Information Management, on Construction sites, is Building Information Modelling (BIM) the Solution?

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Declaration by student

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

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Signature of acceptance and confirmation by student

Abstract

Title of treatise:	Information management, on construction sites, is Building Information Modelling (BIM) the solution?
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More and more delays are being caused on construction sites due to a lack of the correct information necessary to complete the project within the set time frames and cost effectively.

The object of this treatise is to investigate the appropriateness of a BIM as a tool to be used to solve this information management problem. The idea of BIM is explored as well as the current BIM software available to the industry. Finally a case study is conducted to see the effects the use of a BIM has on a construction project.

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Introduction and Background

1.1 Introduction and brief overview of information management and BIM.

Information management on construction sites is a problem that any party in the built environment is aware of. The need for information management is largely due to the time limits and risks associated with modern building projects (Robertze, 2010). It often happens that as a project progresses gaps in the supplied information become evident and delays are caused while this information is sourced. These information gaps are partly due to the large number of specialists that contribute to the design of a building project and the coordination of all this information. Also contributing to this problem is the lack of certainty of the final product details, for example office layouts. Thus such information is often changed by the employer at a late stage causing rushed design changes and clashes with older revisions of the design. Because of this problem it is common practice for contractors, on large building projects, to employ an information manager to act as a coordinator of information. It is normally the duty of this information manager to point out gaps in this information to the relevant consultant (Broxham, 2010). This is clearly a difficult position to be in, as one would not only have to understand the building process, but also what information is needed to complete construction and where this information is most likely to be sourced. This sourcing of information leads to coordination problems and delays, which in turn cost time and money. In order to assist construction project managers with this task several computer based systems have been developed.

Building information modelling (BIM) was developed as design tool in order to help architects, engineers and other parties to design buildings in a shorter time while providing better levels of information to the client and builder (Kymmell, 2008). One of the benefits of BIM is that it alerts relevant parties to gaps in the information early in the design process by showing the weaknesses of the project, by using of the 3D modelling function (Kymmell, 2008). This in turn allows all the required information to be provided in sufficient time for construction. Currently the main benefits of BIM are experienced during the conception and design stages of a project. However BIM has the potential to be more effective in the later phases of a project including construction and facilities management of the building once the construction process is complete. BIM is a relatively new technology and as yet is not well known and therefore is not widely used in the construction industry. It is believed that once BIM has been used successfully on several projects it will revolutionise the construction process; as is the case in the US construction market.

1.2 Statement of main problem.

Information management, on construction sites, is BIM the solution?

The purpose of this research project is to evaluate the ability, and suitability, of BIM to act as an information management tool. It is also hoped that the report will create awareness of BIM and its uses in the South African context. The research will extend through describing the need for information management and will investigate the original intentions of the BIM concept.

1.3 Hypothesis of main problem.

BIM is an answer; however it may be limited in its approach and thus cannot be used in all situations. There are also large barriers to entry for a BIM system, including the fact that the entire professional team, as well as the contractor, need to use the same BIM system in order for it to work as intended. BIM is not the all-in-one answer that is needed thus there is still a need for a tool, which can be used by all participants, to be developed. It must then be concluded that BIM is not a suitable information management solution in the current construction climate; however it may in the near future be used successfully if the industry begins to use the BIM methodology more widely.

1.4 Statement of Sub Problems and Hypotheses.

1.4.1 Why the need for information management, on construction sites?

Hypothesis:

Consultants (engineers, architects, etc.) are at a high risk during the early stages of a project, and thus they do not compile full sets drawings and other required information. A consultant can only be sure that a project will go ahead once the principle contractor has been appointed, this gives him approximately two weeks to complete the basic plans he compiled for tender purposes. It is clear that this practice leaves large gaps in the information needed in the construction of such a project.

1.4.2 Does Building Information Modelling (BIM) cater for information management?

Hypothesis:

BIM is a method of design that is used to help built environment professionals with construction projects from the concept stage through to project close out. Although information management is not essentially a component of a BIM system it is a useful by-product**.**

1.4.3 Can Available Building Information Modelling (BIM) Products be used as Information Management tools?

Hypothesis:

There are many products available that fall under the BIM umbrella, and many of these can be used to manage information. More important than choosing the correct program is being able to use the program chosen correctly and to its full potential.

1.4.4 Has Building Information Modelling (BIM) been used successfully in the past?

Hypothesis:

BIM is a relatively new technology and thus has not been used on many projects; however the projects where it has been used have proved to be a great success. Thanks to the BIM process the information management task is made much easier as many of the traditional requirements are handled automatically by the system.

1.5 Delimitations

The research report will extend only to the South African context, specifically to the current practice used in construction projects. Interviews conducted were limited to the Gauteng area, and to large construction companies. This is because if such a system were to be used it would be implemented by larger construction firms. Literature research was limited by accessibility; every attempt was made to research as much relevant material as possible.

1.6 Abbreviations

- BIM: Building Information Modelling
- IM: Information management
- PM: Project management

- SOM: Skidmore Owings & Merrill
- AES: Architectural Engineering System

1.7 Assumptions

For the purpose of this research report it is assumed that BIM is not widely used in the South African construction industry.

1.8 Importance of the Report.

IM is the collection and management of information from one or more sources and the distribution of that information to one or more audiences (*http://en.wikipedia.org/wiki/information-managment*). It is clear from this definition that IM is important for the successful completion of any building project. And it is obvious that the larger the project the greater the need for an information management system. It will be to the benefit of all construction industry parties if a suitable tool that reduces the burden on all project stakeholders can be found.

This research report holds importance in so far as it will either provide such a solution or eliminate BIM as a possible solution. However if BIM is not widely accepted, sometime in the future, the research will be moot, even if it proves that BIM is a suitable solution. It may prove though that the result of this report will contribute to the adoption of a BIM process on large construction projects.

1.9 Research Methodology

Following a list of the research methods used to complete this report.

1.9.1 Human Resources

Interviews were conducted with relevant construction industry professionals. Interviews have the advantage of being current with the industry, thus giving a very real view into the workings of the sector at the time of interview. The interviews conducted to complete this report were found to be extremely informative and added great value to the research.

1.9.2 Internet Resources

The internet is a resource that provides ample information on any subject. The difficulty is in sorting through the information to find that which is suitable, relevant and reliable.
Several internet search engines were used, including Google, Google Scholar and the University of Pretoria Library website.

1.9.3 Academic Journals and Articles

Academic journals and articles provide a useful resource that are often peer reviewed. The benefit of this type of resource is that the information is normally current and thus more relevant to the research. Many of the papers used for the research were either located via the internet or through the University of Pretoria's extensive library collection.

1.9.4 Text Books

Text books often provide more in-depth information on a subject when compared to articles of the same or similar topic. Therefore the University of Pretoria Library was used extensively to search for relevant text books. The topic of BIM is relatively new and therefore such resources where hard to come by, however several relevant texts were found and used to complete this report.

1.9.5 Product Brochures

Use was made of BIM product brochures. These provide specific information regarding BIM products that are currently available in the market. The benefit of these is that they often provide a developer's point of view on their product, however they may be biased as their aim is after all to sell the product.

Chapter 2

Why the need for information management, on construction sites?

2.1 Introduction

In order to solve a problem one needs to understand what the problem is. The purpose of this chapter is to do just that; define information management (IM) and discover what the causes are that create the need for an information manager on a construction site. IM is a broad term and is applicable to many industries thus the chapter will define the scope of the IM referred to and attempt to eliminate any confusion and ambiguity. This information, and the clarity provided by it, will enable the correct evaluation of the balance of the sub-problems.

2.2 Information Management; a Definition

It is important when defining a phrase to have a clear understanding of the words and, their context, making up the phase. The most relevant meaning of the word information is “the communication or reception of knowledge or intelligence” (Merriam- Webster dictionary, 2007). The dictionary describes management as “the act of managing: the conducting or supervising of something” (Merriam- Webster dictionary). From the above two definitions the following definition can be deduced for IM: The supervision of the communication and reception of knowledge. It is clear that this is an extremely broad definition and it is therefore necessary to define IM further.

The BNET Business definition (2010) for IM states that good IM is getting the right information to the right person at the right time. This definition provides a much clearer view of the IM under investigation. However it is not yet complete. In construction projects the suppliers of information are the members of the professional team and the user of information is the main contractor and his sub contractors. Once this statement is accepted the question of responsibility for ensuring that the correct information is provided on time, to the right people, should be addressed. This will be discussed later in the chapter.

Wikipedia (2010) describes IM as the collection and management of information from one or more sources and the distribution of that information to one or more audiences. It is clear that this side of IM is the responsibility of the main contractor, if the above definition is read in the context of a construction project.

Once all these definitions are considered it is obvious that IM is the responsibility of the entire project team, with each stakeholder having separate responsibilities. The following definition for IM, in the context of the report, can now be provided. IM, in construction, is the process of receiving and storing of information provided by the project professional team (architect, engineer, etc.), by the main contractor and the distribution thereof, where applicable, to the relevant domestic, selected and nominated subcontractors.

2.3 The Construction Process

In order to investigate the need for IM in a construction project one first needs to have a basic understanding of the construction process. According to Nunnally (2007) there are basic phases that most construction projects go through; these include:

- Recognizing the need for the project
- Determining the feasibility of the project, sketch plans and basic cost information are determined at this stage.

- Preparing detailed plans, specifications, and cost estimates for the project.
- Obtaining approval from regulatory bodies.
- Tendering process and selection of contractors.
- Construction of the project.
- Construction completion and lifecycle use of the completed project.

Robertze (2010) argues that this is no longer the case, and that detailed plans and specifications are only completed once it is absolutely certain that the project will continue. This is usually once the principle contractor has been appointed, often only two weeks before construction is to begin. This leaves very little time for the professional team to complete all the detailed information that is required by the contractor. It has therefore become common practice for contractors to provide the professional team with a schedule of information (Broxham, 2010). This system often leads to the fact that built environment professionals are providing the required information just in time. This leaves the door wide open for delays and errors caused by a lack of information.

2.4 On Site Information Management

The management of construction projects can best be described in terms of the project management (PM) triangle; Figure 1. Many companies have different managerial teams for each aspect of the triangle. In the case of Group Five Building Pty (Ltd.), for example, the cost element is managed by the quantity surveying team, the quality element is managed by the operations team and finally the time element is managed by the PM team. It is immediately clear that each team's responsibility over laps that of the other teams. It is therefore impossible for any individual team to successfully complete a project on its own.

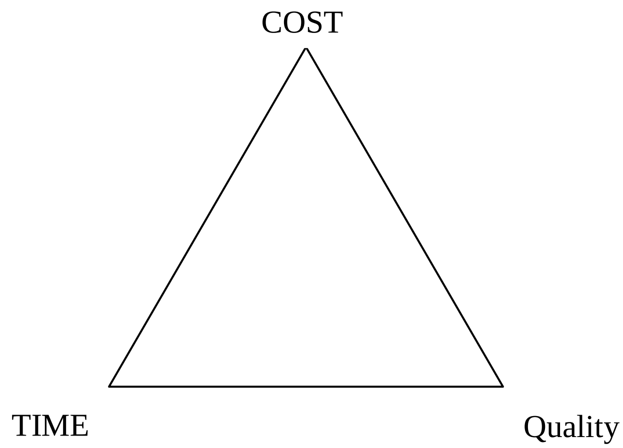

Figure 1: Project Management structure.
Source: Project Management; Kerzner (2006)

From this it is possible to deduct that on site IM is the responsibility of the PM team, as they will have the greatest influence over the time aspect of a project.

When further investigation is conducted into this form of IM the following becomes apparent. There are two separate phases of IM for contactors (Broxham, 2010). The first is the setting up of an information requirement schedule. This is completed in the planning phase of a project and with assistance from programming programs such as CCS. This schedule is drawn up from the information and time line provided by the base program which forms part of the contract data. Once this schedule is complete it is submitted to the client or his representative, this is normally the professional project manager, who is often the principle agent. It is now the responsibility of this person to manage this schedule and ensure that the required information is submitted on time, with the required level of detail.
However, as explained earlier, the professional team is under a large amount of pressure to produce this information and this often leads to information gaps in the drawings and schedules provided to the principle contractor. It is therefore necessary

for the principle contractor to identify an individual who is able to bring these information gaps to the attention of the principle agent and professional team. This then is the second phase of IM management on site. Construction companies have many different methods of managing this process; these will be discussed in a later chapter.

2.5 Gaps in the Provided Information

As already indicated built environment professionals are under a high level of risk during the conceptual phase of a new project. They are therefore unwilling to allocate valuable resources and time to the detailed design of such a project, during this phase (Roberts, 2010). This risk originates from the fact that often projects that seem likely to be constructed are not pursued. The reasons for this are numerous. Because of this fact the situation arises where the principle contractor has been appointed and is due to start construction yet the only information available to him are sketch plans. The professional team is then under extreme pressure to complete and distribute the required drawings and schedules in good time to avoid unnecessary delays. It is clear that such a process will inevitably lead to the rushed design of the project and frequently critical information is omitted from the drawings and schedules provided to the principle contractor.

Traditionally the design and construction phase of a project were treated as separate activities, this is however no longer the case. The design and construction phases of a project are often conducted in parallel; due to the fast tracking of new projects (Austin, 1996). It is clear that this leads to the same potential for information gaps as above. Built environment professionals are under pressure to complete the required information in sufficient time to allow the contractor to order material etc. This therefore becomes a race against time and human error can end up playing a major role in the omission of certain information.

Modern projects often push the limits of technology, due to new client demands, public opinions and current economic climates. This leads to design of modern buildings becoming an ever increasing complex activity (Austin, 1996). From this it is possible to deduce that designers are required to design these buildings with little or no knowledge and experience of the technology intended to be used. This means that designers are often in the dark as to what information the principle contractor will require to construct such a building. Unfortunately this information gap only becomes apparent once the contractor has attempted construction with the provided information. One could argue that designers should consult subject experts during the design phase; however this is not always possible as many of these technologies are new to the industry and do not yet have experts.

According to Austin and Baldwin (1996) the design of a construction project is completed by many stakeholders, these include architects, engineers and other built environment professionals. This fact has the implication that design decisions are very rarely made in isolation; as a decision made about one section of the design will inevitably affect several other design disciplines. Austin (1996) goes on to state that the successful completion of multi-disciplinary projects requires enormous coordination to ensure that all parties are aware of the ever-changing status of the project. This communication is often verbal and informal and is rarely documented, meaning that the management of the design is more difficult. The above factors often lead to information clashes between built environment professionals, which in turn lead to misinformation which is then provided to the principle contractor.

2.6 Summary

After careful evaluation of the collected research it is clear that no one item can be identified as the cause for the IM requirement, this cause is made up of several factors. The most obvious of which is the human error of the design team; due to the time limits associated with the design. Secondly the communication and coordination between design stakeholders and the lack of records of such communication contribute to the need for onsite IM. Another contributing factor is that created by the use of new technologies where required information is often incomplete or unavailable.

These factors, amongst others, contribute to the need for IM on a construction site. This IM is a large responsibility as it has the potential to create major delays which could have serious contractual implications. It is therefore necessary to have a dedicated information manager, normally an in house project manager of the principle contractor. This responsibility falls to the principle contractor as he is in the best position to identify information gaps.

2.7 Conclusion

IM is necessary to ensure timeous delivery of a project, by managing information flow from consultants and to ensure that the project is completed to the required specifications and standards set by the client (Broxham, 2010). This need is created by the information gaps in the drawings, schedules and specifications provided, by the built environment professionals, to the principle contractor for the purpose of constructing the project. These information gaps occur because of several reasons including, human error, and the lack of design time, insufficient product knowledge and miscommunication between consultants.

2.8 Testing of Hypothesis

Original Hypothesis:

“Consultants (engineers, architects, etc.) are at a high risk during the early stages of a project, and thus they do not compile full sets drawings and other required information. A consultant can only be sure that a project will go ahead once the principle contractor has been appointed, this gives him approximately two weeks to complete the basic plans he compiled for tender purposes. It is clear that this leaves large gaps in the information needed in the construction of such a project."

The original hypothesis, while correct, does not give the full picture. There are many other factors that contribute to the need for IM; several of these have been discussed in the chapter. While the original hypothesis failed to define IM clearly the conclusion, of this chapter, provides a clear understanding of IM and thus provides clarity to the factors contributing towards the requirement of onsite IM and the need for it.

Chapter 3

Does Building Information Modelling (BIM) Cater for Information Management?

3.1 Introduction

If you intend to use something to solve a problem you first need to conduct an investigation of the problem. This includes whether the intended use is part of the original intention of the system design or whether the system can be adapted to solve the problem. This chapter investigates BIM. Staring with a definition and the history of the BIM movement, it is anticipated that this chapter will bring to light the original intentions of BIM and whether or not information management is a suitable application of the system. This chapter will provide an understanding of BIM and how it has affected the building/ construction industry since its inception. The conclusion of the chapter should clarify whether or not information management is included in a BIM systems arsenal of abilities.

3.2 Building Information Modelling a Definition

There are as many definitions of BIM as there are people implementing it (Carmona, 2007), thus to fully understand the term several of these need to be investigated. The most traditional understanding of the term BIM is that BIM is simply a 3D model of a building, this definition is often termed “little BIM” (bimwiki.com, 2010). BIM is the process of creating and using digital models for design, construction and /or operations of projects (McGraw-Hill, 2008). Put another way BIM is a more complex computer generated set of drawings allowing one to see the finished product three dimensionally before construction starts. This definition is however fairly inaccurate and insufficient (NIBS, 2010).

Dana (2010) describes BIM as a digital representation of physical and functional characteristics of a facility. Thus it serves as a shared knowledge resource for information about a facility forming a reliable basis for decisions during its life cycle from inception onward. This definition makes it clear the BIM is much more than traditional construction information provided to a contractor. BIM is a complete building project vision for designers, constructions firms and owners to collaborate (CFTA, 2010). Further BIM supports continuous and immediate availability of project design scope, schedule, and cost information that is high quality, reliable, integrated, and fully coordinated (Autodesk, 2003). This makes it clear that BIM is more of a process than a product. BIM is not in its self a technology it is supported by different technologies that contribute towards the process (Autodesk, 2003).

The idea of BIM as a process is a widely supported concept as can be seen in the following definitions. Wikipedia (2010) provides the following as a definition; BIM is the process of generating and managing building data during its lifecycle. The process produces a building information model which contains all relevant information about a project. This includes all information about every aspect of the project including manufacture, supplier, product code etc. (Carmona, 2007). The Tekla Company describes BIM as the process of modelling and communicating the structure of a building in detail to benefit the entire building lifecycle. BIM facilitates the exchange and use of building information in the digital format. This process is termed “big BIM”. According to Easteman (2009) “little BIM”, the model, is the base for “big BIM” the process.

The most comprehensive definition of BIM is provided by Kymmell (2008) “BIM is the act of creating and/or using a BIM is a virtual representation of a building, potentially containing all the information required to construct the building, using computers and software. The term generally refers both to the model(s) representing the physical characteristics of the project and to all the information contained in and attached to components of these models. When BIM is used in a sentence, it will depend on the context whether it means building information model or building information modelling. A BIM may include any of or all the 2D, 3D, 4D (time element—scheduling), 5D (cost information), or non-design (energy, sustainability, facilities management, etc., information) representations of a project."

3.3 A History of Building Information Modelling

The construction project process, as we know it today, originated in Europe during the middle ages (Kymmel, 2008). This process consists out of three tasks, planning, design, and construction. These three tasks are often considered together as they occur within a short period of time. During the middle ages these three tasks would have been completed by a master builder who would complete the project on behalf of the client. Ideas for such projects were normally shown to the client via scale models. This was an efficient manner to which allowed the employer to get a picture of the finished project before construction began. It is important to note that during this time "construction documents" as we know them today did not exist yet (Kymmel, 2008). The process worked well because the master builder had the vision of the building and was himself the onsite manger, thus eliminating the need for information flow between parties. Kymmel states that the advantage of this method was that there was one person to solve problems and address the issues right there on the job, one person who had all the information. However this method had one major drawback, time. Large scale projects often took several generations to complete and as such these models were of great importance and change in master builder often caused a period of crisis for the project (Piterse, 2010). Through time, as building techniques improved, projects became more and more complex; causing the master builder to spend more time off site working on design. This in turn led to the use of two-dimensional drawings as a means of transferring design information from the master builder to the building site (Kymmel, 2008). Following the Renaissance period more and more construction projects were planned and drawn in an office that was generally removed from the construction site. It was around this time that the term architect was used to describe the designer (Kymmel, 2008). With the change of term came a change on site as well, the master builder no longer ran the site, being more concerned with the design. To fill the gap left by the master builder the position of foreman was created (Piterse, 2010); the foreman was responsible for the works on a day to day basis. This split of the master builder into two separate positions was the first major change in the construction process, and as such has had a very large impact on the evolution of the construction industry. Although this split can been seen in a positive light a potential problem did arise, the need for good communication between the parties. The person who conceived and developed the plans for the construction project now had to communicate his or her understanding to another individual (the building contractor) whose task it was to ensure that these plans correctly materialized into a project (Kymmel, 2008). A second complication was that the traditional single owner to master builder relationship was now more complex involving at least three parties; the owner, the architect, and the building contractor (Piterse, 2010). As time passed the need for a formal agreement arose and as such construction documents, similar to those used today, were drawn up and used (Kymmel, 2008). According to Kymmel the primary method used for communication between the architect and the builder, was two-dimensional drawings and other paper documents. Kymmel goes on to say that this method of communication led to many unanswered questions and unanticipated situations on the construction site. Designs become more and more complex as time went by and this eventually created the need for various specialty fields also developed alongside architecture, such as a structural, mechanical, and geotechnical engineering (Eastman, 2009). Kymmel claims that the need for a single overall project background coordinator became even more important, as projects became more complex, even though the single master builder had lost his relevance in the construction of a building. Up until recently this role has been filled by the architect;

however it has become increasingly difficult for him to fulfil his design role as well as this overseeing role (Piterse, 2010). The construction project manager has stepped into this coordination role. It is the construction project manager's job to allow the architect to be concerned with aesthetic and functional issues of the project, and to let the building contractor focus on the project cost and construction processes, such as schedule, quality, and safety, while maintaining a balance between all concerned that will lead to the best outcome for the owner (Eastman, 2009). Although the nature of construction management has changed very little over the last few centuries, there is still a large amount of effort put into making a construction process more efficient (Kymmel, 2008). In an attempt to achieve efficacy several different project delivery methods have been standardized (Piterse, 2010), allowing the most suitable to be selected for each project. The nature of the problems may not have changed much over these last few hundred years, but the complexity of today's construction projects has exaggerated them to an intolerable degree and the expense of these problems are bringing them to the forefront of the owner's mind (Kymmel, 2008).

Several studies have been conducted in the hope of finding a single solution that will solve the majority of these problems, and improve the inefficacy of the construction industry (Piterse, 2009). This has set the stage for BIM, a system that provides detailed information complete models using modern technology. The term BIM was first used by Eastman in the 1970's, however it was Phil Bernstein who was first to use the term in a commercial sense (Wikipedia, 2010). From there three of the largest construction software companies - Bentley Systems, Autodesk and Graphisoft – standardized the term BIM to describe the digital exchange of information. According to Larserin the first BIM product was launched in 1987 under the Virtual Building concept created by Grafisoft's ArchiCAD. BIM has grown from this with support products now offered by most major construction software companies, and has been successfully implemented on several cutting edge construction projects. Of the most notable include Loblolly House (FIG 2), The Royal London Hospital and the World Trade Park's Freedom Tower (FIG 3).

Figure 2: Loblolly House; Maryland; USA

Source: AEC bytes "Building the Future" article (2007)

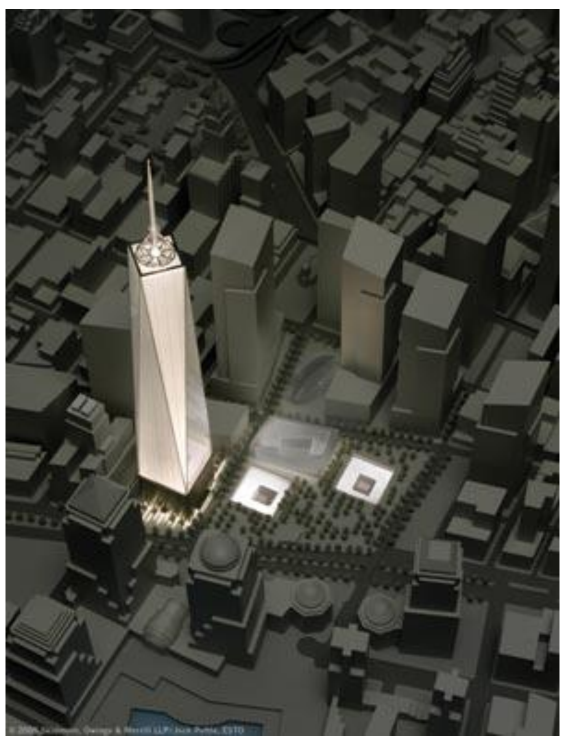

Figure 3: BIM Representation of New York's Freedom Tower.

Source: AEC Magazine "BIM and the Freedom Tower" article (2010)

3.4 Advantages and Benefits of Building Information Modelling

Supporters of BIM are claiming that it is and will revolutionise the way construction projects are handled. These claims are supported by the many advantages a BIM program brings to a project. Autodesk claims the following advantages for its BIM systems.

- Increased speed of delivery (time saved)
- Better coordination (fewer errors)
- Decreased costs (money saved)
- Greater productivity
- Higher-quality work
- New revenue and business opportunities

Autodesk goes on to claim that BIM gives immediate access to critical information during all project phases in the building lifecycle—design, construction, and management.

• In the design phase—design, schedule, and budget information
• In the construction phase—quality, schedule, and cost information
• In the management phase—performance, utilization, and financial information

The ability to keep information up to date and accessible in an integrated digital environment gives architects, engineers, builders, and owners a clear overall vision of their projects, as well as the ability to make better decisions faster (Building Smart Alliance, 2010). This in turn raises the quality and profitability of projects. BIM's primary benefit is the reduction of project risks (Kymmel, 2008). Most of the various construction project delivery methods that have been developed over the past decades have more successfully shifted construction risks from one project team member to another, rather than reducing it to any degree. This leads to the issue of communication. During the construction of any project the most common forms of communication generally revolve on the creation of a common understanding among the participants by visualizing a subject and its issues. It is always useful to have more than one person at an issue and BIM simulations are by far the most effective way to communicate ideas, forms, concepts, and general approaches in design and construction-related issues (Eastman, 2009). The most important aspect of communication is the free access to and flow of information (Kymmel, 2009). A BIM is characterized by the availability of all information that has become part of the project. The benefits of BIM can further be explained by splitting a project into the above mentioned phases

3.4.1 Building Information Modelling Benefits in the Design Phase

Kymmel (2008) claims that simulations allow a virtual test of a design before the actual project is constructed. He continues by stating that with the use of a complete model one is able to visualize the project, to stimulate thought about the project requirements and to assist in describing the project in an efficient manner. The creation of a BIM model requires a lot of preparation on behalf of all the project team members. It is unlikely that a complete high-quality simulation will be developed without the collaboration of the entire project team and the project can only benefit from such collaboration (Eastman, 2009). Project coordination is greatly improved when BIM is used to represent the critical systems of the project. Model views allow the participants to share one another's concerns in any given area and communicate with one another about their collaborative approach to the resolution of conflicts (Kymmel, 2008). This concept visualization is at the root of the communication necessary to collaborate and coordinate. It has been shown repeatedly that early collaboration has large benefits for the planning and construction of a building project (Kymmel, 2008). The development of a virtual model is one of the best means of ensuring early and in-depth collaboration of the project team on most relevant planning, design, and construction issues.

Over the course of a construction project a principle agent, often the project manager must balance the project scope, schedule, and cost. The principle agent's task is made more difficult when changes are made to the design; these changes often cost time and money and negatively affect relationships with consultants, clients and contractors (Autodesk, 2010). With a BIM model it is possible to generate a building simulation for several variations on an idea that can then be evaluated by comparison; this results in a decision for the better alternative to be used in the final product (Kymmel, 2010). It may not be necessary to adapt an entire model to reflect alternative choices; often a small mock-up in a quick modelling tool will be more practical. Traditionally cost and scheduling information is available only occasionally because of the time and effort necessary to create it, thus assessing the impact of a change is a long and laborious exercise (Eastman, 2009). Autodesk states that by using BIM techniques all of this critical information is immediately available, so that project-related decisions can be made more quickly and effectively. The use of BIM eliminates the need for re-coordination and manual checking of work when changes are made, thus eliminating many mistakes that such changes often cause.

Autodesk claims that eliminating the need to re-coordinate every time a change is made frees the design team to focus more on the design and other high-value architectural problems. Autodesk goes on to state that in addition to the above, all of the building design and documentation work can be done concurrently instead of serially because design thinking is captured at the point of creation and embedded in the documentation as the work proceeds. This automatic coordination of design, and changes, eliminates coordination mistakes, improves the overall quality of the work, and helps companies win more repeat business.

3.4.2 Building Information Modelling Benefits in the Construction Phase

The most important element of this stage is speed, and with BIM the contractor is able to concurrently generate information on building quality, schedule, and cost; a task that would traditionally take weeks and a large amount of manpower (Bacharach, 2009). The BIM process helps to reduce construction conflicts, construction waste, and project risk and therefore project cost (Kymmel, 2008). BIM provides added advantage to the contractor with the ease of which estimates for tendering purposes can be created using BIM (Irwin, 2007); this information can also be used for value engineering. The contractor is also able to use BIM to his advantage during his project planning, several construction methods can be explored, site layouts can be experimented with and the effects of specified or selected products can be explored, all which saves time and money (Autodesk, 2010). Kymmel stated that: "Lean construction defines waste as "that which is unnecessary." In this context, analyzing the construction simulation may help the development of more efficient construction procedures, and could stimulate ideas to improve the efficiency of the use of materials, time, and energy." All of which improves the project for the design team, the contractor and most importantly the client. The use of BIM ensures that during this phase that less time and money are spent on process and administration issues during construction because document quality is much higher and construction planning better than that provided by current industry practices (Eastman, 2009). This clearly makes the information mangers task more achievable. Kymmel insists that information should exist only once rather than be duplicated unnecessarily for convenience of individual access. There is a large level of risk associated with the duplication of information for convenience sake, mostly because it creates difficulty for the user to discern whether that specific information is in fact the latest available. Traditionally great care has to be taken to develop a method by which the whole project team supports and has access to the most updated information for the project (Bacharach, 2009). It is often difficult to understand 2D drawings; details can easily be misinterpreted and one has to study drawings intently for simple designs to become clear. A 3D model, however, clearly represents the project and allows the visualization of many of its features, even with surprisingly few details (Kymmel, 2008). This too saves time as builders no longer have to imagine how the building is going to look; they have the final product before their eyes.

3.4.3 Building Information Modelling Benefits in the Management Phase

Facilities management is only recently a use to which BIM has been applied, and BIM has risen to the occasion. Because all construction data is inserted and stored in the model it is possible to use the model for maintenance management. The BIM can be set up to alert the user when inspections are to be carried out and it may be used to find where originally installed products were sourced and purchased from. This in turn allows the purchase of the correct products when the need arises for replacement (Carmona, 2007). BIM makes available concurrent information on the use or performance of the building, its occupants and contents, the life of the building over time and the financial aspects of the building (Autodesk, 2010). Physical information about the building, such as finishes, tenant or department assignments, furniture and equipment inventory, and financially important data about leasable areas and rental income or departmental cost allocations are all more easily managed and available with BIM (Laiserin, 2010). Consistent access to these types of information improves both revenue and cost management in the operation of the building (Bacharach, 2009).

Many of the benefits of the BIM can be viewed as direct benefits, although the largest benefits actually are the indirect benefits (Kymmel, 2008). Direct benefits are qualities such as the improved visualization and the centralization of (project) building information. The indirect benefits include the necessity for collaboration and the resulting better project understanding, and the reduction of project risk. Through the collaboration necessary to create a BIM model and BIM is addressing many of the construction industry's fundamental problems (Kymmel, 2008). Kymmel further indicates that it is up to the BIM participant to make proper use of the process and thereby reap the benefits associated with it. It is possible to assume then that correct use of the selected BIM tool is extremely important in having a successful model. Eastman notes that clients are beginning to see the benefits of using BIM and are no longer willing to overlook the savings in cost, the reduction in contract instructions and the overall better project outcomes. Many developers and other clients; including government departments, especially in the United Sates, are insisting on the use of BIM on all new projects.

3.5 Integrated Project Delivery.

Integrated project delivery (IPD) is encouraging and enabling the vital practice of early collaboration through BIM (Autodesk, 2010). IPD improves on client expectations by easing the integration of project stakeholders. BIM lays the platform for IPD. The idea behind IPD (see appendix A) is that all stakeholders- client, architect, consultants, contractor, etc. - are involved in the project through as many of the project phases as possible. This means getting as many stakeholders as possible involved during the creation of the basic design and concept. This will lead to improved information flow, alternative building techniques and cost savings. The idea of IPD arises out the lean construction concept. One could term it thus; IPD is the combined use of BIM, lean construction and value engineering. When one investigates each of these concepts separately it becomes glaringly apparent that it is not possible to use them to full effect separately. IPD improves BIM's effectiveness as an information management tool tenfold.

3.6 Summary.

BIM is slowly making inroads into the construction industry. It helps to solve one of the industries major problems, communication. BIM provides an excellent tool that facilitates integration and collaboration between the consultants and other stakeholders. This in-turn provides for improved projects with benefits around the table. Used in conjunction with lean construction principles and value engineering BIM is most likely the way of the future. BIM has been slow to be adopted in the industries although the generally feeling is that it will pick up speed as more projects are completed successfully using the process, and the befits of these are not only talked about but seen. This adoption is being driven by government departments and large development agencies, including General Services Administration (GSA) and Walt Disney Imagineering, amongst many others, who insist on the use of a BIM process for all their projects (Carmona, 2007).

3.7 Conclusion.

BIM is a process and this process facilitates better communication and collaboration between all involved parties. As such it provides better quality information which in-turn is easier to manage. Most BIM products are "one stop shops" and thus provide excellent inbuilt information management tools; this is largely due to the fact that all information is included in the model and is thus easily available. It is important to note however that the information contained in the model is only as good as the information inserted into the model.

3.8 Testing of Hypothesis.

Original Hypothesis:

“BIM is a method of design that is used to help built environment professionals with construction projects from the concept stage through to project close out. Although information management is not essentially a component of a BIM system it is a useful by-product.”

The original hypothesis is correct when it claims that information management was not one of the original intentions of the BIM idea. However BIM provides all the tools required for an effective information management system. Thus if BIM is used to its full potential it can be used for information management with great effectiveness.

Chapter 4

Can Available Building Information Modelling (BIM) Products be used as Information Management tools?

4.1 Introduction

There are several major software developers that supply products with functionality in the BIM world; these represent the primary BIM software tools for the construction industry. This chapter takes a closer look at several of the most popular and investigates whether these individual products are suitable as information management tools, or not.

4.2 NavisWorks

Kymmel suggests that for anyone who has not been exposed to 3D models, NavisWorks a great place to start. NavisWorks, a product of Autodesk, is a viewer of models and has many useful applications in almost all phases of the use of the BIM (Kymmel, 2008). The primary function of NavisWorks is to provide 3D model interoperability for the building design and construction field. NavisWorks functions much as a video game so it is easy to learn to view, navigate, and understand virtual environments. NavisWorks has provided a model viewer that can read almost any 3D file format (Kymmel, 2008). This solves the problem created by different software tools being used by a number of different disciplines that all produce 3D models in different file formats. Most of these tools do not import or export one another's native file formats. NavisWorks solves the four problems a project team using BIM faces; it can read different file types from various sources; it can import and handle very large files; it will combine different file types into the same file together successfully and it facilitates graphical communications across the entire project team (Kymmel, 2008). Several other software companies are working on achieving this level of functionality, however at this time NavisWorks is by far the best option

(Autodesk, 2010). One reason that NavisWorks can handle huge files and navigate through the virtual environments so effortlessly is that all models are translated into surface models (Autodesk, 2010). This necessarily removes some of the information from the original model, and what is left is all the surface and spatial information. This is enough to maintain all the visual data and perform sequence and clash analysis (Kymmel, 2008).

Figure 4:
A sample of a model that has been rendered in NavisWorks JetStream Presenter.
Source: Building Information Modeling, Kymmel, 2008

The NavisWorks suite contains Roamer, Freedom and Jetstream. Roamer is the basic "engine" for NavisWorks and allows model combining and viewing, Freedom is a free viewer and Jetstrem (Figure 4) is a model renderer (Autodesk, 2010). Freedom can be used to look at already prepared composite (or single) models in the correct file format (Autodesk, 2010). Kymmel states that Freedom is for users who do not wish to analyze or manage projects, but simply wish to have visual access to the models. Roamer on the other hand is much more versatile (Kymmel, 2008). Special functionality can be added to Roamer with Clash Detective for coordination clash analysis, Publisher for providing files to be viewed with Freedom, Presenter (Jetstream) for preparing high-end renderings of model views, and Time Liner for the creation of construction sequence analysis. Of these add on functions Clash Detective is the most popular; this is largely due to the fact that it provides a quick return on investment (Kymmel, 2008). This return comes from its ability to find and identify all instances where model parts clash (take the same space in the model). The clashes are not only found and listed, but can also be managed through the same software until they are dismissed or resolved. This tool is obviously invaluable for the coordination of a building and between systems (Laiserin, 2002). Time Liner is very useful in providing a simulation of the construction sequence of a project (Kymmel, 2008). By either importing a construction schedule from an outside software or building a new schedule in Time Liner, the 3D model components can be linked to a scheduled task, and thus can be seen appearing (or disappearing) in timed sequence; as if the project were being constructed. This is an excellent way to communicate construction progress visually. Many professionals whose purpose is related to the design and construction of the project (and not the rendering of it) seem to choose NavisWorks (Kymmel, 2008). This is possibly because of NavisWorks' ease of use and high-quality output.

4.3 Google—SketchUp

The original SketchUp was developed by @Last Software and is a simple, powerful and affordable tool (Kymmel, 2008). Google recently took over the company giving SketchUp the backing it needs to become a major software provider to the construction industry. SketchUp is a surface modeller and although it is not trying to be a BIM tool, it can be used as one (Kymmel, 2008). This does mean that the software has limitations in terms of BIM. These limitations are primarily related to the type of information that can be contained in the model itself; that information is mostly related to size, location, and "look." It is not an object modeller, and thus it cannot be treated like one; the components only look like objects, but are actually just collections of surfaces (Kymmel, 2008). In other words "it's just a picture"

(Figure 5). Kymmel states that the ways that SketchUp can be used as a BIM tool lie in its phenomenal ability to quickly convey the essential information about a situation, i.e. the size, location, and look of an object, into a 3D model. He goes on to say that this model does not always need to be part of or be attached to a more complex BIM; it may simply be a communication tool for a specific issue. This in turn can help focus attention on a specific issue, allowing it to be solved quickly and efficiently. A SketchUp model can be imported into NavisWorks and seen together with any other model that may also be imported into the viewer. Once in NavisWorks, it is even possible to run a Clash Detection with the SketchUp model or to use it in Time Liner; but again, its limitations have to be kept in mind, it was never designed as an information-rich modeller (Kymmel, 2008).

Figure 5: A SektchUP model rendered in Google Earth.
Source: Building Information Modeling, Kymmel, 2008

4.4 Bentley Systems

Bentley Systems has long been a household name in construction design software circles. The main product currently offered is called MicroStation TriForma, a strong and reliable 3D platform that addresses all the needs of the various disciplines required to design and construct a construction project (Kymmel, 2008). Bentley has a strong reputation and professionals have very little criticism for the well thought out solutions and support that the company provides. There is however one criticism that is sometimes heard. Some claim that the software is difficult to master, and that it requires a serious IT department to manage a network operating the Bentley's MicroStation software (Kymmel, 2008). This does mean that for a smaller company it can appear too demanding to implement TriForma; therefore Bentley customers are generally large firms that build complex projects. For a professional, however, the need for an IT network is a confirmation that the software is a robust, reliable high-end product. Bentley recommends an evolutionary approach for its clients to fully transit to BIM from the traditional 2D environment (Bentley, 2010). Upgrades in the Bentley product line have never demanded large-scale changes or adaptations from the users; Bentley develops its new products in a way that maintains the stability and reliability that Bentley has become known for. Kymmel claims that Bentley's BIM software aims to address the fragmentation of the construction industry. This fragmentation is experienced in the project teams that consist of several people from different firms and with different goals all involved in the construction process. Further this fragmentation is the cause of much wasted time, risked quality, and limited profitability and competitiveness (Young, 2008). To address this issue Bentley developed the "Build as One" motto, based on the use of a BIM as the hub for a collaborative approach to planning and construction (Kymmel, 2008). Bentley also advises that starting over with a new, incompatible platform, as Autodesk suggests with Revit, is unnecessary to achieve the goals envisioned for the BIM approach to planning and construction. This evolutionary path of software tool development serves the MicroStation TriForma user better (Kymmel, 2008). Most of these users have large investments in both training and software, and discontinuities in technology are undesirable and costly. A second point on which Bentley disagrees with Autodesk is that of data management (Kymmel, 2008). Of the two possible approaches, with one being a federated database and the other being a centralized database, Bentley has chosen to develop the first option. Bentley found that a centralized database throughout all the phases of a project's life cycle is very risky and therefore not reliable. The problem with a centralized database is that it quickly becomes unmanageable for larger and more complex projects (Bentley, 2010). This does not mean that a centralized database is not an attractive alternative for smaller projects. The idea of a centralized data base is a tempting one however when the various experiences of actual projects by different companies are taken into consideration, it becomes clear that the idea of a truly centralized database is fairly theoretical but it will always remain just out of reach and cannot be implemented as would be expected (Kymmel, 2008). Therefore the idea remains intriguing but quite impractical. Bentley claims that a priority for the company is supporting its products with a single comprehensive unchanging platform, on continually extending and improving its functionality, and on augmenting the software as necessary with collaborative products. Using this theme Bentley has evolved its CAD applications into BIM applications in a relatively seamless fashion. This is where Bentley gains some ground on Autodesk as Autodesk does not use this "same software approach (Kymmel, 2008).

4.5 Autodesk

Autodesk's main BIM product Revit is probably the most widely used of the BIM tools; although it is also the youngest of the ones discussed in this chapter as well as the least mature (Kymmel, 2008). Kymmel claims that Autodesk's strength is marketing. Their market share with AutoCAD is enabling them to simply offer Revit as the next upgrade for their customers, hence its popularity. Autodesk appears to attempt no continuity from its previous 3D model efforts and therefore the company shows a certain lack of consideration for the customer, this however does not appear to have damaged Autodesk's market share (Jones, 2008). This may be due to the fact that many Autodesk customers are often simply unaware of any other software possibilities. Despite this Revit is a serious BIM tool, which was already a modeller with good potential before Autodesk purchased it, and the large user base will undoubtedly be very helpful in its further development (Kymmel, 2008). Autodesk is currently selling Revit as a modeller with a centralized database; Young (2008) feels that fortunately this is probably only wishful thinking at this stage. He goes on to say that there is very little evidence that the data contained in a Revit model are any more centralized than those in a TriForma or Constructor model. When one is dealing with information in any BIM, it still needs to be managed wherever it resides, and simply having links to other locations does not centralize the data. Fortunately for users Revit has very similar functionality to the other major solid modellers (Kymmel, 2008). This means that a user can probably model just about anything in any of the software tools. There are various "bells and whistles" that may distinguish one modeller from another, but by and large the actual modelling experience of a seasoned user will not be that different from one software tool to the next. Users should be more concerned with Revit's ability to organize and manage the information that is collected in the BIM over the evolution of the project (Kymmel, 2008); and this is where Revit shows its worth. Revit does not use layers (Autodesk, 2010) and it is unique in this feature. The construction community is still not sure whether this is a positive or negative aspect of the modeller (Kymmel, 2008). On one hand, simpler is better. On the other hand however as a project becomes more complex it may be an advantage to have additional means to sort its elements (Kymmel, 2008). It comes down to the ability of the user to fully understand the nature of the tools used for these processes so that solutions can be approached creatively and the characteristics of a specific tool do not become an obstacle. Another strength of Revit is its ability to link to MS Project and exchange scheduling information in a bidirectional manner (Autodesk, 2010). It is possible for components in the model to be linked to multiple tasks in the schedule, thereby increasing the ability to schedule tasks and see the links between tasks. Autodesk states that Revit also has the ability to export its model quantities to cost-estimating software. Due to the nature of the model, the quantities can be very accurate and thus reflect the status of the project design reliably. There is however a small drawback, it appears that the connection is a one-way transfer of quantitative information and that all interpretations of this information are made in the cost-estimating software (Kymmel, 2008). Users are questioning the functionality of this link to estimating software. There is a feeling that a two way transfer of information would be more appropriate. The Revit modeller has been divided up into several specialised software packages, each of which focuses on a specific section of the design (Autodesk, 2010). The most notable of these are Revit Architect, for architects, and Revit Structures, for structural engineers. Although all these packages have different viewpoints they can all be used together, and it is this combined use that ultimately creates a successful BIM. To conclude, Revit is a young, but potentially powerful tool for the planning and management of construction projects. Kymmel (2008) feels that only time will show whether Autodesk can develop Revit to keep pace with the demands of the design and construction industry.

4.6 Vico

Vico is a relative new comer to the construction software industry and it bases its software on ArchiCAD (Vico, 2010). In 2007 Graphisoft sold ArchiCAD to a German software developer and Constructor, its construction industry software suite, spun off to Vico Software, a newly formed company with the design and construction industry as its primary focus (Kymmel, 2008). ArchiCAD has been a used since the mid-1980s as a professional modeller, and this forms the base for the Vico suite (Vico, 2010). The suite consists further of several other modules that facilitate construction project management; Estimator, which is a cost database, a Line of Balance scheduling software called Project Control, and 5D Presenter which facilitates project presentations, all with a bidirectional link to each other and the model. Modelling in ArchiCAD is simple and straightforward to learn (Kymmel, 2008). The file structure is based on layers and stories that contain all the objects either created by the modelling tools or imported from object libraries. This is similar to most other modelling software. The Navigator is an extremely effective tool for viewing the model; specifically any view that has been saved in a previous session. This applies to both 2D and 3D, and to any layer combination (Vico, 2010). This software has been developed over many years and as such it is refined. However it has not lost the intuitiveness it was known for in the early 1990s (Kymmel, 2008), when it was one of the few professional 3D modellers in the marketplace that are still in use today. The software makes it is easy to create custom objects with the modelling tools and save them as library parts. It is also possible, and not relatively difficult, to create objects by writing code in GDL, which is often an impossible task in other software tools (Kymmel, 2008). The benefit of using GDL to create objects, as opposed to making objects with modelling tools, is that there are almost no limits to the intelligence that can be included in the code (Vico, 2010). Kymmel claims that the other components of the Constructor suite are more interesting for their usefulness to construction project planning and management. Using a recipe, description of the materials, labour, and resources that are required for a specific building component, cost calculations can be created from the model by attaching a link from to a model part. The object then provides the quantities that result in the cost calculation of that component. A recipe is built up of one or more methods or tasks, for example placing concrete, and a method consists of one or more resources (Vico, 2010). This gives recipes a flexibility that allows them to be used for almost any application; one of these benefits is the ability for the cost analysis of a project at any stage, enabling the tracking of the cost changes as the design evolves. The refinement of both the recipes and the model parts over the course of the project's development provide a good cost management tool (Kymmel, 2008). The management of the recipes can become tedious but the system works well and once it is set up it remains functional for various projects where similar recipes can be used. Project-Control is the scheduling tool in Constructor; it is a Line of Balance Scheduler (Vico, 2010). A Line of Balance schedule is a line that represents a task in a project, and its slope indicates the productivity rate of the task. This line shows both time and quantity of work as well as the location where the work takes place (Nunnaly, 2007). The benefit of a Line of Balance is that it is far more visual than a conventional Gantt chart; however this comes at a price. A Gantt chart is more usefully when it comes to showing a large number of tasks that are dependent on one another. Control connects the quantitative information from the model through the recipes in Estimator to the lines of balance in Control (Kymmel, 2008). Control then plots the lines and permits the manipulation of these lines to edit the time element of the tasks. With these tools it is possible to adjust when a task starts and how long it takes, allowing the whole project to be optimized in relation to productivity of crews and work locations. Design updates are synchronized with the schedule by re-importing the model data from Estimator keeping the full model up to date (Vico, 2010). Once all this data is captured the schedule can be imported into the 5D viewer which will then simulate it in a construction sequence. Vico describes its “Design to Build” idea as building a model of the proposed project that reflects the actual construction techniques, including the actual tolerances of the objects in the model. This facilitates proper coordination of the trades without putting effort into unnecessary detail and accuracy. Vico’s second idea, “Build to Design”, refers to the key model points being compared to the actual dimensions in the project by laser survey. This survey checks that the building falls inside the design tolerances and ensures that any prefabricated elements will fit (Vico, 2010). One of this software’s strongest points is its ability to automatically update when design, cost, or time elements are changed (Kymmel, 2008). Since the tasks of a construction schedule typically contain work that is to be done to multiple objects it is necessary to provide a more detailed system to understand them (Kymmel, 2008). This is done with use of a Work Breakdown Structure. Quantities from the methods and resources are then input for the calculation of task durations. All these elements in the WBS have task connections, and the resulting 4D model can now be used for schedule simulation and analysis. The different trades can then be organized into task groups and identified by colour in the 4D model, so that the activity can be visualized in the simulation (Vico, 2010). This level of visualization provides many possibilities to refine the construction process planning (Kymmel, 2008).

4.7 Summary

BIM is here to stay; developers and government departments are insisting on the use of BIM to complete new projects. It will soon be almost impossible to win tenders if you are unable to provide some form a BIM to the client. Thus there are several software developers who provide BIM related products. Obviously these developers are in competition and therefore each bring something different, and unique, to the table. However there are common traits between these different programmes. One of these is that a building information model is intended to contain all information about a building and this information should be available on demand. Choosing the right programme is important but more important is understanding how to use the chosen programme correctly and to its full potential.

4.8 Conclusion

Simply put yes, available BIM products can be used as information management tools. Some are better at it than others but the choice is as choosing between Mercedes Benz and BMW, they both do the same thing, but in a slightly different way. Once a program has been selected it is important to ensure that it is used correctly, it is meant to be an information management tool, not an information manager. The drawback of current BIM systems is the lack of integration between them, thus if BIM is to be used on a project all stakeholders need to invest in a chosen system, this is obviously not always cost effective. It may happen that the client specifies a BIM product to be used with the intention that he uses it as a facilities management tool post construction, this alleviates the buy in cost for the consultants but still leaves the problem of training and use of a system that all parties may not be familiar with.

4.9 Testing of Hypothesis

Original Hypothesis:

"There are many products available that fall under the BIM umbrella, and many of these can be used to manage information. More important than choosing the correct program is being able to use the program chosen correctly and to its full potential."

The original hypothesis is correct. BIM software that is currently available can be used effectively as an information management tool.

Chapter 5

Has Building Information Modelling (BIM) been used successfully in the past?

5.1 Introduction

The best understanding often comes from observing something in action; this chapter is just that, an overview of a project completed using BIM. From this case study it will be possible to see the information management properties of BIM and whether or not information management is a specific use that a BIM system can be put to. It will hopefully be observed that information management is something that a BIM system does naturally. It will also demonstrate that a chosen system will need no, or very little, adaptation to be used as an information management tool. Arguably the most notable project constructed using BIM is the Freedom Tower in New York and it is therefore used for the case study.

5.2 Freedom Tower, New York

5.2.1 Background

11 September 2001 saw the destruction of two of the world's greatest buildings, the World Trade Centre Towers in New York. After the dust settled on the tragedy that shocked the world it was decided to turn the reaming foundations of the two towers into a memorial to immortalize the memory of those that lost their lives (Wikipedia, 2010). In November 2001 the Mayor of New York, Michael Bloomberg, established the Lower Manhattan Development Corporation as a commission, representing all stakeholders, to oversee the rebuilding of the World Trade Centre. This commission organized a competition to determine the use of the land; however these "preliminary designs" were not well received by the public. This led to a second,

more open, competition where the concept proposed by Daniel Libeskind was selected. This concept consisted of the two memorials as well as several other towers, the largest and arguably the most important of these is the Freedom Tower; now know as One World Trade Centre (fig 6).

This is however not the end of the story. At the same time as the commission was running these competitions the lesser of the World Trade Centre land appointed SOM architects to design a new tower. After many negotiations the two designs were combined with the Freedom Tower being designed by Skidmore, Owings and Merrill LLP (SOM) Architects.

Figure 6: BIM Rendering of One World Trade Centre.
Source: AEC Magazine, 2005

5.2.2 Project Information

On July 4, 2004 a ceremonial ground breaking was held to mark the start of the rebuilding process of the World Trade Centre Park. Construction of Freedom Tower was put on hold for a few years until a design could be completed and approved. April 27, 2006 saw the official start of construction. The original completion date of the tower was to be late 2010 but due to a number of factors this has been pushed out. Completion is now planned for April 2013 with the official opening of the building of the building will be later that year (Wikipedia, 2010).

Once complete One World Trade Centre will have 102 stories (SOM.com, 2010), and reach a total height of 541.33m. The final 120m of this is made up of an antenna/ spire, actual roof height is 417m and the top floor being at a height of 400,5m from street level (Wikipedia, 2010). The main function of the building will be office space, with an observation deck on the upper floors. The estimated final cost of the project is $ 2 000 000 000 (glasssteelsndstone.com, 2010).

5.2.3 Key People

Larry Silverstein, of Silverstein Properties, is the current leaseholder and developer of the Trade Centre Complex (Wikipedia, 2010). In 2001 he signed a 99 year lease for the complex, and thus it was his, Silverstein Properties, insurance that was claimed against. This claim is still in controversy as Silverstein properties claimed, in terms of the insurance agreement, that the two planes constituted two separate incidents and therefore required a separate payment for each tower that was destroyed an additional $3.5 billion (Hamblett, 2002). Silverstein fully supports the redevelopment of the site and intends to remain actively involved throughout the process (Wikipedia, 2010). Although Silverstein controls the World Trade Centre Complex and as such is the main developer in the reconstruction, control of the completed Freedom Tower will be solely the responsibility of the Port Authority (lowermanhattan.info, 2010).

David Childs was included in the project due to Silverstein's insistence and according to Wikipedia Childs is one of Silverstein's favourite architects. David Childs developed the original proposal for One World Trade Centre (Freedom Tower) in collaboration with Daniel Libeskind. This design was revised in May 2005 to address security concerns. Childs is the project architect of the new One World Trade Centre, and is responsible for overseeing the day-to-day design development from rough inception to final completion (Wikipedia, 2010).

In 2002 Architect Daniel Libeskind was announced as the winner of the invitational competition to develop a master plan for the World Trade Centre's redevelopment (Wikipedia, 2010). One World Trade Centre was included in his proposal and it had innovations such as aerial gardens and windmills with an off-centre spire. Libeskind denied a request to place the tower in a more rentable location next to the PATH station and instead placed it a block west because in profile it would line up and resemble the Statue of Liberty (Wikipedia, 2010). Although these designs have since been changed Libeskind remains deeply involved in the development of the World Trade Centre Complex.

Tishman Realty & Construction, a company run by father and Son team Dan and John Tishman, has been selected to complete the construction of the new "One World Trade Centre" (Designbuild-network, 2010). John Tishman was actively involved in the construction of the original World Trade Centres and thus gives him a strong emotional connection to the project.

5.2.4 BIM and One World Trade Centre.

With Architect Skidmore Owings & Merrill (SOM) using Revit Building on one of the world's most high profile and important buildings, One World Trade Centre, Autodesk really couldn't have got a higher profiled project to showcase the BIM idea and their BIM product Revit Building (Day, 2005). SOM is making great strides in the use of BIM (Designbuild-network, 2010), implementing 3D design software and sharing the data produced with its construction partners. SOM pioneered a process, in the late 1980's, when it devised its own 3D modelling program named Architectural Engineering System. The idea was that the system would hold all project information allowing the architect to make changes, such as moving a door and the system would solve all the coordination issues arising out of the change (designbuild-network, 2010). At the time however processing capabilities were inadequate and high costs. SOM on discovering that their system was not achieving what the company intended, decided to publish a paper entitled 'Reality before Reality'. This paper confirmed SOM’s preference for a 3D based system stating in the paper that: 'The AES software constructs a full 3D model of all the components of a building, including structural and building services systems. In this way, the building is in effect built and analyzed within the computer before it is built in reality.' Out of the many BIM systems developed SOM chose to use Revit to realize the dream of AES. The firm selected Revit because of its ease of use, associative views, scheduling capabilities and integration with other products, such as AutoCAD (Day, 2005).

On winning the bid to design Freedom Tower SOM decided to test Revit on one portion of the project, specifically the substrata (Day, 2005). Having used AutoDesk's Revit Building package on smaller projects SOM was well aware of the systems potential and felt that Freedom Tower would prove the perfect testing ground for use on a larger project. The substrata of the Tower took up eleven storeys, including below-grade infrastructure and shopping facilities, as well as access to public transport and the World Financial Centre (designbuild-network, 2010). SOM employees found that with the 3D model they could go into their complex design in an intuitive, easy-to-learn manner. Martin Day quotes SOM’s digital design director Paul Seletsky as saying ‘the Revit software was easy to operate, we gave them introductory courses, but architects used Revit right off the bat and required very little training,' Seletsky further stated that. 'Its approach makes a lot of sense to architects – it understands the way they think.'

The intended works were to be developed in an area that has many services and subway tunnels criss-crossing the immediate area, this provided the first opportunity for Revit to show its worth. Architects, along with the project's structural and mechanical engineers, were able to work from elements of one model instead of separate documents; improving coordination and information flow (Autodesk, 2010). This is a completely different approach to design as stated by Seletsky 'In the past, architects worked on individual assignments where they used CAD to draft documents, which would then be assembled. Now, they can model building components which have direct links to their actual characteristics. By using BIM, architects are responsible for assembling parts of a single structure, simulating their ideas in three dimensions, as in real life.' This allows a 3D model to be created from the start of the design rather than being pieced together from the 2D drawings as in a more traditional design process. This in-turn allows designers to see exactly how a structure is affected as they go along (designbuild-network, 2010). It is often a cause for humour when coordination goes wrong, such as a light pole in the middle of a building, or a security camera blocked by a sign, but in reality this sort of mix up is no joke. The use of Revit, on the One World Trade Centre Tower effectively prevented these kinds of problems in the substrata and SOM's planners therefore encouraged their employers to use the software elsewhere in the project (glasssteelandstone.com, 2010). This lead to first the lower and main cores of the tower being designed using Revit, and later the tower's structure, enclosure, cable net, and mechanical, electrical and plumbing system and later the interior layout design being completed using Autodesk's software. "The fact that SOM didn't intend to use Revit Building on anything above ground but its employees led the charge also gives Revit a huge endorsement" (Day, 2005).

SOM as a company was all about improving the Autodesk product and as such invited Autodesk to examine the results of the design, this effectively made Autodesk part of the design team (designbuild-network, 2010). However SOM were not working without a failsafe as Autodesk gave assurances that should Revit not be up to the task of designing the tower Autodesk would do anything necessary to correct the error (Day, 2005). Day goes on to say that one of the drawbacks to Revit, and for that matter all other BIM products, is the large amount of processing power needed to process the extreme amounts of data associated with a model of this size, requiring all users to upgrade their computer systems.

The coordination of the plans of architects, engineering consultants and all other internal services was made infinitely easier (designbuild-network, 2010). The software immediately indicated coordination issues to the design team allowing them to fix the problem while focused on that specific area of design, this in-turn lead to quicker and more efficient design making. The software allowed analysis of footflow and lighting effects and as such improved the time taken to make changes based on these analysis. Seletsky, as quoted by the Designbuild-network, stated that it was possible to analyze the pedestrian flow and lighting using specialized software, yet use of Revit no longer required time for transfer of data to and from these specialized systems, minimizing the time taken to make improvements. The use of a BIM system once again showed its worth when the New York City Police Department demanded that the outer walls of the building be moved further back from the surrounding streets. This caused the footprint of the tower to be moved from its original location as per Daniel Libeskind's master plan (designbuild-network, 2010). This allowed David Childs, the architect of One World Trade Centre, to change the shape of the footprint from a parallelogram to a square. Using traditional design techniques this change could have caused a delay of years however with the use of Revit the SOM design team was able remodel the tower quickly with causing unnecessary delay (designbuild-network, 2010).

According to Phil Bernstein, vice president of Autodesk's building services division and a trained architect, productivity can be improved by bringing design and construction closer together, he was been quoted as saying 'We're focusing on why we can't drive the construction sector efficiently when we are so busy. The recent technical revolution has yet to hit our industry.' (Designbuild-network, 2010). Other industries have driven down costs by having partners in the supply chain working seamlessly together; this is most evident in the car manufacturing industry (Autodesk, 2007). Bernstein believes the construction industry should follow this example, specifically the with reference to information flow between architects and other design consultants and construction firms. To promote this idea Revit created an online collaboration service, Buzzsaw, a system that allows firms to share access to documents such as building plans (Designbuild-network, 2010). SOM has used this service from 1999, and knowing the benefits of its use applied it again to the One World Trade Centre project, this required that the full design team and the construction manager, Tishmann Construction, needed to buy into the BIM idea (Designbuild-network, 2010). Although Buzzsaw is an internet-based system, everyone involved in the design of the project was required to install Revit on their computer systems. It should be noted that the full system is not required for all users. Seletsky explains that users on site and in other remote locations may have limited internet access and as such do not have the computer capacity for access to all project data and further this remote access raises many security issues. Autodesk claims that using Buzzsaw is as easy as using email and therefore the design team needed very little help in getting the system operational (Designbuild-network, 2010). Autodesk has been quoted as saying that the use of BIM, on the One World Trade Centre Project, delivered much greater efficacy than traditional design methods would have. And it appears that the design team agrees; Charles Guerro, vice president at WSP, stated that Revit offered a number of benefits in terms of coordination. He went on to say that Revit allowed designers to quickly address issues which would not have been readily apparent in a traditional 2D approach.

Canto Seinuk Group (CSG) used Revit and AutoCAD to model the tower's foundations, buttress slabs, core walls and columns on the original designs (Designbuild-network, 2010). Following this success the firm is now using another version of the 3D software, Revit Structure, to create new design and construction documents. The Designbuild-network indicated that Tishman Construction found benefit from the system when it came to drawing up and submitting payment claims, by exporting data from the Revit system to Excel and creating quantity take-offs and verify results received from traditional methods; speeding up and improving the process. This is over and above the benefit derived from the improved information flow from the design consultants. According to Autodesk these benefits were only possible because users implemented fundamental changes in their working practices and had firm wide buy in into the BIM idea. This is proved by the process changed implemented by SOM. Once the SOM team realized that by visualizing the project as it would be constructed, and not as a drawing, it was easier to ensure coordination with the extended project team (glasssteelandstone.com, 2010). This lead to a community of designers rather than the traditional your office verses my office approach normally taken in construction design. The use of BIM on One World Trade Centre was more about work sharing than anything else. The feedback Autodesk received from the project has improved this has enabled the software company to improve its multi-user workflow which is now practically seamless for large projects (Designbuild-network, 2010).

Bernstein hopes that as BIM becomes more popular systems such as Revit will be able to meet clients increasingly demanding. Clients will want the flexibility to make short-term changes and a better understanding of what it is they are buying, especially as the environmental impact of buildings becomes more of a focus for getting plans approved. Autodesk claims that with BIM all the information you would or could ever require to understand the impact of a building before you construct it is available at your fingertips.

The fact that Autodesk worked closely with SOM on One World Trade Centre has made Revit stand out of the crowd when it comes to available BIM software. Revit is more than just as a fancy front end for client presentation, which it does well, but at its core it is an extremely strong design tool (Day, 2005). The use of Revit on One World Trade Centre has clearly started a revolution in the construction industry. BIM use is increasing as more and more projects being completed successfully using Revit or similar systems. However it may take more than a decade to get the industry, as a whole, to see the benefits of BIM and 3D modelling, benefits that early adopters, such as SOM, are already enjoying.

5.3 Summary.

The BIM concept has the potential to revolutionise the construction process. As developers, designers and other stake holders become more aware of its advantages it will become more common place. The fact that software developers are interested in improving their products, as in the above case, will help drive this. One of the most noticeable and beneficial advantages is the assistance a BIM system provides the principle agent with managing information.

5.4 Conclusion.

BIM is here to stay; this can only be stated because of its successful implementation on numerous projects, especially in the United States of America. By completing case studies of projects completed using BIM, one can clearly see that BIM provides an excellent tool for the project team to manage information, although the information is only as good as the information inserted into the system.

5.5 Testing of Hypothesis.

Original Hypothesis:

"BIM is a relatively new technology and thus has not been used on many projects; however the projects where it has been used have proved a great success. Thanks to the BIM process the information management task is made much easier as lots of the traditional requirements are handled automatically by the system.”

The hypothesis is correct, however it must be noted that the use of a BIM system will not eliminate the need for an information manager; it will make his task easier and more efficient.

Chapter 6

Conclusion: Information Management, on Construction Sites, is Building Information Management (BIM) the Solution?

6.1 Background to Problem.

Information management on construction sites is a problem that any party in the built environment is aware of. The need for information management is largely due to the time limits and risks associated with modern building projects (Robertze, 2010). It often happens that as a project progresses gaps in the supplied information become evident and delays are caused while this information is sourced. These information gaps are partly due to the large number of specialists that contribute to the design of a building project, and the coordination of all this information. Also contributing to this problem is the lack of certainty of the final product details, for example office layouts. Thus such information is often changed, by the employer, at a late stage causing rushed design changes and clashes with older revisions of the design. Because of this problem it is common practice for contractors, on large building projects, to employ an information manager to act as a coordinator of information. It is normally the duty of this information manager to point out gaps in this information to the relevant consultant (Broxham, 2010). This is clearly a difficult position to be in, as one would not only have to understand the building process, but also what information is needed to complete construction and where this information is most likely to be sourced. This sourcing of information leads to coordination problems and delays, which in turn cost time and money. In order to assist construction project managers with this task several computer based systems have been developed.

Building information modelling (BIM) was developed as design tool in order to help architects, engineers and other parties to design buildings in a shorter time while providing better levels of information to the client and builder (Kymmell, 2008). One of the benefits of BIM is that it alerts relevant parties to gaps in the information early in the design process by showing the weaknesses of the project through use of the 3D modelling function (Kymmell, 2008). This in turn allows all the required information to be provided in sufficient time for construction. Currently the main benefits of BIM are experienced during the conception and design stages of a project; however BIM has the potential to be more effective in the later phases of a project including construction and facilities management of the building once the construction process is complete. BIM is a relatively new technology and as yet is not well know and therefore not widely used in the construction industry. It is believed that once BIM has been used successfully on several projects it will revolutionise the construction process; as is the case in the US construction market.

The intention of this report was to ascertain whether or not BIM would provide an answer to the information management problem. Thus the question "**Information management, on construction sites, is BIM the solution?".**

6.2 Conclusions

In order to discover the answer for the main problem four sub-problems were investigated, each of these investigating a specific aspect of the main problem. In this way the final conclusion can be drawn up.

6.2.1 Sub Problem 1

"Why the need for information management, on construction sites?"

Problem conclusion: IM is necessary to ensure timeous delivery of a project, by managing information flow from consultants and to ensure that the project is completed to the required specifications and standards set by the client (Broxham, 2010). This need is created by the information gaps in the drawings, schedules and specifications provided, by the built environment professionals, to the principle contractor for the purpose of constructing the project. These information gaps occur because of several reasons including, human error, the lack of design time, insufficient product knowledge and miscommunication between consultants.

6.2.2 Sub Problem 2

"Does Building Information Modelling (BIM) Cater for Information Management?"

Problem conclusion: BIM is a process and this process facilitates better communication and collaboration between all involved parties. As such it provides better quality information which in-turn is easier to manage. Most BIM products are "one stop shops" and thus provide excellent inbuilt information management tools; this is largely due to the fact that all information is included in the model and is thus easily available. It is important to note however that the information contained in the model is only as good as the information inserted into the model.

6.2.3 Sub Problem 3

"Can Available Building Information Modelling (BIM) Products be used as Information Management tools?"

Problem conclusion: Simply put yes, available BIM products can be used as information management tools. Some are better at it than others but the choice is as choosing between Mercedes Benz and BMW, they both do the same thing, but in a slightly different way. Once a program has been selected it is important to ensure that it is used correctly, it is meant to be an information management tool, not an information manager. The drawback of current BIM systems is the lack of integration between them, thus if BIM is to be used on a project all stakeholders need to invest in a chosen system, this is obviously not always cost effective. It may happen that the client specifies a BIM product to be used with the intention that he uses it as a facilities management tool post construction, this alleviates the buy in cost for the consultants but still leaves the problem of training and use of a system that all parties may not be familiar with.

6.2.4 Sub Problem 4

"Has Building Information Modelling (BIM) been used successfully in the past?"

Problem conclusion: BIM is here to stay; this can only be stated because of its successful implementation on numerous projects, especially in the United States of America. By completing case studies, of projects completed using BIM, one can clearly see that BIM provides an excellent tool for the project team to manage information, although the information is only as good as what is inserted into the system.

6.2.5 Final Conclusion

Information management is necessary on all construction projects, the larger and more complex these projects become the greater this need (Broxham, 2010). BIM, although not specifically designed to do so, provides a solution to this information management problem through several directions. The greatest of which is the improved coordination during the design stage. The use of a 3D BIM model allows the employer to see the finished project before the construction phase starts and thus make changes at an early stage, minimizing the information management burden on both the professional team and the contractor. This is because by the time the contractor is on site the information is complete. There are currently several software systems that will perform this function, all of which look promising. It can be augured that while choosing the correct system is important, more important is knowing how to use the chosen system correctly (Kymmell, 2008). It is also important to note that while a BIM system helps manage information, the quality of information is still dependent on those that insert it. BIM is a design tool not a designer. While BIM appears to solve many of the information management issues experienced in the construction industry it is hampered as an effective tool due to its large barriers to entry. Because of the lack of integration between system designers it is very difficult to find a professional team that all use the same system. This in turn leads to high start up cost which often discourages employers. Another barrier to the BIM's success is the lack of knowledge about the concept in the industry. BIM is still, relatively speaking, in its infancy and as such does not have a large following. This is expected to change as more and more projects are completed using BIM (Autodesk, 2010). In a sentence BIM does provide a solution to Information management, however a fair amount of change is needed in the construction industry for it to be adopted on a large scale.

6.3 Testing of Original Hypothesis

Original hypothesis:

"BIM is an answer; however it may be limited in its approach and thus cannot be used in all situations. There are also large barriers to entry for a BIM system, including the fact that the entire professional team, as well as the contractor, needs to use the same BIM system in order for it to work as intended. BIM is not the all in one answer that is needed thus there is still a need for a tool, which can be used by all participants, to be developed.   It must then be concluded that BIM is not a suitable information management solution in the current construction climate; however it may, in the near future, be used successfully if the industry begins to use the BIM methodology more widely."

The original hypothesis claims that BIM will not make a suitable information management solution. The research however has proved this false; BIM is more than capable of being used to manage information during construction projects. With so many forms and systems available the question is more about choosing the right BIM system, and using it correctly, than about whether or not BIM can be used. The research has also proved that there are many barriers to entry and as such this will hinder BIM's ability as an information management tool. It can therefore be concluded that while the hypothesis was partially correct its main statement has been disproved and the use BIM will be a suitable and successful information management solution.

6.4 Suggested Future Research

This report has looked at BIM, as an information management tool, in a very broad context. It is therefore suggested that future research looks at the use of BIM, as an information management tool, in the context of specific standardised construction contracts and the effects these will have on the BIM system as well as the effects the BIM system will have on the contract. Secondly a comparison of the different BIM systems available, focusing on their information management properties would provide the industry with a guide when the need arise to choose a system. A final suggestion would be a study into whether or not BIM is likely to penetrate the South African construction market, or will the barriers to entry prove too high.

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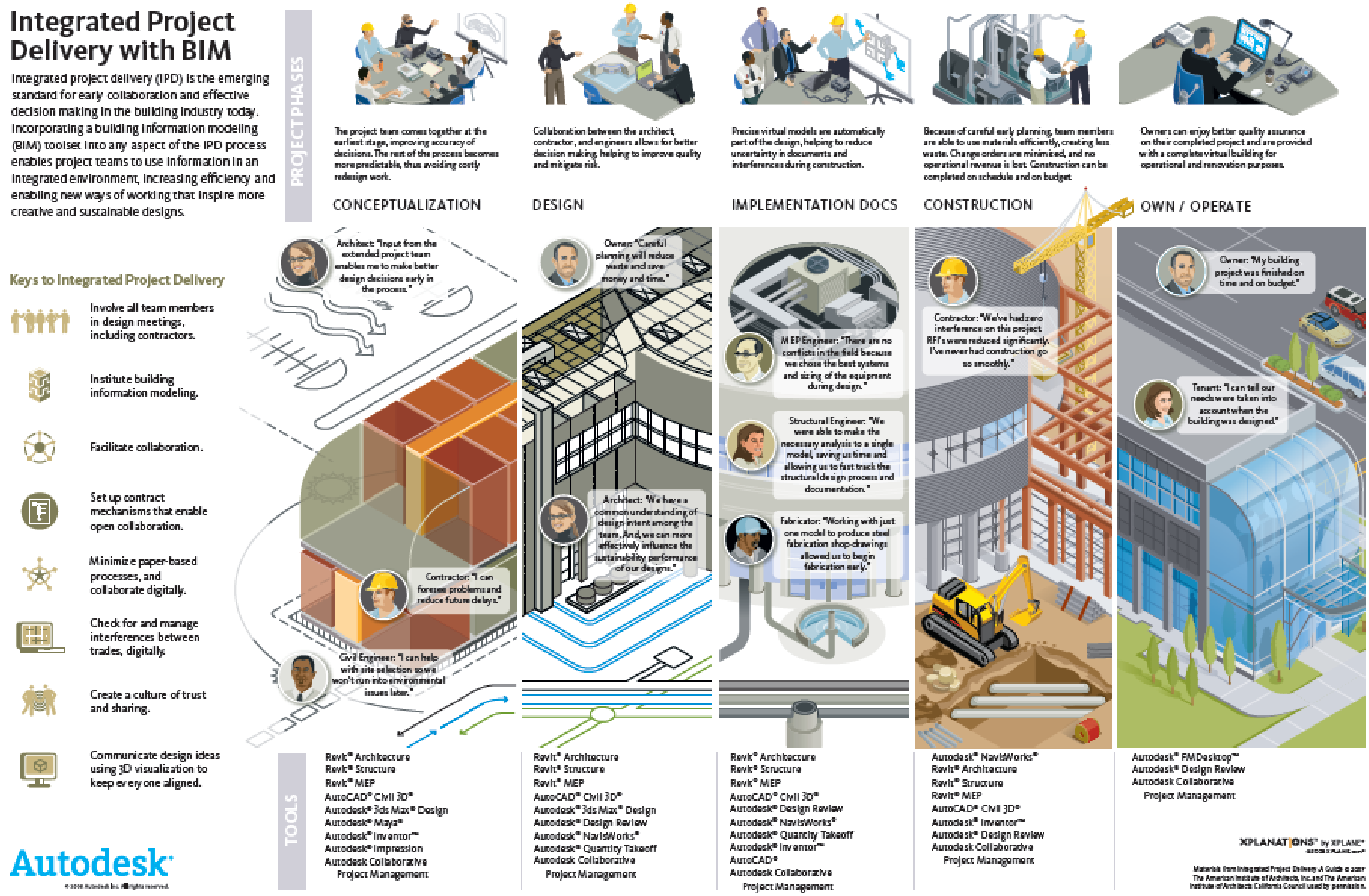
Annexure A:

Integrated Project Development Model

Source: Autodesk, 2010


Integrated Project Delivery with BIM
Integrated project delivery (IPD) is the emerging standard for early collaboration and effective decision making in the building industry today. Incorporating a building information modeling (BIM) toolset into any aspect of the IPD process enables project teams to use information in an integrated environment, increasing efficiency and enabling new ways of working that inspire more creative and sustainable designs.
Keys to Integrated Project Delivery
Involve all team members in design meetings, including contractors.
Institute building information modeling.
Facilitate collaboration.
Set up contract mechanisms that enable open collaboration.
Minimize paper-based processes, and collaborate digitally.
Check for and manage interferences between trades, digitally.
Create a culture of trust and sharing.
Communicate design ideas using 3D visualization to keep everyone aligned.
Autodesk
PROJECT PHASES
The project team comes together at the earliest stage, improving accuracy of decisions. The rest of the process becomes more predictable, thus avoiding costly redesign work.
CONCEPTUALIZATION
Collaboration between the architect, contractor, and engineers allows for better decision making, helping to improve quality and mitigate risk.
DESIGN
Precise virtual models are automatically part of the design, helping to reduce uncertainty in documents and interferences during construction.
IMPLEMENTATION DOCS
Because of careful early planning, team members are able to use materials efficiently, creating less waste. Change orders are minimized, and no operational revenue is lost. Construction can be completed on schedule and on budget.
CONSTRUCTION
Owners can enjoy better quality assurance on their completed project and are provided with a complete virtual building for operational and renovation purposes.
OWN / OPERATE
Architect: "Input from the extended project team enables me to make better design decisions early in the process."
Contractor: "I can foresee problems and reduce future delays."
Civil Engineer: "I can help with site selection so we won't run into environmental issues later."
Owner: "Careful planning will reduce waste and save money and time."
Architect: "We have a common understanding of design intent among the team. And, we can more effectively influence the sustainability performance of our designs."
MEP Engineer: "There are no conflicts in the field because we chose the best systems and sizing of the equipment during design."
Structural Engineer: "We were able to make the necessary analysis to a single model, saving us time and allowing us to fast track the structural design process and documentation."
Fabricator: "Working with just one model to produce steel fabrication shop-drawings allowed us to begin fabrication early."
Contractor: "We've had zero interference on this project. RFI's were reduced significantly. I've never had construction go so smoothly."
Owner: "My building project was finished on time and on budget."
Tenant: "I can tell our needs were taken into account when the building was designed."
TOOLS
Revit® Architecture
Revit® Structure
Revit® MEP
AutoCAD® Civil 3D®
Autodesk® 3ds Max® Design
Autodesk® Maya®
Autodesk® Inventor™
Autodesk® Impression
Autodesk Collaborative Project Management
Revit® Architecture
Revit® Structure
Revit® MEP
AutoCAD® Civil 3D®
Autodesk® 3ds Max® Design
Autodesk® Design Review
Autodesk® NavisWorks®
Autodesk® Quantity Takeoff
Autodesk Collaborative Project Management
Revit® Architecture
Revit® Structure
Revit® MEP
AutoCAD® Civil 3D®
Autodesk® Design Review
Autodesk® NavisWorks®
Autodesk® Quantity Takeoff
Autodesk® Inventor™
AutoCAD®
Autodesk Collaborative Project Management
Autodesk® NavisWorks®
Revit® Architecture
Revit® Structure
Revit® MEP
AutoCAD® Civil 3D®
Autodesk® Inventor™
Autodesk® Design Review
Autodesk Collaborative Project Management
Autodesk® FMDesktop™
Autodesk® Design Review
Autodesk Collaborative Project Management
XPLANATIONS™ by XPLANE®
Materials from Integrated Project Delivery: A Guide © 2007 The American Institute of Architects, Inc. and The American Institute of Architects California Council used by permission.