BUILDING INFORMATION MODELING

Better buildings through digital practice:
Changes in roles and processes

Manasi Jadhav. Student No. 4039572
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Manasi Jadhav
Student number 4039572
jadhav_manasi@yahoo.com

First mentor:
MSc. Dr.ir.A. Koutamanis
Area of expertise: Design and Decision Systems

Second mentor:
MSc. Dr. ir. M. Prins
Area of expertise: Design Management

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## Contents

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>foreword</td>
<td>5</td>
</tr>
<tr>
<td>summary</td>
<td>6</td>
</tr>
<tr>
<td>1.1 research background</td>
<td>10</td>
</tr>
<tr>
<td>1.2 research problem, aim and questions</td>
<td>11</td>
</tr>
<tr>
<td>1.3 overview of research objectives, focus and methodology</td>
<td>12</td>
</tr>
<tr>
<td>1.4 structure of the thesis</td>
<td>14</td>
</tr>
<tr>
<td>2. theoretical input</td>
<td>18</td>
</tr>
<tr>
<td>2.1 introduction</td>
<td>18</td>
</tr>
<tr>
<td>part I: Analysis Framework</td>
<td>20</td>
</tr>
<tr>
<td>2.1 outline of a framework for exploring the aspects to be considered in the initial stages of a BIM Project</td>
<td>20</td>
</tr>
<tr>
<td>part II: a literature based exploration of the BIM aspects</td>
<td>23</td>
</tr>
<tr>
<td>2.1 BIM project preparation</td>
<td>23</td>
</tr>
<tr>
<td>2.2 BIM plan</td>
<td>24</td>
</tr>
<tr>
<td>2.3 information exchange</td>
<td>28</td>
</tr>
<tr>
<td>part III BIM literature cases</td>
<td>30</td>
</tr>
<tr>
<td>2.1 literature cases</td>
<td>30</td>
</tr>
<tr>
<td>part III: BIM approach</td>
<td>42</td>
</tr>
<tr>
<td>2.1 BIM Approach</td>
<td>42</td>
</tr>
<tr>
<td>2.2 process map as per literature</td>
<td>44</td>
</tr>
<tr>
<td>2.3 identifying added responsibilities of project manager</td>
<td>45</td>
</tr>
<tr>
<td>3. research design and process</td>
<td>54</td>
</tr>
<tr>
<td>part I: research approach and strategies</td>
<td>54</td>
</tr>
<tr>
<td>3.1 research purpose and strategy</td>
<td>54</td>
</tr>
<tr>
<td>3.2 the case study as a research strategy</td>
<td>55</td>
</tr>
<tr>
<td>3.4 strategies for reporting the research process and results</td>
<td>57</td>
</tr>
<tr>
<td>part II: the research process</td>
<td>57</td>
</tr>
<tr>
<td>3.5 preparing the case study</td>
<td>57</td>
</tr>
<tr>
<td>part III: ensuring the quality of the research</td>
<td>59</td>
</tr>
<tr>
<td>3.1 validity of the research design</td>
<td>59</td>
</tr>
<tr>
<td>4. case study as agreed</td>
<td>63</td>
</tr>
<tr>
<td>4.1 background and context of the project</td>
<td>63</td>
</tr>
<tr>
<td>4.1 preparation Stage</td>
<td>64</td>
</tr>
<tr>
<td>part II: role of project manager</td>
<td>75</td>
</tr>
<tr>
<td>part III: BIM approach of case study – as planned</td>
<td>76</td>
</tr>
<tr>
<td>5. case study as realized</td>
<td>79</td>
</tr>
<tr>
<td>part I: the case as planned studied with respect to the BIM analysis framework</td>
<td>79</td>
</tr>
<tr>
<td>5.1 preparation stage</td>
<td>80</td>
</tr>
<tr>
<td>5.2 developing the BIM plan</td>
<td>83</td>
</tr>
<tr>
<td>5.3 information exchange plan of BIM use</td>
<td>84</td>
</tr>
<tr>
<td>part II: summarizing the role of project manager</td>
<td>96</td>
</tr>
<tr>
<td>5.1 project preparation</td>
<td>96</td>
</tr>
<tr>
<td>5.2 BIM Plan</td>
<td>97</td>
</tr>
<tr>
<td>5.3 information exchange</td>
<td>98</td>
</tr>
<tr>
<td>part III: Project approach – BIM process as realized</td>
<td>100</td>
</tr>
<tr>
<td>6. reflections</td>
<td>104</td>
</tr>
<tr>
<td>part I: process as per literature vs. case process as planned</td>
<td>104</td>
</tr>
<tr>
<td>6.1 reflection 1</td>
<td>104</td>
</tr>
<tr>
<td>part II: case process as planned vs. case process as Realized</td>
<td>105</td>
</tr>
<tr>
<td>6.1 reflection 2</td>
<td>105</td>
</tr>
<tr>
<td>Section</td>
<td>Page</td>
</tr>
<tr>
<td>------------------------------------------------------------------------</td>
<td>------</td>
</tr>
<tr>
<td>part III: process as per literature vs. case process as realized</td>
<td>105</td>
</tr>
<tr>
<td>6.1 reflection 3</td>
<td>105</td>
</tr>
<tr>
<td>part IV BIM approach vs. project approach</td>
<td>111</td>
</tr>
<tr>
<td>6.1 BIM project initiation</td>
<td>111</td>
</tr>
<tr>
<td>6.2 participant involvement</td>
<td>111</td>
</tr>
<tr>
<td>6.3 decision making structure</td>
<td>111</td>
</tr>
<tr>
<td>6.3 BIM plan</td>
<td>112</td>
</tr>
<tr>
<td>6.4 BIM goals &amp; uses</td>
<td>112</td>
</tr>
<tr>
<td>6.5 information exchange</td>
<td>113</td>
</tr>
<tr>
<td>7. conclusions &amp; synthesis</td>
<td>115</td>
</tr>
<tr>
<td>part I summarizing the conclusions</td>
<td>115</td>
</tr>
<tr>
<td>7.1 process change</td>
<td>115</td>
</tr>
<tr>
<td>7.2 role changes</td>
<td>116</td>
</tr>
<tr>
<td>7.3 challenges</td>
<td>116</td>
</tr>
<tr>
<td>part II synthesis – detailed information exchange</td>
<td>117</td>
</tr>
<tr>
<td>7.1 final results</td>
<td>117</td>
</tr>
<tr>
<td>part III synthesis – overall information exchange</td>
<td>123</td>
</tr>
<tr>
<td>7.1 client initiation</td>
<td>124</td>
</tr>
<tr>
<td>7.2 participant involvement and decision making structure</td>
<td>124</td>
</tr>
<tr>
<td>7.3 BIM planning, goals &amp; uses</td>
<td>125</td>
</tr>
<tr>
<td>7.4 information exchange</td>
<td>126</td>
</tr>
<tr>
<td>part IV- reflection, applicability &amp; contribution</td>
<td>127</td>
</tr>
<tr>
<td>7.1 development and application of framework</td>
<td>127</td>
</tr>
<tr>
<td>7.2 limitations of the framework</td>
<td>127</td>
</tr>
<tr>
<td>7.3 research contributions</td>
<td>127</td>
</tr>
<tr>
<td>7.4 implications of the findings for practice</td>
<td>128</td>
</tr>
<tr>
<td>7.5 recommendations for future research</td>
<td>129</td>
</tr>
</tbody>
</table>
To my late grandfather...
foreword

“Life can either be accepted or changed. If it is not accepted, it must be changed. If it cannot be changed, then it must be accepted.”

Keri Russel

Five years ago when I completed my bachelors’ degree in architecture and joined a new firm to start with my real world of being an architect; I was filled with immense joy and excitement. Along with these feelings I shared an equal level of anxiety to enter the construction world with my own imagination. In the three years of the work experience these feelings were converted to frustration, anger and helplessness. Being a junior architect, I was neither a designer in that big firm nor did I know why I was always changing the drawings even after working so hard to get it right and also beautiful. Eventually it was realized that it wasn’t the fault of being a junior architect, the real reason was way beyond the hands of the senior designers too. It was the complete chaos created by changes, expectations, different interpretations, errors, redoing of designs to meet the goals, juggling between design quality, cost and deadlines. This was a world beyond the control of human imagination.

Three years of this world were enough to strengthen my decision to somehow be in control of this change. This is when I decided to pursue management from this university. The first year of M.Sc thought the basics of management. A wide overview of new concepts and techniques gave a confidence to go back to the world of chaos. However something was missing to make a stronger impact. While thinking about the graduation topic, I looked back at my first year to find some inspiration. I remembered a role of BIM Manager that I performed in a workshop. Understanding this role was quite difficult in the short period of time and then managing the other roles of designer, services, structural, environmentalist with the concept of BIM. Also the deadline of submitting this design in a matter of six weeks had created a complete confusion of BIM in my mind; was it a modeling tool or a managing tool? Reading about it again after a year, I realized it was an extremely powerful tool for management and I had completely misunderstood about it in the workshop. Hunting for this topic gave me thousands of hits and I knew this was a hot topic in the industry. Also my friend who is an architect and was hunting for job after completing his masters, updated me with the industry need of BIM. With this, I also knew this was the weapon that was lacking to get back in the world of chaos and take charge. From that day till now, I have lived an experience that I never had in my academic life before. Throughout this year, there are a number of people who have been my inspiration and support. A short consultation with Architect Sagar Thorat from Free D Geometries bv provided me with a critical insight on the requirement of BIM even more in materializing of complex geometry projects.

To all these, I owe my deep gratitude!

At first I want to thank the main advisor for this work, Alexander Koutamanis- for the opportunities he has given me to explore the subject in my own way and for his support in the ups and downs in the entire process. Having given me the freedom to think in this process, he has as well contributed with his wisdom and advice as I was facing critical crossroads and decisions. I am furthermore grateful to the co advisor Matthijs Prins for the fruitful discussions and helpful feedback. A particular thank to Geoffrey Timmer for being supportive, permitting me to use the case material and for being ready to give his inputs whenever needed.

My sincere thank to the many practitioners and researchers who have sacrificed their time in order to give me insight into their experiences and knowledge, for their interest and feedback.

I am grateful to my friends for being supportive and for being there for me when I needed them the most: Chex and Revz, to Arvind for understanding the pressures of thesis and not being able to spend the good old times together!

Finally my family in India, who made sure to call me before every presentation and relax me. And last but not the least, Sagar with his love and understanding of my tempers during the thesis.
summary

The current AEC industry building process has been fragmented and the paper-based communication is considered to be the main reason behind this. Errors, changes, omissions result in upgrading the design a number of times sequentially by different parties. In addition to this, the various interpretations of a single design intent by different parties lead to even more complexities. With the introduction of ICT technologies like 2D CAD, the time spent on redrafting a change in the design has been reduced. However, the practice of sequential design changes, omissions, errors, different interpretations remain the same. In addition to this, while incorporating the changes and confirming that every consultant is on the same page with respect to design intent; the major aspect of achieving the project goals becomes secondary.

During the last decade, the major shift in ICT for the AEC industry has been the proliferation of Building Information Modeling [BIM] in industrial and academic circles. Implementation of Building Information Modeling (BIM) on a project level requires comprehensive planning by facility owners and project participants (designers, contractors, subcontractors, and manufacturers) to ensure successful transition from a traditional approach to incorporating this new technology into the project workflow. The current status of BIM in design practice reports a lack of planning in general, and limited guidelines available for team members involved in the process. This typically leads to BIM being used for targeted tasks, but not implemented throughout the lifecycle of a building. This is contrary to how BIM was conceived and it does not allow the new technology to reach its full potential in industry construction projects. This ultimately results to the situation of square peg in round hole; wherein the technology is implemented without changing the process.

There has been a great increase in the journal articles and a number of books have been published on BIM. But the role of project manager to handle these changes has largely been ignored. Traditionally the project manager had an overview of the entire design and overlapped them to check for clashes. With this approach, the project manager was well connected with the design and its developments. With BIM Technology, since there is no role definition for project manager, it is uncertain which BIM tools should a project manager use. Or to what extent should he be knowledgeable about a BIM. This entire situation has made the project manager take a step back in the BIM Process. The main objective of this research has been twofold: Firstly, what are the new aspects to be considered in the initial stages of a BIM Process? and secondly, what are the changes in the responsibilities of a project manager while managing the changed BIM Process?

research design and approach

This is a qualitative case study research where in depth study of a single main case study is performed. This research has been designed in six parts along which the report has also been organized.

The first part of the research mainly identifies the main research subject and defines the primary objectives of the research. In the second part, an analysis framework is generated through interplay between BIM Literature and a number of BIM literature case studies. This framework gives parameters to be examined in the literature and the case study. The third part describes the research design, process and strategies. In the first half of the fourth part of the thesis, an in depth case study of the process as planned is performed and in the second half the case study process as realized is performed. In the fifth part a reflection of three processes with two of them at a time is conducted: process as per literature, case process as planned and case process as realized. In the sixth part the results of the analysis are synthesized into an optimal process map with the changed role of the project manager.

theoretical input

The main elements of the framework have been evolved through an extensive literature study. The literature mentions a number of aspects that are considered important while planning. But the following points were selected for the analyses which were also based after a detailed study of thirteen BIM literature cases.

1. Client Initiation: Clients can realize significant benefits from BIM tools and processes but in order to reap these advantages, the client should know what he wants from BIM. This is the guiding line for the future contractual and legal changes that will be a part and parcel of BIM Implementation
2. Participant Involvement: BIM requires early involvement of participants since the design decision phases get proposed in this process. In addition to this it is important that the participants have an early experience with BIM or are willing to learn and collaborate with other participants.

3. Decision making structure: The type of decision making structure affects the total BIM benefits that can be achieved. Preparing a BIM Model but waiting for a decision to be approved at different levels will cause a time lapse and less transparency of decisions and design intent.

4. BIM Planning: All the consultants should give inputs to the BIM Plan which consists of how the communication, information exchange, model exchange take place. Also to what extent the BIM model be completed in each phase, what are the new roles, responsibilities, added resources needed in a BIM Phase of the project.

5. BIM Goals & BIM Uses: BIM Uses are the analysis tools or BIM tools which are connected to the BIM Model. The BIM Uses are important in order to achieve the BIM Goals of the project. These BIM Uses are expensive to invest for a onetime use in the organization. Thus an evaluation of Project goals vs. Organizational goals is needed to finalize the BIM Use.

6. Information exchange: A basic premise of BIM is collaboration by different stakeholders at different phases of the life cycle of a facility to insert, extract, update or modify information in the BIM to support and reflect the roles of that stakeholder. Interconnectedness of different factors is an important issue. The focus only on parts can lead to a lack of integration, thereby reducing the quality of the project in total.

After studying the literature cases it was found that the above mentioned aspects were a reason for the success or failure of the BIM projects.

research strategy and process

After finalizing the aspects to be studied, a framework was developed to analyze the literature and case based on these aspects. Three processes were developed which were then reflected or compared with each other to gain conclusions: BIM process as per literature, Case process as planned, Case process as realized. Throughout these processes, particular attention was paid to the role of project manager and how it changed in the three processes. A concept of Venn diagrams was used to understand the shared, overlapping and individual responsibility of the project manager. The framework, its tools and the Venn diagrams served as the main vehicles for analyzing, organizing, and reporting on the data compiled from the case studies and literature.

case study analysis

The real time single main case study was studied and analyzed in two different parts: Case as planned and Case as Realized. The analysis framework was used organize the information.

The case as planned was studied from BIM documents prepared before the start of the project. These consist of: the BIM Manual, the BIM Agreement, the BIM Process map. After summarizing the conclusions, a process map which showed quite a lot of similarities between the literature process and the planned case process. Also the role of project manager was not included in the process map or in the model exchange.

The inputs for the case as realized was gathered from a number of interviews conducted with the project managers, engineers and BIM Managers of different consultants. The project documents prepared at the end of the preliminary design stage gave a complete picture of what activities were performed, when, how and by whom. By deeply studying the documents, an important feature of information interdependency was observed at many points. A second round of interviews was performed to see how a particular information exchange actually took place, how was the BIM Model used for communication and what was the role of the project manager.
conclusions and synthesis

Having completed the theoretical and empirical parts of the study, an evaluation of the different processes is made and other important observations are discussed.

Upon comparing the processes it is observed that the case process as planned was based on literature which gave a highly optimistic and demanding situation for the consultants doing BIM for the first time. Every case is different with respect to type of client, time, budget, consultants, their capacities to collaborate and many more aspects. Such individual case intricacies should be taken into consideration before planning for BIM.

Upon comparing the BIM process as per literature and Case process as realized, it was observed that in the former process, the preparation time before the start of schematic design stage is long & detailed and the schematic design phase is comparatively shorter and compact with specific steps. In the latter case process, the stage before the start of the project is short and the schematic design phase is long with indefinite number of steps for information exchange.

As a result, this leads to the conclusion that project stages have to be re planned along with redefining the roles with respect to BIM.

The analysis from the information loop studied in the case lead to a new process consisting of: new teams with supporting modeling and knowledge capabilities, reincorporating the BIM tools and BIM model in such a way that it becomes a binding element for interdisciplinary activities and elaborating the role of project manager by integrating him in the core of the BIM Process. Having said this, it is kept in mind that the project manager does not involve himself in the design issues.

Finally a process map for the organization under which the case study was conducted is given along with the new responsibilities of the project manager and tools & skills needed to use the them is overlaid on each aspect of the process.

research contribution

The contribution of this research is fourfold, providing firstly; an analysis framework for exploration, description, analyzing complex and qualitative findings from the literature and case study; secondly a comprehensive way of showing the multilayered responsibilities of the various consultants in the BIM Process; thirdly categorizing the role of project manager in three different responsibilities to manage the new tasks in BIM; fourthly synthesizing all the above findings in one process map. Altogether, this thesis is a detailed and reflective documentation of expected BIM through literature and current challenges in practice for achieving that expected BIM of literature.
1. introduction

The point of departure of this thesis is the need for a more comprehensive understanding of changes in the initiation phase of a BIM enabled project. A single main case study has been explored to gain insight into the process when BIM related activities are performed in a traditional process of a project. Particular attention is paid to the work and interactions of the project manager, and the implementation and use of technologies supporting Building Information Modeling (BIM). Key features of the research are: the broad approach to the problem field manifested by the development of a framework by studying the BIM Literature and BIM Literature cases, analyzing the role of project manager based on the framework and the detailed and reflective exploration of real-life situations.

1.1 research background

The project managers were asked during this research project about the preparation behind leading such a complex project, an important point mentioned was: Based on best practices and experiences, you know what steps may occur during the project. You adjust these steps to the timeframe and the size of the project and the constraints and then you come up with a preliminary schedule which defines more clearly as you progress. This is related to the process leading to achieve the final product. (Cuff 1991) describes design as a social construction. Behind the seemingly simple quotation is a highly complex world of interrelations, interdependencies, communication, integration between actors and process. If we look into the real situation of the AEC industry, we find that the jobs are getting larger and more complex and that the total design is split between dozens of different professions, experts, manufacturers and contractors.

AEC industry meets the digital world

More than thirty years ago the architects and other practitioners involved in the architectural design process faced an entirely new situation due to the new and rapidly expanding Information and Communication Technology (ICT) industry. They have, however, been slow to adapt the new technologies in their work and interaction. Compared to other industries, the Architecture-Engineering-Construction (AEC) industry is lagging behind when it comes to the successful implementation and use of ICT (Gann 2000). Even though there were high expectations as to the potential of the new technologies to enhance growth and to improve processes, the productivity status of the

Most people feel that the introduction of 2D computer drafting in design firms did not significantly change the way architects practiced, but it simply computerized their practice. 3D computer modeling and BIM on the other hand bring a culture change that infuses all aspects of practice not just the drafting portion. But BIM cannot be equalized with 3D computer modeling, since BIM is predominantly a design tool that has many capabilities of which, one is modeling and producing construction documents. The integration of these technologies is expected to lead the AEC industry into a new era characterized by better communication and exchange of architectural design information between project actors involved in all phases of the building’s life cycle.

challenges

Researchers argue that the modest productivity gains achieved from the increased investments in information technology, known as the productivity paradox, are due to neglecting process development when implementing new technologies (Rekola, Kojima et al. 2009). In an interview with a practitioner, the basic problem architects and other practitioners have is how to deal with new digital tools within a project where there is much work to be done and drawings to be produced. Although the team members are very enthusiastic about implementing
new technology, the practitioners involved are constantly running into practical problems that make it easy to fall back into traditional ways of working.

In addition to this, several challenges arise due to the mismatch between the traditional AEC industry and the rapidly developing ICT industry. The slow application of BIM and minor development and changes in construction process has followed from solving the detected problems one-sidedly by only developing technology, process or education of people alone without seeing that the technological issues, work and business process issues, knowledge, and human factors are interconnected in the bottleneck points. The thorough analysis of the questions why has been neglected or results of these analyses have not been transferred from the research scene to the industry (Rekola, Kojima et al. 2009).

(Chastain T, Kalay YE et al. 2002) describe two paradigms of problems related to the encounter between the practice of architectural design and the digital world. They call the first paradigm trying to put ‘a square peg in a round hole’, which describes the problem of adapting new technology to current practice, indicating mismatch between the designers’ tasks (holes) and the tools applied (pegs). This mismatch or gap might be caused by a failure to understand the designers’ tasks, or by the replacement of traditional tools with new ones. They call the second paradigm ‘the horseless carriage’, which characterizes “the shifting perception of a practice as it transforms in relationship to a new technology” and where “the task of transportation is described through the lens of a previous technology – even though the practice of travel had changed” (Moum 2005).

Project management problems are perhaps one of the biggest barriers against reaching full benefits of information modeling enabled integrated design. Implementation of BIM creates challenges to the project management as there are no mechanisms, tools, or rules of thumb for selecting different BIM enabled options for improvements in communicating, analyzing and coordinating designs in most beneficial and cost efficient way. Guidelines and education have been given for designers to create models and for building owners to see their advantages of modeling but the project managers have been left alone (Rekola, Kojima et al. 2009).

1.2 research problem, aim and questions
A crucial question arising out of these observations of trends and movements within the industry and research is how a process would change due to implementation of BIM technology. In addition to learning about new tools, what more is needed from actors to successfully implement this technology. What happens with the complex universe of interactions and interdependencies between processes, roles, and actions that are an integral part of the architects’ and other practitioners’ daily work? Research dealing with ICT related to the AEC industry has been dominated by a focus on the development and improvement of new software and hardware systems, and on technology related to issues of implementing these in practice. (Wikforss Ö and A 2007) criticize that current research “has not resulted in a comprehensive understanding of how new technology works (...) if we consider human, organizational and process-related factors in addition to purely technological factors.”

The point of departure for this work is the growing need for more knowledge on how a building process changes when implementing BIM technology. We lack a comprehensive understanding and overview of non-technical factors, as well as of the changes in the relationships and interdependencies embedded in the encounter between the building process and BIM. This statement of the problem is the basis for formulating the following aim:

To contribute more knowledge on the changes in the processes due to BIM and how the roles get affected resulting from this change
Two research questions are defined to address the aim and to investigate the research problem:

**RQ 1:** What are the changes in the process when implementing BIM in a traditional project (Initiation Stage)?

**RQ 2:** How does the role of project manager change in relation to other actors when BIM is implemented in a project?

To clarify the intention behind these questions some of the words and terms used will be briefly explained here. First there is **BIM**; Building Information Model(ing). There is not a single definition of what BIM is. For the purpose of this dissertation the author would like to use her own definition of BIM that encompasses the most common accepted views on the topic. Building Information Modeling [BIM] is the most commonly used term to describe a set of parametric CAD tools and processes for the creation and maintenance of an integrated collaborative database of multi-dimensional information regarding the design, construction and/or operations of a building. **Traditional Project** is a project that does not implement BIM. The empirical part of the research focuses on actions by project participants in the process when BIM was aimed without changing the actual process to achieve it i.e. in a traditional project. **Initiation Stage** defines the preparation stage of a project before the Preliminary design stage. The reason for selecting the initiation phase was the time limit of the thesis and the schedule of the case process. **Project Manager** in this study is the actor responsible for managing and scheduling the process of the project. The term Project manager will be interchangeably used with client representative. From an overarching view, **other actors** are here practitioners involved in the AEC industry and interacting with the project manager. The main focus here is however the client and the architect (representing the design team).

1.3 overview of research objectives, focus and methodology

Six research objectives are related to the investigation of the two research questions. This section gives an overview of these objectives and the focus of the research, as well as the methodological strategies and instruments applied. A detailed description and discussion of the research design, process and methodology is provided in Chapter 3.

1) Developing a descriptive and holistic framework for studying the initial stages of a BIM Project.

How should the research questions be approached? How can the process change due to BIM be explored? How can the extensive amount of literature be organized? These were the initial questions that revealed the need for a framework. The research problem can be approached and examined from different points of view. In this thesis the problem is examined from the perspective of a project manager. The main idea behind the framework is to lead the investigation to the project managers’ approach to the new aspects identified in the BIM Process. The development of the framework is based on reviews of relevant sources.

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1 Some scholars define it as “a set of interacting policies, processes and technologies generating a methodology to manage the essential building design and project data in digital format throughout the building’s life-cycle” Succar, B. (2008). Building information modelling framework: A research and delivery foundation for industry stakeholders. Automation in Construction, ScienceDirect, 2008 Elsevier B.V. 18: 357–375. Other scholars prefer to define it using papers by commercial BIM vendors. Aouad, G., A. Lee, et al. (2006). "Constructing the Future: nD Modeling." London, UK and New York, USA: Taylor and Francis, used the following definition: “building information model (BIM) is a computer model database of building design information, which may also contain information about the building’s construction, management, operations and maintenance”.

2 Design team consists of a number of consultants (HVAC, lighting, building physics etc). In this thesis, these consultants are included under a design team lead by the architect. It is not possible to study the individual relations between the project manager and the consultants. Hence the architect who leads the design team will be representing these consultants.
literature, research and study of BIM Literature cases. The first two elements of the framework are related to Initial Preparation of BIM project. First there is Project Preparation and focus on client initiation, participant involvement and decision making structure (organizational structure). Second, there is planning level of BIM in project and the focus is on BIM Plan, BIM goals and Uses. Third which is the last element is Information exchange. The results from the analysis of the first two elements and the evolved role of project manager will be applied in recreating the Information Exchange in a BIM Process.

2) Establishing the framework tool

The above created framework will be analyzed in three different processes. First, BIM Process as per literature, in this after analyzing the BIM Literature and cases, few important aspects will be enlisted. These aspects would be necessary when starting a BIM Project. Second, BIM Process as Planned in the case study. The main research tool in this thesis is the single main case study. BIM was planned to be a way of working in this case. Hence a BIM Agreement, BIM Process map and BIM Manuals were prepared. This is the BIM Process as Planned. Third, Actual BIM Process in which the actual case process was studied.

3) Studying BIM Literature cases and strengthening the framework

After studying the BIM Literature few important aspects were identified for the framework. But solely relying on the BIM researchers might lead to the danger of being prescriptive in approach. Hence, a few BIM Literature cases were studied to strengthen the framework. The aim of studying these cases was not to judge whether BIM was successful or unsuccessful but to find what were the challenges or difficulties in achieving BIM. These were then related to the framework and enlisted in the aspects mentioned in the framework.

4) From the previously described framework, analyzing the role of the project manager and his changing responsibilities with respect to client and architect (representing the design team)

In the problem definition it was mentioned that the role of the project manager has not been identified in BIM Projects. Hence after the literature study, the next objective was to find out the new tasks in a BIM Project. Then find out which of these tasks could be a responsibility of the project manager. This was compared with the role played by project manager in the Case Study which did not implement BIM in the initial stages. By doing this, the changing responsibilities of the project manager were studied.

5) Identifying the added skills and tools needed by project manager to manage the Initial Stage of the BIM project.

Once the changing and new responsibilities of the project manager were identified, BIM literature was studied again to find out which BIM tools could help him to successfully achieve these responsibilities. Also a deeper study of changing skills needed to implement these BIM tools was performed.

6) Analyzing information exchange in a traditional process that prepared 3D Model

The case study in this thesis had a 3d Model prepared individually by the architect and other consultants. An information exchange study was performed to find out how the BIM Model was used in the exchange process. Also mentioned before, the project process did not alter for incorporating BIM goals. Hence it was considered a conventional/traditional case process. Summarizing the above, study was performed to find out the advantages/disadvantages of 3D Model, changes in information exchange patterns, changes in the role of actors.
7) Analyzing the role of the project manager in the above mentioned information exchange

The final objective was to study the role of the project manager in the information exchange mentioned in the previous point. The aim is to use the results of the analysis from the framework for the role of project manager and use it to redefine the position of project manager in the information exchange. There by creating a new BIM information exchange process with focus on project manager.

1.4 structure of the thesis
The thesis is divided into five main parts (figure 1.1)

Part 1. Introduction
Chapter 1: briefly presents the research background and some key observations from current practice and research, as well as the research problem, the overall aim and the research questions. Furthermore, the chapter provides an overview of the research objectives defined to answer the research questions, and of the methods and strategies applied.

Part 2. Theoretical Input
Chapter 2: analyses the relevant BIM literature. The purpose is to identify important aspects for the analysis framework. A study of the BIM Literature cases to strengthen the framework developed through literature study is also conducted. Finally a BIM Approach Process map according to the literature is designed. Finally concluding this part is the authors analysis of how would project manager be integrated in this process?

Part 3. Research Design and Process
Chapter 3: deals with the research design and strategies, describes the research process and the methodological tools, and ends with a discussion on the validity and reliability of the work.

Part 4: Case Study
Chapter 4: studies the Case as per planned. This is the first part of the case study analyses
Chapter 5: studies the actual Case process as took place.

Part 5: Synthesis/ Reflections and Conclusions
Chapter 6: gives a reflection of the three processes: process as per literature, case process as planned and case process as realized and examines an extract of the findings from the main case study and literature study.
Chapter 7: discusses the synthesis between the research questions and findings and offers a reflection on the research activities.
figure 1.1: research model
Figure 1.2: Research design to answer the research questions
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part II

theoretical input
2. theoretical input

At present BIM is facing ‘the square peg in a round hole’ kind of situation. The 3D Model is been created but without changing the process or roles & responsibilities of the actors involved in the process. A better understanding of what are the changes required in the early stages of the planning process can be seen as central to achieving a project success in BIM. In this chapter three important aspects are identified which are to be considered when starting a BIM Project: BIM Project Initiation, BIM Planning, and Information exchange structures. This framework is made considering the various levels of a building project.

BIM Project Initiation – Overall level
BIM Planning – Group level
Information exchange structures – Individual level

By considering these aspects, the analysis was performed from a broad to individual level of the process. Based on the analysis, a BIM Approach as per literature will be designed in the concluding part of this chapter.

2.1 introduction

A fundamental pillar of a successful building project is a good building process. Over the years, the development of ICT (Information and Communication Technology) has led to several changes in the AEC industry. The network technologies, advanced visualization tools and CAD (Computer Aided Design) are some examples of ICT, which represent powerful potential of facilitating change and improvement. The participants within the building design process face ICT related benefits and challenges on several levels. Both working processes and role definitions are affected (Wikforss Ö and A 2007). Most people feel that the introduction of 2D computer drafting in design firms did not significantly change the way architects practiced, but it simply computerized their practice. 3D computer modeling and BIM on the other hand bring a culture change that infuses all aspects of practice not just the drafting portion.

Much research today focuses on the development of new BIM Tools and their advantages in the building process. But what aspects should be considered before starting a BIM Project in order to use the complete benefits of these tools has not been dealt with, which is the main idea behind this thesis. Special attention is paid to the changing role of project manager when dealing with the new aspects in the BIM Project.

This chapter presents the outline of the framework for identifying the new aspects to be considered during the initial stages of a BIM Project. After a thorough BIM Literature study, four aspects were found to be important: BIM Project Initiation, BIM Planning, Information exchange structures. Furthermore, this framework will be studied in three approaches: BIM as per literature, BIM as planned in the case study, Process as happened in the case study. These three approaches and the four BIM Aspects are the main components in the BIM Analysis Matrix (fig 2.2), which has been developed as a tool for summarizing the changes in the role of project manager.

In the first part of this chapter, a brief explanation of the framework and the motivation behind it is given. In the second part, examples of contemporary research and literature regarding BIM within the four selected BIM aspects of the framework will be explored, in the third part BIM Literature cases will be studied and in the final part, the BIM Analysis Matrix summarizes the key points of this exploration followed by a process map showing the BIM Approach as per literature.
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Figure 2.1: Research design to answer the research questions
part I: Analysis Framework

2.1 outline of a framework for exploring the aspects to be considered in the initial stages of a BIM Project.

To explore the important aspects in the initial stage of a BIM Project is a huge undertaking. In order to support the exploration and analysis of the multiple and complex amount of information collected from theory, a framework has been developed.

The framework focuses on three aspects of the process; the BIM Preparation, BIM Planning, and Information exchange. The starting point for selecting these aspects is to have an overview of BIM Impact on different levels of the project – from aspects to be considered during project preparation to detail level of information exchanges in BIM.

Before the start of the building design, an important stage of preparing the project for BIM Implementation is needed. Prior to the start of designing, the client should be clear about the project goals he wishes to achieve through the BIM Project. If the client is a onetime builder, there has to be another AEC professional who is knowledgeable in BIM to guide or take initiatives on behalf of the client. During this stage, deciding on which consultants should be involved in the Project based on prior BIM experience or/ and willing to corporate to learn BIM will be important. Communication is in much literature emphasized as a key to success and good decision-making on several levels in the building process (Schön 1991). Having a right organizational and decision making structure which is reflected in the contract is required to implement BIM in an integrated manner. To successfully implement BIM, a project team must perform detailed and comprehensive planning (NBIMS 2007). A well documented BIM Plan will ensure that all parties are clearly aware of the opportunities and responsibilities associated with the incorporation of BIM into the project workflow. A completed BIM Plan should define the appropriate uses for BIM on a project (e.g., design authoring, cost estimating, and design coordination), along with a detailed design and documentation of the process for executing BIM throughout a project’s lifecycle. In BIM (Standard) as the name suggests, refers to the creation and coordinated use of a collection of digital information about a building project. Information exchange is the aspect where BIM will be used as a medium for connecting interdisciplinary actors and as a central information source for the building project. There have not been many approaches regarding the methodology and the relationship between different BIM building process components and aspects. The ambition behind this framework is not to establish a new comprehension of the BIM building process. The three selected process aspects; BIM project preparation, BIM Planning and Information exchange are the central issues in the literature explored. They seem in a dynamic and iterative interplay, to together form a central part of the BIM process in the Initiation stage.

<table>
<thead>
<tr>
<th>Process as planned in the case</th>
<th>Process as happened in the case</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Project Preparation</td>
<td></td>
</tr>
<tr>
<td>· Client Initiation</td>
<td></td>
</tr>
<tr>
<td>· Participant Involvement</td>
<td></td>
</tr>
<tr>
<td>· Decision making structure</td>
<td></td>
</tr>
<tr>
<td>2. BIM Planning</td>
<td></td>
</tr>
<tr>
<td>· BIM Goals &amp; Uses</td>
<td></td>
</tr>
<tr>
<td>3. Information exchange</td>
<td></td>
</tr>
</tbody>
</table>
The framework is further more based on three different approaches of process: the BIM process as per literature, the BIM process as planned in the case study and the process as happened in the case study. The BIM process as per literature is based on the findings from the literature study. The literature does not give a guideline of how a BIM Project should be undertaken. Considering the BIM Analysis aspects, important factors mentioned in the literature regarding the BIM will be summarized.

In the case study conducted, BIM was to be implemented for the first time in the project by most of the consultants involved. Before the start of the project few BIM documents were prepared to help the consultants know their responsibilities and the exchange of the 3D-Bim model. These documents consisted of a BIM Agreement Manual and a BIM Process map. By studying these documents, a process of BIM as planned in the case study will be established. The next process is BIM as happened in the case study. As mentioned before, this was a pilot project for most of the consultants in the project. Hence the pressure of implementing BIM along with the time and budget constraints of the project resulted in going back to the conventional process of managing the project. Although a 3d Model was created by few consultants, it did not realize into a communication medium. Hence it was interesting to observe how the process actually happened in the case and more importantly the reasons for using/ not using BIM.

Based on the three selected BIM aspects and the three different BIM Processes, a BIM Analysis matrix is suggested as a ‘tool’ for summarizing and giving overview of the key points explored (Fig. 2-2), regarding theory and practice. The lines between the different aspects and BIM Processes in the illustration should rather be understood as a ‘translucent’ and ‘breathing’ layer between interdependent elements than fixed border between rigid categories.

Until now, there has not been found literature or research which applies this kind of framework for exploring the BIM aspects in the project. The development of the presented framework is based on the review of contemporary literature, discussions with actors from both research and practice. The framework and the BIM Analysis matrix are in this chapter presented as a possible approach for exploring theory and practice, in order to gain a better understanding and overview of BIM aspects and changes in the conventional building process due to them.
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Figure: Research design to answer the research questions
part II: a literature based exploration of the BIM aspects.

2.1 BIM project preparation

BIM has become one of the most important innovations in managing building projects. The technological development of BIM has been advancing rapidly. Open standards, rules, object libraries, and formats, such as: IFC (Industry Foundation Classes), CIS/2 (CIMSteel Integration Standards), IDM (Information Delivery Manual), and MVD (Model View Definitions), are being relentlessly improved and more and more software applications support the users to work with BIM (Erabuild, 2008).

Despite a sufficient degree of technological readiness, large-scale utilization of BIM in the building industry has not yet taken place due to existing business and legal barriers (Sebastian 2009). Although BIM is often intended to be open and neutral, conflict of interests and local constraints cannot entirely be avoided in a project organization. A project-based collaboration is usually shaped after a procurement process and formalized in a contract for a single project. Sharing knowledge openly and neutrally within the context of a one-off project may become disadvantageous for a stakeholder which would not involve in the next projects. The existing procurement methods have not sufficiently addressed the key issues of open collaboration using BIM, such as: the changing roles and responsibilities of the stakeholders, the demand for new roles, the legal status of the model and shared information, the new distribution of risks, and the new collaboration framework. Collaborating BIM-wise requires restructuring of the order of activities and redistribution of the roles and responsibilities of stakeholders. These are the new issues which must be cleared before the BIM Project starts.

client initiation

Client can realize significant benefits on projects by using BIM processes and tools to streamline the delivery of higher quality and better performing buildings. Clients can use a building information model to: increase building value, shorten project duration, obtain reliable and accurate cost estimates, assure program compliance, (Chuck Eastman, Paul Teicholz et al. 2008).

There are a number of BIM Benefits for the client, but in order to reap these benefits the client should know what are the project goals that can be achieved through BIM. In addition to the legal, contractual & organizational challenges, an important requirement is that the client should know why he needs to implement BIM. Clients struggle to translate their ambition and objective of BIM into effective project implementation strategies. Traditionally, the responsibility of the client was limited to fixing a budget, schedule and drafting contractual terms for the project. In BIM, the client has to think about organizational structure best suited for BIM, which goals should be achieved through BIM, what will the BIM Model be used for, investment in the new technology, selecting the right participants for collaboration etc. Also, the project objectives and BIM objectives should be the same. This will help in developing a single contract which includes BIM agreement. It should also be taken into consideration to what extent the contract defines the works of the consultants. BIM being a new way of project approach which demands greater transparency of work and high level of collaboration, a lot of new aspects with respect to integration and work processes will be faced by the consultants. In such cases, should the contract be a ruling document or can the criticality of the situation demand redefining the contract rules. Taking into consideration all these aspects, the role of the client and his aim to achieve a BIM Project is an important aspect to be considered.

Developers and serial builder clients getting educated about all these issues is justified. But for a onetime builder client investing time in learning & taking important decisions with respect to work processes of actors might not be a wise decision.
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participant involvement

Building design is a broad and collaborative undertaking, involving a wide range of issues that require technical detailing and focused expertise. It is in this broad context that BIM must operate, by both enhancing quality and coordination.

The preferred design process of BIM shows that maximum effort should take place in the early design stages (figure 2.3). This makes it clear that the various consultants should be involved early in the design process. The task is not limited just to their early involvement in the project, but goes beyond that level which includes working collaboratively, understanding interdisciplinary work cultures, having a common goal for the project. The main challenge in adopting BIM technology is getting all parties of a design project to agree on new methods of working, and for documenting and communicating their work (Chuck Eastman, Paul Teicholz et al. 2008).

decision making structure

The type of decision making structure will impact the entire building process and might create problems in maximizing the benefits from BIM. The kind of delivery process chosen will have an effect on the duration of flow of information within the consultants which will in turn have an impact on the cost and time of the project (Wikforss Ö and A 2007).

As the building industry becomes more and more complex with a number of specialized consultants involved in the process, the amount of information created is massive. The main reason behind selecting the aspect of decision making structure is that it should enable in organizing the complexity of information generated. Faster information distribution, better access to information and more powerful communication tools contribute to an acceleration of the planning process, making a higher decision frequency possible (Moum 2005). Integrating BIM Technology in the information exchange will help to simulate and visualize the building, make information available whenever wanted and to make the process transparent. This might imply that all the consultants are working in a parallel and same pace in the process resulting in quick and early decisions in the design team. All these advantages implicate that the teams should be able to trust these new technologies when making important decisions, they have to be quick and more importantly the analytical and quantitative nature of the technology can cause an imbalance between knowledge, innovation and information. This might also result in important decision makers taking a step back in this process.

2.2 BIM plan

When properly implemented, BIM can provide many benefits to a project. The value of BIM has been illustrated through well planned projects which yield: increased design quality through effective analysis cycles; greater prefabrication
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due to predictable field conditions; improved field efficiency by visualizing the planned construction schedule; increased innovation through the use of digital design applications; and many more (Birx 2006). There are also examples of projects where the team did not effectively plan the implementation of BIM and incurred increased costs for the modeling services, schedule delays due to missing information, and little to no added value. Implementing BIM requires detailed planning and fundamental process modifications for the project team members to successfully achieve the value from the available model information. Going from 2D to 3D is not easy and requires serious preparation and an organized approach. (Sheryl Staub-French and Atul Khanzode 2007) identify the following steps in this process:

- Identify the Potential Uses of the 3D Models
- Identify the Modeling Requirements
- Establish the Drawing Protocol
- Establish a Conflict Resolution Process
- Develop a Protocol for Addressing Design Questions

BIM is not just a new technology but a changed work process which demands a lot of planning at all stages of the process: When, how and who should coordinate the model, what are the new requirements in terms softwares, talents needed in the process, how should the project deliver stages be organized and what is the medium of deliverables. This is an important task for all the consultants to collaboratively give inputs on. Juggling between the tasks of decision making of the project and at the same time thinking about the future requirements for the BIM Plan would result in a chaos of decisions. The question remains, who should make this BIM Plan?

One of the ways of giving input to the BIM Plan is by focusing on the inefficiencies of the current project. It might be beneficial to make a list of aspects in a traditional building process which are inefficient and think about how BIM can help to make them more efficient. This implicates that’s senior engineers/designers should be involved giving part of the inputs to the BIM Plan.

**BIM goals & uses**

For the project members, it is extremely essential to identify how BIM can be of utmost importance to them with respect to the project as well as to their organization. These are the BIM Goals of the project. These goals could be based on project performance and include items such as reducing the schedule duration, achieving higher field productivity, increasing quality, reducing cost of change orders, or obtaining important operational data for the facility. When business owners are unable to connect BIM implementation to clear business goals, change tends to occur slowly or not at all, and the obstacles seem insurmountable (Olatunji, She 2009). Once the team has defined its BIM goals, then the specific BIM uses on the project can be identified. The identified BIM Goals can be converted to its corresponding BIM Use (Figure 2.4)

<table>
<thead>
<tr>
<th>Priority (1-5)</th>
<th>Goal Description</th>
<th>Potential BIM Uses</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-Most important</td>
<td>Value added objectives</td>
<td>Design reviews, 3D Coordination</td>
</tr>
<tr>
<td>2</td>
<td>Increased Field Productivity</td>
<td>Design authoring, design reviews, 3D coordination</td>
</tr>
<tr>
<td>3</td>
<td>Increased effectiveness of design</td>
<td>Design authoring, design reviews, 3D coordination</td>
</tr>
<tr>
<td>1</td>
<td>Accurate 3D model for FM team</td>
<td>Recorded models, 3D Coordination</td>
</tr>
<tr>
<td>2</td>
<td>Track progress during construction</td>
<td>4D Modeling</td>
</tr>
<tr>
<td>1</td>
<td>Review design progress</td>
<td>4D Modeling</td>
</tr>
<tr>
<td>2</td>
<td>Eliminate Field conflicts</td>
<td>3D coordination</td>
</tr>
<tr>
<td>3</td>
<td>Identify progress during construction</td>
<td>4D Modeling</td>
</tr>
</tbody>
</table>

**Figure 2.4: An example of BIM goal and its corresponding BIM Use**

The BIM Use identified should be placed in the process at the right position. If this BIM Use is undertaken by an engineer without collaboration of the team members, then the process would be similar to a traditional process. As a result it would be impossible to extract the complete benefits of BIM. An important part of developing a BIM Use plan is describing the BIM Use in terms of:

- An overview of the BIM Use,
- Potential benefits,
- Required team competencies
- Selected resources that can be referenced for additional information about the BIM Use
- Prioritizing the BIM Uses in high, medium and low categories
- Identifying the subordinate BIM Uses necessary to reach the final BIM Use.
- Responsible parties
- Information exchanges
- Calculating the risk vs. value of each BIM Use and making a collaborative decision whether to implement the BIM Use or not

The above mentioned points can be divided into: Level 1 which gives an overview of the BIM Use and Level 2 which goes into more detail regarding the application of a BIM Use in the process (figure 2.5)

BIM Uses are a part of the BIM Plan. When the different BIM Uses are connected together, an integrated information exchange will take place. Hence BIM Use is an important aspect to be considered during reflections. Figure 2.6 shows a number of BIM Uses identified in the literature. In order to decide on a specific BIM Use, it’s important to consider whether this BIM Use will help in achieving the project goal.

Figure 2.5: Level 1 & Level 2 maps of BIM Use

Figure 2.6 shows the various BIM Uses that can be applied in a BIM Process. These BIM Uses are sub divided under four specific functions: Design Communication, System analysis, Estimating and Scheduling. These functions and the BIM uses under them are not discipline specific. For example, 3D Design coordination is not a design specific BIM Use. It is undertaken by all the consultants involved in the BIM Process to check for clashes. This implies that all the BIM Uses can be considered as a medium for connecting various disciplines together. Having said this, the concern arises that if this is not a discipline specific function, then who decides and plans these Analyses. Who takes the responsibility of integrating all of the disciplines together using the BIM Use?
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**BIM Uses in Design**

- **Design Communication**
  - Design Authoring
  - Programming
  - Existing Conditions Modeling
  - Design Reviews
  - Constructability
  - 3D Design Coordination
  - Virtual Mock ups

- **System Analysis**
  - Site Analysis
  - Engineering Analysis
    - Structural Analysis
    - Energy Analysis
    - Lighting Analysis
    - Mechanical Analysis
    - Other Analysis
    - Sustainability Criteria Analysis
  - Code Validation
    - Evacuation Planning
    - Security Validation

- **Estimating**
  - Cost Estimating

- **Scheduling**
  - Phase Planning – 4D Modeling

*Figure 2.6: BIM Uses in Design*
2.3 Information Exchange

Explained in the previous section, a number of BIM Uses can be applied in a project. Also, it can be seen that these BIM Uses are not discipline specific. The input to a BIM Use may be from a single discipline, but its result will have an effect on more than two disciplines. A continuous input and feedback loop between the consultant and analysis will take place.

To add to the importance of information exchange, references to few BIM Definitions are made below:

The National BIM Standards (NBIMS) offer a definition of BIM:

"Building Information Model (BIM) is a digital representation of physical and functional characteristics of a facility. As such it serves as a shared knowledge resource for information about a facility forming a reliable basis for decisions during its lifecycle from inception onward. A basic premise of BIM is collaboration by different stakeholders at different phases of the life cycle of a facility to insert, extract, update or modify information in the BIM to support and reflect the roles of that stakeholder. The BIM is a shared digital representation founded on open standards for interoperability (NBIMS 2007)."

FMI in collaboration with CMAA’s Emerging Technology committee developed an alternative definition of BIM:

"Building Information Modeling (BIM) refers to the creation and coordinated use of a collection of digital information about a building project. The information can include cost, schedule, fabrication, maintenance, energy, and 3D models. The information is used for design decision-making, production of high-quality construction documents, predicting performance, cost estimating, and construction planning, and eventually, for managing and operating the facility (D’Agostino et al., 2007)"

These definitions prove that BIM will help in collaboration between various disciplines which will in turn result in an integrated information structure. Having said this, there exist a number of steps before 3D Models can completely harness the BIM applications.

Until now, the generation of 3D models as a foundation for simulations has been cumbersome and expensive (Moum 2005). This often resulted in simulation of limited parts of the total design. But the design problem is multi-dimensional and interactive. Interconnectedness of different factors is an important issue. The focus only on parts can lead to a lack of integration, thereby reducing the quality of the project in total (Lawson 2006). The possibility of importing 3D product models into simulation software reduces the model building effort and thus the building could be simulated and tested in total (Kiviniemi A, Tarando V et al. 2007).

Also, the ability to absorb information is limited, and when confronted with too much information, the receiver can lose the overview, or worse, completely ignore the message communicated; thus leading to crucial information being lost and unrecognized. An information overload could possibly result in a loss of focus on the important aspects that might get aggravated in the future. Generally, who will decide which information is important and which is not. How will the information get stored, or get conveyed to the right discipline. Who decides on the transfer of this information?
Better buildings through digital practice

Figure 2.7: Research design to answer the research questions
part III BIM literature cases

2.1 literature cases

In the previous sections the important BIM aspects to be considered in the initial stages of the project were mentioned. These were considered as per the BIM Literature and researchers view points of BIM. In order to test the importance of the aspects identified in actual practice, few literature cases were performed. The intention of studying the cases was not to find whether the projects were successful by using BIM but to focus on the challenges they faced when implementing BIM and which aspects required more planning before implementing BIM. These cases are studied from the following journals:

- AIA Journal, Integrated Project Delivery: Case Studies
- (McGraw-Hill 2009), The Business Value of BIM. Getting Building Information Modeling to the Bottom Line
- (McGraw-Hill 2010a), The Business Value of BIM in Europe. Getting Building Information Modeling to the Bottom Line in the United Kingdom, France and Germany
- (McGraw-Hill 2010b), Green BIM. How Building Information modeling is contributing to green design and construction

The first three cases have been explained in a more detailed manner

1) Sutter Health Fairfield Medical Office Building

Description: The initial project team consisted of Sutter Health (the overall corporate entity), Sutter Regional Medical Foundation (the local Sutter affiliate,) HGA (Architect) and Boldt (Builder).

Collaboration: After the selection of the architect, the owner asked the architect to meet the builder to see if the firms’ cultures are aligned. The principals met and decided it was good fit and to proceed. Also, the firms had previously worked together on traditional design-bid-build projects in the Midwest.

Contract: The three-way contract called for the core team of owner, architect, and builder to collaboratively select the main design-build subcontractors very early in the design process. The Integrated Contract Agreement is a three-way contract between the owner, the architect and the builder. Each party is held accountable to each other as equal partners.

Summary, Conclusion and Challenges:

1. The above case shows that along with early involvement of the participants, an active involvement of the owner is needed.
2. Initiation by the owner to understand the working cultures between two disciplines and aligning goals will help in the long run of the project. This shows that every participant’s opinions are valued.
3. The line of responsibilities between two disciplines was diminished due to requirements of the Integrated Contract which stated that each party is held accountable to each other. This could be backed with financial incentives to make the clause stronger. Having said this, a clear line between costs and profits should be defined.
4. This means that, a very detailed, well thought of contract will have to be drafted. The inputs from the experience of the participants would help in making the contract more acceptable and robust.

Important aspects of Reflection: Client Initiation, Participant Involvement, Defining goals, Decision making structure

2. Walter Cronkite School of Journalism, Arizona State University

Description: The Cronkite School is a build-to-suit venture by the City of Phoenix for Arizona State University (ASU) and financed by a city bond measure.
Collaboration: The designers and builders were selected as one team. The builder's preferred mechanical, electrical, and glazing subcontractors were introduced to the selection committee and began work simultaneously with the Design and Executive Architects and the Builder. The architect brought mechanical, electrical, and plumbing engineering in house. **Builder chose its subcontractors in a qualifications-based process, having to know BIM.** Other than the criteria of project type and familiarity of working with public agencies, **one of the important reasons of selecting the team was how well these teams worked together.** The engineers drew single-line diagrams of systems which were turned to the subcontractors for detailed modeling. **This transition was very seamless. The two sets of engineers sat across each other in the BIG room and designed collaboratively.**

Contract: The contract was a two-way owner/designer-builder contract as prescribed by City procurement regulations. **The team made a conscious decision to sign the contract but not to let it dictate behavior** as the participants believed that following the two-way contract would hamper the goal to save time and cost. **Many IPD features were put in place on a non-contractual basis.**

Decision Making: Project oversight was managed by an Executive Committee meeting every other week with high level representation of all participants and stakeholders – frequently. Decisions were arrived by consensus and very rarely did issues have to go to a higher authority for resolution. This kind of collaborative, quick, and final decision making process was the key to achieving such an aggressive schedule.

Communication: The design and executive architects worked together in a —BIG! room. According to the project manager, “**If you didn’t have the right people in the room you couldn’t make the decisions when they needed to be made.**” Every Monday the latest design ideas were published in large sets and size of drawings. REVIT was considered to be useful software for program validation and an interactive 3D programming tool in live user group meetings.

Goals: Time and Cost was a constraint in this project. Usually the architect did not perform quantity take off in a traditional design-bid-build project. But in this project due to the trust and common goal of cost efficiency, **BIM Model was used to test the cost of different design ideas on a daily basis.**

Challenges:
- In order to be successful, the teams had to change the behaviors they were used to.
- Not enough time to engage in the kind of team building required for such intense collaboration
- Due to different software’s used, translating models back and forth turned out to be cumbersome and problematic process resulting in inefficiency.
- The subcontractors were typically uncomfortable with the uncertainty and chaotic nature of early design.

Summary:
- There was early involvement of participants including the contractors.
- All the team members had a common goal to save time and money. They together decided that this was the common goal and no contract should dictate over it. This should the trust they had in each other.
- During selection of participants, an important clause was to test whether the teams can successfully work together. This was a prerequisite.
- The strong division between different phases of a project was diminished in this project due to:
  - The design and executive architect worked together in the same BIG room.
  - The sub consultants modeled the 2D drawings of the engineers and designed in collaboration in a BIG room.
  - Before the start of the project, adequate time should be devoted for team building
  - Since the subcontractors are included in the early stage of design, the process of reaching a design solution after number of iterations must be more efficient. This could be achieved through experience and training.
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- Interoperability between different software's should be resolved.

Important aspects of Reflection: Participant Involvement, Defining goals, Decision making structure, BIM Use

3. Encircle Health Ambulatory Care Center

Description: Encircle Health is a three-story, 156,000 square foot ambulatory care center combining physician practices with ancillary diagnostic services, including imaging, radiology, endoscopy, pharmacy, and testing labs, each of which own an equity stake in the building. It is not a typical medical office building; the design is based on a -pod concept, where related practices share flexible space and equipment and use a centralized reception office.

Contract: An integrated form of agreement (IFOA) was signed by owner, architect, and builder. The contract provided for a performance contingency, consisting of at-risk profits, plus typical contingencies, with a formula to split funds remaining in the pot at the end of the project.

Collaboration:
- The core project team was selected on the basis of existing relationships and the IPD experience both team had acquired.
- Mechanical, electrical, plumbing/fire protection, and glazing subcontractors were selected collaboratively by the core team.
- This selection was based on in addition to fee proposal, the qualification to commit personnel.
- The subcontractors were in project from the start of the schematic design phase.
- The design process was highly collaborative between designers and builders.
- Architects and its consultants designed systems as single line diagrams plus performance criteria which the subcontractors used as a basis for their designs. All systems were modeled in 3D.

Decision making:
- The overall schedule as it was jointly prepared did not change during the project, although it was constantly and interactively adjusted in detail during weekly meetings.
- A thorough programming process was conducted by Architect, consulting each of the tenant/owners on space and equipment requirements. The builder and the subcontractors were in attendance at many of these meetings.

Communication:
- The Core team of the owner, architect and the builder met weekly to resolve routine issues. Under the direction of the Core team were specialized component teams including MEP, interior fit-out, etc.
- The primary computer model was held by the builder.
- In addition to BIM, the builder maintained a project web site for information exchange open to all participants.
- Goals: Project goals, developed collaboratively by the core team, included budget, schedule, and a requirement to attain LEED Silver or higher

Challenges:
- Several of the participants wished that the major field foremen had been more completely integrated into the process. As a rule these field workers were the most skeptical of the new process.
- There was a general consensus that a more precise method of distinguishing design refinement from scope change is needed.
- In some cases, the scheduling of trades such as fire protection had to be adjusted because things were happening so much faster than usual.
- The project manager said: When you have a hand in establishing the schedule and see how your trade fits into the whole process, you tend to believe in it and act accordingly. Slack is greatly reduced. The interactive scheduling process showed you the logic of where everything had to go – you trusted it and had ownership over it, and if you didn’t fulfill your promises you felt you had let down the team.
Summary:
- The teams were selected based on prior working relations and their commitment to do IPD.
- The scheduling process should be developed to suit this new IPD Process.
- A rigorous programming phase in which requirements are well defined must be part of IPD.
- Most of the consultants, contractors and field workers must be included in the integrated process. This will reduce any contracting attitudes towards the process.
- The strong division between different phases of a project was diminished in this project due to:
  - The design and executive architect worked together in the same BIG room.
  - The sub consultants modeled the 2D drawings of the engineers and designed in collaboration.

Important aspects of Reflection: Client Initiation, Participant Involvement, Defining goals, Decision making structure

4. PCL Construction Case study

The following case study is of PCL construction based in Denver, Colorado. This case will not talk about a project but will describe the company's goals with respect to BIM and what obstacles do they face while fully converting to BIM

Goals:
The 102-year-old firm is undergoing a transformation that uses BIM to make virtual design and construction (VDC) an everyday part of its practice. Following are the goals set by PCL:
- In five years, PCL wants BIM to be fully integrated into what they do.
- Mission is to build projects twice—once in the virtual world and once in the real world.
- Through BIM, the company aims to improve risk management and communication.

In order to achieve these gains, PCL has undertaken the following measures:
- Change in the organization's internal hierarchy. The company has hired at least one full-time BIM modeler in each of its 12 U.S. districts.
- The company places an onsite modeler on its BIM projects, taking the place of a project engineer.

Challenges:
Having mentioned the goals of the company and measures taken to accomplish them, PLC also faces certain challenges.
- The company is hesitant to fully integrate estimating functions—or 5D—into its BIM work. The company isn't ready to toss out its proven practices and is investigating how to retain its existing estimating processes and making BIM work within that framework.
- They also fear that in the end, they don't want to be a modeling company. PCL is a construction company and BIM is a tool used to get there.

Conclusions:
Finding a proper balance between tested old methods of estimating and new technology of BIM estimating might ask for role changes or greater software development. This might mean, teaming up of young professionals who are new to the industry but at the same time curious to learn new technology and old professionals who have tested a method through tough times and not quite ready to give up that easily.

Important aspects of Reflection: Client Initiation, Participant Involvement, Defining goals, BIM Plan
5. Texas A&M Health Science Center

Goals:
- Satterfield & Pontikes Construction Company saw BIM as a way to drive the risk out of its bid and give it an edge on the competition.
- They took lessons from this project and applied them to the hard bid environment.

Preparation:
- Satterfield & Pontikes Construction Invested $250,000 worth of resources into modeling for Texas A&M Health Science Center
- Prior to bid, the designer, FKP Architects of Houston, provided 60 percent-complete architectural, structural and MEP plans.
- Satterfield & Pontikes dedicated a crew of modelers and estimators to dig through the details for six weeks.

Benefits:
- In the end the bid came down to a better understanding of key quantities and pricing because the unknowns were reduced due to modeling the details.

Challenges:
- The company invested nearly ten times the resources upfront that it would normally put into a similar hard bid job.

Conclusions:
- There has to be clear defined goals before starting a BIM Project and a drive to take all possible measures to achieve this goal
- Collaboration and understanding between design teams is extremely important.
- It is important to be flexible in your approach. Satterfield & Pontikes Construction grew up as a hard bid contractor, but when alternative deliveries starting hitting, they had to get smarter.

6. Sutter Health Medical Center Castro Valley

Goals:
- The main goal was to find effective discipline-based chains of data exchange that would allow building information to flow easily from each designer to the appropriate trade contractors and on to the fabricators

Preparation:
- 10-party IPD contract that brought together all major players, including those who usually would be hired as sub consultants or subcontractors.
- The team invested in extensive planning from the outset.
- The team strategized about how best to facilitate a seamless flow of ideas and communication among multiple parties.
- To speed decisions and streamline processes, BIM and BIM-related tools were used.
- Although everyone knew technology would drive the project’s success, the BIM Project Integrator’s strategy was to avoid specifying which programs should be used.
- Interdisciplinary exchange methods were developed to keep the project tightly coordinated. 3D was the standard.
- Communication didn't migrate entirely to the servers. The team meets every week to review the design using 3D models.
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Benefits:
- Although significant time was spent early in planning, Manager of Technology says the project has outpaced projects executed under traditional delivery methods.
- It was done at no added cost and resulted in higher-quality and better coordinated deliverables.
- Hundreds of multidiscipline design coordination issues that are typically resolved during construction were identified and resolved early in design.
- With issues coordinated early, the design proceeded with much more certainty, leading the team to expect reduced rework or changes during construction.

Challenges:

Conclusions:
- Developing an integrated contract including all the players who are important in the decision making process could be a prerequisite.
- Investing time during early phases of the project for planning and resolving the ways of unobstructed communication would also be considered a prerequisite. The engineers would have to think about ways of collaborating efficiently and should give this input while early planning stages. This might result in developing the role of the engineers.
- Flexibility in choice of BIM Tool to be used. This might imply that the software would be an issue to tackle.

Important aspects of Reflection: Client Initiation, Participant Involvement, Defining goals, Decision making structure, BIM Plan, BIM Uses, Information exchange

7. St. Joseph Health System

Goals:
- To successfully create a mock-up, focused on a project's most potentially problematic condition of facade

Preparation:
- Phasing the modeling of the façade with the fabrication schedule

Benefits:
- Due to modeling the mock up in BIM, 45% of all panels were modified, affecting over 20,000 square feet of building surface.
- Vice President of Construction at St. Joseph Health System, Jim estimated that the potential extra cost of not having identified these issues in advance would have been $1,387,500.

Challenges:

Conclusions:
- Identifying Risk vs. Value of a particular BIM Use is important. This is not a prerequisite for BIM, but an important aspect to be considered while deciding which BIM Use to be made.

Important aspects of Reflection: Participant Involvement, Defining goals, BIM Use

8. Department of Energy

Goal:
- Prevent problems using BIM Technology
- Use BIM for spatial coordination
- model everything down to ⅛-inch conduits
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Preparation:

Benefits:
- Thousands of collisions were identified due to clash detection
- Virtually —walking through—every room with the operations staff uncovered over 500 serious problems
- Independent cost estimators calculated a $10 million savings generated by the modeling effort.
- It enabled better constructability as it showed how a certain element or detail is made.

Challenges:

Conclusions:
- It is important to know how the model should be used to efficiently perform the design and construction process. Who should do this? This might indicate that the engineers should undertake dual responsibilities: technically as well as strategically. This could mean a change in responsibilities of the professional

Important aspects of Reflection: Participant Involvement, Defining goals, BIM Plan, BIM Uses, Information exchange

9. Maximilianeum Expansion, Munich, Germany

Goal:
- To bridge the data exchange gap between designers and facility managers

Preparation:
- Making the goals clear from the client’s side.

Benefits:
- In order to accomplish the goal of data exchange between designers and client and using this data for future facility management purpose, the designers made sure that the data was accurate. This led to a more efficient practice of information storage.
- This also demanded greater coordination between the project team
- The designers could create multiple iterations of the design
- Ease in information addition to the model
- Ease in ability to regularly calculate quantities

Challenges:
- The contractor had no idea what BIM is
- The technology had added benefits that the design team could not explore since they did not possess the capabilities to explore those benefits

Conclusions:
- It is important that the client has a clear goal and understand the benefits he can get from the model. This might be a prerequisite for the client to understand what BIM is and how he can get the maximum benefit through it. Also an added responsibility for the designer or the project manager to educate the client on this.
- There is an unequal balance between the extent to which technology has developed and the designer’s capability to harness that technology. In this case, the technology might have an upper hand. But at the same time, there are specific user/designer needs that are still not addressed by the software designers. This is an unbalance
between both the fields: context insensitive approach. This might be considered as prerequisite or changing roles of the designer.

Important aspects of Reflection: Client Initiation, Participant Involvement, Defining goals, BIM Uses.

10. Aylesbury Crown Court

Goal:

Preparation:

Benefits:

- BIM was used as a communication tool to the client
- Could efficiently track costs in real time to keep the client apprised of budget issues.
- The model also helped speed critical changes to the design.
- Due to the analysis tools connected to BIM, it gave the designers a broad-brush view of the sustainability of the project and allowed them to have that commentary with the engineers

Challenges:

Conclusions:

- Understanding what benefits can you achieve by using BIM. This could be a prerequisite to the team. Also focusing on the inefficiencies of the traditional project can help in narrowing down the benefits you want to achieve through BIM.

Important aspects of Reflection: Defining goals, BIM Plan, BIM Uses

11. ESEAN Palomar Medical Center West

Preparation:

- The entire design and construction team from client to engineers to contractors had a common vision.

Benefits:

- Ability to facilitate an integrated design approach.
- Helped in putting the team together.
- Helped in making the construction process more sustainable
- Transparency with the use of BIM added to the green goal
- BIM Analysis led to an efficient structural system, reducing material, money, time without compromising on structural integrity.

Challenges:

Conclusions:

- All participants having a common vision is a prerequisite
- The designers took a greater initiative in making the team understand the goals and objectives. This might be the changing responsibilities of the architect.
- Important aspects of Reflection: Client Initiation, Participant Involvement, Defining goals, Decision making structure, BIM Plan, BIM Uses, Information exchange
12. Shanghai Tower

Goals:
- BIM Used to deal with complexity of the structure, coordinate an international team and achieve the Green Goals.

Preparation:

Benefits:
- BIM was beneficial to understand the entire scope of the project
- Could understand the complex structure due to BIM
- The process went a lot cheaper and faster
- Helped in increasing the owner’s input in the project.
- Helped in designing the most efficient structural system

Challenges:
- Complex structure of façade and structure

Important aspects of Reflection: Client Initiation, Participant Involvement, Defining goals, BIM Plan, BIM Uses, Information exchange

13. U.S. Food and Drug Administration Headquarters

Goal:

Preparation:
- People were dedicated to coordinating the model.
- Digital design coordinator was present in every discipline and every team.
- The team was committed to doing BIM

Benefits:
- The Environmental Consultant tested different massing diagrams
- Helped to reform the formerly intuitive decisions taken by the architects

Challenges:
- Since the project was of massive size, 12 to 20 models were needed to design the building. This created a challenge to envision the project holistically.
- They found that for large projects, they pushed the limits of the software.
- Overloading the model with number of components and details can crash the computer.
- In the BIM Process, the engineer still has to build an entire independent model and then connect to the BIM Model. Had these connections being more robust, even more number of iteration could be possible between 2 disciplines.

Conclusions
- There is a lot of art and finessing to working with and coordinating the models and no one should believe that you can just model everything and take pictures, Design team head. Changing roles and responsibilities of a profession.
- Need of more efficient connections between different discipline models: Prerequisites

Important aspects of Reflection: Participant Involvement, Defining goals, BIM Plan, BIM Uses, Information exchange
summary
In this section conclusion from BIM literature and Literature cases will be done with respect to the identified aspects of reflection:

<table>
<thead>
<tr>
<th>Aspects</th>
<th>Literature Process</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Preparation Stage</td>
<td></td>
</tr>
<tr>
<td>a. BIM Project Initiation</td>
<td>• Should ideally be by the owner and he should align the BIM Objectives in the contract</td>
</tr>
<tr>
<td></td>
<td>• The owner should be flexible in the contractual agreement</td>
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<tr>
<td></td>
<td>• Also the consultants should be more flexible in their approach</td>
</tr>
<tr>
<td></td>
<td>• The literature identifies the need of a BIM Execution Plan.</td>
</tr>
<tr>
<td>b. Early Involvement of participants</td>
<td>• Selection of the right team of people</td>
</tr>
<tr>
<td></td>
<td>• The teams should understand each other’s working culture</td>
</tr>
<tr>
<td></td>
<td>• It is good to have experienced BIM teams on the project</td>
</tr>
<tr>
<td>c. Collaborative Decision Making/Control</td>
<td>• Teams are set up to manage decisions and work flows</td>
</tr>
<tr>
<td></td>
<td>• There should be strong communication routes between the consultants</td>
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<td></td>
<td></td>
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<tr>
<td>2. BIM Plan</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• The BIM Plan identifies additional resources, training needs, added roles and responsibilities</td>
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<tr>
<td></td>
<td>• The BIM Plan should allow the team members to measure the progress</td>
</tr>
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<td></td>
<td>• The BIM Plan should be continuously developed</td>
</tr>
<tr>
<td></td>
<td>• The person/team developing this BIM Plan should have the appropriate knowledge of additional support required for implementing the BIM Use.</td>
</tr>
<tr>
<td></td>
<td>• The BIM Plan should consist of BIM Goals and corresponding BIM Uses</td>
</tr>
<tr>
<td>a. BIM Goals and BIM Uses</td>
<td>• Identify the project goals as well as organizational goals.</td>
</tr>
<tr>
<td></td>
<td>• Involvement of management team and senior level members would be needed to establish the goals.</td>
</tr>
<tr>
<td></td>
<td>• Identify a specific BIM Use for the corresponding BIM Goal. This might need a combination of managerial and technical decision</td>
</tr>
</tbody>
</table>

Table 2.1: BIM Analysis framework summarizing the key points of the explorative literature
- List down the team competencies, additional resources, additional information for this BIM Use

- Decision to invest in a BIM Use should be done after weighing Risk vs. Value of the particular BIM Use.

- Develop a detailed plan of information exchanges for the BIM Use. This should be done in coordination with engineers, modelers and decision makers (managers)

- Identify the subordinate BIM Uses which are essential to complete the present BIM Use

**3. Information exchange**

- There are a number of consultants whose designs might change due to the output of this analysis.

- A methodology to have an efficient communication of this analysis output to various consultants has not been dealt with the literature.

- The team has to be more collaborative internally as well as externally

- The information flow has to be more parallel rather than adversarial or sequential.
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Figure 2.8 Research design to answer the research questions
BIM PROJECT INITIATION STAGE

- Understanding working cultures
- Consulting experienced teams

PARTICIPANT INVOLVEMENT

- Selecting the right team
- Including BIM experienced teams
- Understanding working cultures

DECISION MAKING STRUCTURES

- Organizing decision structures
- Organizing work flows
- Identifying communication routes
- Identifying knowledge and information exchanges

Overlapping responsibilities

BIM Process as per literature - 1
Preparing the BIM Plan

Client

Identifying additional training needs, softwares

BIM PLAN

Preparation Stage 2

Client

Consultants

Identifying how to measure the BIM Progress

BIM GOALS & USES

Start of Schematic design Stage

Client

Consultants

Identify BIM Uses for decided project goals

INFORMATION EXCHANGE

Client

Consultants

Validate program

Architect

Consultants

Author schematic design

Develop individual models

Project deliverables as per BIM

Modelling & documentation guide

BIM Collaboration guide

Risk Vs. Value of a BIM Use

Consultants

Identify project goals as well as organisational goals

Consultants

Consultants

BIM GOALS & USES

Identify BIM Uses & respective BIM goals

Consultants

Consultants

Inspect additional software needs

Consultants

Overlapping responsibilities

Client

Consultants

Consultants

Consultants

Consultants

BIM Process as per literature - 2

figure 2.9(2)
part III: BIM approach

2.1 BIM Approach

Throughout previous section of this theoretical study an array of findings have been explored and reported on. This section culminates all these findings into a BIM Approach. The focus is on the aspects identified in the BIM Analysis framework

Table: BIM Analysis Framework - focus on literature study

<table>
<thead>
<tr>
<th></th>
<th>BIM Process as per literature</th>
<th>BIM Process as planned in the case</th>
<th>Process as happened in the case</th>
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</thead>
<tbody>
<tr>
<td>1. Project Preparation</td>
<td></td>
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<tr>
<td>- Client Initiation</td>
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<tr>
<td>- Participant Involvement</td>
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<tr>
<td>- Decision making structure</td>
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<tr>
<td>2. BIM Planning</td>
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<tr>
<td>- BIM Goals &amp; Uses</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>3. Information exchange</td>
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</tbody>
</table>
2.2 process map as per literature

In the process map as per literature (figure 2.9), it can be seen that the new roles and responsibilities of the client and consultants are identified. The activities indicate that along with the consultants, the client has to be quite knowledgeable of BIM. But if there is a client who is building just once, and if the process is planned to take place in the above (figure 2.9) manner, there will be a lot of difficulties. Also the process map (figure 2.9) shows that the consultants have to be collaborative, decide on knowledge, communication exchanges and many more aspects. Having said this, who takes the responsibility to check whether these goals are met? When the case is so fragile with the client being a onetime builder, the responsibility of overlooking whether the BIM Collaboration, modeling, information and knowledge exchanges are met is an extremely important aspect. In traditional projects, the project manager acts as the client representative to manage the coordination among consultants. In this research, we identify the role of the project manager in the process map of figure 2.8 and redraw the map (figure 2.10)
BIM Project Initiation Stage

- Identifying BIM Objectives
- Selecting the right team
- Flexibility clauses in BIM Contract

Participant Involvement

- Including BIM experienced teams
- Understand working cultures

Decision Making Structures

- Organize decision structures
- Organise work flows
- Network solutions

Organisational structure

Overlapping responsibilities

Preparation Stage 1

BIM Process as per literature – 1 (with project manager)
2.3 identifying added responsibilities of project manager

The project management’s mission is to lead a building project on a clear path towards the achievement of the predefined objective. Project management focuses on three main aspects, i.e. quality, cost and time (Wijnen et al., 1993, from (Sebastian 2009)). Consistent with these three aspects, project management aims at delivering a building that meets the previously set quality level within the budget and the planned duration. With the increasing complexities of the projects and the new issues to be considered in the BIM Project, the role of project manager is reanalyzed in this part.

As mentioned in the problem statement of this research, none of the literature of BIM mentions how the role of project manager changes or what are his added responsibilities while managing a BIM Project. Hence this role has to derived rather than studied. Also, the project manager we are considering here is also the client representative and the latter is a onetime builder and has no knowledge of BIM. This situation is considered since the case study also has a similar condition. The process of deriving the role of project manager is as follows: For each aspect mentioned in the previous table, the role of project manager or client representative will be done. In order to do this effectively, concept of Venn diagrams is followed. Figure 2.11 explains what each section of a Venn diagram represents.

From figure 2.11 it can be seen that the overlaps of A, B & C are not similar. The extent of overlap indicates the extent of responsibilities shared between the other members.
1. preparation stage

1a. project initiation

The client considered here is a onetime builder, Hence it’s the responsibility of the project manager to educate the client, advice formulating the brief and finding the right consultants. This has to be done in addition to his regular responsibilities of scheduling, costing and organizing the project plan.

The above mentioned responsibilities cannot be handled by a single manager. Also the skills needed to manage these are not limited to managing the project with respect to time, money and quality. So we organize the identified new responsibilities of the project manager into:

- Decision making tasks – Decision makers
- Collaboration tasks and - Collaborators

The decision makers are responsible for taking the important decisions regarding time and budget on behalf of the client.

New tools: Cost estimating and 4D modeling are the two BIM Uses that can help the decision makers in the BIM Process.

New Skills: In addition to taking important decisions and having a good project experience, the decision makers will have to manipulate, navigate, and review a 3D model. So, not a very high proficiency but basic level of Modeling is required.

The collaboration managers will deal with the system as well as the actors and mainly focus on new, innovative and smooth collaboration between actors, define communication protocols.

New tools: Design authoring, design reviews and 3d design coordination are the BIM Tools that can help the collaboration managers in the BIM Process.

New Skills: With respect to the knowledge needed for handling the BIM Tools, a basic knowledge of 3d tools will be required i.e. to manipulate, navigate and review the 3D Model.

The information manager is the manager who will be actively involved in the 3D Model compared to the above two managers. He would be responsible for checking whether the 3D Model has achieved the level required in a certain stage of the project, management of the information in terms of data flow and storage, identify communication errors, tracking the analysis (BIM Use) processes. He would also be responsible to check whether the results of the analysis performed in the BIM Process are received by all/ required parties.

New tools: There are no specific BIM Tools for this manager, but he should be able to model to a certain extent and be able to read and navigate the same.

New Skills: But he should be a level higher than the above two managers in handling the 3D Model.
All the above managers should be in coordination with each other in the entire process and give the other two managers the necessary information embedded in BIM.

Table 2.2 organizes the above mentioned managers with their responsibility, tools needed and skills needed to undertake the responsibility.

The different levels of BIM Knowledge is explained below:

1. **Lower level:** They have the ability to open the BIM files, navigate around within the model, create views, and print selected views.

2. **Basic Level:** They can add and revise information to the model and make basic modifications to object families.

3. **Medium Level:** They can import geometry, manage links to the 3d Model, and ability to use model checking tools.

**Table 2.2: Role of project managers in Project Initiation Stage**

<table>
<thead>
<tr>
<th>Type of manager</th>
<th>Responsibility</th>
<th>BIM Tools needed</th>
<th>Skills needed</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Decision maker</strong></td>
<td>Scheduling, costing, advice in brief and contract formulation, educating the client</td>
<td></td>
<td><em>Medium level of proficiency in handling the model</em></td>
</tr>
<tr>
<td><strong>Collaboration manager</strong></td>
<td>Finding right consultants, advice in brief and contract formulation, educating the client</td>
<td></td>
<td><em>Basic level of proficiency in handling the model</em></td>
</tr>
<tr>
<td><strong>Information manager</strong></td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>
1b. participant involvement

Figure 2.13 Venn diagram Participant Involvement – Literature Study

When selecting consultants for a project, traditionally the selection was based on the experience of the consultants to handle such complex project. In BIM Project in addition to this, aspect of whether the consultant is experienced in BIM or willing to do BIM project has to be considered. The client representative should also collaboratively with the consultants understand each other’s work cultures, team capabilities and advice each other of how to work with BIM.

Table 2.3: Role of project managers in Participant Involvement

<table>
<thead>
<tr>
<th>Type of manager</th>
<th>Responsibility</th>
<th>BIM Tools needed</th>
<th>Skills needed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Decision maker</td>
<td>Consultants who can handle complex projects</td>
<td>-</td>
<td>Experience, Lower level of modeling knowledge of BIM</td>
</tr>
<tr>
<td>Collaboration manager</td>
<td>Decision about teams experienced and willing to learn BIM, Understand work cultures</td>
<td>-</td>
<td>Knowledge of BIM, Basic level Modeling knowledge of BIM</td>
</tr>
<tr>
<td>Information manager</td>
<td>Understand work cultures, identify team capabilities</td>
<td>-</td>
<td>Medium level knowledge of BIM</td>
</tr>
</tbody>
</table>
The client representative should advice the client on the type of organizational structure best suited to do BIM. He should also collaborate with the consultants on deciding the communication structure among themselves, identify BIM tools that can be used, collaboratively decide on goals etc.

Table 2.4: Role of project managers in Decision Making Structures

<table>
<thead>
<tr>
<th>Type of manager</th>
<th>Responsibility</th>
<th>BIM Tools needed</th>
<th>Skills needed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Decision maker</td>
<td>Organizational Structure that suits best,</td>
<td>-</td>
<td>Experience and lower level BIM Knowledge</td>
</tr>
<tr>
<td>Collaboration manager</td>
<td>Organizational Structure that suits best, Set collaboration goals, Establish BIM Communication protocol, work meeting procedures,</td>
<td>-</td>
<td>Basic level BIM Knowledge</td>
</tr>
<tr>
<td>Information manager</td>
<td>Identify BIM Tools, Information needed/ not needed, Identify network environment,</td>
<td>-</td>
<td>Basic level BIM Knowledge</td>
</tr>
</tbody>
</table>
2. BIM plan

![Venn diagram of BIM Plan – Literature Study](image)

**Figure 2.15 Venn diagram BIM Plan – Literature Study**

The project manager should along with consultant’s advice client on defining a BIM Goal which should be corresponding to deliverables needed and the Level of Development (LOD) of BIM Model in each deliverable. At the same time the client should be helped in fixing BIM Goals. Also the project manager along with consultants must give inputs in making the BIM Plan, evaluating the BIM Plan after each stage and continuously develop the BIM Plan.

<table>
<thead>
<tr>
<th>Type of manager</th>
<th>Responsibility</th>
<th>BIM Tools needed</th>
<th>Skills needed</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Decision maker</strong></td>
<td>Fixing goals &amp; deliverables</td>
<td>-</td>
<td><strong>Basic level of BIM Knowledge, ability to relate goals to deliverables</strong></td>
</tr>
<tr>
<td><strong>Collaboration manager</strong></td>
<td>Fixing goals &amp; deliverable, Evaluation of the BIM Plan, giving inputs to the BIM Plan, developing the BIM Plan,</td>
<td>-</td>
<td><strong>Basic level of BIM Knowledge</strong></td>
</tr>
<tr>
<td><strong>Information manager</strong></td>
<td>Giving inputs to the BIM Plan</td>
<td>-</td>
<td><strong>Basic level of BIM Knowledge</strong></td>
</tr>
</tbody>
</table>
2a. BIM goals and BIM uses

Figure 2.16 Venn diagram BIM Goals & Uses– Literature Study

Along with the client and consultants, the project manager should decide on which BIM Tools should be used. This should be done after weighing the Risk vs. Value of the BIM Tool for the project as well as organization as these BIM tools are very expensive.

<table>
<thead>
<tr>
<th>Type of manager</th>
<th>Responsibility</th>
<th>BIM Tools needed</th>
<th>Skills needed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Decision maker</td>
<td>Evaluating the risk vs. value of a BIM Use for the project</td>
<td>-</td>
<td>Knowledge of the BIM Tool and its long term benefits, Lower level of BIM</td>
</tr>
<tr>
<td>Collaboration manager</td>
<td>Identifying which BIM Tools can help in smoother communication</td>
<td>Design review, Design authoring</td>
<td>Basic level of BIM</td>
</tr>
<tr>
<td>Information manager</td>
<td>Able to understand the required BIM Uses for the project and the problems faced by consultants in achieving the BIM Goal due to lack or inefficient use of a BIM Use</td>
<td>-</td>
<td>Knowledge of which BIM Uses required for achieving the BIM Goal, Medium level knowledge of BIM Tools</td>
</tr>
</tbody>
</table>
3. Information Exchange

There is an immense amount of information created through the analysis, clash detection, 3D coordination and various BIM Uses performed in the process. The results generated from these activities have to be properly managed and made sure that the respective actors are known about the changes. Also, the information created at this level has to be communicated to the upper levels of decision makers. Till now, this responsibility was in the hands of the senior design consultants. But they could not have an overview of the changes caused by certain information. Hence a project manager who is able to understand the BIM Model and the BIM Analysis is an important aspect while managing the information generated.

Table 2.7: Role of project managers in Information Exchange

<table>
<thead>
<tr>
<th>Type of manager</th>
<th>Responsibility</th>
<th>BIM Tools needed</th>
<th>Skills needed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Decision maker</td>
<td>Getting a decision approved</td>
<td>-</td>
<td>Experience, lower level BIM Knowledge</td>
</tr>
<tr>
<td>Collaboration manager</td>
<td>Scheduling the information exchange, managing and storing the information, tracking the information exchange and its process</td>
<td>3d coordination, design authoring, 4D Modeling</td>
<td>Medium level BIM Knowledge, managing information exchanges</td>
</tr>
</tbody>
</table>
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part III

research design & process
3. research design and process

In the previous chapter the BIM literature was studied in detail. This chapter will focus on the case study approach. The first part of this chapter introduces the approach and strategies underpinning the research design. The purpose of the research is described as mainly explorative, and the research design has been developed by using a flexible strategy. Whereas the scope and research questions have been defined through a long process, the decision to apply a case-study strategy was made early, based on the initial aim of the research and the desire to better understand and learn from the current status of practice. Qualitative and open-ended interviews are the main sources of evidence. The second part of the chapter provides an overview of the research process; from preparing to conducting and documenting the case study and interviews, to analyzing the data collected, to the reporting of the findings and the processes.

part I: research approach and strategies

The investigation of real-life situations encounters an array of challenges and pitfalls which have influenced the choice of research approach, strategies and methodological instruments. “In real-world practice, problems do not present themselves to the practitioner as givens. They must be constructed from the materials of problematic situations which are puzzling, troubling, and uncertain” (Schön 1991)

3.1 research purpose and strategy

Finding out what happens when implementing BIM in the little understood and complex world of AEC is, according to (Robson 2002), a typical feature of research with an exploratory purpose. The explorative nature of the research is furthermore underpinned by the two research questions, starting with a ‘what’and ‘how’, and several of the related research tasks.

The research process is based on two main co-existing phases (Fig 3.1). The results from these two phases lead to the final result.

<table>
<thead>
<tr>
<th>Approach</th>
<th>In depth</th>
</tr>
</thead>
<tbody>
<tr>
<td>Focus</td>
<td>Analyzing the case study for answering the research questions (objectives 4-7)</td>
</tr>
<tr>
<td>Based On</td>
<td>- Case study analysis</td>
</tr>
<tr>
<td></td>
<td>1. Case process as Planned</td>
</tr>
<tr>
<td></td>
<td>2. Actual Case process</td>
</tr>
</tbody>
</table>

Figure 3.1 The main phases of the research process.
The research phases are characterized by different approaches to the research problem. In the first phase, a broad overview was used in order to gain an understanding of the field and to identify important findings and relationships. In the second phase, the framework developed in the first phase is used to analyze the case study. The results from both the analysis are used to recreate a process map by redefining the role of project manager.

3.2 the case study as a research strategy

Bearing in mind the main aim and the research questions, a case-study strategy for investigating the real-life project and for establishing the main empirical body of the work has been applied. (Yin 1989) defines the case study as a research strategy arising out of the need to understand complex phenomena and to “retain the holistic and meaningful characteristics of real-life events”

understanding the context of the projects studied

Schön emphasizes the importance of considering the problem setting or context when solving real-life problems; “the process by which we define the decision to be made, the ends to be achieved, the means which may be chosen”. Investigating a case as a part of a context is a central feature of the case-study strategy (Yin 1989).

qualitative vs. quantitative case-study approaches

“... quite recently, increasing recognition of the value and appropriateness of qualitative studies has emerged. This may perhaps be in acknowledgement of the potential for such methodologies to get beneath the manifestations of problems and issues which are the subject of quantitative studies, and thereby, to facilitate appreciation and understanding of basic causes and principles, notably, behaviors’.” (Yin 1989)

The quotation above describes some typical features of a qualitative approach which are here found to be important for responding to the problem statement

aim of the case study

The aim of the case study has been mainly to gain access to the information required to address the two research questions. Particular attention was paid to:

- The planning, ambition and strategies for implementing BIM in the case. This would be done through studying the BIM agreement, BIM Process maps prepared for the case.
- Studying the actual case with an aim to find out to what extent was the planning mentioned in the previous point implemented. If not, the reasons for not following the planned process
- The role of BIM in the daily work of the actors with a focus on project manager
- The changing relations between the actors due to BIM
- The project actors’ experiences from implementing and using BIM (perceived benefits and challenges).
- The initial project process (e.g. work methods, tasks, routines, aims with focus on the aspects of the framework)

selecting the case

As indicated in the introductory chapter, one main case study was conducted. Around thirteen literature cases were studied to strengthen the analysis framework. The literature cases were not selected on the basis of BIM success in the project. The primary aim was to find out what were the challenges faced by the actors success factors required when implementing BIM.

One important criterion for selecting the actual case was that it should be a good arena for learning and for accumulating knowledge about how BIM works in practice. Also it was important that the case was trying to implement a new
technology in real-life project situation. Other important criteria was that the case should be on going, this would be beneficial to have first hand and immediate experiences of the actors involved in the project.

**case study design**

The case was studied on different levels; the overall project level, the design team level, and the individual role of project manager level. The framework developed for the analysis helped in maintaining these levels, repeating here again: the project preparation (overall project level), Developing the BIM plan and BIM Goals (team levels), and Information exchange (individual level, focusing on role of project manager).

The case study was investigated through two lenses: first, the planned BIM process and second, the actual case process. Since this building project was one of the pilot projects for the management company for implementing BIM, it also represents a unique case. Its uniqueness is characterized by the ambition to implement BIM for the first time in a complex project.

(Yin 1989) recommends basing the case study on multiple sources of evidence. The main empirical body of this work is based on data collected from interviews and documentations.

**interviews**

The qualitative research interview attempts to understand the world from the subject’s point of view, to unfold the meaning of peoples’ experiences, to uncover their lived world prior to scientific explanations.” (Yin 1989)

According to Wikipedia, interview is an interchange of viewpoints between two persons who are conversing on an issue of mutual interest. Obtaining access to knowledge embodied by the key actors involved in the building projects was regarded as crucial to gain valuable insight into not very visible and explicit processes and events. For this purpose the open-ended (or semi-structured) interview was found to be the most appropriate approach since it enables an informal and conversational interview situation guided by a pre-defined set of issues to be dealt with.

**selecting the respondents**

To answer the research questions, the group of respondents had to provide insight into the change in process or expected change in process due to BIM, changes in the interdisciplinary interactions due to BIM. The respondents selected were project managers at different levels, Cost engineering consultant, BIM Managers from the architect and consultants. These were the consultants responsible for managing the decisions and handling the 3d model. Although the respondents involved in management did not directly perform design tasks or use the technologies studied, their decisions were important to understand the flow of information. Project managers were therefore regarded as a valuable source of information about BIM ambitions, BIM preparations, expected BIM results and other process related strategies whereas the BIM Managers provided information regarding challenges and barriers for successfully implementing BIM, importance of BIM planning and goals and use of 3d Model for information exchange.

The respondents’ different points of view and perspectives thus together provided a good picture of the actual building process from the project level, to the team level and down to the individual user of the technology.
3.4 strategies for reporting the research process and results

Organizing the information of such a complex topic was an important objective while reporting the findings. Interviews were an important medium for communicating knowledge embedded in practice. Since the thesis revolves around processes and information flow, it became important to convert the interviews into understandable process maps. By doing this, the challenges and loop holes of the process became even clearer. The intention is to support the overview and understanding of key aspects of the work.

part II: the research process

As a consequence of the strategies and approaches chosen, the research process has been iterative and cyclic, rather than linear and straightforward. Figure 3-2 illustrates the relation between the data collection, the analysis, the framework and the structure of the thesis. The following section describes the main elements of this research process.

3.5 preparing the case study

Key elements for investigating the case study were the interviews and case documents. Based on the aim of the case study and the research questions, an interview guide was developed (figure 3.3). The research topic has generally been met with much interest and enthusiasm by the persons contacted and interviewed. Their openness and willingness to give access to relevant documents and to sacrifice their time for interviews have been encouraging indications about the relevance of the research topic.
### 3.6 conducting the case study

Table 3-2. Overview of the data collected from the case study

<table>
<thead>
<tr>
<th>Amount of interviews</th>
<th>MAIN CASE</th>
</tr>
</thead>
<tbody>
<tr>
<td>9</td>
<td></td>
</tr>
</tbody>
</table>

| Interview rounds     | 1. end of preliminary design stage (4)  
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2. during value engineering stage (3)</td>
</tr>
</tbody>
</table>

| respondents          | Project managers ((2010a))  
|----------------------|-------------------------------|
|                      | Cost engineering experts ((2010a))  
|                      | BIM Managers ((2010a))  
|                      | Architect – from other BIM project (1) |

| Other sources of information | PD Evaluation report  
|------------------------------|----------------------|
|                              | BIM Manual  
|                              | BIM Agreement  
|                              | BIM Process map  
|                              | Observed the model through computer |

All the interviews were carried out in the respondents’ locations, with the exception of one interview which had to be made by phone. The open-ended interview with one respondent at a time was the most common situation. Few respondents were interviewed two times over a four month period, which enabled a better impression of the consistency of their experiences and an overview of the process.
The type of interview varied from situation to situation. Firstly, the different roles, experiences and background of the respondents called for different questions. Unlocking the knowledge from the respondents was the most important aspect in the interview. Hence after the first two to three interview questions a general idea about the extent to which the questions must be detailed was known. Due to the practice-related nature of the questions, most respondents had very clear opinions about the issues questioned. Personally, I found it positive to give the respondent full attention throughout the entire situation, avoiding looking into papers or writing notes, which I believe might have distracted the respondent and disturbed the conversational atmosphere in the interview situation.

All interviews (both with project and context actors) have been audio-recorded and transcribed. The first interviews were transcribed word for word. Later, the important points were noted down which lead to sieving the expression words, halts and repetitive meaning sentences. Thus the time-consuming transcription process was speeded up and the readability of the text was improved. However, these adjustments were made carefully so the meaning or the content of the respondents’ comments were not interfered with. Together with the audio-recordings, the transcriptions establish the ‘raw’ interview data which have been used for further analysis and explorations.

studying project documents

The documentary information base from the building projects and their context comprises different websites, minutes from meetings, descriptions of R&D projects and agreements, BIM manuals and project manuals, and also project documents (e.g. plans, sections, 3D renderings, screen dumps perspectives and so on) and project presentations. The Preliminary design evaluation report was an important source of evidence for understanding all the consultants approach to the project. This report contained all the drawings which gave an idea to what extent the drawings were detailed in the Preliminary Design Stage and the expected design work to be completed till the Final design Stage.

part III: ensuring the quality of the research

Performing a qualitative research might lead to situation which is subjective to individual opinions. This could create a danger wherein the case might be based on soft and marshy grounds. Although findings from qualitative research and case studies of practice represent valuable contributions to scientific knowledge there has to be enough proof to ensure the validity to the findings.

3.1 validity of the research design

Two of the tactics to test the validity of the results, identified by (Yin 1989) are mentioned below: construct validity, external validity

Table 3-3. Case-study tactics for three out of four design tests. Illustration derived from Yin 1989

<table>
<thead>
<tr>
<th>Tests</th>
<th>Case study tactics</th>
<th>Phase of the research in which tactic occurs</th>
</tr>
</thead>
</table>
| construct validity | • use multiple sources of evidence  
• establish chain of evidence  
• have key informants review draft of case study report | data collection  
data collection  
composition |
| external validity | • use theory in single-case studies  
• use replication logic in multiple-case studies | data collection  
data collection |

the construct validity of the research

As indicated by the table above, two strategies for ensuring the construct validity of the research are recommended. The first is to use multiple sources of evidence. The purpose of collecting data from three sources of evidence (documentations, interviews, and physical artifacts) has here been twofold. In some situations one source provides supplementary information for another. In other situations, the
different sources highlight the same phenomenon from different angles. Since the interviews establish the main part of the empirical body, it has also been an issue to validate the respondents’ viewpoints. Due to the limited time period of the research, few numbers of respondents could be interviewed. Hence the triangulation of the interview data could only be done by interviewing the key respondents’ at least two times in different phases of the project.

The second strategy for establishing construct validity was to ensure a chain of evidence. One of the challenges in using the flexible design strategy is to establish coherence between the main elements of the research design; the problem statement, the aim and research questions, the tasks and the methods applied, the findings and the conclusions. Regular checks were made throughout the entire process of the internal consistency between these research-design elements. Do the findings actually address the research aim and questions? Do the findings impact the observed research problem?

The third strategy for ensuring the construct validity is to let key informants review the case-study reports. It has therefore been important to inform the respondents about the progress of the study and its results. Regular presentations were made to the key respondents and their feedbacks were incorporated in the research.

the external validity of the research

The research seeks to contribute more knowledge on the new aspects to be considered when preparing for a BIM project and how the role of project manager would change in comparison to a traditional project. An array of factors and relations have been revealed and explored in the real-life project and also literature by using various methods and techniques. After a detailed study of the BIM related literature the aspects of the analysis framework were derived. In order to avoid the danger of being prescriptive by following the literature, a number of literature cases were studied in parallel. The intention of analyzing these literature cases was not to generalize the findings by focusing on the benefits for the case by doing BIM, but to identify the challenges faced by the actors. This helped in narrowing down the aspects to be considered while preparing for BIM. This helped in strengthening the significance of the analysis framework.
Better buildings through digital practice

**Figure 4.1: Research design to answer the research questions**
4. case study as agreed

This chapter describes the case study as it was planned. The study of this planning is illustrated through the BIM Analysis Framework. The intention is to find out to what extent the planning was done, who were involved in the planning process, what aspects were involved, what were the references through which this case was planned for the BIM Process. In the first part of the chapter the planning of the case is presented according to the framework. In the second part, the responsibilities of the project manager identified in the planning are presented. Culminating the two parts, the final part gives the BIM approach planned in the case with a focus on the role of project manager.

4.1 background and context of the project

The Case studied is maintained as anonymous since the project has just completed its Preliminary Design Stage and will be starting the design development stages in coming months. Also, the building comes under high security level and hence the details cannot be published in the report. The client is a onetime builder and had launched a worldwide architectural competition for the design of the case project. The competition started in May 2008 and ended in October 2008 with final selection of the architect by the end of 2008. The architect was awarded the contract as design team leader with the best tender for the commission for the architectural and technical work and who best met the contract conditions.

The structural, HVAC and building physics engineers came in the preliminary design stage of the project and worked as a design team under the architect. The competition drawings became the starting point for the consultants for further development of the design.

The project is a complex with five office buildings and a tower. The project was divided into four stages: Preliminary design, Final Design, Execution Drawings and Construction. The client had asked the architects to do the project in 3d CAD/ BIM. The architects prepared the following documents as a reference and guide to develop the BIM Project. These documents were prepared by the architect from March 2010 to October 2010. They were available to the rest of the consultants during the start of the Preliminary Design Stage.

1. BIM Agreement - This BIM Agreement is based on the AIA document C106 – 2007 Digital data Licensing Agreement, AIA Document E202-2008 Building Information Modeling Protocol Exhibit the Building Information Modeling Execution Plan from the Pennsylvania State University Computer Integrated Construction Research Group and the Autodesk Communication Specification. This Agreement was established to develop the framework in which the BIM is to be developed and completed between the developers and the users of the BIM. It includes the Architect, Consultants and the Client. Its intension is to improve the communication and collaboration between all parties, to reduce the number of problems encountered during the project development process and increase the quality of the documentation.

- The important aspects of BIM detailed in this agreement are as follows:
- Scope of BIM Project
- BIM Process Design
- Collaboration Procedures
- Modeling Requirements, Project Goals and BIM Objectives
- Level of Development for Specific BIM Tasks
- BIM Development Sample Tasks by Project Phase
2. **BIM Process Map** – This Process Map shows a planning of how and when the model is linked and transferred among the consultants.

3. **BIM Model Division Plan** – This document shows how the model is to be divided by the individual building elements such as the office wings, tower, base warehouse and parking garage.

**part I: the case as planned studied with respect to the BIM Analysis framework**

**Table 4.1: BIM Analysis Framework - focus on BIM as planned in the Case**

<table>
<thead>
<tr>
<th>Process as per literature</th>
<th>BIM Process as planned in the case</th>
<th>Process as happened in the case</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1. Project Preparation</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Client Initiation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Participant Involvement</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Decision making structure</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>2. BIM Planning</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• BIM Goals &amp; Uses</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>3. Information exchange</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**4.1 preparation Stage**

Developing the BIM Agreement was the first step towards preparing for the BIM Project. Although the BIM Agreement was drafted with reference to the AIA Document, it also mentions that this agreement should be further developed in cooperation with all parties involved. Under the term of Preparation, the following characteristics will be explored:

**integrated project initiation:**

The integration of the consultants starts with the client initiation and the type of contract signed. Also sometimes, a service provider may initiate the BIM Development. This was a Pilot project for all the consultants; a service provider initiation was not an option. The BIM Agreement developed had no connection to the Contract Agreement. Neither did the BIM Agreement redefine its source information (AIA Document) as per this case specific organizational structure. For the successful development of a Building Information Model (BIM) an execution plan should be developed before starting the project. All work to be completed within this agreement is limited to the project’s contract. Any work that is requested by the client that is beyond the scope of the contract will be considered extra services. Only the client has the ability to increase the scope of work (BIM Agreement October 6, 2010). The agreement does not tell what steps should be taken if the client increases or changes the scope of work in middle of the project. As we have contingency funds for untimely risks in project, should there also be a contingency plan?
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<table>
<thead>
<tr>
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</tr>
</thead>
<tbody>
<tr>
<td>LDD</td>
<td>Level 3</td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Landscape</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Existing Site Model</td>
<td>Design Site Model</td>
<td>Site Landscape Model</td>
<td>Site Landscape Model</td>
<td>Site Landscape Model</td>
<td>Site Landscape Model</td>
<td>Site Landscape Model</td>
</tr>
<tr>
<td>Landmark Model</td>
<td>3D Landmark Model</td>
<td>Internal Landscape Models</td>
<td>Internal Landscape Models</td>
<td>Internal Landscape Models</td>
<td>Internal Landscape Models</td>
<td>Internal Landscape Models</td>
</tr>
<tr>
<td>Architectural</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AutoCAD plan information</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Architectural Model (Complete project)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Architectural Model</td>
<td>Architectural Model (Divided into subsystems)</td>
<td>Architectural model with linked structural model and system models</td>
<td>Architectural model with linked structural model and system models</td>
<td>Architectural model with linked structural model and system models</td>
<td>Architectural model with linked structural model and system models</td>
<td>Architectural As-Built Model</td>
</tr>
<tr>
<td>Engineering</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Structural Model</td>
<td>Structural Model (Divided into sub-models)</td>
<td>Structural Model (Divided into sub-models)</td>
<td>Structural Model (Divided into sub-models)</td>
<td>Structural Model (Divided into sub-models)</td>
<td>Structural As-Built Model</td>
<td></td>
</tr>
<tr>
<td>Mechanical Model</td>
<td>Mechanical model</td>
<td>Mechanical Model (Divided into sub-models)</td>
<td>Mechanical Model (Divided into sub-models)</td>
<td>Mechanical Model (Divided into sub-models)</td>
<td>Mechanical Model (Divided into sub-models)</td>
<td></td>
</tr>
<tr>
<td>Lighting Analysis</td>
<td>Lighting Analysis</td>
<td>Lighting Analysis</td>
<td>Lighting Analysis</td>
<td>Lighting Analysis</td>
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<tr>
<td>Extra Tasks</td>
<td></td>
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<td></td>
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<tr>
<td>Cost Estimating (BIM Group)</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>4D Planning</td>
<td>4D Planning</td>
<td>4D Planning</td>
<td>4D Planning</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Fabrication models</td>
<td>Integration into owner's FM system</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Manasi Jadhav 4039572 Design & Construction Management
early involvement of participants:

The process map in figure 4.2 shows that all the design consultants are involved in the project from the start of the project. But the map doesn’t show the involvement of the client or project manager or contractor in the process map. The project manager is responsible for sequencing the events of the project in coordination with the design team. The connection between the decision makers and the design team is not evident in this process map. The agreement does not mention the approach of the participants towards BIM Project.

collaborative decision making/control

The BIM Agreement states that for the creation of a successful BIM all parties involved with its creation should have open communication. This means information should be openly shared and the authors of the information create information as accurately as possible and maintain the information they generate through the design process. Many of the problems that occur during the development process should be anticipated. For an integrated development of a project, all the parties involved in the project irrespective of their involvement in the creation of BIM should have an open communication.

the BIM agreement organizes the collaboration procedures as follows

The Architect will establish the project’s geometry and exchange a model file with the engineers. The engineers will develop their models based on the geometry supplied. The engineer’s models will be linked into the architectural model. At an agreed point the project the structural model will be permanent part of the architectural model. To have a smooth running of this coordination, the architect and the engineers should meet frequently for design coordination. It also forms a model delivery schedule of Information exchange for submission and approval. This shows a much planned collaboration between the design team. The Agreement does not mention the collaboration levels within the teams i.e. should the decision makers form a team or mid level project engineers form a team or should there be a mix of these teams.

jointly developing goals

The Agreement doesn’t mention any jointly developed goals by the client and design team. The competition brief for the architect does state the following, “The most recent information and prognostications available are provided. However, it should be stressed that this is an ongoing process and that nothing which is stated here is completely final. Especially with regard to particularly relevant variable factors, such as for example the actual or expected workload of the client and the related question of staffing levels/number of workplaces, a number of unknown factors beyond the control of the client continue to exist. Consequently, it should be understood by all concerned that the client may, as appropriate, elaborate, supplement or even reconsider its views and considerations regarding some of the requirements for the permanent premises”

This indicates that the client expected the design to undergo continuous changes. Hence the objective with respect to design is creating a flexible architectural concept, which allows changes during the planning process and beyond. This wasn’t a jointly developed goal but one of the criteria for managing and making the design.

summary

Following is the summary of the above mentioned characteristics:

- The source of the BIM Agreement is through literature, indicating sufficient amount of similar aspects. This is not case specific
- This document has been developed at the start of the project by the architect. It does not involve the inputs from the client or other consultants
- The connection between the contract and this document is missing
- Contingency plan of redeveloping the BIM Agreement in case of changes in the scope of the project from the client is not dealt with.
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- The process map shows an early involvement of the participants
- But it misses the inclusion of client and decision makers in the plan
- The ways of collaboration between the design teams is explicitly detailed in terms of information exchanges. It elaborates on how the model be developed and information related to it exchanged.
- It lacks to reflect the exchange of knowledge between teams
- The Agreement doesn’t identify any jointly developed goals of the project, although the client has explicitly informed the design team to create a flexible architectural concept.

**developing the BIM Plan**

In order to understand how the BIM Plan for the Case was developed, an overview on the following questions will be performed:

- The reason for developing the BIM Plan
- What does the BIM Plan consist?
- How the BIM Plan was be developed?

**reasons for developing the BIM plan**

The BIM Plan was developed to establish the framework in which the BIM is to be developed and completed between the developers and the users of the BIM. This includes the Architect, Consultants and the Client. Its intension is to improve the communication and collaboration between all parties, to reduce the number of problems encountered during the project development process and increase the quality of the documentation. This document will create a road map for the development of the BIM that will direct the process through the phases of the project.

**what does the BIM plan consist?**

This document outlines the level of development the model should achieve at each phase of the project, the uses of the BIM, the collaboration procedures between the design team and the method of information exchange between all parties involved with the creation of the BIM and its use. It mentions the responsibilities of the BIM manager and the Design team with respect to the BIM Model.

**how the BIM plan was be developed?**

The BIM Plan was developed by the architect and is based on the AIA document C106 – 2007 Digital data Licensing Agreement, AIA Document E202-2008 Building Information Modeling Protocol Exhibit the Building Information Modeling Execution Plan from the Pennsylvania State University Computer Integrated Construction Research Group. The BIM Plan was developed at the start of the project and it states that the document should be continuously developed reflecting the additional resources, abilities needed to perform. In addition to this, the map should be verified at the start and end of each phase.

**summary:**

- The BIM Plan is developed to improve communication and collaboration between parties
- Reduce the number of problems encountered and create a road map for the development of BIM.
- It states to what extent should the BIM Model be developed at each project phase
- It identifies the responsibilities of the BIM Manager and the rest of the design team with respect to the BIM Model
- It also mentions that the process map and the BIM Plan should be verified at the start and end of each phase. This will help to identify the added abilities and infrastructure required to complete the BIM Phase smoothly
identifying the BIM goals & BIM uses

BIM goals

The BIM Agreement explicitly mentions that in order to create an efficient working environment through BIM, scope of BIM services should be adequately defined. According to the contract, the project must be developed using 3D CAD/ BIM. There is a large difference between the two working methods as CAD is dependent on vectors in space to define a 3D spaces whereas, BIM uses intelligent objects that contain information about the project to be constructed. It was decided that BIM will be the method of working on this project.

Since the scope of the BIM services was undefined, basic level of BIM services will be the basis of the documentation. So the goal of modeling was set to model the required BIM Objects in 3D with appropriate level of parameters attached. For this Level of Development (LOD) of the Model for the each phase was described. Figure 4.2 and the text below explain the LOD:

Level 0 – Requirements model
This level of model defines the requirements related to the project including municipal and local planning regulations. It also defines the project’s relationship to its surroundings. The client’s requirements are defined in this type of model.

Level 1 – Volume model (AIA LOD 100)
This level of model builds up the projects overall 3D form both interior and exterior. The model can be used for the study of the project’s geometry, shadow studies and wind analysis. Economic consequences of different design options can be evaluated. Functions can be assigned to individual zones within the model. Different construction methods can be assessed.

Level 2 – Room Model

Rooms in the model are defined. It is possible to make calculations for gross and net area as well as volume. Thermal, acoustic, fire, and lighting analysis can be conducted. The rooms start to play a more central role in the project’s development.

Figure 4.3: Model Level of Development (LOD) as per BIM Agreement

Level 3 – Object Model (AIA LOD 200)
Building components are defined as objects. Objects become the building blocks of the BIM model. Characteristics are assigned to the objects and become part of the project database. Objects are defined by type such as walls, floor and doors.

Level 4 – Building Component Model (AIA LOD 300)
The building component model is a further development of the Level 3 - Object Model. The objects are built to a higher level of detail without describing specific products, but can describe how the project is constructed.
**Level 5 – Construction Model (AIA LOD 400)**
The connections between objects is defined and built into the model. Materials are defined and become part of the model. Specific products can be defined and takeoff’s and cost estimates can be performed. The model can be used for tendering, production and time planning.

**Level 6 – As-Built Model (AIA LOD 500)**
The as-built model becomes a record of what was constructed and can be used for facilities management. Improved quality of design was one of the important goals of the project.

This shows that the goal of development of the model in each phase was decided in advance.

**summary:**
- The contract stated that the BIM could be developed either in 3D CAD or BIM. This indicates that the client should have been given more knowledge on what BIM is and what can he get from it
- The scope of the BIM services was undefined
- The level of developing the model was established according to the AIA document. The model level for all the phases of the project was established in quite an early stage. This indicates that there was less involvement of other consultants in deciding the content of each phase.
- The overall goal of the BIM plan was to have a good quality of design, coordination communication and collaboration between the parties.

**identifying the corresponding BIM Use**
The table 4.2 lists down the BIM Goals, its corresponding BIM Use and its priority compared to rest of the BIM Uses.

*Table 4.2: BIM goals and corresponding BIM Uses*

<table>
<thead>
<tr>
<th>BIM Goal</th>
<th>BIM Use</th>
<th>Priority</th>
</tr>
</thead>
<tbody>
<tr>
<td>Improve Communication</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Improve Collaboration</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Increase Quality of documentation</td>
<td>Collision detection software, design analysis tools</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>CFD – Computational Fluid Dynamics, acoustics, vibration, environment, structure</td>
<td></td>
</tr>
<tr>
<td>Reduce problems during project development process</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Regular cost estimates</td>
<td>IBIS4BIM</td>
<td>1</td>
</tr>
<tr>
<td>4D Modeling</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Programming</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Lighting Analysis</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>
From the table we can infer the following:

- The BIM Uses were not prioritized in the BIM Manual
- Improved communication and collaboration were identified to be the common objective to be achieved through BIM. But there were no BIM Uses identified which could help in achieving this goal
- Increased quality of documentation was supported by many BIM Uses (analysis tools, clash detections etc). All the possible analysis tools have been included in the document. Each analysis has a specific goal. For example, environmental analysis leads to an energy efficient building. This specific goal of each analysis is missing, although all of them contribute to better quality of design.
- Also in the last 3 rows, BIM Uses are mentioned, but no specific goals achieved by them.
- Cost estimating goal is successfully achieved through IBIS4BIM developed by the client representative

**Summary:**

- There were overall goals of the project to improve communication, collaboration and design quality of the project. But no specific BIM Use was identified to help the participants achieve this goal.
- Goal of efficient cost estimating was successfully achieved through a software developed by the client representative. The agreement mentioned a lot of BIM Uses with no final goal of the BIM Use.
- The literature mentions almost the same number of BIM Uses as mentioned by the BIM Agreement. This shows that the reference from literature has been really strong and less on the practicalities of the project.
- There has been no prioritizing of the BIM Uses. Which BIM use should precede or succeed which other BIM Use has not been clearly developed.

**Information Exchange**

In this section the information exchange plan in the BIM Agreement will be explained in two sections:

a) Information exchange tasks of each consultant

b) BIM development tasks of the consultant

**Information exchange tasks of each consultant**

All parties involved should be notified of the tasks required in relation to information exchange as early as possible in the project development process, so they are aware of the level of work expected.

**Architect**

- Communication of design intent to the consultants and contractor.
- Coordination of information regarding life safety, code compliance and accessibility.
- Issuing of BIM information to consultants throughout the design process.
- Clash detections of consultant’s models against the architect’s model and notify the consultant so the clash can be corrected.
- Tracking of where the BIM model has been transmitted.
- Model coordination.
- Verification that the BIM meets the client’s requirements.
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consultants

- Review and verification of the architects design.
- 3D modeling of the systems in software that is compatible with architect’s BIM creation tool.
- Clash detection of engineering trades
- Environmental analysis and simulation of design
- Update project team regarding changes to the model required by the engineering trades
- Making recommendations to the design team to improve performance, and make the manufacture of systems more efficient.

In figure 4.4 these tasks mentioned above are broadly classified in three divisions:

a) Tasks related to Model information – Type a - model
b) Tasks related to experience and knowledge – Type b - experience
c) Tasks related to experience as well as Model Information – Type c – model + experience

I. responsibilities of the architect:

Type a: model
- Issuing of BIM information to consultants throughout the design process
- Clash detections of consultant’s models against the architect’s model and notify the Consultant so the clash can be corrected.
- Tracking of where the BIM model has been transmitted.
- Model coordination

Type b: experience
- Communication of design intent to the consultants and contractor.
- Coordination of information regarding life safety, code compliance and accessibility

Type c: model + experience
- Verification that the BIM meets the client’s requirements

Figure 4.4: Information exchange responsibilities of Architect
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II. Responsibilities of the Consultant

**Type a: model**
- 3D modeling of the systems in software that is compatible with architect’s BIM creation tool.
- Clash detection of engineering trades

**Type b: experience**
- Review and verification of the architects’ design.
- Making recommendations to the design team to improve performance, and make the manufacture of systems more efficient.

**Type c: model + experience**
- Verification that the BIM meets the client’s requirements.
- Update project team regarding changes to the model required by the engineering trades.
- Environmental analysis and simulation of design.

---

**BIM development tasks of the consultant**

- **Baseline conceptual model**
  - Audit and deliver the completed model to:
    - BIM Manager Services
    - BIM Manager Structures
    - BIM Manager Other Consultants

- **Review model, ensure compliance**
  - BIM Manager Architect
  - Link or combine disciplinary models

As seen in figure 4.6, once the baseline conceptual structure has been created, the architect’s BIM manager will send the model to the sub-consultants so they can develop their designs. The sub-consultants’ designated model managers will audit and deliver the completed models to the architect’s model manager. The architect’s BIM manager will review the models to ensure compliance with the phase requirements.

Once the models meet the requirements, the architect’s BIM manager will link or combine cross-disciplinary models. The architect’s BIM manager should also eliminate duplicate or redundant objects, and accurately name the aggregate model and store it in the collaborative project management system.
The role of the BIM Manager in the above Model development process depends to a greater extent on his ability to audit, review the consultant’s model, and ensure compliance with the phase requirements and linking of the model.

**summary:**

- The person/team performing the information exchange tasks in the BIM Process should possess the ability to handle Model information as well as transfer experienced knowledge to the modeling team.
- The BIM Manager’s responsibility is to review and link the consultant’s models efficiently. In addition to this, he should also understand the phase requirements and ensure its compliance. So his responsibilities range from modeling capabilities to knowing the state of the design phase.

From the analysis conducted in this chapter, the summary is listed below:

*Table 4.3: BIM Analysis framework summarizing the key points of BIM as Planned in the Case*

<table>
<thead>
<tr>
<th>1. Preparation Stage</th>
<th>Agreed process in the Case</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. BIM Project Initiation</td>
<td>- Client asked for a 3DCAD or a BIM Project</td>
</tr>
<tr>
<td></td>
<td>- The contract was drafted before the BIM Agreement</td>
</tr>
<tr>
<td></td>
<td>- The connection between the contract and the document is missing</td>
</tr>
<tr>
<td></td>
<td>- The BIM Agreement states that all the work to be completed is within the project contract</td>
</tr>
<tr>
<td></td>
<td>- The agreement does not mention the approach of the client or the consultants in the project</td>
</tr>
<tr>
<td></td>
<td>- The source of BIM Agreement is through the literature</td>
</tr>
<tr>
<td></td>
<td>- It misses the details of the specific case</td>
</tr>
<tr>
<td>b. Early Involvement of participants</td>
<td>- All the teams were involved from the start of the project</td>
</tr>
<tr>
<td></td>
<td>- The involvement of client or project managers is not seen in the Agreement. These are the decision makers of the project</td>
</tr>
</tbody>
</table>
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<table>
<thead>
<tr>
<th>c. Collaborative Decision Making/Control</th>
<th>For every consultant except the architect, this is the pilot BIM Project</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>The BIM Agreement is developed by the architect with no inputs from the consultants, client or project managers</td>
</tr>
<tr>
<td>All parties should have an open communication</td>
<td>Through BIM Plan the team aims to reduce the number of problems encountered and create a road map for the development of BIM</td>
</tr>
<tr>
<td>Problems that will occur in the project should be anticipated</td>
<td>It identifies the Level of Development of the BIM Model in each phase</td>
</tr>
<tr>
<td>The organization of a project team is not discussed</td>
<td>It identifies the responsibilities of the BIM Manager</td>
</tr>
<tr>
<td>The ways of collaboration between the design teams is explicitly detailed in terms of information exchanges. It elaborates on how the model be developed and information related to it exchanged.</td>
<td>It also mentions that the process map and the BIM Plan should be verified at the start and end of each phase.</td>
</tr>
<tr>
<td>It lacks to reflect the exchange of knowledge between teams</td>
<td>The verification and results of this Agreement should act as a living document of reference for rest of the projects.</td>
</tr>
<tr>
<td>According to the BIM Plan, all the consultants should progress at the same pace in the project</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>2. BIM Plan</th>
<th>The goal of the BIM Plan is to improve communication and collaboration between parties</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Through BIM Plan the team aims to reduce the number of problems encountered and create a road map for the development of BIM</td>
</tr>
<tr>
<td></td>
<td>It identifies the Level of Development of the BIM Model in each phase</td>
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<tr>
<td></td>
<td>It identifies the responsibilities of the BIM Manager</td>
</tr>
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<td>The verification and results of this Agreement should act as a living document of reference for rest of the projects.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>a. BIM Goals and BIM Uses</th>
<th>The BIM Uses were not prioritized in the BIM Manual</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Improved communication and collaboration were identified to be the common objective to be achieved through BIM. But there were no BIM Uses identified which could help in achieving this goal</td>
</tr>
<tr>
<td></td>
<td>All the possible analysis tools have been included in the document</td>
</tr>
</tbody>
</table>
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- The specific goal of each analysis is missing
- The literature mentions almost the same number of BIM Uses as mentioned by the BIM Agreement. This shows that the reference from literature has been really strong and less on the practicalities of the project
- There has been no prioritizing of the BIM Uses. Which BIM use should precede or succeed which other BIM Use has not been clearly developed
- The BIM Goals and uses are not prioritized

4. Information exchange for a BIM Use

- The person/team performing the information exchange tasks in the BIM Process should possess the ability to handle Model information as well as transfer experienced knowledge to the modeling team
- The BIM Managers responsibility is to review and link the consultant’s models efficiently.
- In addition to this, he should also understand the phase requirements and ensure its compliance.

part II: role of project manager

In the planning of BIM in this project, the role of project manager and client has not been considered in any of the stages. This results in a very disjoint representation of responsibilities of client, client representative and consultant that resulted in figure like 4.7. Also one of the reasons of this approach was the type of contract as it was decided that the model will be developed by the design team.

Figure 4.7: Venn diagram Case as Planned
Preparation Stage 1

- Project Contract Drafted
- Client asked for 3D CAD/BIM
- BIM Agreement developed by the Architect
- BIM Agreement should be continuously developed and verified by all consultants
- All consultants progress in same pace

Consultant - Architect

All Consultants

BIM Approach – Case as planned – part 1

figure 4.8(1)
BIM Approach – Case as planned – part 2
part III: BIM approach of case study – as planned

From the study of the documents prepared for performing BIM in the case project, a process map (figure 4.8) is drafted which shows the approach applied. After studying the process map and the summaries from table 4.3, the following analysis and conclusions are stated:

One of the main reasons for planning the BIM Project was through the initiation by the client to have a 3D CAD/BIM for the project. The architect had an experience with BIM Projects and hence initiated the process of preparing the BIM Documents. This BIM Agreement is based on the AIA document C106 – 2007 Digital data Licensing Agreement, AIA Document E202-2008 Building Information Modeling Protocol Exhibit the Building Information Modeling Execution Plan from the Pennsylvania State University Computer Integrated Construction Research Group. This shows that the approach drafted is based on the BIM Literatures. The main consequence of this way of formulating the BIM Documents for a practical project was limited thought given to the specific details of the projects. This is with respect to the technology already in use by different actors, the level of involvement of actors, the specific goals of the project, the expected deliverables from the BIM Project etc.

The BIM Manual, process maps and the 3D Working Method enabled a degree of shared understanding of how to build and exchange the 3D models. But the 3D Working Method was prepared in Danish Language which was not translated for the rest of the international consultants who were involved in the BIM Process. Also the ways of working and modeling were drafted by the architect with no inputs from the consultants. This was one of the barriers to the implement a common ground for BIM Model.

The process map in figure 4.8 shows that the client had contact only with the architect during the start of making the BIM Documents. In the rest of the process, the client and the project manager have not been involved in the BIM Process. The remaining process is developed solely by the consultants. This makes the point even more clear that the reference to literature has been strong while preparing the BIM Documents since the literature too does not define the role of project manager in BIM Process.

The Level of detailing of the model is gradually increased for Level 0 to Level 6. But in the Process map, the requirement of LOD (figure 4.3) of the model for preliminary design stage is Level 3. Level 0 to Level 2 in which the requirements, volume and rooms are defined are not included in the process. This shows that the expected level of proficiency from all the consultants is quite high. This could be a barrier taking into consideration the limited time available to learn and test the new technology.

Also, the stages of the LOD Model show the increasing number of architectural elements; from Requirements Model (LOD 0) – Volume Model (LOD 1) – Room Model (LOD 3) – Object Model (LOD 4) – Building Component Model (LOD 5) - Construction Model to As Built Model (LOD 6). At no level it mentions the integration of the other consultant’s models. A similar LOD Stage Model for services, landscape, structural and other consultants in needed so that all the consultants are in the same LOD Stage during a project phase.

The main aim for developing the BIM Plan is to improve communication and collaboration between parties. Hence open communication is an important aspect mentioned in the document. Also the process map (figure 4.2) shows that all the consultants are at the same pace in the project. This is level of ambition should also be supported by the type of contract drafted as till present this is the main document that rules the workflows.

The process map in figure 4.8 and 4.2 show a number of analyses to be performed on the model. These analyses are not connected to any specific goals. This disconnection could result in lack of motivation to learn and invest in a particular analysis. The level of ambition of selecting a particular analysis or achieving a BIM Goal should directly be connected to the readiness of the AEC industry, the current abilities of the technologies and the expected non-technological barriers.
conclusions

This chapter has explored the important aspects mentioned in the BIM Agreement and its related documents prepared for guiding the actors to implement BIM in the Case Project. After studying these documents, the first viewpoint indicates that a large number of expectations have to be met in order to achieve the planned BIM Process. The aims and benefits that can be achieved through the stated BIM steps in the documents are not stated by the architects, engineers and other consultants but relate to the large number of benefits mentioned in the literature due to BIM. Having said this, it is clear that there are still many challenges to be dealt with before all the aims and visions formulated in the BIM Documents can be actualized.

The above discussion points out a few aspects while considering the planning of a BIM Project: The client should know what BIM is and what can he achieve from it. If he is a onetime builder, an appropriate consultant (could be project manager) should understand clients wishes and convert them into the project goals. From the process maps it is evident that the responsibilities of the project manager with respect to BIM have not been considered. It shows that the BIM Approach projected in this BIM Plan focuses more on the modeling aspect. The effect and benefits of BIM on the managerial and decision making level have not been dealt with. Hence it might result in a lesser motivation and power to implement BIM. Lastly the balance between the level of ambition versus the potential of the technology, skills of the project actors in using the technology and adapting to new working methods and processes, the resources the individual has to learn and test and the organizational traditions for using the digital tools and particular work method has to be more detailed while preparing a BIM Plan.
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Figure 5.1: Research design to answer the research questions
5. case study as realized

In the previous chapter a study of how the case was planned prior to starting the BIM was explored. This chapter explores the process of the case study as it was realized and the role of the project manager of how he handled the process. The BIM Analysis framework will be a guiding tool to organize the immense amount of information gathered. The focus is on the process of the project and the role of the project manager. Considering that most for most of the consultants this is a pilot project in BIM, it was important to study the approach taken by the team members. The case at present (June 2011), will be starting its Final Design Stage.

The first part of the chapter will explore the case on the basis of the BIM Analysis framework. The second part will study the role and responsibilities of the project manager based on the tasks he handled. Finally in the third part a process map will be prepared based on the conclusions from the first two parts. This process map shows the approach of the actors and also identifies aspects that are not explored in the literature.

The data for this case has been gathered from interviews, the PD Evaluation Report of the case and direct observations.

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<table>
<thead>
<tr>
<th>Part</th>
<th>BIM Process as per literature</th>
<th>BIM Process as planned in the case</th>
<th>Process as happened in the case</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Project Preparation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Client Initiation</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>• Participant Involvement</td>
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<tr>
<td>• Decision making structure</td>
<td></td>
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<td>2. BIM Planning</td>
<td></td>
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<td>• BIM Goals &amp; Uses</td>
<td></td>
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<tr>
<td>3. Information exchange</td>
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</table>
5.1 preparation stage

This section shall give an overview of the aspects considered before the BIM Project was initiated. The preparation stage will be divided and explained as per the following aspect.

i. Integrated Project Initiation
ii. Early Involvement of participants
iii. Collaborative Decision Making/Control

integrated project initiation

The decision to have a BIM Project was initiated by the client. Through the interviews and project documentation the following points were identified which were stated by the client in the contract under BIM requirement:

- The client is a onetime builder with not much knowledge in the construction industry.
- As per the contract drafted by the client, the project should be done in 3D CAD or BIM (There is a large difference between the two working methods as CAD is dependent on vectors in space to define a 3D space whereas, BIM uses intelligent objects that contain information about the project to be constructed).
- The contract mentions that the architect should do the project in BIM.
- The architect is the head of the design team.
- The organizational structure between the consultants is of Design-Build wherein the architect is the head of the design team.
- Before the consultants were on board, the architects drafted the BIM Agreement Plan which states ways of collaborating and exchanging information in a BIM Project.
- The goals from the client for BIM Project were not defined.
- The briefs by the clients were being evolved to be more specific even during the PD Stage.

early involvement of participants

The project management team, the architect and the structural, services, landscape, security, building physics consultants were in the project from the Preliminary Stage. So the consultants were in the project from the beginning stage. The contractors would be on board in the end of the design development phase. All the consultants have agreed to do BIM in the project, although it’s a learning experience for few of them. Figure 5.3 shows the timeline of participants. The Timeline mentioned in figure 5.3, extents from the start of the competition phase till the start of Design development Stage. During this phase, the following important aspects took place in a chronological order:

a) Start and End of Competition Stage with three finalists
b) Jury Decisions and negotiations leading to the finalist.
c) Client Representative for cost engineering and management appointed
d) 1st Version of security brief developed
e) Engineering experts, structural & services consultant, security engineering experts appointed
f) Preliminary Design Stage started
g) Technical and functional brief developed
h) Landscape consultant appointed
i) Start of Permit Procedures with the Municipality
j) BIM Agreement developed
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*figure 5.3: Participants Timeline*
k) End of Preliminary Design Stage

l) Evaluation of PD Stage

m) Start of 1st Value Engineering Phase

BIM necessitates early involvement of design team in the project to give their expert advice on design decisions. As seen from the timeline, the consultants are introduced in the project around the PD Stage which is almost at the start of the project.

**collaborative decision making/control**

Before understanding the decision making structure, an overview of the evolvement of the organizational structure from the competition phase to PD stage is given below.

**a. competition Stage**

During the competition stage, the client had appointed an independent cost consultant to finalize the budget of the project (figure 5.4). Along with the design, budget was one of the important factors to distil the three most suitable designs for the project.

![Figure 5.4: Competition Stage Organisational Structure](image1)

At the conclusion of the competition, after receipt of the Jury’s decision, the client started the negotiation with the 3 prize-winners under equal conditions to negotiate the contract terms and conditions including the respective fee offer.

![Client](image2)

![Management & Cost Consultancy Groep](image3)

![Negotiations to optimize building costs](image4)

![3 Competition Finalists](image5)

**Figure 5.5: Negotiations with 3 competition finalists**

The client invited the prize-winners to revise, if considered necessary, their design concepts in line with the recommendations issued by the Jury and / or additional requirements set by the client. After having examined and evaluated the (revised) design concepts, the client invited the prize-winners to negotiate the contract terms and conditions. During this stage, a new project management team (with cost engineering experts) representing the client was responsible for the negotiations (figure 5.5) with the competition finalists to help them optimize the costs.

**b. preliminary design stage**

After the competition phase, the aim was to conclude a general planning contract with the architect as design team leader which will include the coordination of the work of expert engineers from the most important disciplines such as structural engineering, building services, energy consulting (figure 5.6). The architect would also be the coordinator of the design team.

![Figure 5.6: Negotiations with 3 competition finalists](image6)
The Management and Cost Engineering team is the representative of the client and attends the meetings held with the client as well as the design team. The client, the management team and the Architect meet weekly to discuss the project. This is the Core team of the project. If the issues are not resolved in this meeting, then it goes to the higher management team. The Architect conveys the decisions made in the weekly meeting to the design team. As yet there has been no team created which involves mid-level project participants to resolve routine issues or who perform the modeling activities.

Also, according to the organizational diagram, the architect is the head of the design team and is at least one step ahead of the rest of the consultants. This is in contrary to the BIM Plan provided in the agreement (figure 4.2) which shows that the entire design team is in the same pace.

**summary**

- The client is a onetime builder
- The BIM initiation was by the client.
- As per the contract drafted by the client, the project should be done in 3D CAD or BIM
- All the consultants and designers were in the project in the PD Stage
- All the consultants had agreed to do BIM
- Few of the consultants had an earlier experience with BIM but for the rest, it’s a learning experience
- The organizational structure of the teams is that of Design-Build contract
- The architect is the head of the design team
- The main decision making team includes client, the project managers and the architect
- This team meets every week to discuss the project issues
- The collaboration within the design team is strong, but they haven’t used any BIM Tools for effective communication

**5.2 developing the BIM plan**

The BIM plan was developed by the architect with reference to the AIA Document from the Pennsylvania State University Computer Integrated Construction Research Group and the Autodesk Communication Specification. As seen in the timeline figure 5.3, the BIM Agreement was developed in the Preliminary Design Stage after the consultants were in the project. This means that the BIM Agreement was solely drafted by the architects without the incorporation of consultant’s views. Also this agreement was developed at the start of the project but was not updated in corresponding phases.
identifying the BIM goals

From the interviews and the project documentation it was clear that there were no goals identified in which BIM could be used.

identifying the corresponding BIM uses

Since there were no BIM Goals, there weren’t any corresponding BIM Uses identified by the project participants. However, there were a few Analysis performed. The Project management had an active cost engineering team that used IBIS4BIM software to extract costs from the model. The Building Physics Consultant used the following analysis: wind analysis (Computational Fluid Dynamics – CFD), Day lighting analysis (Equivalence), Shading Analysis (Radiance). But none of these analyses software was connected to the BIM Model.

5.3 information exchange plan of BIM use.

In the following section, an overview of information exchange is shown. Planning an information exchange indicates elaborating, which information should be communicated when and by whom. This is the basis of integrating information which is the idea behind the concept of Building Information Modeling. One of the benefits of using BIM for information exchange is less input and output time.

The case under study is a building with complexities in terms of user groups, multiple information exchanges. It is not possible to mention all the information exchanges that took place in the process. However, snap shots of certain information interdependency maps will be shown in this section. In order to explain the concept of how the information exchange actually took place in the case, the day lighting analysis will be detailed.

During the PD Stage, the architects developed the design conceptualized during the Competition Stage. Advice from structural consultant was taken for the basic layout of positions for structural elements. During the Preliminary Design Stage, the architects developed both 2D Drawings as well as BIM Model. The starting point for all the consultants were the plans/Model completed midway during the PD Stage, the briefs and the regulations. The development of the briefs was a continuous process with regular updates from user group.

delighting analysis

information interdependency

Brief Description: The day lighting analysis was performed by the building physics consultant. The starting point for their study was the architect’s drawings/model, the regulations and the technical brief from the client. The study could be divided in two parts: Internal and External. The internal study focuses on the effect of daylight in the interior of the building which has an effect on the interior layout, location of rooms etc. Also the location, design and depths of brise soleil (sun shading), might change which will result in changes in the structural connectivity. The software used is RADIANCE EQUIVALENCE. In the external study, the effect of daylight outside the building is studied. For this purpose, a shading analysis is performed which consists of the building model along with the surrounding structures. The results from this study could have an effect on the massing of the building, the facade design, structural design (Figure 5.7).
DAYLIGHTING

Software used: RADIANCE EQUIVALENCE

Daylighting results used to optimize planning & Layout of offices

Layout, internal functions, architectural design

Structural design of external canopies: Brise Soleil

Coordination needed

Starting Point
Mid way of PD Stage, PD Plans, NEN 2057, Technical Brief

Internal

External

SHADING ANALYSIS 3D Computer Model + Buildings in the surroundings

Test for possibility of Sunshades on facade

Results from investigation

Implications on

Results from investigation

Implications on

Architectural Design

Facade Design

Structural Design

Figure 5.7: Information interdependency – Day lighting Analysis

Manasi Jadhav 4039572
Design & Construction Management
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actual information exchange process

Figure 5.8: Information exchange – Day lighting Analysis
Figure 5.8 shows the information exchange map of the actual process that took place. The process is explained below:

- **Step 1** - The building physics consultant requested his engineer to perform the day lighting analysis.

- **Step 2** - The analyst recreated the building model as per analysis requirement and performs the analysis. This recreation was necessary as the analysis software could not accept the model created by the engineer. Also, due to software issues, the analysis could not take place more than a certain number of times in the process.

- **Step 3** - The results from the analysis are given to the engineer by the analyst.

- **Step 4** - The engineer then informs the building physics consultant.

- **Step 4a** - This is the case when an analysis has to be performed. The scenario is slightly different when 3D Modeling had to be performed.

- **Step 4b** - In that case, the building physics consultant informs the engineer about a change. The engineer along with the 3D Modeler performs the change in the model.

- **Step 4c** - This model is then given to the BIM Manager of the Building Physics Consultant.

- **Step 4d** - He then cleans the model of unwanted or duplicate objects. This model is saved or transferred to the BIM Manager of the Architect who links the model with the architectural model.

- **Step 5** - In the first scenario after Step 4, the results of the analysis are given to the Main Architect (since it’s a Design Build Contract & architect is the head of this design team).

- **Step 6** – The architect informs about these changes to the project manager and to the rest of the design team in different times.

- **Step 7** – The communication of the change to the design team by the architect can take place in various manner:
  - Email or
  - personal communication

This might create a problem like misinterpretation of information. The architect might think that the change mentioned by the building physics consultant affects the façade design only and hence he might just inform the façade consultant. But in reality, it might be affecting a number of other disciplines which is not in the knowledge of the architect (information interdependency). This will result in loss of information to many consultants.

- **Step 8** – The rest of the design team consultants will inform their respective engineers of the change and the Loop 1 of the communication will be repeated (many steps involved in this: x number)

- **Step 9** – Parallel to this, the project manager will discuss if necessary with the client about change and discuss with the architect.

- **Step 10** – The design team will also give the results to the architect.

- **Step 11** – The architect will then inform the Building Physics Consultant whether to go ahead with the change or No.

- **Step 12** – The Building Physics Consultant will inform the engineer who will inform the modeler to incorporate or not to incorporate the change.

**summary**

This shows the number of steps involved in the actual process to communicate a decision and finally approve it.
The following aspects could be summarized from this process:

1. BIM Model not used for communication
2. The architect is in the centre of the entire communication
3. The input of project manager is not direct
4. Number of communication loops happened successively
5. A number of problems could take place if the message is not conveyed to the right consultant or if there is a loss of information
6. The process takes place sequentially. This result in a lot of time wasted in waiting for the information
7. Analysis could take place for a fixed number of times due to lack of interoperability.
8. Also, the model had to be recreated for analysis since the analysis software considers central line and the actual engineering model has wall or external line for defining a space

**other analysis**

The previous section gave a detail explanation of information interdependency and information exchange of day lighting analysis. In this section a few more information interdependency analyzes will be shown. The actual information exchange will not be shown as the day lighting analysis gives a complete idea of how the exchange took place.
In the following section, all the figures will be shown first and the explanation of each figure will follow later.
Figure 5.9: Information interdependency – Fire Analysis

**FIRE ANALYSIS**

**COMPETITION STAGE**

**PRELIMINARY DESIGN STAGE**

Starting Point
Mid way of PD Stage, PD Plans

Example: Evacuation Strategy

Security

Safety

Example: Facade Design

JUDGES
WITNESSES
ACCUSED
ATTORNEYS

different categories of people separate during fire

Location of corridors, staircases

Implications on

Implications on

Facade Layout, Structure

Material quantity, specifications

Internal Planning

Spread of fire through facade

Distribution of fire resistant glass, closed windows, open windows

Facade
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**STRUCTURAL ANALYSIS**

**COMPETITION**

- Starting Point
  - Architectural drawings from Architects

**PRELIMINARY DESIGN STAGE**

**Tasks Performed**

1. Extent of structural systems explored:
   a. Type of Slab Construction
   b. Options for façade system
   c. Foundation system assumed
   d. Underwater drainage assumed

2. Future Extension Scenarios thought of

3. Bomb Blast Calculations

4. Underwater drainage

**Implications on**

- Execution of ground borings, soil & ground water investigation
- Detailed ground & Soil Report not ready

**Implications on**

- 1. Excavation design – existing trees
- 2. Foundation Design
- 3. Design of structures
- 4. Underwater drainage

**Effects of demolishing existing buildings on:**

1. Soil Conditions
2. Bearing capacity of foundation

**Timeline in process – Structural Connectivity**

**Figure 5.10: Information interdependency – Structural Analysis**
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noise analysis

preliminary design stage

starting point
mid way of pd stage, pd plans

external noise load

mer – noise model
(used to calculate noise load on facades)

façade design

implications on

construction of walls

thickness, materials of walls

internal noise load

implications on

technical brief

internal sound insulation

depends on

interior design, decision as per aesthetics

preliminary design stage

competition stage

figure 5.11: information interdependency – noise analysis
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**information interdependency of fire analysis:**

Figure 5.9 shows the information interdependency of fire analysis. This study could be divided into security and safety. The building consists of different categories of people. It is important to design an evacuation layout where neither of the categories collides with each other. The result of this study could have an implication on the location of corridors, staircases, width of passages, the design of the layouts. In the safety part of the fire study, the spread of fire in the building from internal and external of the building is considered. The results of this study could have an implication on the façade design, the distribution of fire resistant glass, materials, specifications, internal planning etc.

**information interdependency of structural analysis**

Figure 5.10 shows the information interdependency of structural analysis. The figure shows three aspects of structural design: Extent of structural systems explored, future extension scenarios and bomb blast calculations. Although the three aspects are studied, the bomb blast calculation aspect will be further detailed.

1. **Extent of structural system explored:** The starting point for the structural consultant was immediately after the competition stage. They advised the architects on the basic structural elements for the design. The architects incorporated these conceptual structural layouts when developing their design in the Preliminary Design (PD) stage. During the PD Stage, the following structural systems were explored:
   - Different types of slab construction
   - Different options for façade systems explored

Few design decisions had to be assumed or postponed as the required information to progress with the design was not ready during PD Stage. The foundation system and under water drainage system was assumed as the detailed ground and soil report wasn’t ready during the time of design decision. This report contains information regarding:

- Execution of ground borings
- Soil Investigation data
- Ground water Investigation data
- Position of existing trees (that should be retained)

The site has some existing structures below the ground whose exact locations will be mentioned in the report. A lot of design decisions are dependent on the above information. Some of them are stated below

a) Excavation Design: The layout of the excavation of ground depends on the safe distance to be maintained from the existing structure below ground (underground tunnel, pipeline). Also, the roots of the existing trees under the site have to be taken into consideration before the excavation.

b) Foundation Design:

c) Position of underwater drainage

d) Designing of subordinate structures on the site

In addition to the existing trees and underground structures that need to be retained, there are some structures that need to be demolished. The demolishing the existing structures will/ can have an effect on the soil structure and its bearing capacity. These aspects will have to be taken into consideration before the final design of the foundation system.

**Bomb Blast Calculations:** The case under study demands a high security. Various terror risks are taken into account for this case. One of them is the bomb blast calculations. The structural design should resist the extreme possible destruction that can be caused by an explosion. Along with this the façade design & detail, glass strength and façade calculations have to be coordinated with both the structural design and the bomb blast calculations.
information interdependency of noise analysis:

Figure 5.11 shows the information interdependency of noise analysis. The study of external noise could have an effect on the type of façade. The software used for this purpose is MER noise model. The internal noise study could have an effect on the type of construction material used, its specification, interior designs, layout etc. No software was used for this study.

conclusion

The above examples show the complexity of information in a project. This emphasizes the importance of a planned and organized information exchange.

The first part of this chapter has presented a broad and in depth study of the process realized the case. The BIM Analysis framework (table 5.2) summarizes some of the explored aspects with respect to process.

<table>
<thead>
<tr>
<th>Aspects</th>
<th>Actual Process in the Case Study</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1. Preparation Stage</strong></td>
<td></td>
</tr>
<tr>
<td>a. BIM Project Initiation</td>
<td>• The client is a onetime builder</td>
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<td></td>
<td>• The BIM initiation was by the client</td>
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<td>• As per the contract drafted by the client, the project should be done in 3D CAD or BIM</td>
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<tr>
<td>b. Early Involvement of</td>
<td>• All the consultants and designers were in the project in the PD Stage</td>
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<tr>
<td>participants</td>
<td>• All the consultants had agreed to do BIM</td>
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<td></td>
<td>• Few of the consultants had an earlier experience with BIM but for the rest, it's a learning experience</td>
</tr>
<tr>
<td>c. Collaborative Decision</td>
<td>• The organizational structure of the teams is that of Design-Build contract</td>
</tr>
<tr>
<td>Making/Control</td>
<td>• The architect is the head of</td>
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<table>
<thead>
<tr>
<th>2. BIM Plan</th>
<th>BIM Goals and BIM Uses</th>
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</thead>
<tbody>
<tr>
<td>- The BIM Plan was developed by the architect at the start of the project</td>
<td>- The goal of the BIM Plan was to have a better communication, but the project teams used the conventional methods of communication</td>
</tr>
<tr>
<td>- This wasn’t updated in the progressive periods</td>
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</table>

| Information exchange for a BIM Use | |
|-----------------------------------| |
| - In the PD Stage, the architect developed the design in 2D as well as BIM model | |
| - The result of a particular analysis affects the information of many more aspects that are directly/indirectly linked with the result | |
| - The BIM Model was not | |

- There weren’t any specific project goals which could benefit from BIM
- Also, there weren’t any specific BIM uses in the project.
- The consultants used a few analysis tools.
- The IBIS4BIM software was used to extract quantities from the BIM Model. This resulted in active cost estimation in the process.

The main decision making team includes client, the project managers and the architect

This team meets every week to discuss the project issues

The collaboration within the design team is strong, but they haven’t used any BIM Tools for effective communication
used to convey the new results of the analysis or tests

- The teams used the conventional approach for communicating

- This lead to an increased loop of information exchanges before the output was received.

- Interoperability between the analysis tool and the BIM Authoring tool is still not easily available or very expensive

- At such moments, the risk vs. value of a BIM Use is realized

- The architect was responsible for conveying the information to the rest of the consultants as he is the head of the design team. This resulted in the architect being steps ahead of the rest of the consultants.

- The project manager is responsible for the scheduling of the stages and various decisions.

- But they weren’t involved in the BIM Process of the design team

- This resulted in a step back in the decision process for project management team as compared to the BIM process
part II: summarizing the role of project manager

In this section the role of project manager is shown as it occurred in the case process. The activities performed by project manager are identified for each aspect mentioned in the previous table.

5.1 project preparation

**client initiation**

- Initiate Project
- Make contract

- Identify Consultants

- Scheduling
- Costing
- Organisation

**Figure 5.12: Venn diagram Project preparation- case realized**

The project manager advised the client on the selection of consultants. But this was to a very less extent and the client had the larger responsibility of selection. The project manager was responsible for the traditional aspects of time, cost and organization.

**participant involvement**

- Identify teams who can handle such complex projects

**Figure 5.13: Venn diagram Participant Involvement- case realized**

In the preparation stage, the consultants were not involved in any decision making process. Also the project manager was only involved in giving advice to the client on capabilities of the consultants with respect to handling of the complex project.

**decision making**
The project manager was responsible for schedule meetings. The agenda for meetings was decided in collaboration with the consultants. Although the diagram shows that there is an overlap between consultants and client, this overlap is very minimal.

### 5.2 BIM Plan

- Schedule meetings
- Establish drawing standards
- Communication within design teams
- Establish software solutions

![Figure 5.14: Venn diagram Decision Making- case realized](image-url)

The project manager was not involved in making the BIM Plan. Hence this results in a very disjointed Venn diagram.

![Figure 5.15: Venn diagram BIM Plan- case realized](image-url)
**BIM goals & BIM uses**

The project manager was not involved in selecting any BIM Uses for the project. Although there were no BIM Goals, the project manager and the Client had project goals of delivering the project within decided time budget. This resulted in the project manager scheduling the stages and deliverables along with the client.

**5.3 information exchange**

The information exchange in this context is a design decision that takes place in the project. The entire process of generating a design solution is within the design team. The project manager was not involved in this process. The only point at which the project manager gets involved is in the end and start of the information exchange i.e. communicating with the design team head of the problem raised in the project (start) and getting a solution of problem from the design team (end) and communicating the same with the client. Hence the project manager does not have an active role in this exchange.
**conclusion**

From the above VENN diagrams it can be concluded that the role of project manager was focused mainly on scheduling the important decision and communicating the revisions or changes to the client. The communication of the revisions and design changes to the consultants/ design team was done by the architect (he being the design team leader). Also the extent of overlap between the project manager and consultant (architect) is quite minimal which shows that the shared responsibilities between the two were very less. Since the architect communicated the design changes to the rest of the consultants (design team), the project manager had not much communication with the latter. This resulted in a disjointed Venn diagram or quite a minimal overlap of responsibilities between the project manager and the consultants.
**Project Initiation for 3D CAD/BIM**

**Client Selection of architect through design competition**

**BIM PROJECT INITIATION STAGE**

**Client**

**Preparation Stage 1**

**BIM PROJECT INITIATION STAGE**

**Selection of architect through design competition**

**Participan involvement**

**Selection of HVAC, structural, landscape and other consultants**

**Making the BIM Plan**

**Consultant - Architect**

**Organisational contract drafted**

**Communication between decision makers every week**

**BIM PLAN**

**BIM Plan prepared by Architect**

**Consultant - Architect**

**Preparation Stage 1**

**Overlapping responsibilities**

- **Client**
- **Consultants**
- **Architect**
- **Project Manager**

**BIM GOALS & BIM USES**

**BIM Plan**

**Preparation**

**Stage 1**

**Design and schematic drawings ready**

**Design Build Contract**

**Competition brief**

**BIM Agreement, BIM Process map, and other documents**

**Project Approach – Case as realized – part 1**

**figure 5.18(1)**
Project Approach – Case as realized – part 2

figure 5.18(2)
part III: Project approach – BIM process as realized

Figure 5.18 shows the process as it happened. The process map is drawn on the lines of the BIM Analysis Framework and below every aspect of the framework are the VENN diagrams showing the role of the project manager in each of the above aspect. In the following paragraphs, each of the analysis aspect will be explained along with the outputs generated for the aspect and how these outputs were used for further communication.

1. preparation stage

BIM Client initiation: The client wished to do the project in 3D CAD or BIM. With this option considered by the client, it is clear that he wasn’t aware of what BIM is, since there is a large difference between the two working methods as CAD is dependent on vectors in space to define 3D spaces whereas, BIM uses intelligent objects that contain information about the project to be constructed.

With this concept of 3D CAD/ BIM, the next step was selecting an architect through competition. The competition brief did not mention the need of using BIM in the project; however a clause was stated that the architect should be able to perform the design services using 3D CAD/ BIM.

So the competition brief was the only document produced in this analysis aspect which was used by all the competing architects for the brief and preparing the design.

Participant Involvement: The architect was selected through the competition and the schematic design was produced. The engineers and other design consultants were selected based on the ability to consult with respect to the complexity of the project and also the ability to do the project in BIM. This implicates that there was an early involvement of the participants and also the requirement to perform the project in BIM was fulfilled by everyone. Not all the consultants were proficient or experienced in BIM, for some it was a learning experience and a pilot project. This gives a view that there was willingness in the participants to learn, cooperate and do BIM.

The architect was involved in producing the competition or schematic drawings and making the BIM Manual. The consultants were not actively involved in making the BIM Manual but informed the architect about the softwares they used and accordingly the architect incorporated these in the BIM Manual.

From the Venn diagram it can be seen that the project manager was involved only with the client (to advice on the selection of other consultants), the responsibility of finalizing the concept design was shared between the architect & client and the architect and the consultant shared information regarding softwares which were included in the BIM Manual.

Decision making structure: The organizational structure was drafted by the client which was a design build contract and the architect was the head of the design team. The decision makers from the all the project teams would be meeting every two weeks for design discussions and solving the design issues.

The results from these meetings were knowledge generation and exchange from the design team heads. This knowledge would be transferred to the rest of the consultants of a design team through personal communication or emails.

In the decision making structure Venn diagram, the project manager shares the responsibility of solving the design and scheduling issues with the consultant. If the issues are not solved in these meetings, the project manager would take the issue to the client for reaching a solution.

The activities performed in this stage and the outputs generated suggest that, the result of the organizational structure formed is not incorporated in the BIM Planning document prepared by the architect. BIM demands a collaborative approach where all the consultants are equally placed in the organizational structure. With design build contract, the architect is the head of the design team and he is at a higher level compared to the other consultants. The resulting difference in the level of responsibility wasn’t coordinated in the BIM Plan of the project.

Concluding the study of preparation stage, the following points can be summarized:

- The design consultants other than the architect were willing to do BIM and were involved just after selecting the architect. So an important step of coordinating and convincing the consultants to do BIM was resolved.
While preparing the BIM Plan by the architect, there were hardly any inputs from the consultants although it was agreed by all to do BIM. This could result in a major gap in the process in the future since the necessary aspects of level of proficiency of other teams using BIM, extent to which investment in an analysis tool or BIM Use tool can be afforded and the time required to all teams on the same level of working for BIM is not considered.

In addition to the above concerns, the knowledge generated in the design team meetings was communicated and transferred through personal communication of 2D drawings. This goes back to the traditional ways of dealing with a conflict or design issue.

2. BIM plan

**BIM Planning:** The BIM Plan was developed solely by the architect with reference to the BIM Literature and research papers. This resulted in focusing more towards achieving the best possible BIM project with all the BIM Concepts incorporated and hence, overlooking the inexperience of the consultants and client in doing BIM.

The Venn diagram reflects this situation and shows only the architect involved in making the BIM Plan.

**BIM Goals & Uses:** There were no BIM Goals and no BIM Uses identified in the project. Although there were project goals of completing the project in time and budget, these goals weren’t converted to BIM Goals.

Hence there is no Venn diagram for this aspect. Not knowing what to achieve through doing BIM could result in a lack of motivation to perform BIM.

3. Information exchange

In the process map an information exchange of a design change or analysis is shown. The schematic design is completed by the architect producing 2D drawings. In order to show the pattern of information exchange among the consultants, a design change or analysis request by the project manager is shown. This request is communicated to the architect by the project managers through an email or a personal communication. The architect informs the respective consultant of the change through the same medium of communication. The consultant performs the analysis or design change which results in an analysis output or changed drawings incorporating the change. These drawings / analysis results are sent to the architect. The architect checks whether this solution fits the design with respect to technicalities, aesthetics and other factors. If no, then the engineer has to perform the analysis again to get a more feasible solution. If the decision is accepted by the architect, then the latter incorporates these changes in his drawings. The architect then informs the project manager about change. The project manager checks whether this design solution fits the required budget, time and quality. If the decision is no, then the consultant has to redo the analysis to get the requirements satisfied by the project manager and architect as well. If the project manager accepts this change which means that the design change has met the time, cost, quality, technical and aesthetic requirements, then it is approved by the client.

Once this decision is approved by the client, project manager and the architect; the design team is informed about it and the drawings are updated. Along with this, the 3D model is also updated. The process map also shows the kind of outputs produced at each decision making stage. They are mostly personal communication, emails or 2D drawings.

The Venn below the process map shows a chain of circles in almost a linear pattern. The consultants are in contact with the architect but not with project manager & client. The architect is in contact with the project manager and the consultants but not with the client to a regular extent and the project manager is in contact with the client and architect but not with the consultant. So the decision making process is elongated, tiring and repetitive.
reflections & conclusions
Figure 6.1: Research design to answer the research questions
6. reflections

Throughout the last chapters an array of finding from the three processes has been explored and reported on. This chapter reflects on these processes by comparing two approaches at a time. The purpose of the reflection is to find out the differences in the approaches, reasons for these differences and the changing role of the project manager. In the first part of the chapter, reflection between the process as per literature and case process as planned is made. In the second part, case process as planned with case process as realized is made. In the third part process as per literature with case process as realized is done. Finally a detailed comparison between Process as per literature which will be termed as BIM Approach and case process as realized which will be termed as Project Approach will be performed.

The sequence of the reflection is as follows:

1. State the conclusion of each aspect of reflection
2. Identify the important aspects of process change
3. Identify the changing role of project manager

6.1 reflection 1

The source of the BIM Agreement, the basis on which the case project was planned to do BIM is from the AIA Document and other research institutes. Hence a lot of similarities with respect to processes could be found. A few aspects that are different will be elaborated in the conclusions chapter. Also the role of project manager cannot be compared as the Case Process as Planned does not identify his role in the BIM Process. Which means the role of project manager derived from the literature case process cannot be compared to the role of project manager of the case process as planned.

Figure 6.2: Scheme of Reflections of processes
part II: case process as planned vs. case process as Realized

6.1 reflection 2

The situation in this reflection is similar to the first Reflection. The role of project manager is not defined in the Planned Case Process. Hence there is no comparison of this role in this reflection. Also as mentioned before, the source of the Case Process as planned is from literature which is similar to Process as per literature. Hence it would be wise to compare the Process as per literature on Case Process as Realized as both the variables: process and role of project manager exist and are different.

part III: process as per literature vs. case process as realized

6.1 reflection 3
AI project initiation

Table 6.1: Reflection: project initiation - process

<table>
<thead>
<tr>
<th>Project Initiation</th>
<th>Literature Process</th>
<th>Actual Case Process</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initiation</td>
<td>By Owner</td>
<td>By Owner</td>
</tr>
<tr>
<td>BIM Objectives</td>
<td>Align BIM Objectives in Contract</td>
<td>No BIM Objectives in Contract</td>
</tr>
<tr>
<td>Contract</td>
<td>Owner should be flexible in contract</td>
<td>Project should be in 3D CAD/BIM</td>
</tr>
<tr>
<td>Approach</td>
<td>Consultants flexible in approach</td>
<td>Consultants approach not mentioned</td>
</tr>
</tbody>
</table>

conclusions for process

The responsibility of the owner is increased in the initiation stage. In addition to the contract, a BIM Agreement should also be prepared. Combining the contract and BIM Agreement or having them separate depends on the client. If separate, which document should take priority has to be considered earlier. The contract should not only consider the hard aspects but also soft aspects like approaches of the consultants. For all this, the client should be educated about BIM. If he is a developer or a builder, the investment of time is justified. But if he is a onetime builder, this responsibility should be taken by a client representative. Following gives a summary of the changes in the role of project manager

Table 6.2: Reflection: project initiation- project manager role

<table>
<thead>
<tr>
<th>Project Initiation- Role of Project Manager</th>
<th>Earlier Responsibilities</th>
<th>New Responsibilities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scheduling</td>
<td>Educating the client</td>
<td></td>
</tr>
<tr>
<td>Costing</td>
<td>Advice in brief formulation</td>
<td></td>
</tr>
<tr>
<td>Organization</td>
<td>Advice in contract formulation</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Advice in finding Right Consultants</td>
<td></td>
</tr>
</tbody>
</table>
BJ participant involvement

Table 6.3: Reflection: participant involvement- process

<table>
<thead>
<tr>
<th>Participant Involvement</th>
<th>Literature Process</th>
<th>Actual Case Process</th>
</tr>
</thead>
<tbody>
<tr>
<td>Timeline of Consultants</td>
<td>Early Involvement</td>
<td>First Architect Rest came in PD Stage</td>
</tr>
<tr>
<td>Work Cultures</td>
<td>Should Understand</td>
<td>No measures taken but all agreed to Collaborate</td>
</tr>
<tr>
<td>Role of Experienced Teams</td>
<td>Inputs from Experienced teams</td>
<td>Inputs given but limited</td>
</tr>
</tbody>
</table>

conclusions for process

The participants should not only come early in the process, but they should plan on ways of collaboration, understand each other’s working cultures, and give inputs on BIM Development process. The experienced BIM teams should advice other teams on ways of using the BIM model most efficiently.

role of project manager

Table 6.4: Reflection: participant involvement- project manager role

<table>
<thead>
<tr>
<th>Participant Involvement- Role of Project Manager</th>
<th>Earlier Responsibilities</th>
<th>New Responsibilities</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Identify teams to handle complex projects</td>
<td>Experienced/ willing to learn teams</td>
</tr>
<tr>
<td></td>
<td>Understanding work culture</td>
<td>Identify team capabilities</td>
</tr>
</tbody>
</table>
C] collaborative decision making

Table 6.5: Reflection: collaborative decision making- process

<table>
<thead>
<tr>
<th>Collaborative Decision Making</th>
<th>Literature Process</th>
<th>Actual Case Process</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type of Contract</td>
<td>Collaborative, Integrated</td>
<td>Design - Build</td>
</tr>
<tr>
<td>Communication Protocols</td>
<td>Should be Established for all teams</td>
<td>Existed but within Design Team</td>
</tr>
<tr>
<td>Modeling standards</td>
<td>Should be Established who model</td>
<td>Established within design team</td>
</tr>
<tr>
<td>Data exchange possibilities</td>
<td>Should be Established who use model</td>
<td>Established within design team</td>
</tr>
<tr>
<td>Teams for decision making</td>
<td>Different levels of teams should be established</td>
<td>Only Decision makers</td>
</tr>
<tr>
<td>Identify BIM Tools for Information exchange</td>
<td>NO tools</td>
<td></td>
</tr>
</tbody>
</table>

Conclusions for process

Selecting a contract wherein all the consultants can best use the model for communication and collaboration should be selected. The communication protocols, modeling standards, data exchange possibilities are the new aspects that have to be considered in the preparation stage. These protocols should be extended to all the consultants involved in the project. Interdisciplinary teams should be formed at all levels and not only the decision making teams.

role of project manager

Table 6.6: Reflection: collaborative decision making- project manager role

<table>
<thead>
<tr>
<th>Collaborative Decision Making - Role of Project Manager</th>
<th>Earlier Responsibilities</th>
<th>New Responsibilities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Schedule meetings</td>
<td>Set Collaboration Goals</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Identify BIM Tools</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Information needed/ Not needed</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Identify Network environment</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Establish communication protocols</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Work/ meeting procedures</td>
<td></td>
</tr>
</tbody>
</table>
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D] BIM plan

Table 6.7: Reflection: BIM Plan - process

<table>
<thead>
<tr>
<th>BIM Plan</th>
<th>Literature Process</th>
<th>Actual Case Process</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reason to develop</td>
<td>To identify additional resources, training needs, added roles and responsibilities allows to measure progress</td>
<td>To plan the model transfer</td>
</tr>
<tr>
<td>When should it be developed</td>
<td>Continuously</td>
<td>At start of project, not updated</td>
</tr>
<tr>
<td>Who Develops</td>
<td>Collaboratively</td>
<td>Architect developed, no inputs from consultants</td>
</tr>
</tbody>
</table>

conclusions for process

The BIM Plan is a guiding map for the consultants on how to collaborate, exchange information, identify new roles, team capabilities in the process, model exchange methods. Hence the BIM Plan has to be developed continuously and in collaboration with team members. The person/team developing this plan should be knowledgeable of all the above aspects mentioned. This could be a new role and an added responsibility in the project team.

role of project manager

Table 6.8: Reflection: BIM Plan - project manager role

<table>
<thead>
<tr>
<th>BIM Plan Role of Project Manager</th>
<th>Earlier Responsibilities</th>
<th>New Responsibilities</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>None</td>
<td>Fixing Goals</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Giving Inputs to BIM Plan (schedule)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Evaluation of BIM Plan</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Define deliverables as per Level of Development</td>
</tr>
</tbody>
</table>
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E] BIM goals and BIM uses

Table 6.9: Reflection: BIM goal & uses - process

<table>
<thead>
<tr>
<th>BIM Goals &amp; BIM Uses</th>
<th>Literature Process</th>
<th>Actual Case Process</th>
</tr>
</thead>
<tbody>
<tr>
<td>BIM Goal</td>
<td>BIM Goals correlated to BIM Deliverables and LOD</td>
<td>None</td>
</tr>
<tr>
<td>BIM Uses</td>
<td>Select on Risk Vs. Value</td>
<td>Few BIM Uses were performed, but they were disjointed with the BIM Model</td>
</tr>
<tr>
<td>Information Exchange</td>
<td>Information exchange plan helps in identifying subordinate BIM Uses</td>
<td>None</td>
</tr>
</tbody>
</table>

Conclusions for process

The Level of Development of model at each stage and the detail of deliverables are correlated. This in turn depends on the BIM Goal the client has set. The model has to be accurate at all scales if the BIM Goal of the model is to use the Model for facility development. If the goal is not clear, the consultants are in a chaos about the extent of developing the model. Hence setting a BIM Goal is very important. Value Management should be an important aspect in BIM Process. The BIM Uses are analysis tools which are very expensive. The advantages of investing in these tools have to be considered before buying/ not buying them. If the project team has to have the complete advantage of using a BIM Process, these BIM Uses should be connected to the BIM Model. Finally, all these BIM Uses should be placed on the BIM Plan to identify the kind of inputs they need when and in which format. This is a new responsibility which can be handled by a team who has knowledge about the BIM Use and the BIM Plan.

Role of Project Manager

Table 6.10: Reflection: BIM goal & uses - project manager role

<table>
<thead>
<tr>
<th>BIM Goals &amp; BIM Uses - Role of Project Manager</th>
<th>Earlier Responsibilities</th>
<th>New Responsibilities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Schedule project</td>
<td>Identify Project goals with client</td>
<td></td>
</tr>
<tr>
<td>Check for completion of deliverables</td>
<td>Decide on BIM Tools based on Risk vs. Value for project and organization</td>
<td></td>
</tr>
</tbody>
</table>
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part IV BIM approach vs. project approach

The previous parts of this chapter gave a brief overview of comparisons between the processes. In this part a detailed comparison of the BIM Approach and Project Approach will be done over the process maps created for each approach. Each aspect of the analysis framework will be investigated in detail and the following points will be the guiding principle while making the comparison:

- Activities performed/ not performed in each aspect
- Reasons performing/ not performing these activities
- Outputs generated in each aspect of each process
- Benefits achieved and challenges to be faced while achieving an optimum BIM Approach

In all the comparisons, it is assumed that the client is a onetime builder with no knowledge of BIM.

BIM Approach – refer figure 2.9
Project Approach – refer figure 5.18

6.1 BIM project initiation

- In the BIM Approach, the BIM Project is initiated by the client. The client along with the project manager identifies which BIM Objectives can be achieved with the budget and timeframe of the project. A draft Contract is prepared which has BIM objectives incorporated along with some flexibility clauses. The flexibility clauses are needed so that the contract does not become a strict working document and create difficulties during collaborations.
- In the Project Approach, the project started with a competition. Before the start of competition itself, the client knew that he wanted to do the project in BIM or 3D CAD. The client later prepared the competition brief. The competition brief did not have any BIM requirements.
- In the BIM Approach a draft BIM agreement which is line with the project contract is compiled as one document. The project manager had an important role in this part of the process

- In the project approach, the client knew that he wanted a BIM Project. But this motivation was limited till here and a conventional design approach of preparing the competition brief was started.
- In the BIM Approach there are more steps involved in understanding BIM and preparing draft BIM Agreement before the consultants are involved. In the project approach, the initiation was started by the client but the output was a conventional competition brief.

6.2 participant involvement

- In the BIM Approach, the consultants are selected not only based on their experience to do the complex project but also their willingness to do it in BIM and their extent of cooperation.
- All the consultants are placed on the same level and their input is valued while preparing the organizational structure which is important for smooth collaboration.
- In the project approach, the architect is selected through competition and the schematic design is already completed. The consultants are selected after this design stage. Parallel to this, the architect starts preparing the BIM Plan with minimal input from the consultants. Also due to the type of organizational structure i.e. design build,
- Preparing the BIM Plan after the design is complete can also be considered to be an advantage as the scope of BIM can be realistically aimed for with respect to the complexity of the design.

6.3 decision making structure

- In the BIM Approach, aspects related to means of communication, decision structures, work flows, identifying communication routes, knowledge and information exchanges are resolved. Communication and information exchange protocols are produced in this stage. All these decisions are taken with the inputs of the consultants.
- In project approach, the organizational structure and means of communication between the decision makers is decided without inputs from the consultants.
- So, although the consultants were decided before making the organizational structure, this early involvement wasn’t converted to early inputs.
The above three aspects give a picture of strong gap between the consultants and the clients. These three aspects are the first few important steps to be considered before starting the BIM Project. It is here that the inputs from the consultants can be used to make the BIM Plan workable. The focus is not only on the consultants who are experienced with BIM, but also who are new. It is important to know the extent to which the inexperienced consultants devote time and money to learn a new collaboration method. The power of the implementer is a driving force to realize any benefits or challenges. Since we are considering a onetime builder client, the project manager should shoulder these responsibilities on behalf of the client.

Also, in the two process maps it can be seen that the contribution to outputs in each analysis aspect show clear distinction. In the BIM Approach, the outputs have a contribution of the consultants, client and project manager. In the project approach, the outputs are individually produced. This method of working is also seen in the Venn diagram overlaps. The BIM approach has larger extent of overlap which indicates larger shared responsibilities. The project approach has less extent of overlap which gives us a picture of fewer inputs from other consultants.

6.3 BIM plan

- In the BIM Approach, a number of activities are performed while making the BIM Plan. Although this aspect focuses on the planning of the BIM Project, it has to go under a deeper layer to make the BIM Plan successful.
- Softer issues like strategies, learning curves, ambitions, organizational vs. project goals, skills, behaviors, interests, backgrounds, experiences, complexity of work, interactions are the elements embedded under this BIM Plan.
- This means the BIM Planning requires an extreme understanding of each other’s work cultures in order to make a workable BIM Plan.
- In the project approach, the BIM Plan was complete in all respect. This can be seen from the Case Project as planned. Ways to model, model exchange, communication protocols, modeling guides were incorporated in the BIM Plan. But these were prepared by the architect alone. This lacked the experience/ inexperience of the consultants. The BIM Plan showed a very optimistic picture to perform the BIM Project.

- In the project approach it can be seen two different documents (project contract and BIM Agreement) are prepared by two different parties (client and architect) in two different paths.
- The outputs generated in both the approaches reflect the contribution of the actors. In the project approach, the architect was solely responsible for the BIM Plan, in BIM approach, the consultants and project manager were collaboratively involved. The Venn diagrams overlap also indicate the extent of shared responsibilities.

6.4 BIM goals & uses

- The BIM Uses are the analysis or BIM tools that help in achieving the project goals. In the BIM Approach, a BIM Use is finalized after knowing the project goals, weighing between project and organizational goals and the risk versus the long term value of investing in that BIM Use. Only after these requirements are known, a BIM Use is finalized.
- An important consideration in this is, what does the client want from BIM? If he needs BIM just as a virtual model for construction, the BIM Use might vary. If the client needs BIM as a as built model for facility and maintenance, the BIM Use is different. Hence the involvement of the client or project manager on behalf of the client is needed.
- In the project approach, no BIM Goals were set. But a number of BIM Uses were identified. This resulted in a lack of drive to invest or learn these BIM Uses.
- As mentioned in the previous sections, the outputs and the Venn diagrams indicate the contribution and extent of shared responsibilities among the consultants. In the project approach, no BIM Goals or BIM Uses were implemented. In the BIM approach the project deliverables are fixed which are in coordination with the goals and uses.

The aspects till now focused on the preparation stage before starting the BIM Project. From the process maps it can be clearly seen that the BIM approach demands immense preparation and collaboration. Most of the outputs in the analysis aspects are generated after contribution from the consultants. In the project approach, two distinct paths are shown (project path and BIM path).
6.5 Information exchange

- In the BIM Approach, before the schematic design is authored, the program is validated. This architect prepares the schematic design in either 2D or 3D. The consultants take these drawings as the base and prepare their individual 3D Models. An analysis is performed to check whether the project goals and design objectives are met. Once these objectives are met, the individual model is combined into one model to check for clashes.
- This shows that the focus is not only on designing but a continuous check whether the design meets the project goals.
- In the project approach, a long chain of information exchange is shown. After the schematic design was completed, two approaches were taken; 2d drawings and 3d modeling.
- Considering an example of an information exchange:
- A design change is requested by the architect or project manager. The architect informs this to the respective client. The design change or analysis is performed whose results are communicated to the architect. The architect accepts or requests the consultant to revise the change. Once the change is accepted by the client, this is informed to the project manager by the architect. The project manager checks this change against time and budget and accepts or rejects the proposal. If it is rejected, the consultant has to redo the analysis. If it is accepted, the project manager finalizes it with the client. In case it gets rejected, the whole process is repeated.
- While having this consultant to architect to project manager to client information exchange, an underlying information interdependency aspect is not even considered here. This means, the other consultants getting affected by a certain design change is not looked at in this exchange.
- Once the design is finally approved, the 2D drawings are updated. In parallel to this, the 3D model was updated.
- The outputs generated are 2D drawings or emails or personal communication.

This information exchange portrays a few important views:
- The focus of this exchange was mainly on approving of design
- The important aspect of checking with the project goals has been overlooked
- A single design change has to pass through various levels of consultants to be accepted.
- Considering the impact a small design change of one consultant can bring to the rest of the consultants is not imaginable by a single professional or human brain.
- This is like triggering a chain reaction of events which would be overlooked now, but might blow up in the future causing even greater problems.
Figure 7.1: Research design to answer the research questions
7. conclusions & synthesis

This chapter concludes with the research findings for the research questions and synthesis of the conclusions into two process maps: a detailed information exchange map and an overall process map. The first part of the chapter will summarize the conclusions from the research findings. In second part a detailed process map solution for information exchange is provided which is followed by third part in which an overall view of the process map with the initial stages detailed out is shown. In the fourth part, the chapter offers a reflection on the research activities, particularly the development and application of the framework. Moreover, the contribution of the research in relation to the overall framework is described and the chapter rounds off the thesis by looking at the implications of the findings for the practice and providing recommendations for future research works.

part I summarizing the conclusions

This research started out with a mission to find out
- What are the changing roles and responsibilities of actors in a BIM Process with a focus on the role of project manager?
- What are the new steps in the preparation of a BIM Project?
- What are the existing challenges for BIM Implementation

To answer these questions, we analyzed relevant literature & literature case studies and carried a detailed single case study which implemented BIM as pilot. The most important step in reaching the result was reflecting the processes of literature and case.

The following section will give the conclusions of the new aspects in the process of BIM Preparation Stage.

7.1 process change:

**BIM stages:** Through literature it was found that an extensive amount of preparation is needed before a BIM Project actually starts. Within this preparation stage important decisions regarding type of contract best suited for BIM in this project, selecting appropriate consultants who either have an experience with BIM or are willing to learn BIM or both, understanding work cultures, team capabilities. In addition to this, deciding on communication protocols, collaboration goal & strategies was also found to be an important aspect before start of project. After this analysis, it can be stated that although effort is needed in the PD Stage for an integrated development, an additional stage of Preparation has to be added before that (figure 8.1). This should consist of the client and the consultants.

**contract:** The literature mentions that an Integrated Contract should be prepared for successfully developing a BIM Project. After the case analysis it was observed that the contract should also contain a BIM Agreement incorporated within the contract. In addition to mentioning the deliverables and what is to be built, the contract should consider new characteristics of how the project be built, collaboration approaches among consultants, model transfers and other clauses surrounding the modeling activities. Input from experienced BIM Teams can help the client in formulation of the BIM Contract. While formulating the contract, it should also be considered which aspect should be mentioned in the contract and which should be under non-contractual agreement. This is important since a contract should not become a dictating document when formulating collaboration goals.

**BIM plan:** A BIM Plan should be developed by all the parties involved in developing the model. The input to this plan should not be only through the decision makers, but also by a team member who actually works on the model. By
involving people who work on the model, the investment decision on a particular BIM Software will have less chances of going unaccepted. The BIM Plan should follow the case specific details for eg: the type of organizational structure.

**BIM goals:** Through the case interviews it was very clear that all the consultants were unsure how to develop the BIM Model in further stages. This was due to a very important aspect that was missing: BIM Goal. The client had not set any BIM Goals for the project. It was not known how will the model be used later; as a fabrication model or for operations and maintenance or just for construction. This creates a problem in developing the model to a certain level and also fixing requirements for the deliverables. Hence BIM Goal is an essential part.

**Information exchange:** Information exchange was studied in the actual case process. After studying a few information exchanges, it was seen that a building project contains immense amount of information created continuously. Considering the architect to be the head of design team, it is not possible within the knowledge of the architect to know which consultant will get affected by the result of certain analysis. In order to prevent the loss and spread of incorrect information, lessen the time between input and output of a decision, the BIM model should be used for communication. All the consultants should be a part of the information loop. This is important to see individually how a decision affects their scope of work. Also the information exchange process has to parallel and not sequential. BIM Communication tools should be used to optimize this information exchange.

**7.2 role changes**

When the literature and case process was compared, the following points were observed:

- Boundaries between roles were less integrated in the actual process. This was also due to the type of contract signed. Hence the connection between type of building contract and collaboration procedures is very strong
- The responsibilities of the roles were extended to managing and collaboration along with designing and modeling.
- A change in the behavior of the consultant is necessary.
- The responsibilities of all the roles should be identified with respect to the BIM Model.
- Through case interviews it was observed that senior team members were not involved in the BIM Process. This resulted in a slight skepticism from them regarding BIM. Hence all team members should be completely integrated into the process.
- In order to integrate the senior member’s knowledge with BIM Technology, proper teams should be formed. This will help in exchanging knowledge and information at the same time.
- Role of project manager: In addition to the responsibilities of time, cost and quality; the project manager should set up collaboration strategies.
- We have seen though that BIM is an Information Management Tool that goes way beyond its design functions. For this reason the author is pretty certain to say that it is the PM who should lead the BIM Management the same way the PM is the leader in setting up other protocols in a project.
- There are some challenges for this since most Project Managers in PM Firms seem to not be very computer savvy. We are not suggesting that the PM should be in charge of building the BIM Model, but we do say that the PM should set up the protocols, the standards and the role of each stakeholder related to BIM in consultation with the consultants.

**7.3 challenges**

Along with a number of benefits observed and realized in BIM, many challenges have also been identified. They are as follows:

- Through the analysis it was understood that the client should be clear of in his idea of BIM and lead the entire team. Problem arises if he is onetime builder. Even though we suggest that the client representative should advice him in taking decisions, the owner will have to spend time in planning forefront. Can he invest that time for a one time project?
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- Every decision has to be justified based on cost vs. value. Value is a qualitative measure. It is important to find ways of quantifying them.

- Also even while selecting a software or making a process change, the team should be involved as they are the ones who will have to change their course of work.

- This also results in increased time in making a decision

- After so much collaboration and coordination, productivity will be improved, but design time equally get extended

- Rework will be avoided but coordination time will be increased

- Software and analysis interoperability is a major problem for a continuous information exchange.

- It is not fair to omit the proven methods of working which have been successful after being tested in tough times. To mould BIM Technologies with these proven methodologies is a new challenge for companies.

- It’s a fact that collaboration will lead to success of the project. But thinking in a different way, collaboration means some teams have to step down and some teams have to step higher in their ways of working to come at the same level of working. This might result in clashes of opinions. Also, an organization might lose its identity in the process of leveling itself for other team members.

- Finally, it is important for the tools to be user friendly, or else the good designers might feel like a skilled musician not being able to play this new instrument

part II synthesis – detailed information exchange

7.1 final results

conclusions from actual information exchange

In Chapter 5, the actual information exchange process was studied and the following points were generated as a result of the analysis:

- BIM Model not used for communication
- The architect is in the centre of the entire communication
- The input of project manager is not direct
- Number of communication loops happened successively
- A number of problems could take place if the message is not conveyed to the right consultant or if there is a loss of information
- The process takes place sequentially. This result in a lot of time wasted in waiting for the information
- Analysis could take place for a fixed number of times due to lack of interoperability.
- Also, the model had to be recreated for analysis since the analysis software considers central line and the actual engineering model has wall or external line for defining a space

This process map is once again shown in figure 7.2

guideline for making the final process

The aim of making a final process map was to integrate the conclusions derived from the analysis. They are listed below:

- Reducing Fragmentation of process
- Easy Communication of design intent and complex construction information
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- Setting up a process for identifying and resolving conflicts
- Diminish lines of responsibilities
- change in team behaviors
- Integrating everyone in BIM Process
- Using Model or BIM Tools for communication
- Identifying responsibilities with respect to BIM
- Integrating modeling information and design knowledge in teams.

The final process map after integrating the conclusions is given in figure 7.3. The problem of interoperability of analysis tool is not solved since this is a software problem. In next few years, we assume there will be greater interoperability and no recreation of model for the analysis input
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Figure 7.2: Information exchange in actual process
Figure 7.3: Final Integrated Process Map

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features of final process map

Below are the salient features of the process map after integrating the conclusions.

1. Every stage has a team performing a task and not an individual. The teams are formed in such a way that there is a combination of design knowledge as well as modeling information. By doing this, we define each role with respect to BIM. Also, every team member is involved in BIM, hence there will not be skepticism from senior team members who cannot work in BIM.

The grading of the members according to Design Knowledge and Modeling Knowledge is shown in table 8.1 (1= High, 4=Low)

Table 7.1: Grading of members 1

<table>
<thead>
<tr>
<th>Actor</th>
<th>Design Knowledge</th>
<th>Modeling Knowledge</th>
</tr>
</thead>
<tbody>
<tr>
<td>Main Engineer</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>Engineer 1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Engineer 2</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Model Manager</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>3D Modeler</td>
<td>4</td>
<td>1</td>
</tr>
</tbody>
</table>

The actors involved and their responsibilities in this process are as follows:

Table 7.2: Responsibilities of actors 1

<table>
<thead>
<tr>
<th>Actor</th>
<th>Responsibility/ Project Actions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Main Engineer/ Architect</td>
<td>Responsible for taking important design decisions and communicating with other consultants</td>
</tr>
<tr>
<td>Engineer 1/ Architect 1</td>
<td>Responsible for helping the main engineer/architect read the BIM Drawings. Responsible for giving inputs to 1. the BIM Plan along with BIM Modeler and 2. The team regarding important decisions made by main engineer</td>
</tr>
<tr>
<td>Engineer 2 / Architect 2</td>
<td>Responsible for making the model along with 3D Modeler.</td>
</tr>
<tr>
<td>Model Manager</td>
<td>Responsible for integrating, cleaning the model, knows about phase requirements, standards</td>
</tr>
<tr>
<td>3D Modeler (Has no</td>
<td>Responsible for helping Engineer 2/ Architect 2 in making model</td>
</tr>
</tbody>
</table>
2. The teams are formed in such a way that every team has a give and take of design and BIM Knowledge. They are as follows

<table>
<thead>
<tr>
<th>Teams</th>
<th>Actors</th>
<th>Knowledge Contribution (Design Knowledge + Modeling Knowledge)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Team 1</td>
<td>Main Engineer + Engineer 1</td>
<td>1 + 3</td>
</tr>
<tr>
<td>Team 2</td>
<td>Engineer 2 + 3D Modeler</td>
<td>3 + 1</td>
</tr>
<tr>
<td>Team 3</td>
<td>Engineer 1 + Model Manager</td>
<td>2 + 1</td>
</tr>
</tbody>
</table>

Resulting from this combination we have a connected Venn diagram.

3. The integration also takes place interdisciplinary. In figure 7.3 in the second column (performers’ teams -2) we see the exchange of information takes place between teams 2 of different consultants. Such kind of information exchange also took place in traditional processes. But they were through emails of telephones. This resulted in a sequential information transfer. The questions were answered probably a day later after referring the drawings. Also, such kind of information exchange results in loss of information or misinterpretation. In the process map of figure 7.3, these information exchanges take place through design reviews which is a BIM Communication Tool (Refer figure 2.6). This results in instant answering to design problems and integrating the two interdisciplinary teams through a common BIM Use. In conclusion to this point, it can be said that in the new process Information Exchange takes place instead of Information Transfer.

4. In this column of performers various activities take place like analysis. In the previous chapters it was mentioned that it is important to schedule these analysis properly as for conducting a particular analysis, results from number of other analysis are required. Hence a scheduler from the project management team should be involved in this stage. He can develop an analysis schedule with durations using the project sequence the main project manager has established. 3D/4D model allows the animation of specific time periods within the schedule that can be viewed. Therefore it will help the project management team to transfer the scheduling knowledge possessed by schedulers to the rest of the consultants.

For this a team of 3D Modeler and scheduler is needed. This states that the project management team should have a slight knowledge about modeling.

5. In the Integrators column a Model manager and engineer 1 is involved. The model manager will integrate the previous teams model after cleaning deleting unwanted objects. he will also be responsible for checking the model for phase requirements. The engineer 1 will be in collaboration with model manager and have a give & take on inputs for the BIM Plan, deciding on softwares, need of added support. These are important input which will then be given to the main engineer.
while making important decisions of investment in software and manpower (team 1).

6. In the decision makers column at the last, the project manager can view the changes along with the rest of the decision makers. This makes all the decision makers at the same level. Although the project manager is in contact with the client, so he will have a greater influence. While extracting the output from the final model, there will be a lot of information from all the consultants. To organize this information properly, the project manager will need an information manager who has slight knowledge of BIM. This is needed to extract the needed information and converting it into a format which is readable by the main project manager.

Conclusions

All these points mentioned in the previous section confirm that this new process map is more integrated, collaborative and uses BIM Tools to connect with every consultant.

part III synthesis – overall information exchange

In the previous part, a detailed information exchange with various team capabilities and integration was formed. In this section the process is zoomed out and a solution for the entire process is given.

The previous chapters helped in identifying the benefits, challenges loop holes in the process as described in the literature and as realized in the case. Taking these analyses as the starting point, a process map is designed indicating the steps that need to be considered, the role of project manager and how it handles the new responsibilities and the outputs or protocols that should be generated. Giving a final solution in the form of process map (figure 7.5) would be contradicting my analyses of overlooking the case specifics while implementing BIM. However, few steps that are important in order to prepare the project for BIM are shown in the process map. The explanation of the process map will be done in the following steps:

1. Explain the activities in the process
2. Explain the role of project manager and the various activities he performs
3. The advantages of these new activities in the process map and new responsibilities undertaken by the project manager
4. The challenges that will be faced while achieving these new activities and responsibilities

The entire process map is divided into four stages:

1. Client Initiation
2. Participant involvement & Decision making structure
3. BIM Planning, goals & uses
4. Information exchange
7.1 client initiation

**process activities:** The client who is a one-time builder initiates the project. He appoints the project manager who should understand the client’s expectations. The project manager should advise the client on the benefits and BIM Goals that can be achieved through using BIM. With this, both of them should prepare a draft of the BIM scopes achievable with the time, budget and involvement of the client. Having done this, either the consultants or the architect should be selected first. These consultants should be capable of handling the project size and be capable of performing BIM. If the latter is not achievable, the consultants should be willing to cooperate and learn BIM.

**responsibilities of the project manager:** The main activities that can be seen in this stage is advising the client on BIM and identifying consultants who can cooperate to achieve BIM. Hence from the three identified responsibilities of decision, collaboration and information; the first two will be required in this stage. The decision maker will be responsible for advising the client on the possible goals achievable through BIM in the time period and budget. The collaboration manager will be responsible for identifying the right consultants who can collaborate in the project.

**advantages:**
- By educating and advising the client on the realistic goals achievable through BIM with the time and budget, the client has no misunderstandings of the BIM concept.
- By selecting the collaborative BIM consultants, the BIM goals are discussed with everyone that can be accepted, rejected or modified with proper inputs.

This clarity at the start of the project will prove advantageous in the later stages.

**challenges:**
- The challenges are that the project manager should be knowledgeable about BIM. A prior experience in BIM Project can be considered to be a requirement.
- Selecting the architect or consultant first is an option. Both of these have their own advantages and disadvantages: if all the consultants are selected together, everyone will be in the same pace in the project which will have a better coordination and collaboration. However, the design will be in a process of development and the initial thoughts of the architect will be interrupted by the rest of the consultants leading to frustrations from the architect. If the architect is chosen first, the schematic design is ready which an important basis for redefining the goals.
- It is difficult to know whether the consultants can collaborate on BIM if this is their first BIM project. The extent to which they contribute to learning BIM while project deadlines are running parallel is again a matter of concern. Again there is a dilemma between having consultants who can do BIM but no experience in the type of project and having experienced consultants but no BIM knowledge is a matter of risk.

7.2 participant involvement and decision making structure

**Process activities:** In this stage, the BIM goals are finalized on the basis of the schematic design, with inputs from the client, project manager, consultants. Having done this, decision on ways of communication, exchange of data, information & knowledge, software and network solutions, team capabilities should be decided in collaboration with the project manager and consultants.

**responsibilities of project manager:** In order to organize the communication and information exchange structure, the type of organization structure is the deciding factor. No amount of planning for proper information exchange will be successful if the organizational structure is not in line with the flow of information exchange planned. Hence the decision maker and collaboration manager must together decide
on an appropriate organizational structure. In addition to this, the collaboration manager must decide on collaboration goals, BIM communication protocols and the work meeting procedures. The task of identifying the BIM Tools for the project managers, network solutions and deciding on the information needed/ not needed for the project in future stages is undertaken by the information manager. An equal input from the three project managers will be needed in this stage.

**advantages:**

- This stage completes the most important planning tasks before the project can take off. It eventually enables all the consultants along with project managers to be on the same page.
- The ways to handle the teams’ in-capabilities, software problems are discussed collaboratively.
- Setting up collaboration goals will inspire all the teams to take extra efforts in the project.

**challenges:**

- The team members have to find for themselves how to fix collaboration goals
- In order to know the team capabilities, software issues, inputs from various levels of the employees have to be taken.
- Encouraging the senior professionals to get acquainted with BIM by identifying ways of knowledge exchange is a challenging task. But if this is achieved BIM will be supported at all levels in the organization.

### 7.3 BIM planning, goals & uses

**Process activities:** In the previous stage, the team capabilities and software solutions helped to know which BIM Goals can be achieved. The next step after finalizing the BIM goals is to know how this can be achieved. Two important activities, firstly; finding a proper balance between organizational BIM goals & project BIM goals and secondly, weighing the risk vs. value of investing in a BIM Use. Once this is answered, BIM Uses for the project is finalized. This will lead to the next step of knowing the project deliverables that can be achieved from the BIM Goals & Uses finalized.

**responsibilities of project manager:** This is the last stage of planning before the design can start in BIM. The inputs from all the three project managers will be required to make decisions. The information and collaboration manager mostly will be using the BIM Tools for managing the design. Hence their capabilities and opinions will matter while finalizing the BIM tools for project management. This decision has to be strengthened by the decision maker manager who will weigh the importance of investing in a BIM tool against the risks.

**advantages:**

- The decision of how and in what format the project deliverables are produced is backed with a strong decision of BIM goals.
- This connection between goals and deliverables will motivate the consultants to use the BIM tools rather than just investing and not using them.

**challenges:**

- Evaluating the Risk vs. Value of a BIM Use is a challenging task. Firstly, quantifying value of a BIM Use is a tough task. The risk is based on the fact that there will be projects in the future wherein this BIM Use can be utilized. If there is no BIM project in the future, the investment will not get the required returns.
7.4 information exchange

Process activities: After deciding on the BIM Plan, goals and uses, the BIM Design stage will start. In this section a snapshot of an information exchange in BIM is shown. Assuming a certain stage of design is completed and the project manager or client requests for a change to a consultant. Consider him to be consultant 1. He performs the analysis or changes the model to incorporate the changes and updates his model with the change. This is then incorporated to the central model. At this point, rest of the consultants can see the changed model and verify it on the basis of design and required project goals. The project manager who also has access to the central model, checks the changed model with respect to schedule, cost estimation, required goal for the project and approval from the client. If all these parameters are accepted, all the consultants update their individual model. If not then consultant 1 has to incorporate the changes mentioned by the consultant and the project manager and reload the model. At this point, the clash detection takes place to achieve the required quality of the model and design. This ends the information exchange for consultant 1. But before ending it, the model is again checked for schedule, budget and required goals set for the project.

Responsibilities of project manager: The main tasks of the project manager in this stage are: checking the design for budget & schedule, checking if 3d coordination results in a major design change and getting the design changes approved by the client. These tasks are performed at regular intervals in the information exchange, thus keeping the project goals and design quality in control at all stages. Tools like 4D Modeling, cost estimating, 3d coordination, design authoring are used to help project managers get access to the BIM Model. They do not have to perform any modeling activities, but check for alerts so as to take managerial steps earlier.

Advantages:
- In the earlier stages it was mentioned that BIM Uses are based on the BIM Goals of the project. When we say that the design is checked for compliance with the required BIM Goal, it means, running these BIM Uses (which could also be lighting analysis) at regular intervals. So the design communications as well as checking for project goals are run in parallel resulting in giving importance to both the aspects.

Challenges:
- In this information exchange, the project manager is placed at the core of design communication. It should be taken into consideration that he does not influence or give opinions for design changes. These precautions have to be taken while framing the contract or performing modeling activities.
- By the end of one such exchange, immense amount of information is created. The information manager has to keep a track of this and sieve it into desired/ non desired information
part IV- reflection, applicability & contribution

7.1 development and application of framework

In this section I reflect upon the research actions with particular focus on the development and application of the framework.

The seven objectives described in the introductory chapter have guided and supported the research process and efforts to address the two research questions. The first three of these were related to the development of the analysis framework which then was applied to the last four objectives. This framework was developed and improved throughout the entire research process.

The framework was useful in defining focus and scope, in establishing the research and case-study design, in selecting the respondents and in guiding the interview situations. It has particularly supported the analyzing and organizing of the collected data. The framework tools provided helpful overviews of the research findings and their relationships. Generally it can be concluded that the framework proved to be useful in merging the two dimensions of ‘processes’ and ‘roles’. It has played a crucial role in the efforts to address the overall aim and the research questions. In addition, combining the analysis framework with a number of research strategies and instruments for data collection proved to be helpful in acknowledging the complexity of the real life situations.

The multilayered nature of the framework also resulted in several challenges. One of these particularly in the first phase of the research was to identify the important analysis aspects from the number of requirements mentioned in the BIM literature for a successful BIM Planning. This step had to be continuously modified taking into consideration the progress of the ongoing case and the data available from it. This challenge was foreseen and already mentioned in the introduction of the framework. In order to avoid the danger of being prescriptive with the framework, thirteen literature cases were studied in detail which helped in strengthening the analysis framework. A further challenge was the difficulty in indicating the changing role of project manager with respect to other consultants. The use of Venn diagrams proved to be helpful in understanding the overlapping, individual and shared responsibilities in a visual form.

Overall, the research provided inputs from an overarching process level down to single role level.

7.2 limitations of the framework

The generation of this framework was a result of interplay between the literature and case study. The application of this framework to study the process of a different project might require altering few aspects. Also, this framework was specifically designed for the initial stages of BIM Planning. The exploration of issues in the Final design stages or any other stages would require reconsideration of the framework outline.

7.3 research contributions

The overall aim of this research is, here repeated: To contribute more knowledge on the changes in the processes due to BIM and how the roles get affected resulting from this change.

The contribution of this research is fourfold, providing

- firstly; an analysis framework for exploration, description, analyzing complex and qualitative findings from the literature and case study;
- secondly a comprehensive way of showing the multilayered responsibilities of the various consultants in the BIM Process;
- thirdly categorizing the role of project manager in three different responsibilities to manage the new tasks in BIM;
- fourthly synthesizing all the above findings in one process map. Altogether, this thesis is a detailed and reflective documentation of
expected BIM through literature and current challenges in practice for achieving that expected BIM of literature.

The research contributions are significant for the research field in several ways. In the widest context, the framework and the findings generated by its application contribute to a flow of knowledge from research to practice and vice versa. The reflection of processes strategy could be an approach researchers could use to gain knowledge on real-life practice and especially finding the reasons for doing or not doing a certain activity in the process. The concept of Venn diagram gives a clear picture of changing roles in the practice.

7.4 implications of the findings for practice

The practitioners involved in the current AEC industry face a shift from 2D and document-based design tools to technologies supporting 3D object-based modeling and BIM. Although several benefits could be harvested from implementing and using the technologies supporting 3D object-based modeling and BIM, the practitioners were still struggling with an array of challenges of the ‘square-pegs-in-round-holes’ types. The implications for practice suggested below indicate fields for further focus, effort and discussion.

- The findings indicate that a number of steps have to be taken before the BIM project actually starts its design phase.

- The case study analysis linked a large number of explored factors with to processes and roles responsible for smoother integration of BIM.

- It is not just the early involvement of participants important for BIM Preparation, but their openness to collaboration, admitting the lack of skills or difficulties in adjusting their work cultures is equally necessary.

- The findings also indicate the importance of understanding and handling downstream and upstream interdependencies between strategies and guidelines for implementation, and the needs and experiences of actors involved in real-life projects.

- Learning a new technology is not so difficult. Today a number of high end softwares are being available in the market and they can be mastered in a few weeks time. The greater challenge is process. How we integrate the new tools to help make the process faster and organized.

- The disciplines started in the case project to develop their design solutions successively (for instance; at first the architect, then the structural engineer, HVAC and other consultants). The findings indicate, however, a need for simultaneous development and specification of geometry and design information across the design disciplines to enhance the potential of the technology to support interdisciplinary work.

- The final process solution integrated the project manager in the BIM Process. However, he is needed to learn just a few BIM Tools (4D modeling, design authoring and design reviews) to help him manage his decisions. This implicates that it is not a difficult task for the project managers to use BIM. However they should know what is BIM and how can the client benefit from it.

- BIM was adapted to traditional processes and established practice of design. The implemented technologies have not fundamentally changed the practitioners’ work and interactions. The findings imply that up-skilling is not only a matter of mastering and operating software, but also of learning and adapting new work methods.
The immense amount of BIM Literature published and identified gaps in the research suggest that many more real like case studies be implemented to embrace the complexity of real-life problems and to contribute to a more comprehensive understanding of what is going on in practice. The following actions are recommended for further development and improvement:

- Applying the framework to more real life projects to improve the definition.
- Studying the role of project manager in successful BIM Projects and find the common thread for dealing with BIM Projects.
- Architect being the creator of the design, in lot of cases he is the design team head taking design decisions. Studying the collaboration and interactions of project managers and architect.
- Testing the applicability of BIM Manuals, how and when should they be upgraded
- Studying the BIM Implementation with various organizational structures (design build, design team, design bid build etc.)
- The complexities of the design will increase in the Final Design stage. Studying the role of project manager in this stage will be a more challenging perspective.
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