efficiently and timely, and at higher and accurate standards.

There is however still many factors that needs to be evaluated and barriers that need to be overcome before quantity surveyors will be able to fully implement BIM into their work environment. Quantity take-off and estimating software will need to be upgraded to overcome shortcomings and be made consistent and compatible with BIM software. This must provide for different file formats to enable the share of data effortlessly between the different consultants involved. Quantity surveying software should therefore be developed to be used in a fully collaborative environment. The upgrading of software and implementation of new methods into a working environment usually brings forth various expenses and training needs that will need to be addressed. In the case of BIM there are also various legal issues that will need to be taken into concern to overcome legal pitfalls created by BIM, such as professional responsibility and risk allocation, insurances and copyrights.

The changing role of the quantity surveyor lies in the ability to remain key advisors on the financial and contractual decisions on construction developments. Quantity surveyors need to keep reinventing themselves and continually add value and enhance their professional services (Ashworth and Hogg, 2007). Implementing BIM into a quantity surveying firm will enable quantity surveyors to do their work more accurately and efficiently, which will give them a competitive advantage. The successful implementation of BIM will however not happen without affecting the quantity surveying profession in some way or another. The cost management functions of BIM will change the process of cost management of construction projects, which will shift the responsibilities of the professionals involved, forcing quantity surveyors to focus on different parts of the cost management process and create new responsibilities and opportunities for themselves, and rearrange the structure that they work in.

6.2 SUMMARY

BIM is a 3D design and modelling technology that contains costing and scheduling elements made possible by its parametric and object-orientated characteristics. The cost management functions of BIM will bring various advantages to the production side of quantity surveying. The full implementation of BIM will however have an effect on the responsibilities and the structure of the quantity surveying profession that will need to be evaluated in order to fulfil successful implementation of BIM.

6.3 CONCLUSION

The aim of this research report was to study the influence of BIM on the quantity surveying profession. One of the most apparent and vital consequences that will result from implementing BIM into the quantity surveying profession is the effect that it will have on the traditional roles and responsibilities of the quantity surveyor and the structure of quantity surveying firms. BIM's capabilities of automating the production of bills of quantities, which is one of the quantity surveyors fundamental tasks, will have both positive and negative effects on the quantity surveying industry. The automatic production of bills of quantities will enable quantity surveyors to get involved in the early design stages of a construction project and make designers aware of cost implications and manage costs from early on. This will enable designers to design to a cost instead of quantity surveyors costing to a design, which will satisfy the employers need for cost effective construction.

In the past measurement was usually undertaken by senior quantity surveyors, but over the years it has diminished into a task delegated to more junior personnel while professional quantity surveyors take up more strategic roles

(Ashworth and Hogg, 2007). With BIM automating quantity take-off, junior quantity surveyors will not play such a significant role in quantity surveying firms as before. This could change the need for large production teams in quantity surveying firms and cause quantity surveying firms to become smaller. The reduction in labour hours and human resource due to the automation of this vital task can have an impact on the professional fees earned by quantity surveyors. As fewer resources are placed into the production of cost information, professional fees will have to be adjusted accordingly.

The time saved by BIM capabilities will give quantity surveyors the opportunity to develop and focus on other activities that might not be seen as essential in traditional practices, but that will offer major benefits to employers. New services can be rendered by quantity surveyors such as managing the vast and continuous data exchange between the different consultants of a BIM based construction project, or they can specialise in existing practices such as value management.

The continuously changing and technologically evolving construction industry has forced quantity surveyors to evolve with it in order to meet these ever changing needs. The research in this report has confirmed this statement, and has shown that BIM, although a great advantage to the construction industry, will oblige quantity surveyors to keep reinventing themselves and develop the scope of their services in order to maintain their leading role as construction cost managers.

6.4 FURTHER RESEARCH

The research in this report is subject to various limitations and leaves opportunity for further and more extensive research.

The following are general areas that can be used for future research projects:

- The use of Building Information Modelling in South Africa
- Building Information Modelling: Setting trends for multi-purpose construction firms
- The use of Building Information Modelling in facilities management
- The effect of Building Information Modelling on the legal aspects of the construction industry

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