Betrachtung und Analyse des Projektmanagements im BIM-gestützten Bauprozess

Observation and analysis of project management in BIM-based construction process

Raginie Prasad

Thesis for the Master of Science Study Course Advanced Construction and Building Technology

Autor: Raginie Prasad
Matrikelnummer: 
Betreuer: Prof. Dr.-Ing. Frank Petzold
Betreuer: Prof. Dr.-Ing. André Borrmann
Betreuer: Cornelius Preidel, M.Sc.
Ausgabedatum: 15. November 2015
Abgabedatum: 04. April 2016
In cooperation with Drees & Sommer AG Munich, a Project Management Company.

Supervisors and guides for the thesis project at Drees & Sommer are (in alphabetical order of surnames):

Markus Krupitz, Project Partner

Simon Rogalski, Project Partner

Stefan Schweitzer, Senior Project Partner, Geschäftsführer.
“BIM is here to stay.”
—Steve Jones, McGraw-Hill
Acknowledgement

I would like to express my sincere gratitude to my advisor Prof. Dr. André Borrmann for the expert advice and Herr Cornelius Preidel for continuous guidance and support of my master thesis and related research. Their counsel and immense knowledge steered me in the right the direction at all times of research and writing of this thesis.

I am much grateful to my guides at Drees & Sommer, Herr Markus Krupitz, Herr Simon Rogalski, and Herr Stefan Schweitzer for all the encouragement and support they provided me during the thesis. Their expert knowledge in projects, and work culture, inspired me to make the most of my time during the research. Without their help and effort to connect me to the interviewees and continuous support during the interviews, it would have not been possible to conduct this research. I thank them heartily for all the favors.

I would like to deeply thank the participants for the thesis research interviews, Herr Udo Keller (ZWP Ingeniure), Herr Gerd Jülich (Climaplan), Herr Franz Madl (Pbb Planung + Projektsteuerung), Herr Niklas Brandman (Wolff + Müller) and Herr Peter Liebsch (Drees & Sommer) for their valuable time and sharing of expert knowledge/ professional experience during the interviews. It was an enlightening experience for me to interact with industry experts and helped me tremendously with my research.

I would take this opportunity to thank my family, my parents (Ravindra Nath Pasad and Saroj Prasad) and both my sisters (Rashmi Prasad and Rajni Prasad) and their families, for their never ending support, kindness, love and confidence in me which motivated me to do better each day. I thank them for believing in me more than I did myself. They are a constant source of encouragement to me throughout my years of studies. I am also thankful to my best friend Saurav Singh, for accepting all my requests, listening to me, and always being there for me, which helped me recover from stressful days and continue working for the thesis project.

For each and every helping hand, I am thankful as these accomplishment would not have been possible without them. Thank you.

Raginie Prasad.
Abstract
The management of information flow throughout a construction project is crucial due to its magnitude and complex nature. Building Information Modeling (BIM) is a new approach to planning and construction using digital technology, which also makes an impact on the organizational structure of the teams and work processes involved. The implementation of BIM-based processes logically influences the role of the project manager within the organization. It generates additional tasks, such as managing multi-dimensional data and collaborating with participating companies to ensure the smooth flow of information. In this thesis, the current stage of BIM implementation in construction projects in Germany is investigated through personal interviews and case studies. The major drawbacks, level of implementation, and the level of control over digital data have been uncovered. The emphasis of this research is to define the information exchange process for specific tasks or phases during a project and on formulating process flow-diagrams which illustrate the information exchange requirement within the involved firms at that particular stage. This streamlines the data exchange processes and tasks through reducing probable errors in data exchange. Where large projects are concerned, there are numerous advantages to the client and all participating companies when BIM-based construction methods are implemented. Through the research, the best practices and major obstacles of a pilot project is studied and how it affects roles, responsibilities and process in the management of a construction project.
### Abbreviations

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>BIM</td>
<td>Building Information Modelling</td>
</tr>
<tr>
<td>AEC</td>
<td>Architecture Engineering and Construction</td>
</tr>
<tr>
<td>IPD</td>
<td>Integrated Product Development</td>
</tr>
<tr>
<td>NIST</td>
<td>National Institute of Standards and Technology</td>
</tr>
<tr>
<td>IFC</td>
<td>Industry Foundation Classes</td>
</tr>
<tr>
<td>IAI</td>
<td>International Alliance for Interoperability</td>
</tr>
<tr>
<td>IFD</td>
<td>International Framework for Dictionaries</td>
</tr>
<tr>
<td>COBie</td>
<td>Construction Operations Building Information Exchange</td>
</tr>
<tr>
<td>BCF</td>
<td>BIM Collaboration Format</td>
</tr>
<tr>
<td>OGC</td>
<td>Open Geospatial Consortium</td>
</tr>
<tr>
<td>IDM</td>
<td>Information Delivery Manual</td>
</tr>
<tr>
<td>MVD</td>
<td>Model View Definition</td>
</tr>
<tr>
<td>NBIMS</td>
<td>National BIM Standards Project Committee</td>
</tr>
<tr>
<td>NIBS</td>
<td>National Institute for Building Sciences</td>
</tr>
<tr>
<td>FIC</td>
<td>Facility Information Council</td>
</tr>
<tr>
<td>PIM</td>
<td>Project Information Model</td>
</tr>
<tr>
<td>LOD</td>
<td>Level of Detail</td>
</tr>
<tr>
<td>MEP</td>
<td>Mechanical Electrical and Plumbing System</td>
</tr>
<tr>
<td>ROI</td>
<td>Return on Investment</td>
</tr>
<tr>
<td>HOAI</td>
<td>Honorarordnung für Architekten und Ingenieure (German) - Schedule of services and fees for architects and engineers in Germany</td>
</tr>
<tr>
<td>VOB</td>
<td>Vergabe- und Vertragsordnung für Bauleistungen (German) - Construction Tendering and Contract Regulations in Germany</td>
</tr>
<tr>
<td>OEM</td>
<td>Original Equipment Manufacturer</td>
</tr>
<tr>
<td>FM</td>
<td>Facility Management</td>
</tr>
<tr>
<td>PIM</td>
<td>Project Information Model</td>
</tr>
<tr>
<td>AIM</td>
<td>Asset Information Model</td>
</tr>
<tr>
<td>------</td>
<td>-------------------------</td>
</tr>
<tr>
<td>SME</td>
<td>Small Medium Enterprises</td>
</tr>
<tr>
<td>OOM</td>
<td>Object Oriented Modelling</td>
</tr>
</tbody>
</table>
# Table of Contents

Acknowledgement ................................................................................................................. 2  
Abstract .................................................................................................................................... 3  
Abbreviations ............................................................................................................................. 4  

1 **Introduction** ......................................................................................................................... 9  
   1.1 Aim of the Project and Survey .......................................................................................... 10  
   1.2 Research Question and Objectives .................................................................................. 10  
   1.3 Methods of Investigation ................................................................................................. 11  
      1.3.1 Literature study ........................................................................................................... 11  
      1.3.2 Qualitative survey ....................................................................................................... 12  
      1.3.3 Structured observation ............................................................................................... 12  
   1.4 Structure of the Thesis ...................................................................................................... 14  

2 **BIM – Building Information Modelling** ............................................................................. 16  
   2.1 BIM Introduction .............................................................................................................. 19  
      2.1.1 Open vs. Closed BIM; Big vs. Small BIM .................................................................. 19  
      2.1.2 Interoperability .......................................................................................................... 20  
      2.1.3 Information delivery Manual (IDM) and Model view definition (MVD) .................. 20  
      2.1.4 BIM-model content definition process ....................................................................... 25  
      2.1.5 Level of detail ............................................................................................................. 27  
   2.2 BIM Guidelines and Standards ......................................................................................... 29  
      2.2.1 BIM in the USA .......................................................................................................... 31  
      2.2.2 BIM in the United Kingdom ....................................................................................... 33  
      2.2.3 BIM in Germany ......................................................................................................... 37  
      2.2.4 BIM in the European Union ....................................................................................... 38  
      2.2.5 Standards in Germany and other countries ............................................................... 39  

3 **Qualitative Survey and Inferences** .................................................................................... 41  
   3.1 Questionnaire .................................................................................................................... 41  
   3.2 Survey Background .......................................................................................................... 41  
   3.3 Analysis of Results .......................................................................................................... 42  
      3.3.1 Status of BIM implementation .................................................................................. 42
3.3.2 Advantages of BIM-based methods ........................................................... 42
3.3.3 Hindrances in BIM implementation ........................................................... 43
3.3.4 Software and tools ................................................................................... 43
3.3.5 Legal regulation and norms .................................................................... 44
3.3.6 The role of (BIM) Project Managers ......................................................... 44
3.3.7 Acceptance of BIM in AEC industry ........................................................ 45
3.3.8 Future prospects ....................................................................................... 45
3.3.9 Special Concerns ....................................................................................... 45

4 Data exchange requirements and Process-flow ............................................ 47

4.1 Defining Exchange requirements .................................................................. 47
4.2 Study of Management Processes at different stages in Construction .............. 49
  4.2.1 Case 1: Tendering and Contracting ............................................................ 51
  4.2.2 Case 2: Supplement management (change of order) ................................ 54
  4.2.3 Case 3: Billing for work executed on site by contractors ............................ 56
  4.2.4 Case 4: Site monitoring and Report ........................................................... 58

5 BIM-Based Project Management .................................................................... 60

5.1 The optimized process with BIM Implementation .......................................... 60
5.2 BIM–based Construction Process Map .......................................................... 60
  5.2.1 Case 1: Site Monitoring with BIM-based method ...................................... 61
  5.2.2 Case 2: Clash detection ........................................................................... 64
5.3 Development of Project Manager’s Role and the team ..................................... 69
  5.3.1 New tasks for Managers (BIM-Based Project) ........................................... 69
  5.3.2 Project Documentation ............................................................................ 76
  5.3.3 Schedule planning ................................................................................... 77
  5.3.4 Planning Strategies .................................................................................. 78

6 Best Practices and Future prospect for Project Manager ............................... 79

6.1 Roche Project – Basel .................................................................................... 79
  6.1.1 Project Introduction .................................................................................. 79
  6.1.2 BIM based project: Tasks and Processes ................................................ 80
  6.1.3 Management of BIM-based Project: Roles, Responsibilities and Team
        Structure ........................................................................................................ 81
<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>6.1.4 Advantages of BIM-Method</td>
<td>82</td>
</tr>
<tr>
<td>6.1.5 Obstacles faced in implementation of BIM: People, Processes and Software</td>
<td>82</td>
</tr>
<tr>
<td>6.1.6 Return on Investment</td>
<td>83</td>
</tr>
<tr>
<td>6.1.7 BIM in Future concerning German Market</td>
<td>84</td>
</tr>
<tr>
<td>6.2 Future Prospects for the project manager</td>
<td>84</td>
</tr>
<tr>
<td>7 Conclusion and outlook</td>
<td>85</td>
</tr>
<tr>
<td>7.1 Inferences</td>
<td>85</td>
</tr>
<tr>
<td>7.2 Future Outlook</td>
<td>86</td>
</tr>
<tr>
<td>Index A – Interview Questionnaire for Chapter 3</td>
<td>87</td>
</tr>
<tr>
<td>Index B – Detailed Analysis of Interviews</td>
<td>89</td>
</tr>
<tr>
<td>Index C – Questionnaire used for Interview Chapter 6</td>
<td>90</td>
</tr>
<tr>
<td>Index D</td>
<td>91</td>
</tr>
<tr>
<td>D.1 List of Figures</td>
<td>91</td>
</tr>
<tr>
<td>D.2 List of Tables</td>
<td>92</td>
</tr>
<tr>
<td>Index E: Compact Disc</td>
<td>94</td>
</tr>
<tr>
<td>Bibliography</td>
<td>95</td>
</tr>
</tbody>
</table>
1 Introduction

In the construction industry, the process through which information is managed, presented and interpreted requires a high level of technical knowledge and expertise. Furthermore, it is critical to consider the various interdisciplinary stakeholders involved in the project (Kassem, Brogden, & Dawood, 2012)

Due to the complexity and the amount of data generated for every construction project, it is essential to follow a standard process to use, share and control the information for preventing data loss, breach or misinterpretation. Building information modelling (BIM) has been quite a buzzword in recent years. It refers to the 3D model based process that assists architecture, engineering and construction (AEC) professionals to collaborate and exchange digital data with the help of efficient tools which is transforming the way construction projects are designed, engineered, built, and managed. It is further extended to more dimensions making the model data rich which is explained in chapter 2.

In contrast to the classic method of 2D planning, and fragmented data generation and sharing; high quality data and its easy access is one of the most important characteristic of this model. It must be noted that it is no ‘magic wand’ for the construction of complex structures. It is only a method which guides us in this digital era to create, manage and represent information that aids the construction project from the conception stage until the end of building life-cycle.

Since BIM is an upcoming technical topic in construction industry, a lot of research has been carried out since the past few years. In many countries and projects, this technology has also been implemented and the theory applied to practice. Current research (Bryde, 2013) suggest positive performance and advantages. There are a number of statistical data already generated related to this topic but what still missing is in-depth details of the status of German construction industry and its response to changing technology in the field of building construction (Autodesk). German construction industry seems to be bounded to certain limits in technical evolution there it comes to planning and construction of buildings (Market Monitor - Construction industry - Germany, 2015).

There are certain pioneers in Germany who have already tested the BIM based technology within projects, but the majority of the companies seem to be following the traditional process. (K Kessoudis, 2014), (Germany | Companies | The BIM Hub, 2016). These pioneers have been also known to implement, modify and upgrade the technology to suit their project needs, thus gaining maximum available advantage. These examples are studied along with further research to fulfil the objective of the thesis.
1.1 Aim of the Project and Survey

The focus of the project is to study current practices in a project management company and how the digital construction data is exchanged in a project between different participants of the AEC industry from a project manager’s perspective. Cooperation and collaboration between the project participants from different disciplines is highly beneficial for any project successful completion of the project as they must work very closely within the project. When BIM-based methods are applied to plan and execute the project, there is a demand for all the participants to include new services and tasks and to upgrade work-processes.

As a result, the project involves developing and analyzing data-exchange process diagrams for different phases of the construction. During the research work at Drees und Sommer AG, different project-phases were studied. Through personal interviews and survey, the participants’ exchange requirements were determined. With this knowledge, this thesis suggests project management processes that would be updated with BIM method implementation in future.

1.2 Research Question and Objectives

The scientific questions of this research thesis are:

a. To what extent is BIM currently used for planning in construction companies in Germany?

b. How do the planners and contractors assess implementation BIM-based methods?

c. What are the concerns in the area of data exchange and interoperability?

d. How does a BIM-based construction project affect the role of a project manager?

To answer the above questions, systematic approach to the method of research and its analysis is required. The objectives of the research methods used for the thesis are:

1. To assess different standards which are currently in practice, levels of development in a construction project, and future BIM implementation goals in countries like the USA and the UK, and to compare them to German standards and levels of implementation.

2. To interview participating companies with the support of Drees & Sommer regarding BIM implementation level, acceptance and experience with previous projects, and to analyze and document the results.

3. To develop data exchange process maps for different stages of construction and suggest process maps for use cases according to BIM-based methods derived from the research.
1.3 Methods of Investigation

Among the numerous types of research methods available, such as quantitative methods, literature research, qualitative methods, empirical methods, reviews and research evaluation, the following methods were found the most suitable for the research of this thesis and justified accordingly in the subsections.

The following diagram shows the application of chosen methods during the timeline of this project.

![Diagram showing research timeline and methodology application]

Figure 1.1 The research timeline and methodology application for this master thesis project.

1.3.1 Literature study

The literature study was carried out to find the current status of development of standards and legal regulation in BIM framework in Germany as well as in USA and UK in detail. Ongoing researches around the world, government mandates, development of software and availability of technical prowess in the market is a part of this study. The sources of this study being books, research papers, reports and internet.

Clarity of idea is the most important thing to establish while starting a research project as it lays the foundation of the research. This was attained by thorough literature study. The formulation of main goals, proper understanding of the problem chosen and a sure way to know if the proposed question in this research has already been answered or not is all dependent on the knowledge gained from books, papers and research articles published with similar theme.
1.3.2 Qualitative survey

In-depth interviews carried out with the collaboration of Drees und Sommer has thrown light on the view of key players in construction projects with regards to BIM implementation - from initiation to execution and handover of the project. The participants of the interview come from various background such as architecture, building construction, building services planning, object monitoring and project management. This qualitative survey pertains to large construction projects and the details of the participating companies are in chapter 3. Personal experiences recorded on software used for BIM, subsequent new tasks for the team, and differences in approach to perform and execute tasks, point to specific problems that are encountered and advantages that were derived by implementation of BIM-based construction method.

It is noteworthy as to why this method of in-depth personal interviews was chosen as the research method. Quantitative survey could not fulfill the aims and answer the research question posed in this project. To analyze the level of technical awareness and actual status of implementation of BIM in projects, which vary a lot by nature, qualitative methods are more apt as these methods are well suited for in-depth descriptions of events, behaviors, opinions, knowledge and beliefs. The type of projects, the tasks at-hand to be fulfilled, the team members and the client for each project is different, hence classification of such data into limited number of categories is generally not possible.

The main advantage of the qualitative research is that it is capable in providing complex and in-depth details of the peoples’ responses to a subject matter. (Qualitative Research Methods: A Data Collector’s Field Guide, 2012). Qualitative methods are also effective in identifying intangible factors, which in this project’s context is technical development, software acceptance, workplace regulations, standards, collaborating with other companies and the legal aspect of contracts and scope of work with remunerations.

These factors, as complex are they are themselves, are interacting with each other which makes it unique in every step. It requires rich and personal data collection to analyze the situation. The focus of the qualitative research is on gaining rich and profound understanding of the specific situation in question. The outcomes of qualitative analysis may be extended to similar situation, or people or work processes, but a research targeted on the precise circumstance yields accurate results.

1.3.3 Structured observation

Structured observation was a part of the thesis while working with Drees & Sommer. It was carried out during discussions with the team over day to day activities and tasks for project manager in various phases of the projects. This led to a first-hand experience on how things work and how collaboration with other companies are formed for successful completion of tasks.
This method was applied with several ongoing projects mostly focusing large construction of office and factory premises. Current practices and methods regarding construction project management and project controlling during different stages of a project were observed and discussed within the team. Although each project is different and needs personalization in scope of work and performance measures due to the client and project requirements, there is a set procedure which is guided by HOAI\(^1\) and VOB\(^2\) for carrying out the tasks for each work phase (Leistungsphase\(^3\)) of the project as it indicates the payment structure for each phases.

![Figure 1.2 Structured observation research and its deduction](image)

Structured observation has several benefits as a research methodology. Firstly, data obtained from observational techniques are direct and primary, especially with regard to processes and behaviors. With this technique, biases are reduced or eliminated. Thus data collected from observations are more objective and accurate. Secondly, observations collect rich data. By following a standard protocol for data collection, through the observations of the events, we are able to record the beginning, the progress, and the consequences of these events. It can also enable analysis of various attributes of information, for example, the parties involved, the information exchange process and pattern, and their correlation with the tasks at hand. Furthermore, this method of research

---

1. Honorarordnung für Architekten und Ingenieure (German) - Schedule of services and fees for architects and engineers in Germany
2. Vergabe- und Vertragsordnung für Bauleistungen (German) - Construction Tendering and Contract Regulations in Germany
3. Leistungsphase (German) Substantiv, feminin : Service phase
allows collection of objective and authentic data. With carefully designed observation, rich data are expected to be collected (Xu & Luo, 2014).

1.4 Structure of the Thesis

The structure of the project is as follows:

![Chapter sequence and contents of the thesis]

**Chapter 2** pertains to the literature study and its analysis. It throws light on standards of information management and delivery during construction projects. A brief overview of technical BIM terms such as data exchange, interoperability, information delivery manual, exchange requirements etc. are in this chapter. The standards from the USA and the UK are studied in depth, and subsequently compared to the current status of BIM-implementation and development of standards in Germany. Thus, the resulting analysis shows where Germany stands currently and where is it lagging behind.

**Chapter 3** outlines the survey questionnaire used for the qualitative analysis in the thesis. The survey was executed through personal interviews with planning and construction
companies based primarily in Germany and working for countrywide construction projects. The survey background and the analysis of research data is presented in this chapter underlining the major topics such as acceptance of BIM in Germany, major obstacles faced in the implementation of BIM, and the government policies regarding the same. This survey was executed in German and translated into English.

**Chapter 4** contains information pertaining to data exchange during a construction process. Specific phases of the currently ongoing projects were studied. Out of these, four specific cases have been chosen to be represented, which repeat in all of the projects. They are the standard processes to handle construction projects at various stages. Detail process maps have been developed for these cases where data exchange between the participants at this specific time and sequence is shown. These are based on classic project management processes as studied in the structure observation part of the research.

Further in **Chapter 5**, with the study of BIM-based construction management processes, and on the basis of qualitative survey through personal interviews, data exchange process maps have been optimized for BIM-based processes. It is generated with the suggestion on how similar companies in German construction market could work in different phases to fulfil the mentioned tasks when BIM is implemented. The chapter also details out the changing role of the project manager as additional BIM-based tasks are required to be taken care of. There is a need to apply new strategies to execute new tasks in a BIM based project. Changing roles, team structure and additional responsibilities for the project manager is discussed in this chapter.

**Chapter 6** outlines the best practices used in the management of the construction project by Drees & Sommer at Basel for the client Roche. It is one of the best known projects in Europe which is executed by applying BIM principles. Detailed interview with the participant of this project throws light on many facets of this project. It further extends to future prospects for the project manager and implementation of BIM-based methods to projects.

**Chapter 7** concludes the thesis with summarizing the main inferences of the thesis, such as concerns about the construction regulations in Germany, progression of new technology and methods, most important developments and upgradation that need to be carried out in a project management firm with BIM method implementation and the future outlook of the construction industry towards BIM.
2 BIM − Building Information Modelling

Building information modelling (BIM) is a concept based on a collaborative 3D model which can be used from the start to end of a construction project and building life cycle. Traditional building design focuses on mainly 2D drawing and details. BIM extends to 3D and beyond (with cost and time parameters) covering a wide range of information such as, but not limited to geographical information, building geometry in 3 dimensions, material and attributes of building objects, energy analysis, structural details, and cost of building parts. Therefore, it provides extensive geometrical as well as semantic information in the form of detailed instructions to aid the construction process. BIM focuses on standardizing the work processes as well as the software and model objects used for a project.

Participants of a construction project can work together with an open BIM model, which is essentially an integration of architectural, services, static, energy models. Easy exchange of data is possible with more clarity to the project. BIM-based method has several digital tools for clash detection and quantity take-offs (explained further in chapter 4 and 5) which makes this process faster and more efficient than the traditional construction process.

The diagram below throws light on the life cycle of the BIM project:

![Figure 2.1 The life cycle of BIM based construction project. Source (JTB World, 2010)](image)

According to buildingSmart, an organization focusing on research and development of BIM standards worldwide, standardized BIM process benefit all the stakeholders involved in the project. Owners, architects and facility managers are benefited as the traditional process of generating the data all over again is eliminated with BIM, saving much time and effort. Software market is expanding as BIM is based on digital technology. The
contractors, manufacturers, authorities, maintainers and operators are benefited as the processes are streamlined through BIM implementation (buildingSmart, 2014). BuildingSmart works extensively for standardizing formats in open BIM for interoperability (detailed explanation in section 2.1).

BIM has great potential to transform the process of design and construction. It has already been tried and tested in various projects all over the world. Since the advantages are clear and abundant, many countries are trying to adopt it soon in public projects. BIM has been already implemented in different levels since the last ten years in chosen projects in America, Singapore, England and Norway and few other countries (Emmanuel Di Giacomo, Autodesk Inc., 2015). There are also numerous hurdles in implementing this method in projects. One of them is controlling and sharing massive amount of digital data.

There have been successful noted pilot projects and with the state government regulation to make BIM mandatory in above countries, there is a wave of change expected in the construction industry in the following years (Borrmann, 2015). In Germany the development of standards by DIN and VDI have just started and a beneficial introduction to German market for public projects can be expected to follow in future.

Research organizations around the globe are in the process to standardize the technical terms and quality of data pertaining to BIM. According to PAS 1192-2 by The British Standards Institution (2013), Figure 2.2 shows the maturity level of BIM.

<table>
<thead>
<tr>
<th>Level 0</th>
<th>Level 1</th>
<th>Level 2</th>
<th>Level 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>CAD</td>
<td>Proprietary formats</td>
<td>Proprietary formats COBie</td>
<td>ISO-Format</td>
</tr>
<tr>
<td>Drawings</td>
<td>Geometric models</td>
<td>Discipline-specific BIM models</td>
<td>Integrated, interoperable building models for the entire life cycle</td>
</tr>
<tr>
<td>Paper</td>
<td>Exchange of individual data</td>
<td>Centrally managed files, common library objects</td>
<td>Cloud-based model management</td>
</tr>
</tbody>
</table>

**Figure 2.2** The four levels of Maturity as defined by the British Standards Institution in 2013. Based on diagram by Borrmann, A., König, M., Koch, C., & Beetz, J. (2015). Copyright holders are Mark Bew and Mervyn Richards (2008)
Level 0 denotes very basic CAD drawings primarily in 2D for complete design and working drawing for a building. The data is used and shared in the form of 2D prints and digital copy. It is also documented for building lifecycle as hardcopies.

Level 1 includes basic 3D models along with comprehensive 2D drawings. The exchange of data is in individual formal and not collaborative, also the 3D may be only for visualization purposes hence not in object-oriented modelling format with detailed information and attributes of building parts.

Level 2 indicates development in the direction of BIM principles and detailed 3D object oriented modelling with attributes for every building part with additional information. This model is made by several different disciplines of participants of a project such as architects, energy consultants, building services planners, fire protection consultants etc., therefore following proprietary format or COBie (Construction Operation Building Information exchange).

Level 3 is the ideal BIM where a single integrated interoperable model is used for the entire lifecycle of the project. The exchanged format is within the scope of an international standard and he exchange and sharing of data is executed in a cloud-based platform. The details pertain to information contained in the model in form of digital data, attributes, additional original equipment manufacturer (OEM) information or properties of objects associated with the model.

The need for coordinated information flow within construction projects of larger volume is evident. The benefits of improved communication and documented information have already made its case. The implementation of BIM-based methods also requires changes in the form of collaboration and contractual regulations between the stakeholders.

These expectations are materialized in the idea of Integrated Product Development (IPD), big room, project partnering and project alliancing (Miettinen, 2014). The BIM handbook (Eastman C. E., 2011) suggests that “The benefits of integrated practice receiving wide review and extensive experience using IDP on specific projects has been accumulated. Leading AEC firms increasingly recognize that future building process will require integrated practice of whole construction team and will be facilitated by BIM.”

Singapore has a big presence in construction market related to BIM. The level of implementation is high and is back up by the government on public projects ( Performer, 2015). There are a number of successful BIM based project executed in the previous years in Singapore hence a study of companies from this country is highly relevant to indicate what BIM principles can achieve in future for Germany too. Singapore’s BCA Academy has launched world’s first BIM e-submission system and has been lauded as one of the major catalyst for transforming the way construction industry in Singapore thinks and works. McGraw hills smart market report (McGraw Hill, 2014) shows more than 80% efficiency in major aspects of building construction and design such as resolved conflicts, improved productivity, reduced rework and wastage and improved visualization and presentation.
2.1 BIM Introduction

2.1.1 Open vs. Closed BIM; Big vs. Small BIM

With varying levels of implementation of BIM within the participants of the AEC industry, it is important to differentiate between the types of BIM in use currently.

Little BIM means that the use of tools is limited to one company and one discipline and there is no BIM data exchange with other disciplines. Whereas big BIM signifies cooperation of all participants involved in planning and execution of the building. They may use different tools within their company to work on a common BIM data model.

Closed BIM is referred to the close software environment used for BIM purpose (for example, a single platform used for all BIM requirements) whereas the open BIM means open model based data exchange within different software and disciplines using IFC or similar exchange format (Holger Kreienbrink, 2013). For example, buildingSmart provides open BIM data formats with the aim of improving interoperability in BIM throughout the construction industry worldwide. BuildingSmart’s mission is to standardize the exchange formats and develop a strategy to implement open and big BIM where different discipline participants for a project can work together simultaneously at the BIM data model irrespective of the software tools used by each of them. (buildingSmart, 2014)

The following diagram shows the relation between the above mentioned categories of BIM.

---

Figure 2.3 Development path of BIM; from little and closed to open and big (iBIM). Based on the diagram by (Borrmann, 2015)
2.1.2 Interoperability

During the planning and construction phase, files and models need to be shared and used between the participants of a company. The BIM tools used for these process must be interoperable. The capability of software packages to be interoperable implies that it can be faster and prevents loss of data while converting file types through not having to regenerate new building geometry for each tool that is used to carry out the analysis and collaboration between stakeholders (Lee, 2015). The importance of this interoperability of file formats and models across all the teams involved within a BIM project is a pressing concern within BIM which is continually being intensely developed. Interoperability is a key component in the future success of BIM projects and needs to be carefully considered at every step (Danny McGough, 2013).

Furthermore, National Institute of Standards and Technology (NIST) has estimated that at least $15.8 Billion per year is lost due to lack of interoperability during the building supply chain (GCR, 2004). This loss comes from:

- Continued paper-based business practices.
- Lack of standardization.
- Inconsistent technology adoption among stakeholders.
- Redundant paper-based records management across all facility life-cycle phases.

The Industry Foundation Classes (IFC) is the BIM related specification with considerable number of implementations. The IFC specification, developed by International Alliance for Interoperability (IAI), now known as buildingSmart, started from the vision that the STEP methodology based integrated product model would cover all vital information about the building in its life cycle (Pazlar, 2008). Although after years of development and several IFC specification releases, the exchange and sharing of building and construction lifecycle information has not been completely defined and standardized.

IFC is a neutral open file format which does not belong to any vendor. It uses a plain text file which represents architectural and construction data in a universal computer data format. IFC standards facilitate interoperability of data through various software, by “importing and exporting” IFC data file from one format to another. Most latest updates of the software products for BIM supports IFC exchange format (Borrmann, 2015).

The success of BIM implementation depends on use of open data exchange standards and interoperability. As a result, open data standards have been mandated for several public sector and some private sector building design and construction projects (Trivedi, Gaurang, 2015).

2.1.3 Information delivery Manual (IDM) and Model view definition (MVD)

The methodology developed by buildingSmart to capture and specify processes and information flow during the lifecycle of a project is known as Information Delivery Manual (IDM) methodology and the product of this method is IDM, which is also now an ISO standard (29481). It is a document which contains different kinds of information which is
2 BIM – Building Information Modelling

to be communicated between which parties and at what phase, which is known as “Exchange Requirements” (ER). The main purpose of the IDM is to make sure that specific data are communicated in such a way that it can be interpreted by the software on the receiving side. This document is supplemented continuously with additional detailed specification of information exchange processes. (Jan Karlshøj, BuildingSmart, 2011)

IDM forms the basis of Model View Definition (MVD). According to buildingSmart, the MVD defines a subset of the IFC schema, that is required to satisfy one or many Exchange Requirements defined in the IDM. MVDs are created by the software developers by interpreting the IDM. Therefore, the MVD corresponds to the IFC data model created on the basis of the Exchange Requirements listed in the Information delivery Manual.

The IDM includes generating a Workgroup, developing a Process Map, defining the set of use case exchanges being addressed by the Workgroup, describing the Activities involved and most importantly, the Exchange Requirements (Eastman C. E., 2011). It captures the user needs and specification of the exchanges in a form that can be interpreted into technical exchange specifications, called a Model View Definition (MVD), which is the next stage of this effort. The completed IDM document set is contractually agreed upon in BIM execution plan.

A company executing BIM based projects, can use these standards and IDM as a guide to form their own process maps within the tasks at hand as according to NBIMS the Standards are appropriately mature for use by industry.

According to buildingSmart’s workshop in Copenhagen, IDM and MVD development as carried out in Norway is depicted in the following diagram:
After the scope of IDM is defined by the work group, the creation of use case, process maps, and detailed exchange requirement document follows. These three steps shown above creates data that is required to develop the MVD. In the fourth step, the vast amount of data is handed over to the tech group which then captures this knowledge for software implementation.

According to buildingSMART for the development of IDM, the focus of the process should be to (IDMC, 2011):

1. Follow the methodology of IDM.
2. Communicate and coordinate with IDM developing teams.
3. Review the IDM carefully before finalization.
4. Follow standard approval process for the official recognition of the IDM.
5. Ensure if the IDM should and needs to be supported by using IFC extension.

As the concerns of IDM development are taken care of, the focus will be on MVD development. The main objectives of MVD is to produce IFC data model corresponding to exchange requirements as defined in the IDM. It is important to follow IDM process and
formats in order to provide meaningful software implementation. To achieve this, the data may be refined or merged.

According to GSA and Statsbygg, a sample Information delivery manual table could look like the following:

Table 2-1 the sample chart for Information delivery manual as suggested by BIM guidelines and Standards Manual - GSA and (Statsbygg, 2013) (Norway)

<table>
<thead>
<tr>
<th>Project / Building Information</th>
<th>Type of Information</th>
<th>Information Needed</th>
<th>Descriptions and Comments</th>
<th>Required</th>
<th>Optional</th>
<th>Data Type</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Project</td>
<td>Project ID</td>
<td>Unique identifier for the project</td>
<td>X</td>
<td>string</td>
<td>n/a</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Project Name</td>
<td>Name assigned to the project by the client or designers</td>
<td>X</td>
<td>string</td>
<td>n/a</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Building</td>
<td>Building ID</td>
<td>Unique identifier for the building</td>
<td>X</td>
<td>string</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Building name</td>
<td>Name assigned to the building by the client or designers</td>
<td>X</td>
<td>string</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Geographical location</td>
<td>Geographic location, expressed in degrees, minutes, and seconds longitude and latitude.</td>
<td>X</td>
<td>latitude, longitude</td>
<td>degree, minutes, seconds of rotation</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Elevation</td>
<td>Base (datum) elevation for the building -- relative to sea level</td>
<td>X</td>
<td>real number</td>
<td>metric or imperial</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Building Story</td>
<td>Building Story ID</td>
<td>Unique identifier for the building story</td>
<td>X</td>
<td>Alpha-numeric</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Building Story Name</td>
<td>Name assigned to the building story by the client or designers</td>
<td>X</td>
<td>string</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Story height</td>
<td>Vertical length measure from top of slab to top of slab for the building story above</td>
<td>X</td>
<td>number</td>
<td>metric or imperial</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Base elevation</td>
<td>Base (datum) elevation for the building story -- relative to building elevation.</td>
<td>X</td>
<td>number</td>
<td>metric or imperial</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Design Gross Area</td>
<td>Area measure for the building story, using measurement rules defined for &quot;Design Gross&quot; in the owner's requirements documentation.</td>
<td>X</td>
<td>number</td>
<td>metric or imperial</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Building parts</td>
<td>Identification</td>
<td></td>
<td>X</td>
<td>string</td>
<td>n/a</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Construction Type</td>
<td></td>
<td>X</td>
<td>string</td>
<td>n/a</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
2 BIM – Building Information Modelling

<table>
<thead>
<tr>
<th>Classification</th>
<th>Values</th>
<th>X</th>
<th>faceted strings</th>
<th>n/a</th>
</tr>
</thead>
<tbody>
<tr>
<td>Placement</td>
<td>Relative to the Building Story</td>
<td>X</td>
<td>real numbers</td>
<td>metric or imperial</td>
</tr>
<tr>
<td>3D Geometry</td>
<td>X</td>
<td>various</td>
<td>metric or imperial</td>
<td></td>
</tr>
<tr>
<td>Material Description</td>
<td>X</td>
<td>string</td>
<td>n/a</td>
<td></td>
</tr>
<tr>
<td>Statistical load capacity</td>
<td>X</td>
<td>string</td>
<td>metric or imperial</td>
<td></td>
</tr>
<tr>
<td>Supplier Information</td>
<td>X</td>
<td>string</td>
<td>n/a</td>
<td></td>
</tr>
</tbody>
</table>

Table 2-1 is a sample of how an IDM chart can be developed. It does not contain the comprehensive list of building elements, but only a few to demonstrate how the requirement for each element is drafted. For example: the generic building element “Wall” should contain an identification according to its type, type of construction, location with respect to the model reference point, 3D geometry details, material, load capacity, supplier information and so on. The attributes can always be extended or modified as required. When objects contain more information, the model is considered to be richer and hence more purposeful.

Other than IFC and IDM/MVD there are a list of other file format and exchange protocols currently in market (Trivedi, Gaurang, 2015):

- buildingSmart Data Dictionary bsDD - Previously known as IFD (international framework for dictionaries), bsDD is a catalog of common industry concepts that construes the disparate terminology due to market, language, professional jargons etc. bsDD is the BIM standard that conveys the meaning of information that is exchanged.
- Construction Operations Building Information Exchange (COBie) - COBie can be viewed in the form of simple standard data spreadsheets for exchange of information that is needed for facility and asset management. It can be used for all types and size of projects.
- BIM Collaboration Format (BCF) - an XML based format that supports workflow communication connected to IFC models.
- Open geospatial consortium (OGC) - the OGC is an international industry consortium for developing standards for geospatial enabled technologies. 519 companies, government agencies and universities participate in the process of setting publicly available interface standards.
- BIMXML - this XML schema represents a simplified subset of BIM data for web services

According to buildingSmart alliance, the formula to achieve open BIM implementation looks like the following diagram:
2.1.4 BIM-model content definition process

The planning of a BIM based project must start early and the processes defined at the preplanning stage (Borrmann, 2015, pp. 130-132). The project participants’ roles and responsibilities need to be defined. Data exchange process and contents in terms of who needs what and when and, in which detail and quality is generally decided at the project start. As identified in chapter 6 later through the survey that this detailed documentation process helps to avoid confusion in the project execution phases. The method suggested by BuildingSmart and Borrmann, 2015 for the definition of IDM and MVD with clear attributes and information exchange processes is as follows:
Figure 2.6 explains step-by-step procedure of creating model views based on specific requirements of exchange within several participants of the project. The first step is to assign roles and responsibilities for each participant. When this is finalized, the second step is to formulate flow charts of processes that often reoccur during the project execution. In the third step, the data required (exchanged) by the participants of the project at each activity in the process map must be defined. The Process Maps is based on Business Process Model and Notation (BPMN) which is a standard graphical representation for business processes and workflows.

From this process maps, the detailed ‘Exchange Requirement’ can be deduced and finalized in the fourth step. Once the detailed exchange requirement is developed, the (IFC) model can be established based on these requirements as the fifth step. Finally, the last step will be to use the Model View Definition as filtered model according to the requirements. The MVD is represented in mvdXML format which is an XML schema in which MVD is available.

An example for the definition of recurring process as stated in Figure 2.6, is a study of quality control based on BIM methods by (Chen & Luo, 2014) shows the process map of this phase of construction.

By analysis of this flow chart, the following has been noted:
1. Digital data is in 4 D, i.e. 3D model is integrated with scheduling software to collaborate time line with model data.
2. BIM model is used to generate design and construction data thus resulting in construction.
3. It follows with comparison of the built structure with product template to determine the quality status.
4. A set template is required for the quality inspection
5. Construction plan and BIM model go together and must be dynamic to schedule adjustment and quality status reporting.
6. The quality checking and adjustment stages go into a loop until the desired quality is met on site with the constructed part of the building.

This is clarified with the workflow generated to fulfil this task on site as in Figure 2.8:

![Figure 2.8 Workflow of BIM-based construction quality model. Based on the model by (Chen & Luo, 2014)](image)

It can be estimated here that heavy data flow between each of the steps of this process is required. It is necessary that the digital data is correct as per design and construction regulations and checked for clash and quality before the construction execution takes place.

Sharing and exchanging the data in each step between the planer, project manager, contractor and sub-contractors need to be carefully handled. Loss of data during exchange or format conversions is to be avoided.

### 2.1.5 Level of detail

It is important to define the minimum level of detail required in the BIM model and the level of definition in non-graphical format. Essentially, all parties involved in planning of
the project must follow these requirements while developing the model. Generally, this specification is agreed upon at the start of the project, and it needs to be included in the work contract. According to PAS 1192-2 2013 (BIM guide for the UK), the level of definition, which is also known as LOD defines what details to expect from the BIM model at each stage depending on the LOD categories which ranges from 100 to 400. Level 100 being the lowest and 400 being the highest level of detailing done in the BIM model (BSI Group, 2013).

The Figure 2.9 gives an idea of what the LOD mean in terms of graphical representation.

![Figure 2.9 Graphical representation of the LOD as defined by AIA. This example shows a steel column and its connection to the underlying component. Source (Borrmann, 2015)](image)

Based on the LOD definition by (BIM Forum, 2015), for example, a model object ‘door’ can be of various grade of level of detail, such as:

1. LOD 100: 2D line drawing the object, location with reference to drawing
2. LOD 200: 3D object, showing the type of door (approx. size, shape, location)
3. LOD 300: design specific model object, with material, specific size, shape, location
4. LOD 350: actual door model with manufacturers details, parts details, specific size/shape/location
5. LOD 400: as 350, plus special mounting details, object properties and strength
6. LOD 500: additional information such as supplier, date of purchase, date of delivery etc. may be included in the model object

Non-geometrical information must be included in the BIM model object depending on the level of detail specified as per the requirement. Referring to the details associated with the description of LOD, the BIM forum describes which kind of information an object can contain. The recurring processes defined in Figure 2.7 and Figure 2.8 also depend on LOD as each party must comply to the current LOD defined in the Exchange Requirement and hence the BIM execution plan. All data exchange processes, therefore, must be follow the standard LOD framework.

The additional attributes (non-geometrical information) such as manufacturer’s details, logistic details, part warranty details, mounting and installation, detailed material and
finish, cost, service and replacement details, material properties, load and deflection point, and so can be added to the objects in the BIM model to make the BIM model richer.

2.2 BIM Guidelines and Standards

According to the BIM guide (Eastman C. E., 2011), the purpose of a BIM standard is to select and specify the appropriate information entities from a schema for particular use cases (or data exchange scenarios). The selected entities that comprise a model view definition are a subset of all those in the schema. The BIM standards is regularly updated and supplemented with additional guidelines and currently they also include recommended technical implementation, updated processes, terms and specifications.

It has been quite a few years since BIM-method has been in practice in USA, Singapore, Hong Kong and a few European countries. To find out the global level of implementation, a number of surveys have been carried out. Autodesk has done numerous market research for finding out the current level of implementation in many countries. The list below gives a clearer outlook.

Table 2-2 the current level of BIM Implementation around the world. Based on the report by Emmanuel Di Giacomo from Autodesk at European BIM Summit at Barcelona (Emmanuel Di Giacomo, Autodesk Inc., 2015)

<table>
<thead>
<tr>
<th>BIM Standards and Mandates: Directives</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>The UK</strong></td>
</tr>
<tr>
<td><strong>France</strong></td>
</tr>
<tr>
<td><strong>Norway</strong></td>
</tr>
<tr>
<td><strong>Denmark</strong></td>
</tr>
<tr>
<td><strong>Finland</strong></td>
</tr>
<tr>
<td><strong>Netherlands</strong></td>
</tr>
<tr>
<td><strong>Hong Kong</strong></td>
</tr>
</tbody>
</table>
South Korea

The Public Procurement Service made BIM compulsory for all projects over SS$50 million and for all public sector projects by 2016.

This table gives an overview of the current developments in the listed countries and the future plans for standardizing and implementation of BIM methods in construction projects in the upcoming years.

National and international institutions from the countries such as the UK, Norway and the USA have already published BIM Standard Guidelines and are using it purposefully in public projects. These are proactive countries who are interested in discovering the potential of BIM in future projects. The following table generated by Autodesk which is based on McGraw Hill Construction SmartMarket Report (McGraw Hill, 2014) throws some light on it.


<table>
<thead>
<tr>
<th>Country</th>
<th>Organization</th>
<th>Guideline/Handbook</th>
<th>Background/Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Australia</td>
<td>Australasian Procurement and Construction Council</td>
<td>National BIM Guide</td>
<td>BIM Fluency for the construction industry believed to be crucial to maintain competitive advantage.</td>
</tr>
<tr>
<td>China</td>
<td>Ministry of Science and Technology</td>
<td>National BIM Standard (by 2016)</td>
<td>National adoption may be driven by infrastructure rather than buildings, through smart city management and mass transit projects. Carbon reductions are a near-term priority.</td>
</tr>
<tr>
<td>France</td>
<td>Ministry of Ecology, Sustainable Development &amp; Energy and Ministry</td>
<td>BIM Road map in draft form by end of 2014</td>
<td></td>
</tr>
<tr>
<td>Germany</td>
<td>Federal Office for Building and Regional</td>
<td>Planning BIM Guide for Germany</td>
<td>Guide intended to provide structure for future BIM National Mandate</td>
</tr>
<tr>
<td>Country</td>
<td>Agency/Authority</td>
<td>Information</td>
<td>Notes</td>
</tr>
<tr>
<td>--------------</td>
<td>------------------------------------------------------</td>
<td>------------------------------------</td>
<td>----------------------------------------------------------------------</td>
</tr>
<tr>
<td>Hong Kong</td>
<td>Hong Kong Housing Authority BIM</td>
<td>Standards, user guides, and library components for contractors</td>
<td>Use BIM for the Design Stage by 2015</td>
</tr>
<tr>
<td>Japan</td>
<td>Ministry of Land, Infrastructure, Transport and Tourism 2013</td>
<td>Guidelines for architecture BIM Models</td>
<td>In addition to the 2013 guidelines, The Japan Institute of Architects put forth BIM guidelines in 2012</td>
</tr>
<tr>
<td>Malaysia</td>
<td>Public Works Department</td>
<td>BIM Guideline Standard (2016)</td>
<td>Concern of readiness of industry to adopt BIM, industry groups have recommended government provide training &amp; Tax breaks.</td>
</tr>
</tbody>
</table>

### 2.2.1 BIM in the USA

BIM defined by National Institute for Building Sciences (NIBS) is an improved planning, design, construction, operation, and maintenance process using a standardized machine-readable information model for each facility, new or old, which contains all appropriate information created or gathered about that facility in a format useable by all throughout its lifecycle (NIBS, 2007).

National BIM Standards (NBIMS) Project Committee is a committee of the NIBS Facility Information Council (FIC). The FIC’s mission since 1992 is to improve the performance of facilities over their full life-cycle by fostering a common, standard and integrated life-cycle information model for the AEC & Facility Management (FM) industry. This information model will allow for the free flow of graphic and non-graphic information among all parties to the process of creating and sustaining the built environment, and will work to coordinate U.S. efforts with related activities taking place internationally (NIBS, 2016).

The NIBM classifies the term BIM in three categories:

- A product
- An IT based standardized collaborative process
As a basis for the life cycle of the building facility management

According to NBIMS, BIM represents information management in a project, where data is contributed and shared by all project participants. It means to deliver the right information to the right person at the right time. For project participants, it is a source to facilitate all the teams to work together for project delivery.

In 2005, the NBIMS prepared the charter with the following guidelines:

1. Full original copyright protection to individual contributions.
2. Work of the Committee is share freely among the members of the team, also copyrighted by NIBS not for its gain but for protection of team’s intellectual property.
3. Nomenclature specific to north American business practice is used in National BIM standard
4. Other countries can convert to their own units and use the same
5. Future plan is to map is to the other countries to attain international interoperability.

Implementation of National BIM standard is said to achieve specific benefits to all parties such as:

Owner:

- Collective information on the planning and operation of a facility
- Requirements to achieve the goals and actual performance expected.
- Occupant’s details and security of use of the facility, throughout the life.

Individual stakeholders/suppliers:

- Efficient e-commerce, transparent and consistent business.
- Seamless digital exchange of required information during the project execution without the risk of misinterpretation or loss of data.

Other participants:

- Performance visualization in 3D, 4D and easy to understand visual format.
- Discovering problems and conflicts while in conceptual stage itself.
- Prediction of lifetime utility consumption of all design options and better decision making platform.
- Limit wastage of resource of all kinds by building the project virtually before committing to the construction.

Scope of NBIMS

The standard encompasses business processes in all phases of a facility. It is estimated that ca. 250 – 300 transactions will describe 95% of all the possible transactions with the most important ones such as capturing early design information, exchange of data during each...
phases and automated code checking along with adopting newer standards in pre-cast concrete and steel structure design. For the NIBM, BIM means to provide a detailed digital model containing all information for the planned or existing building in question. This information is valid and applicable to the entire life cycle of the building, starting right with the conception phase and should be at the disposal of all the concerned parties.

The final deliverables by NBIM standards is a document containing sections such as:

1. Name, creator, and project stages for which the requirement is used.
2. A BPMN diagram for the process.
3. The aims and content of the requirement. Identification of other standards and inferences used for NIBM standard.
4. A technical description of the scope of work and deliverables for incorporating exchange requirement between the teams and the description of the expected results of this exchange requirement.
5. Instructions and change management materials of implementing the standard.
6. The scope of maturity of the standards and future plans for additional development.

The NIBS has detailed out the following hierarchy for the scope of the NBIM Standard development and implementation in future projects:

![The hierarchy of development of Standards for BIM by NIBS. Picture Source: NIBS and buildingSmart alliance (NIBS, 2016)](image)

2.2.2 BIM in the United Kingdom

According to McGraw Hill SmartMarket report, The United Kingdom has very ambitious and forward thinking policy regarding the implementation of BIM-based process. All
centrally funded public projects (buildings and infrastructure) are to deliver level 2 BIM data for the entire project lifecycle by 2016. From the owners’ point of view, they plan to actively increase the share of their projects that involve it, with almost half (38% in UK and 40% in US) saying BIM will be used on more than three quarters of their work within two years, that is, until 2016 (McGraw Hill, 2014).

BIM fluency is viewed as an essential skill set for the future development of the industry. Current goals of this mandate is to:

- Cut lifecycle costs and carbon consumption by 20%
- Transform itself into an efficient, integrated and collaborative industry and services that are in demand worldwide.

The BIM task Group is supporting the Governmental Construction Strategy and helping them to deliver the objectives to strengthen the public sector’s capability in BIM implementation. The task group constitutes of experts from industry, government, institutes and academia.

Publically Available Standards (PAS)

The Publically Available Standards (PAS) is one of a number of documents published on the BIM Task Group website (BSI Group, 2013) in support of the strategic objectives in level 2 BIM implementation. PAS 1192-2:2013 is written on the existing code of practice PAS 1192:2007 and is the updated version. The main principle behind this document is to standardize the information exchange requirement and processes. It contains detailed guidelines for information delivery at different stages such as procurement, mobilization, and production.

PAS details out the information delivery cycle in a Common Data Environment (CDE) which is single source of information for any given project, used to collect, manage and disseminate all relevant approved project documents for multi-disciplinary teams in a managed process. (BSI Group, 2013). A CDE may generally use an external server or a file based retrieval system such as cloud. Figure 2.11 gives an overview of the information flow in a common data environment. The information delivery and project management cycle shows the generic process of identifying a project need (which may be for design services, for construction or for supply of goods), procuring and awarding a contract, mobilizing a supplier and generating production information and asset information relevant to the need as the management processes. This cycle is followed for every aspect of a project, including the refinement of design information through the seven project stages shown in green. It represent the information delivery process known as the CDE. When all data in a project, BIM or non BIM, are shared using single CDE, confusions and doubts can be avoided in process execution (BSI Group, 2013).

---

4 More information at http://www.bimtaskgroup.org
Level 2 modeling requires a lot of details and specific processes regarding the information control and exchange. PAS1192-2 lays down fundamental principles to achieve level 2 BIM modeling standard. This document is targeted at organizations and individuals from several background such as procurement, design, construction, delivery, operation and maintenance of the building or infrastructure.

The focus of this document specifically on project delivery, where the most of the information (graphical and non-graphical) collected from design and construction activities are known as the project information model (PIM).

Beginning with the assessment or statement of need for existing and new assets respectively, it progresses through the various stages of the information delivery cycle. The requirements within this PAS conclude with the delivery of the as-built asset information model (AIM). This is handed over to the employer/client by the supplier once the PIM has been verified against the actual construction.

**Digital Build Britain: Level 3 BIM implementation**

After the initiation of Level 2 BIM, the task group has already laid out strategy for the implementation of level 3 BIM which is known as the fully functional big and open BIM. In February 2016 this strategy as published by the government of the UK (HM Government, 2015).
2 BIM – Building Information Modelling

It is said that the UK construction industry is a big contributor to the growth of UK as according to the forecast, it is expected to grow over 70% by 2025. It also plays a critical role in meeting the climate change targets for the UK. The government’s strategy has taken a world lead in adoption of level 2 BIM technologies. It has helped to ensure 20% savings on CAPEX\(^5\) as shown by the benchmarking case studies. Due to development of technology market, and high performance computing, complex analysis and automatization, the next step is logically to develop Level 3 strategy which will be known as “Digital Built Britain”

The vision of the Digital Built Britain is to introduce complete new approaches such as:

1. To enable the stakeholders and suppliers, including small medium enterprises (SMEs), to find best suitable lifecycle solutions and offer bid to supply solutions
2. To improve technical solutions and to reduce costs by questioning the existing roles of consultants, contractors and suppliers
3. To develop new business models for infrastructure and asset design, delivery, operation and adaptation, based on wider use of service performance data;
4. To protect the availability of data, with adequate security measures and protocols so that the threats may be deterred, detected, or the consequences of an attack minimized

The implementation phases, which are divided into 4 phases namely 3A, 3B, 3C and 3D are described as follows:

---

\(^5\) Capital Expenditure: Investment focused on the delivery of new assets

2.2.3 BIM in Germany

2.2.3.1 BIM Leitfaden

According to the research report BIM Leitfaden⁶, experience in 3D modelling is quite limited to the BIM users in Germany. The reason being that it is only created for visualization during the preplanning of the projects and design discussions with the client. It is mostly used for a bigger influence during the phase of awarding of contract. (Egger, 2013).

It was the first one of its kind project report that serves as The BIM Guide for Germany is a guide for all those interested in BIM method and provides a first, practical introduction to the subject and the associated requirements. According to BIM Leitfaden, in Germany, BIM is currently used almost exclusively in some private, institutional client projects, however, the public sector has little experience and still does not provide desires for the application of BIM method.

The creation of a complete BIM Handbook containing binding guidelines is hereby encouraged and deemed necessary. For this purpose, a structure is proposed as the BIM Leitfaden so that the BIM policy can be further developed for Germany.

This guideline contains the introduction of BIM-based method within the German Public works department. The main focus is on the analysis of its compatibility with the current legal and regulatory framework of the public works department. The review of the framework is currently ongoing and problems in procurement, potentials, and contract. Necessary solutions and suggestions related to the free structure of architects and engineers with the relation to BIM services are being incorporated. From the perspective of the federal building administration, the focus is on the processes related to planning and building construction and thereby, proceeding towards the formation of new regulations.

The most common problems faced during handling BIM data that need to be targeted are:

- Quality of Data, insufficient or conflicting.
- Most obvious errors in information and design.
- Accidental omission, false representation.
- Lack of proper exchange, data available but not shared.

⁶ (German) Leitfaden: Manual, Handbook, Guide
2.2.3.2 Planen Bauen 4.0

In Germany, the Planen Bauen 4.0\textsuperscript{7,8} Society was found on 20.02.2015 with the support of the Federal Ministry of Digital Infrastructure and many other organizations along with the Chamber of Commerce. The society focuses on implementation of modern technology such as BIM in the construction sector to gain advantages of design and construction operation as well as to optimize the processes.

According to this society, the profitability of German construction industry has declined in recent decades. With parties in conflict with each other, construction disputes have soared just like the planning and construction costs. Meanwhile quality and criteria such as schedules and budget compliance have suffered. They stand on firmly for BIM as an opportunity and a key component to bring about changes in these situation for the betterment.

This society is in a development phase currently, though, it is fully committed to represent Germany’s endeavors to promote international initiatives in the standardization of the technical processes, in particular, BIM implementation in construction Industry. A number of tasks are expected to be executed by this society, such as, monitoring of the pilot and reference construction projects, knowledge transfer on digitization in the construction industry, and participation in the further development of BIM-compatible specimen contracts. The development of guidelines for quality assurance in software products and services and their certification is also included in their scope of works; as well as; the acquisition, allocation, and administration of grants and funds for research projects in the field of digital design, construction and operation

2.2.4 BIM in the European Union

In Brussels on 21 January 2016; Europe’s leading public clients held their first official steering committee host a great regional concentration of government-led BIM programs (Adam Matthews, 2016).

The European Commission has awarded the EU BIM Task Group funding for two years (2016-2017) to deliver common European network aimed at the support and implementation of the use of BIM in public works. The group consists of representatives such as, public estate owners, infrastructure operators, policy advisers and procurers of currently fourteen EU member states. Additionally, these public sector individuals have nominated a number of industry advisers to be a part of the Task Group to contribute.

The group will produce a handbook which contains common principles to guide the public projects participants and policy makers to introduce and implement BIM-based strategies to their projects. This Handbook will be focused on the technical procedures to

\textsuperscript{7} (German) Planen: Planning; Bauen: Building
\textsuperscript{8} For more info refer: http://planen-bauen40.de/
procurement, cultural and skill development and the benefits case for the stakeholders in a public project.

The reason for the EU member states collaborating together for the future of the digital construction is that they don’t want to compete with each other. In the sense that sharing the best practices and being united, they may faster achieve the transformation that is aimed for. It may generate more productivity and bring forward the European construction sector together as world class, open and fair.

It is established that the EU Task group does not compete with buildingSmart, rather it represents the public stakeholders related to BIM with national and international standards such as ISO, CEN and buildingSmart. Their scope is not to create or compete with the standards, but to develop common guidance and practices when BIM is introduced in public projects.

2.2.5 Standards in Germany and other countries

The development of German Standards according to BIM principles is on its way. The Association of German Engineers (VDI) has published the agenda for the achieving the goals of developing BIM guidelines. The field of actions it contains is regarding people, processes, technology and framework. It will contain specific guidelines about roles and responsibilities along with the details on BIM participants, experience, knowledge and skills of the participants, and partnership with collaboration and communications. Guidelines regarding automation, BIM Controlling (4D, 5D, performance reporting, and claim management), data exchange and management, quantity calculation, analysis of variants, and visualization will be covered in the technology section. Regarding work methods and planning code of conduct, BIM model and data exchange, sustainability, quality standards of information, tender offer comparison and data security will be taken into account. The complete BIM framework guidelines will include tenders and contracts, intellectual property, common standards and formats, HOAI compliance, and responsibilities / liability. The guideline series from VDI and VDI BIM handbook is being developed dynamically to encompass all topics regarding BIM implementation in Germany (VDI, 2015).

The ministry of infrastructure has announced BIM mandate for public infrastructure projects from 2020. Since the BIM implementation in Germany has not been fully realized, it is natural that the standards regarding the BIM based project is still in the development stage. Whereas, the guidelines and standards in USA and UK are more elaborate used widespread than in Germany currently as they have already implemented BIM in several phases and numerous projects.

The USA have started initiating with standards formulation and digitization of construction process since 2005 (NIBM Charter). They have already been a long way into BIM implementation and have specific plans for wider implementation in future. The UK have mandated BIM level 2 on public projects since 2016 and strategies for level 3 is already drafted. Since these countries started earlier, they have better formulated standards
available to be used in both public and private projects. Germany is expected to be implementing BIM based methods in more projects in the coming years, hence experience on executing BIM based projects would rise. Therefore, maturity of the guidelines and the standards can be surely expected before or by 2020.

German standards are more closely related to the BIM guideline and standards of the UK units, and norms are similar in these two countries, whereas the USA has completely different unit of scale, although they have tried to develop their guideline to suit international system, and in future make it more suitable to switch between units.
3 Qualitative Survey and Inferences

3.1 Questionnaire

The questionnaire used in personal interviews can be found in Index A. It was originally in German language. The questionnaire is translated in English for the thesis.

3.2 Survey Background

The survey was executed with the support of four participant companies:

Climaplan is a building services planning company which has Germany wide presence and focuses on projects in Bayern and Munich. They are specialists in working with modern sustainable technologies. They have more than three decades of experience and approximately eighty staff working with architects and clients to plan building services especially in the field of heating, cooling, utility services, energy consulting, alternative energy and thermal simulations among others.\(^9\)

ZWP Ingenieur-AG is also building service planning and engineering company with branches all over Germany and approximately three hundred employees. Operating in Munich since 2002, they specialize in comprehensive building technology services planning and consulting from first to last phase of the construction. The core services they offer are also in the area of facility-related environmental protection and facility management.\(^10\)

Pbb Architects and Engineers represent renowned architectural and construction engineering company based in Ingolstadt. They offer a wide range of services including architectural design, building services planning and design, construction engineering and controlling. They have a long experience in realizing big and complex projects especially industrial and commercial in nature.\(^11\)

The Wolff & Müller Group is one of the leading construction companies in Germany in private hands. Since founding in 1936 it is a tradition-conscious, family owned company with headquarters in Stuttgart. The core business is based on the field of in construction, material and services. The business unit construction is represented in the construction and civil engineering, in construction and civil engineering, in civil engineering, steel construction and in building renovations.\(^12\)

The survey was executed with the support of Drees und Sommer in the time frame of November 2015 to March 2016. The survey was done in the form of detailed personal interviews based on the questionnaire attached in index B. Each interview was of one and

---

\(^9\) More information at http://www.climaplan.de/
\(^10\) More information at http://www.zwp.de/de/
\(^11\) More information at http://www.pbb.de/
\(^12\) More information at http://www.wolff-mueller.de/
a half hour duration and in-depth experiences and opinions were recorded. Therefore, a very rich quality of data was obtained by this method of research.

The types of projects discussed in the interviews are of commercial and industrial nature. Generally tending to be large and complex, these projects are located countrywide in Germany and are owned by world renowned clients.

### 3.3 Analysis of Results

The data from the survey was analyzed and categories into the following relevant themes which covers the complete scope of the interviews. For detailed information on each theme, please refer Index A.2.

#### 3.3.1 Status of BIM implementation

The implementation of BIM is in its early stage. It varies from starting with the pilot project and little BIM to using BIM for some phases of the project. In general, since there is no mandate on BIM use on public projects until now, the number of BIM based projects executed are low in number. A complete and open BIM is not seen to be executed from start to end phase. The private companies have interest and are enthusiastic to upgrade to new processes and adopt new technology based methods, but there are several hurdles faced in this process.

When BIM based methods are used, it is most commonly used for 3D visualization, clash detection. Therefore, for the planning companies, it has been most useful in concept and detailed design phases, and for the construction company it has been implemented in execution as well as project conception phase. For the construction company, BIM is for used regularly for the proposal phase and at least five projects have been executed in the execution phase.

#### 3.3.2 Advantages of BIM-based methods

The best noted use of BIM based method in all the interviews was in clash detection. Starting from the preplanning stage, this tool have been helpful in avoiding many errors in design and subsequent problems on site in the later stage.

1. Better visualization led to better understanding of the project details by all the participants including the client and it provided more vivid options for presentations.
2. Quantity and cost certainty is measures to be very high with BIM-based methods. It is also easier to calculate, revise and compare quantity and costs with multiple design options.
3. Transparency in design and work is seen to be increased along with much better communication within teams collaborating for the project.
4. The quality of the work has tremendously increased by this method, hence clients are pleased with the results and company’s image becomes better in the market as compared to competing firms not using BIM.
3 Qualitative Survey and Inferences

The return of investment cannot be yet measured in terms of number but in terms of advantages and gains in other aspects. Since BIM is not completely implemented therefore, it is too early to predict financial gains.

3.3.3 Hindrances in BIM implementation

The following obstacles are experienced in the implementation of BIM-based methods.

1. The implementation of BIM-based method required more time in the concept phased of the project as compared to the non BIM-based project. Therefore, the client needs to understand that the project time line will required to be adjusted in the same way.
2. It is also evident in the BIM-based process that changes in design or project requirement/goals by the client at a later stage creates more burden on planners and on the budget.
3. Data quantity and its consistency is also a problem with BIM-based planning. The amount of integrated data is too much to handle and the software do not completely support the needs of the user.
4. DIN norms and HOAI in Germany doesn’t suit the BIM based planning process hence it is a major barrier in the implementation.
5. Collaboration is very important but is often missing as not all participants of the project are using BIM-based methods, therefore the relevant information required from the architects or structure engineers by the building services planners are missing in this case. Since the focus of the disciplines are different, and with different working principles the collaboration is a huge challenge in the early phase.
6. With multi user access to the building model, it is more difficult to control the data and track the changes.
7. Decision making process is slow in the early phases as flexibility is focused on by most stakeholders. As in classic construction process and also in a BIM-based construction process, design freeze is important to be met and planning discipline must be imposed upon to avoid multiple revisions and delay at a later stage of the project.

3.3.4 Software and tools

The technology which supports the whole concept of BIM has itself proved to be a barrier to successful BIM implementation on many instances. In the survey research, it has been found out that the software have the potential of realizing numerous tasks but in some cases, it lacks the focus on users need and is hard to regulate. The following points sums it up:

1. The software which is widely used by most of the participants is Revit and Nemetschek Allplan. The main concepts and functions of Revit matches users need the most and Allplan is based on German standards of construction hence they are preferred to work with.
2. Among others, MH software is preferred by the building service planners as it tailor made for this specific discipline.
3. The other tools and model checking software used are RIB iTwo, Solibri Model Checker and Autodesk Navisworks.
4. In many cases, users did not find a software solution that suits all their needs, hence they had to develop their own plug-ins, libraries or add-ons to the software.
5. For planners and designers, the limitation of the software is also seen in the amount of data it can handle. With large projects, it becomes increasingly difficult to manage complete project files.
6. The view of Construction Company is different in this regard. Since they need to analyze the model continuously and control the data, they are using central “Citrix” server for powerful computation and storage. It can be accessed from any normal capacity computer system securely.
7. Most employees need training to use the software and they are made available internally by the companies or through software companies.
8. As the construction industry is highly fragmented, each participant uses different tools as per their needs and availability. BIM based method has not been fully implemented in the cases studied for this research, hence, less experience in using IFC for interoperability is evident.

3.3.5 Legal regulation and norms

It has been established through the survey that HOAI and other legal norms and guidelines in Germany have not developed as fast as the technology has. These strict guidelines and standards have very less scope of variance and integration of new methods. Hence BIM-based planning and execution processes have been suffering.

HOAI is a remuneration guide which splits the whole construction process into nine phases. It does not relate to changes in the processes or variance or detailed factors that apply to the transitions in phases. Hence with introduction of new technology, it is logical that special services and process changes will need to be addressed by HOAI otherwise there are less perks for the companies to adopt the new method.

DIN norms used for design and planning of the building currently does not suit the BIM based process, and it creates a major problem for the planners in implementing BIM.

3.3.6 The role of (BIM) Project Managers

According to the survey, it has been found out that implementing BIM method means there are additional tasks such as BIM database management, model coordination, integration of old and the new processes, client consultation regarding BIM, and taking care of the planning discipline and documentation. The project manager needs to handle new tasks along with the classic project management tasks. The role of the BIM project manager is very dynamic in nature.
3 Qualitative Survey and Inferences

The essential skills that the BIM project manager needs to have are:

- High affinity to technology and good software skills
- Technical know-how in the field of construction
- Ability to control and assess digital data as well as the communication between parties.
- Ability to understand the data exchange requirement and processes
- Ideally a BIM all-rounder with ability to guide and train the team regarding BIM software and processes

3.3.7 Acceptance of BIM in AEC Industry

This question had mixed responses during the survey. People who have high affinity towards technology and are convinced with the concept and advantages of BIM, are motivated to implement it and to explore new technologies for the upgradation of the industry. On the other hand, a contrast in attitude and the way of thinking have been identified by the participants of the survey while interacting with different stakeholders.

Resistance to change in the work culture is a major challenge for incorporating BIM. It is true that the concept is new and its implementation, complex. Nevertheless, technological changes will be successful only when all participants will be driven to support it.

3.3.8 Future Prospects

The BIM-based methods seem to be promising in future. The early adopters of this method are quite convinced on the future prospects as certain potential is seen in this method. BIM plays an important role for construction industry in future as government’s plan is to make it mandatory for public projects. It is also a sensible and practical tool and helps the construction industry to technologically upgrade with time.

There is a need of collaboration by all participants and an understanding that the processes need to handled differently with BIM. The technology needs to be more mature in the coming years and implementation of BIM would be smoother. Software developers and the users need to cooperate and work together closely to so that the needs of the users is supported well by the software developed. From the government’s side, a revision in legal norms and guidelines is required with supports BIM implementation.

3.3.9 Special Concerns

From the planners’ point of view, one of the major concern is the lack of “design freeze” at the planning stage. Although this concern is not related to BIM-based methods exclusively, it is also valid for general planning procedure for the smooth flow of the project. For building planners it is essential that the design revisions are timely communicated and with the integrated BIM model in future, although it’s easier to track revisions and changes, a planning discipline is required to control the changes in the model.
BIM-based method of construction requires a lot of planning at the first stage. This phase of detailed documentation and planning of BIM implementation to the project should be included as “Phase 0” in the project.

At the preplanning stage, the requirement of relevant data by each disciplines must be addressed. The focus is not only on which kind of information is required by whom and when, but also on what is not required. Exchange of irrelevant data also creates confusion and complication in handling/using it.

Software market is expanding day by day but software suites that address all needs of the user is still lacking in the market which is a cause of major concern. Without proper tools, implementing BIM to its full potential is inconceivable. In future, managing the integrated BIM model is incomprehensible without proper tool support.

There are concerns over providing proper technical education with regards to BIM and futuristic approaches in construction by the universities. Trained graduates with high software and technical knowledge applicable to realistic projects are sparse.
4 Data exchange requirements and Process-flow

4.1 Defining Exchange requirements

Exchange Descriptions is a manual that identifies the information contents of the digital data exchange. They categorize the objects, processes properties, relations and classifications which are both relevant to the importing files or documents and available in the exporting the same (Eastman, et al., 2011). This exchange requirement manual should easily be able to express a general understanding of (in terms of data):

1. What is required?
2. When is it required?
3. By whom is it required?

According to the personal interviews with construction companies, it has been found out that the clarity of data is as important as the ease of exchange and sharing. Furthermore, it is essential to consider the data that are not required and exclude it while sharing. Excessive cluttering of file and irrelevant data may cause confusion and probable errors in further application.

It is also necessary to point out here that sharing of only relevant data for each of the parties is important. Unnecessary clutter of data and overflow of irrelevant information delays the work process and makes it prone to faults, hence needs to be avoided.

The data exchange and interoperability is of utmost importance in an open BIM project. Since the types of data are numerous and also the tools used to generate each of them by numerous project participants sharing of these data seamlessly is an enormous task. For open BIM, the following diagrams shows the variety of data required for a Project.

During information exchange within a project, there is a need to share relevant and quality data to avoid confusions and probable errors in generation of plan, design and details by each of the participating companies. (US GSA, Statsbygg, and Senate Properties, 2011)

The criteria for exchange of data needs to be defined before the stage where consultants need to coordinate the construction with a full-fledged BIM model. Throughout the design and construction periods, there is need to maintain these exchange requirements standards of design programming for a building project. The requirements consist of project criteria, owner requirements, building codes, local provisions, design guidelines, safety rules, the other governmental regulations, and space coordination and other functional constraints. Because validating the thousands of requirements manually is tedious for domain professionals at a certain phase, they increasingly employ automated rule-based checking to evaluate a design model. To automate this process, using a validation software package that provides rule-set templates and associated checking parameters is a suitable method.
The predefined templates allow users to customize embedded parameters that reflect individual constraints (Lee, 2015, pp. 176-195)

Information provided through the exchange requirements include:

- Basic information about the building and its spatial containment topology.
- Information about spaces, including identification, geometry, intended use, classification, intended occupants, and floor area.
- Information about technical services (Heating, ventilation, plumbing, fire protection) and building automation requirements.
- Information about several types of building elements, including: type identification geometry, and connections (both physical and logical).
- Information about specialized services (interior, security and special use case like medical, energy efficiency), planning and construction execution technique.
- Information about schedule of the project, budget, timeline, bidders, contractors and subcontractors, legal and contractual protocols.
- Information on management of project, quality control, client, and software and techniques used for execution of the project.

This list is not exhaustive as each project has different needs and thus different information requirements. In general, with the about information, the need to define which participating company needs which information and when, is critical. Major obstacles of implementing BIM based methods has been seen in Model coordination and information exchange. With correct definition of exchange requirements, drafting of an Information Delivery Manual (IDM) can follow with will clearly define the above requirements as standards for the process map generation.

Figure 4.1 Defining steps for the preparation of the “exchange requirement” document
After the process map is generated, the detailed document containing exchange description can be formulated. It is highly necessary for this document to be elaborate and self-explanatory to both the current and future users. This text document is a detailed and identifies:

- The purpose and general content of the data exchange
- The level of detail of the data
- Expected use of the data
- Mandatory information contents

This document must provide clear guidance on functional aspects of each exchange by the respective field experts. (Eastman, et al., 2011)

### 4.2 Study of Management Processes at different stages in Construction

Each task for project management needs a strategy to deliver it efficiently. These processes can be optimized or executed with the help of different tools to suit different type of project needs. A study of these processes for each project phase is essential. Generally, a project consists of initial phases such as preplanning and planning, execution phases and project closure and handover phases.

**Process-flow diagrams**

An important part of the BIM-based methodology is the observation of the processes how digital building information is created, altered, used and shared. Usually various specialist planners and companies execute these processes together and are accordingly required to coordinate. In major construction projects this process scenario can be very complex. (Borrmann, 2015) The process circle in the BIM-based project management includes, among others planning, communications, data exchange, financial, controlling, execution and management processes.

The most convenient way to identify the context of an exchange is by placing it in a process map. It is adopted by NBIMS for unique use cases. (Eastman C. E., 2011) The process map clearly identifies the roles of people sending and receiving data. Below is an example of how this process map looks like. It is based on the ‘Business Process Modeling Notation’ (BPMN)\(^\text{13}\) as a tool for process illustration. The diagramming tool used here is Visio which has plug-ins for BPMN shapes.

\(^{13}\) For more information, refer: [www.bpmn.org](http://www.bpmn.org)
To understand how the process map works, please refer the figure above. It shows a part of the complete process and the main contents of the map is identified. It differs from a simple flowchart and as it has multiple project partners defined in swimming lanes and there are dedicated lanes for information exchange where documents and message contents at each data sharing step is defined.

Other symbols and shapes, for example, decision making activity and start or end of a process are all the same as a regular standard flow chart. The process flow diagrams also clearly identifies the responsible partner for each of the process activity.

The following diagram shows the legend which helps the user to understand the diagram explained above better.

There are certain activities that are executed within two or more companies together as it needs high level of coordination among them. Construction project manager is required to
coordinate and execute tasks and the green dotted line encompassing activities denotes that. Furthermore, there are several activities which require important documents from other processes to be available at hand for reference, so that this activity can be successfully carried out. There are denoted within the blue dotted lines.

The shapes denotes the respective type of activity as per the legend, and the arrows are the connectors which shows the sequence these activities follow in the whole flow chart. Points to consider are:

- Every flow diagram for processes should have a start and end event marked clearly.
- The decision making activity has minimum two options ahead of it, which is defined by a positive and a negative outcome of the decision.
- The arrow pointer point to the direction of flow of the activity. Double pointed arrow means coordination is required between the two parties involved in those activities.
- The arrow with a dotted line denotes probable inputs required from one participant of the project discipline to the other.
- The data exchange swimming lane essentially means that the data is uploaded as shared within a known server platform (in this case VOR, Virtual Objekt Raum) and with appropriate access rights, the target participant(s) of the project can view, edit and forward the data.

Activities and use cases in the process map are not meant to describe all the actions within the processes of interest; many will not require data exchanges, and some exchanges may be made between users within the same company or team.

### 4.2.1 Case 1: Tendering and Contracting

Tendering for suppliers and contractors is a process that takes place after the construction permit of the building is obtained from the legal authorities. The process described here is called selective tendering as the submission of tenders is allowed only by invitation (BIM information manager, 2016). A list of possible suppliers and contractors is made, according to previous experience or suggestions from the client or the architect, which are known for their track record to be suitable for the building to be constructed. This suitability is measured in different criteria such as the size of the company, nature and complexity of previously executed works and references.

Next step of the process is to execute negotiation meeting with all the chosen contractors. This process is standard and involves the preparation/creation of the final legally binding documents such as prices of work and materials, conditions of work, extra charges for supplements, work hours and payment, discounts and special terms agreed upon.

A number of documents are developed at this stage, such as:

- Work contract and its limitations
- Special aspect in Construction regulations
- Work specification
• Work order
• Work Execution protocols

This is not an exhaustive list because as per project type and requirement, the need for additional documents may be deemed necessary.

These documents are the basis on which the comparison of bidders is made, and rightful decision of awarding of contract is met. With careful consideration and evaluation of all documents the winning firm is declared and the contract for the trade is signed off. All these documents, including the comparison of bidders and final decision, final order and specification of work, schedules and legal documents are uploaded to the server with access to all participants of the project. The Process Map on the next page shows this process in detail.
4.2.2 Case 2: Supplement management (change of order)

After the work contract is signed with the specialist planners or contractors for the respective construction trades, the work commences as per the schedule. The changes in initial order can be because of several reasons. Variations in design by client or the architect, solution to a problem on site, discovery of new requirements, quality of work executed, difference in gross estimation and final amount of material and work are few of the reasons. These reasons are discovered mostly during site visit by all or any of the parties. The requirement for changes are then identified by the client with inputs from the responsible participants. By email, the information is shared and a request for change in order is carried out by the contractor involved.

This supplementary document is now shared with the Architect/object monitoring company and it is checked for technicality and correctness of calculation. The supplement document must include:

- The new price offers for materials and work.
- The calculation sheet with surcharges as specified in the original purchase order
- The supplement grounds as the case may be.

The contract supplement is compared to the original work specification document for price and quantities and also to the new offers. These prices generally have an extra surcharges levied on them as they were not included in the original order. The calculation sheet must give all the details for the surcharges. The cover page of the supplement order has important information such as the total order amount, discount etc. Once this document is verified it is passed on to the project manager for further review.

The project manager must check the supplement document for plausibility and computational errors. When the document is verified and corrected, he must include the amount of new order in the cost monitoring document and calculate the financial risks. If the amount is within the limit, then the new supplement order is passed. If not then further actions by the client is required. For insufficient grounds for the change of order, the document can be rejected at any stage. The Process Map on the next page shows this process in detail.
4.2.3 Case 3: Billing for work executed on site by contractors

Once the work at site is (partially) completed, the contractor can generate the bill for the same and share it with the object monitoring team to be verified. This bill contains the actual work done on site and the actual quantity of the materials used. The quantities need to be verified on site by the object monitor along with the price verification from the contract work specification document. Once this bill is verified, it is uploaded and shared with the project manager for further corrections.

The project manager’s task is to verify the calculations and discount in the bill. The next step is to verify the total order amount and previous payments, if any. At the end it should be updated in the cost monitoring sheet. The document that needs to be available during this process of verifying the bill is the order document, the contract with specification of work and the supplement contract, if any. The project manager must take care of the total order amount in the contract and the total bill amount. According to the general rule, the percentage of work done on site should roughly be equal to the percentage the bill amount is to the total order amount. For example:

If the total order amount (including supplements) for a contractor is 500,000.00 Euros, and work completed on site is 65%, then the bill amount until this stage should be approximately 325,000.00. There is a scope of tolerance, but if the bill amount is very high (for example, almost 90%) at this stage, the project manager must check with the contractor and object monitor and obtain reasonable grounds for the bill amount before approving it. The Process Map on the next page shows this process in detail.
4.2.4 Case 4: Site monitoring and Report

As a rule, the site monitoring is generally scheduled once a week and this schedule is agreed upon by all the major participants of the project. The project manager sets an appointment for site visit and executes the site monitoring process with the architect, major contractors, and planning engineers. It depends on the owner, or the size of the project, if they want to participate in this process. The project manager generally takes a tour of the complete site, and checks the status of the major elements. He must note down the actual work done and the quality status of the construction. The documents to be referred for this activity are:

- The architectural drawings
- Detailed discipline drawings
- Construction Schedule
- Previous site monitoring report

The minutes of the site meeting is documented and at the end of the day reported to the respective suppliers/contractors. The solution or the following instructions are discussed on site between concerned parties and the agenda of next site visit is developed.

In any case, the site report at the end of every month is presented to the client. This report includes the project progress, cost monitoring progress and major highlights of the month in terms of goals achieved and hurdles confronted. In further site monitoring process, the issues from the previous report is reviewed and checked for resolution. The Process Map on the next page shows this process in detail.
5 BIM-Based Project Management

5.1 The optimized process with BIM Implementation

According to the research paper by Poirier in the Canadian journal of Civil Engineering (Poirier, 2015), transformations in practice with the implementation of BIM was observed. With digitization and new tools, the activities within a process is changed in a few cases, and in some, it required a complete overhaul of the process execution. Based on the implementation of BIM, the data generated is also found to be more reliable and consequently less errors/problems were faced during the construction.

In this thesis, two use cases have been selected and process flow diagram for the same is generated, to have a better view on how tasks can be carried out with BIM implementation. Site monitoring is one of tasks that has been optimized and the task of clash detection is completely new. Without the BIM technology, the clash detection was not possible before, and the engineers and architect could only try to find clashes comparing 2D drawing. It would be mostly discovered at the time of construction execution, that there is a clash between building elements, and resolving these issues requires much more time and resource as expected.

5.2 BIM–based Construction Process Map

The following cases represent the optimized process maps for construction management processes which are executed with BIM based methods.

The following legend shows the notations used in the following BIM based process maps. It defines clearly the type of activity, the tools required for the activities to be carried out, and it also indicated which of the processes are collaborative. This indicated the tasks are usually carried out with the collaboration of two or more participants of the project.

Figure 5.1 BIM-based project management process flow-diagram legend for reference
5.2.1 Case 1: Site Monitoring with BIM-based method

With the implementation of BIM, site monitoring becomes easier. According to Autodesk\(^\text{14}\) and Hochtief\(^\text{15}\) Site monitoring solutions have diverse advantages.

- 3D visualization provides a better way to plan and coordinate site activities, the logistics of moving construction materials and vehicles, and the layout of the site.
- 4D simulation helps to correctly assess the schedule so that target and actual work done on site is monitored smoothly.
- Variances in construction schedule and quality can be analyzed easily with the help of construction simulation.
- It combines mobile technologies (iPad / smartphone / android device) at the construction site with cloud-based collaboration and reporting.
- Construction quality can be tracked using easy-to-use and customizable templates.
- Use of pushpin markers (in both 2D and 3D) helps quick communication of location, status and description of issues.
- Web based reporting of site status and sharing makes it easy to archive and document information.

According to Trimble Corporation’s Tekla BIMsight\(^\text{16}\), the BIM based product by them has several features. All information that is written/marked on paper during the site meeting can be entered into the mobile device directly. No scanning, uploading or renaming of data files is required in this process. The 3D model allows for better structuring of quality

---

\(^{14}\) (Autodesk, 2016)  
\(^{15}\) (HOCHTIEF ViCon - BIM world - Use of mobile deviceson construction sites for monitoring of quality in conjunction with BIM, 2016)  
\(^{16}\) For more information, refer: https://www.teklabimsight.com/
assurance, acceptance, construction logbook etc., and all content can be looked-up with the search function. Up-to-date building information is thus available to project management at all times for monitoring and reporting.

The process map for site monitoring activity with BIM based method is different than the classic process mainly in terms of technology used. The process includes activities such as:

1. Setting up, updating a time schedule via 4D sequenced model.
2. Systematic compilation and documentation of the process with the help of site monitoring tool.
3. Site target and actual status comparison with BIM data
4. Coordination and evaluation of the works with the other participants / specialists on site, detection of defects, recommendations for the client

The Process Map on the next page shows this process in detail.
5.2.2 Case 2: Clash detection

Clash detection is known as one of the best applications of BIM-process. Due to the complicated models in each of the building disciplines, it is recommended to start conducting clash test in preconstruction stage itself as incompatibilities and inconsistencies, which would severely impact the construction process later. There are a number of software which assists architects and engineers in clash detection, such as Navisworks and Solibri Model Checker. With a non-integrated model, specific disciplines of building model can be tested for clashed within the specific companies. This would be the first step of generating an error free model, which will be used later for model integration. After integration of all the discipline models together into the final model, at a later stage, it can be again checked for clashes within different discipline elements, such as, an architectural element with plumbing element.

According to Autodesk knowledge network (Autodesk Navisworks, 2014), there are many default types of clash tests to choose from:

- Hard clash test and Hard (Conservative) clash test: in the first option, two objects taking up the same space is detected. For example, a beam which is going through a plumbing run is clashing and is discovered through the test. Since Navisworks’ geometry consists of triangles, this test may miss the clashes between elements where none of the triangles intersect such as parallel pipes exactly overlapping each other slightly at the ends. However, choosing the Hard (conservative type) gives all resulting items that may clash. This may give some false positive but is definitely more thorough method for clash detection.
- Clearance clash detection checks geometry within a specific distance from other geometry. In short, it checks tolerances between elements according to the set rules.
- Duplicates can be detected using the clash detection tool too, to ensure that the same elements/objects are not drawn or referenced twice on the same point in the model.
- Soft clash detection is done to detect potential clashes between moving components. The clash detective can be linked to animated objects to support soft clash detection. It can further be linked to the timeline schedule simulation to allow interference checking during the lifecycle of the project.

The main advantages of Clash detection includes:

1. Removing/resolving the various design conflicts occurring and makes the project error free.
2. Minimizing the overall cost of project and delays, which may have occurred, at the time of installation and construction stage due to clashes.
3. Minimizing coordination errors and difference of opinion between personalities of different domains.

5.2.2.1 Case 2A: Clash detection (Integrated BIM-Model)

For clash detection process, the table below can be referred as a guideline which directs teams in general in terms of types of activities involved and data required/generated to
execute those activities. The process can have slight variations as per the team and requirements of the project and owner. This table is developed with the study of Norwegian BIM standard guidelines (Statsbygg, 2013) and research paper by (Seo, 2012).

<table>
<thead>
<tr>
<th><strong>Activity</strong></th>
<th><strong>Step 1: Data preparation</strong></th>
<th><strong>Step 2: Clash detection conduction and clash resolution</strong></th>
<th><strong>Step 3: Documentation and report</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Data Required</strong></td>
<td>BIM Model (Discipline Specific: according to LOD)</td>
<td>Converted Models for Clash Detection</td>
<td>Clash detection result</td>
</tr>
<tr>
<td><strong>Data to be referred</strong></td>
<td>Design and construction Regulation</td>
<td>BIM guidelines, Process Plan</td>
<td>Regulation of Construction/Budget/owners goal</td>
</tr>
<tr>
<td><strong>Participants</strong></td>
<td>Architect / Engineer</td>
<td>Architect / Engineer</td>
<td>BIM Coordinator /Owner/Architect</td>
</tr>
<tr>
<td><strong>Data generated</strong></td>
<td>Converted Models for Clash Detection</td>
<td>Clash detection result</td>
<td>Remarks, BIM data Document</td>
</tr>
</tbody>
</table>

When the models are integrated together into one Big/Open BIM, it becomes all the more necessary to execute clash detection of all types, as explained before, to ensure the clashes are resolved before the construction starts. This should be done at the detail design phase.

The process map denotes the site monitoring process which starts with fixing a schedule and preparing agenda for the site meeting. The next step is collaborative and along with the project manager, the architect and the specialists take part in the process. Real time issue detection with the help of sequenced and data rich model is possible and the status can be updated and shared with the participants immediately along with comments, instructions and pictures. There is more clarity on what is lacking and what needs to be done. Generation of the report is easy with the BIM based tool and further, the implementation of solutions can be tracked online from the updates by responsible participants and also by site monitoring.
5.2.2.2 Case 2B: Non-integrated BIM-Model

In case of Closed/little BIM, i.e. single discipline model (non-integrated), clash detection is executed at an early stage so that when the model is exchanged and integrated with other disciplines, it is error free in itself. For example, when a plumbing services model is generated, and clash detection is executed, the clashes between the plumbing pipes and installations itself is can be resolved first. During pre-planning and design phase, this step is necessary. The following BMPN diagram will detail out the clash detection process of a non-integrated BIM model.

This process takes place within a company where discipline models are checked for clashes. Once the discipline models are free of issues, they are ready for integration with the complete building information model. The clash detection process and types of clashes to detect is the same as the integrated process. Depending on the size of the project, a BIM specialist may be required for model administration, or the planners with BIM skills and experience can take up the new tasks.

The Process Map on the next page shows this process in detail.
5.3 Development of Project Manager’s Role and the team

To facilitate project planning and management with BIM, the differences between a standard project delivery method and BIM-based method must be addressed (Kymmel, 2008). It is essential to find out in which ways the skills of the project manager and the tasks that is set for project controlling need to be updated and modified to suit the new BIM-based construction project demands. With an addition of array of new objects such as “nD model”, digital data integration, attributes and model simulation, clash detection and timeline incorporation, data security, collaboration with other companies in regard to BIM model and coaching team members, following only the classic project management will not suffice and a change is inevitable. Therefore, for executing a successful BIM-based construction project, discovering the new role of Project manager is quintessential.

5.3.1 New tasks for Managers (BIM-Based Project)

Implementation of BIM-based processes to a construction project means additional responsibilities for the project manager. I will here refer to this role as “BIM Project Manager” throughout the paper. As per the analysis of requirements of the BIM-based projects, this diagram gives an overview of the main role the new BIM Project Manager will handle during project execution.

The BIM Project Manager will be the channel of all communication and information exchanges between the architect and specialized planners and be answerable to the client for all purposes. Although the classic project management tasks could be made relatively easier to execute with digital data, high level of technical knowledge would be required to control the information flow. There will be also a need to revamp the complete process of

---

17 BIM Project Manager: Project Manager for BIM-based Construction Projects
project management and controlling as the requirement of BIM-based project is comparatively different.

5.3.1.1 Planning BIM Implementation

The BIM process is a planning and managing process for building construction, and it is important for this process itself to be planned and managed carefully (Kymmel, 2008, pp. 81-83). According to the author of the book BIM – Planning and managing construction projects with 4D CAD and simulations, steps to be followed while planning the BIM implementation should be carefully considered according to the project goals.

The following diagram throws some light on the BIM Implementation planning process which essentially follows a bottom-up principle.

![Figure 5.4 The bottom-up BIM implementation planning method](image)

The first step to implement BIM based construction planning process is to define the goals of the project. This task is achieved by the collaboration between the client and the project managing company. It is very important to draft realistic goals and targets adhering to BIM principles. Best practices from previous projects or case studies from similar BIM based construction projects would come handy here.

The second step involves the detailed description of the deliverables for the complete project. After the goals are defined, it would be quite what the major milestones of the
project are. Level of detail (LOD) pertaining to the BIM model needs to be set at this stage along with the specific requirements from the participating contractors and special planners. The focus will be on the desired quality of the product as well as the time schedule for the same. The format of the deliverables should be fixed at this point, such as pdf, $nD^{18}$ model, simulations, printed documents etc.

The process required to be executed for each of the deliverables are planned in step three. Project controlling, financial overview and budget monitoring, clash detection, construction simulation, energy calculation, contract and supplier management, and facility management are a few examples of the processes required to be planned for the listed deliverables. The processes are all about generating information and managing it.

The next step is to estimate the resource required to achieve the goals and produce the deliverables using the processes listed. It will be in the form of finance, personnel, software and hardware requirements, material and time. As far as project management firm is concerned, it is very important to define the team for the project and to ensure that they have the necessary skill set and technical support. It may be necessary to train the team members to match the level of BIM implementation.

5.3.1.2 Project team dynamics

The role of the project manager and the team is to be defined in the next phase of BIM implementation. Depending on the size of and goals of the project, the project management company will need to have dedicated personnel and a ‘BIM Team’ to manage the project implementing BIM based methods or the participants of the existing team can be identified as per skills as to contribute to the BIM-based project management processes.

This team structure needs to be dynamic to suit the incoming projects and/or the company’s business model. The roles and responsibilities need to be defined according to project requirements. During the analysis of project management processes, the following roles and responsibilities, which suits the structure of teams and projects at Drees & Sommer have been developed:

1. Technical Role: As project data developer.
2. Managerial Role: As controlling of processes and information within the project.
3. Leadership Role: As the communication channel and to coordinate with project participants.

---

$^{18}$ $nD = 2D, 3D, 4D, 5D$ and so on. ($n =$ Number)
The above figure explains the tasks of a BIM-based project manager in three levels.

1. The first basic responsibility is the data generation and development. This includes 4D and 5D digital data as per the project requirements for schedule and cost management which are common tasks for managing a construction project as per the scope of work. In a project which required BIM method implementation, this a highly technical role. A good grasp on the BIM software and analytics is required.
   
   a. Generation and synchronization of digital data such as Schedule and cost
   b. Manipulating BIM model and attributes
   c. Checking and ensuring model accuracy
   d. Software control
   e. Data extraction

2. The second level of responsibilities include controlling, defining and optimizing the project management processes with regards to the project requirements and deliverables. This role will also include the task of digital data administration and sharing/exchange with the participant companies of the project. Technical knowledge of handling nD models with specific tasks such as clash detection, virtual inspection, simulation, and updating schedule and cost management with respect to the BIM model. The tasks include:

   a. Model analytics
   b. Simulation and inspection
Managing digital data flow and compatibility
Data protection and security
Editing information and change management

3. Third level of responsibility would be to coordinate and communicate during the complete execution of the project with the other stakeholders. This is necessarily a leadership role. Less technical knowledge would be sufficient but experience in leading large and similar projects would be highly desirable. The person in this role must be able to coordinate a project within the project management team as well as with the other companies. Planning BIM implementation is a task of this role such as:

   a. Level of detail of the model
   b. Tools used
   c. Team/Responsibility structure
   d. How does the information flow within the stakeholders
   e. Project milestones and timeline with respect to BIM based method

The size of the BIM-based project management team largely depends on the project requirements and the company size and its business model. Below are some examples of the possible team structure according to the above listed roles and responsibilities.

Case 1: Individual personnel for each role

This case can be applied to large companies with multitude of BIM-based projects with dedicated requirements from the client’s side.

![Figure 5.6 Case 1 – Team structure with dedicated personnel for each role](image)

Case 2: (Leader + Manager) and Developer

In many companies, it may be possible that the project manager with very good experience on managing large construction projects receives technical training and is able to perform both tasks of leading the project as well as managing the digital data as per the
requirements. This case can be applied to medium size projects where dedicated personnel are not necessary and BIM based software training is made available.

Figure 5.7 Case 2 – Team structure with dedicated personnel for the project digital data developer and combined responsibilities for project leader and manager as a single role within a project management company

Case 3: Leader and (Manager + Developer)

When the BIM-based project developer with vast technical knowledge to handle the software has experience on project management processes, it is very helpful if these two roles are combined. The person who develops the 4D and 5D data to synchronize it with BIM model has the best knowledge on how to simulate and manage the digital information in the next level.

Figure 5.8 Case 3 – Team structure with dedicated personnel for the project leader role and combined responsibilities for project manager and digital data generator role within a project management company

Case 4: (Leader + Manager + Developer)

For instance, if the BIM-based construction project’s requirement is manageable by one employee with the knowledge of BIM-process; it may be wise to employ him/her to manage processes and information related to BIM, whereas the other team members, as necessary, may support in classic project management activities at various levels. This case
is particularly applicable where the implementation of BIM based process in a construction project is at the beginning stage and it is only partly implemented.

Nevertheless the team member having the required skillset to manage all the responsibilities together can also be a potential in-house BIM trainer for the company and help the other colleagues with to gain technical skills with respect to BIM-based processes.

![Diagram](image)

**Figure 5.9 Case 4 – Team structure with dedicated personnel for all the major responsibilities regarding BIM-based processes within a project management company**

### 5.3.1.3 Tools and information management

Tools refer to the software and plugins used for the BIM based processes to achieve desired deliverables. It may be developed internally by the company to fulfil specific tasks. Major concern here is the interoperability of the files. As discussed in previous chapter, multitude of software and file type used by different participants of a project makes it quite difficult to manage the exchange of data without information loss or incompatibility during sharing of digital project information.

The types of BIM-based digital information generated during the project are:

1. **Visualization and illustrations:** used for marketing or for clients understanding of the project goals in 3D and walkthroughs. This is mainly generated by the architects and relatively easier to handle by the project managers as it is only used for clarification of design purposes.
2. **Building components** such as Mechanical electrical and plumbing system (MEP) systems, concrete structures, doors and windows, beams and columns, interior layout, automation system and walls and partitions. In the BIM model, these would be detailed as object oriented modelling (OOM) with the level of detail (LOD) as specified during the project planning stage.

As these data would be generated by different participating companies, it is essential to synchronize and converge the BIM model carefully and within
interoperable formats of files, hence data might be lost or misplaced. There are scores of software including self-developed plug-ins.

3. Material specification and cost will be generated in relation to the BIM model along with the schedule of the project. When these data are converged with the 3D BIM model, it will add more dimensions to it.

4. Data regarding structural simulation, material logistics, security, energy efficiency, building environment, and green certificates will be generated in digital format in a BIM based construction project. This would be relatively easy to generate, recall and handle and revise as per the requirements within the model with suitable plugins and software.

5. Project execution documents such as bills, quantities, contracts, protocols and supplements will be generated during the project. Since this data must be available in hard copies and prints, it is also necessary to make digital copies of it to be shared in a common server or cloud platform for constant availability. This process is already in practice with most of the project and companies.

6. As-built BIM model will be the last set of data that would be updated and revised on several occasions as per the execution of project. This complete bundle can be then handed over to be used by the facility management team for the building’s life cycle.

The information feedback loop should be planned and followed according to the data exchange requirements and needs to be continuously revised and improved.

5.3.2 Project Documentation

According to FTR International Inc., 2016, an experienced company in BIM implemented projects in USA, the document control process mainly follows these significant steps below:

1. Document Management
2. Numbering System
3. Designation of Responsibility and Authority
4. Streamlining of Approval Process
5. Document Retention
6. Process Flowchart
7. Manuals and Work Instructions

Clear lines of communication with all the stakeholders, in each phase of the project is of prime importance. Within the BIM based process, monitoring of all Request for Information (RFIs), documentation of project’s progress and costs, weekly and monthly meetings are mandatory as in the classic process, although the tools used would be different (FTR International Inc., 2016).
With BIM and technical advancement, there are several possibilities available today to control and manage the project documents. This mammoth task requires much effort and time of the architects, planners and the project managers. BIM based software is able to provide package of bidding documents, control over it, modification of contracts as well as as-built drawings tracking system. Ideally, BIM project data will be stored in a cloud based server for ease of access and use. One such example of the software is Autodesk BIM 360 Docs. It has the capability to organize logically the bulk upload and improve publishing faster, with access controls at five different levels, making sure authorized access and optimal work flow. Like most other software for controlling documents, it is possible to update all document with the changes in BIM model, switch from 2D to 3D and vice versa, and comment and create mark-ups to share with other participants and can be used in web, tablet and on phones (Autodesk, 2016).

The most helpful feature is version control and rollback possibilities for drawing without making much effort. A good number of problems at construction site is due to changes in design during construction and late, unclear or insufficient information in construction document.

5.3.3 Schedule planning

Phases of a BIM-based construction process differ in timelines vastly as compared to the classic construction project. The BIM-based project in general require more time for preplanning and design as it needs to be adequately detailed and done with the use of BIM tools. At the end the models from several participants such as architects, MEP, structural engineers, energy consultants etc. must be integrated together to form a complete BIM model. This integrated model must be linked to the project schedule to simulate construction process with timeline. This takes huge amount of time at first but the effort pay off during execution with less conflicts and errors and more clarity of the design details. Revisions are also less likely due to better preparedness, hence avoiding rework. Significant amount of time is saved during the documentation as with BIM-based project, documents are generated, revised, updated and archived all with the modification in the BIM model itself.

Here is an overview of how the timeline looks like with classic and BIM-based projects.
The task of the project manager here is to coordinate with the client, and other stakeholders during the very start of the project and plan the timeline which suits the BIM-based process. For smooth flow of all processes and successful implementation of BIM-based methods, this task is crucial. If process planning with respect to BIM does not match the timelines, there could be stress and time crunch to complete the BIM model, compromising the quality and integration of all information. This would certainly create more problems while execution phase and thus losing the value of BIM implementation to the Project.

5.3.4 Planning Strategies

It is important to prepare well for the implementation of BIM. The strategy to plan with BIM must be laid out before the planning process starts as it affects the subsequent processes. During schematic design, scheduling (4D) and estimating (5D) must be taken care of. The BIM models need to be developed correctly from the start. For scheduling, the model has to be built considering the actual building construction process. It is important to build each floor and subsequent elements of the model in the same sequence as the construction would be done so that the Scheduling software can be linked to the building elements properly (Matthew Hill, 2012).

For estimation (5D), project parameters must be added to the model. It is because:

1. Filtering of the schedules is possible so that estimation can be linked to it.
2. The model elements must have adequate information attached to it so that estimating tool calculates the element properties such as types and size for estimation.

It is very laborious for estimating to try and count all of the elements of a process project from a 2D plan. With BIM implementation, it becomes easy to collaborate the design and construction process. Typically, this is why the strategy works faster from schematic design through construction of a project.
6 Best Practices and Future prospect for Project Manager

This chapter is based on the interview with Herr Peter Liebsch, head of digital design, Drees und Sommer Frankfurt. This interview took place on 7th March 2016 through video conference between Frankfurt and Munich office of Drees und Sommer. The questionnaire used for this interview is attached in Index C – Questionnaire used for Interview Chapter 6.

6.1 Roche Project – Basel

Roche is a world leader in research based healthcare and pharmaceutical company whose headquarter is in Basel, Switzerland. The Building 2 and pRED (Pharma Research and Early Development) in Basel are the new facilities for office and research labs which brings more than four thousand the Roche employees together in total. The new office building 2 in the interior of the Roche site will be 205 m tall (approximately 50 floor) and provide space for up to 1,700 office workplace The development is aimed to be state-of-the-art and sustainable.

![Figure 6.1 An architectural view of the future developments (labs, offices and infrastructure) at Basel by Roche.](source: (Roche, 2014)]

6.1.1 Project Introduction

Designed by architects Herzog de Mueron, the complete project is a masterpiece. The building 2 and pRED are parts of the development and are based on open BIM principle.
The project is managed by Drees & Sommer with the general construction management (GCM) service where all phases from conception to handover is taken care of by one company. Currently in the conception phase, the project is expected to be completed within 2021 – 2022 (Roche, 2014).

Software in use: Autodesk Revit and TriCAD (based on Bentley Microstation) is used for this project.

6.1.2 BIM based project: Tasks and Processes

The project management tasks are extended with additional BIM management tasks. The new tasks and processes are based on the BIM model and the database. There are also some classic project management processes that would be converted into BIM-based process when using the digital model as the basis of the work.

The BIM-based project management requires that all tasks and processes in the construction lifecycle of the building to be documented very precisely at the first stage. As the project is complex, clarity in scope of work, tasks, and processes helps the team in further stages to avoid confusion, delays, and redundancies in data. This first step of creating the document is challenging in itself, and requires more time and effort in the beginning. It’s not only the documentation, but also collaborating and obtaining information from all participants along with decision making process on a lot of topics.

The following diagram gives a general overview of how the classic project management and BIM-based project management is related to each other.

---

19 (General Construction Management, Drees & Sommer, 2013)
6.1.3 Management of BIM-based Project: Roles, Responsibilities and Team Structure

The role of a Project Manager in a BIM-based project is very demanding, and lot of hurdles and challenges are to be faced. The Project Manager ideally assumes dual role; managing both the project and the BIM model database.

As the BIM-based method needs a strategic approach combining the new and classic principles of management for a project, it is also logical that the role of the manager for a BIM based project would also include a combination of classic and new responsibilities. The first step of implementing BIM-based method in a project is to start with defining roles and responsibilities for each participant of the team, define model requirements, specify elements properties and exchange process and define quality management process, among others. Planning for a BIM-based project must include every detail related to the tasks, processes, and the model.

The BIM Manager must have experience in executing projects of equal complexity and a very good knowledge of the software and tools used for BIM. A variety of skills are required to implement and manage BIM-based projects such as hands on experience of building construction from start to end, understanding of BIM principles, expertise on BIM software and, soft skills for collaborating and coordinating with the diverse project participants.
The structure of the team managing a BIM-based project must be very dynamic. Since the tasks are a strategic combination of project management and BIM management, according to the requirement of the project, several roles may be handled by one person. The responsibilities and roles of the BIM Manager and team members must be defined depending on level of experience and skills.

It is necessary for the BIM team members to get training for the use of BIM-based software and, coordination and management of BIM-based processes. It is also advantageous for the BIM team members be have previous practical experience in handling BIM-based projects. They should have expert know-how of procedures and processes involved in a BIM-based project. In this regard, experience from other countries where BIM implementation is on a higher level may prove fruitful.

6.1.4 **Advantages of BIM-Method**

The method in itself is found to be very useful in increasing the quality of visualization of the project as compared to 2D detail drawings. This refers to all parts and subparts of the project and not only the outer view.

The level of understanding is much higher between all the project participants and hence everybody can track the areas where coordination is required in 3D. Decisions are based on higher level of information, hence, more reliable. In ideal setup, the process is more efficient and faster after the preplanning phase.

The major advantage for the clients is that the project has higher clarity and visibility and they can also monitor the progress of the project to the very last detail. The BIM model is integrated and contains complete information of all project disciplines. Therefore, it is easier for the clients to check if the goals and requirements of the project is correctly transferred into design and construction details.

Once all the stakeholders of the project understand the basic principles and advantage of BIM based methods, they are accepting it. They are able to understand the potential of this method and that with digitization, the design and construction processes are much more efficient.

Roche is very much interested in taking BIM forward into the projects and maximizing the possibilities offered by the open BIM model and this method.

6.1.5 **Obstacles faced in implementation of BIM: People, Processes and Software**

The concept of design and detailing may not have changed much but the core processes definitely need to be handled in a different way in a BIM-based project. With CAD, all parties were able to suit their needs and work in their own ways, but BIM is a collaborated effort. The set procedures and details required to carry out a specific task is agreed upon as a first step, and ideally followed by each project participant. Maintaining the standard quality of data is, invariably, the participant’s responsibility. Unsystematic execution of
processes may create major problems in the subsequent phases. Referencing the individual files to the main BIM model is one such task. In case of initial implementation and pilot projects, ensuring that all parties adhere to the specified planning discipline may be the project BIM Manager’s task.

Regulating massive amount of data is the significant to handle BIM based projects. Data is fragmented in a classic project between different teams and participants and it is often complex to connect various parts of the related information. Whereas, in a collaborated BIM model all the information is available at one place, which assists project and documentation control. Although building a collaborated open BIM model is a complex task itself and required time and expertise. According to Herr Liebsch’s experience, when this task is fully realized once, it becomes easier in future to handle and reuse the data. Consequently, with the numerable benefit of this process, one may not want to go back to the old ways of handling data, especially in a complex project like Roche’s.

A lot of problems with data exchange in open BIM arises from the misconception of basic principles. One such examples is that the open exchange format IFC is meant to be used in a one-way exchange and not two-way as the general conception is. The expectations from this process of exchange by the users is totally different from what it can actually do.

From an architect’s point of view, Autodesk Revit’s principle of working and basic concept suits the BIM-based requirements of planning and construction Bentley Microstation or other programs available in market. RIB iTwo has proven to be a useful tool for the 4D and 5D planning. Once the complete model setup is done, it can be used to extract all the possible data very easily.

Control of contractor’s model is not generally possible as in this case, as they are not working together with the integrated BIM model from the planners. The contractor model contains information that they need for internal processes and hence this data is not integrated or shared. Therefore, in this case, the project manager has less control over the changes in original design.

6.1.6 Return on Investment
As this is one of the pilot projects in Swiss scenario, it is difficult to measure return on investment in term of money, and calculation of returns of investment is not possible at this early phase of BIM implementation.

For benchmarking, there not enough BIM based projects in Swiss/German market to be able to estimate the return on investment (ROI). Contrary to the USA and the UK, where hundreds of projects have been already executed with the application of BIM methods, it is now easy for these countries to generate reports on returns on the investment.
6.1.7 BIM in Future concerning German Market

The implementation of BIM-based process is necessary in future projects as it is proven to be logical and has multiple advantages. It has been made mandatory by the German government from 2020 for infrastructure projects. A lot of change is also seen in the private market. Clients are enthusiastic with the technological change and are asking for BIM implementation. They understand the benefits and see great potential in this method. They are looking forward to work with the design team with a futuristic outlook. It is important for the projects that the BIM-based methods are implemented step by step and according to the resources available.

Even with the introduction of BIM in the newest version of HOAI, it is far from corresponding to the BIM-based process of construction. There is much scope of improvement and addition of BIM based tasks and structure of the project correlating the remuneration for the respective performance. The basic description of tasks and division of project into phases do not suit the new requirements and structure of the BIM-based projects. For better implementation of BIM in future projects, reforms in HOAI is necessary.

6.2 Future Prospects for the project manager

It is a very challenging role to handle BIM-based projects for the project managers in future. As previously established, additional tasks and responsibilities require additional skills and deep understanding of the fundamental process. The integration of project management and BIM management teams and tasks would be seen in future because they are interconnected. For the efficiency of the entire management team, strategic implementation of BIM-based process will be required to control the management process.

From the research and surveys executed for this thesis, it can be inferred that in future, the role of the project manager is going to become very dynamic and diverse with the implementation of BIM in a project. The performance expectations from the project manager is going to increase, as he is supposed to handle not only the classic processes but also the new processes and task related to digitization of the project, coordination of this information and controlling of enormous amount of data.

Seamless integration of new, old and transforming processes in the complete project is important, hence the project management team must consist of members with various expertise who can work together and carry out all the responsibilities required by the project. For the Project Manager / Management Company, additional responsibilities and new methods of functioning is expected in future.
7 Conclusion and outlook

7.1 Inferences
Building information modelling has been proved to be a useful tool for construction projects. Despite the hurdles faced with BIM implementation, the stakeholders of the construction industry in Germany are enthusiastic to use BIM-based methods as they see much potential in it. As it is an early phase of BIM implementation in Germany. A lot of solutions to the obstacles are still to be found out. Nevertheless, the advantages this method has to offer has been recognized.

Among other benefits of using this method, it has been demonstrated during the research and survey for this thesis, that early detection and removal of error, enormously increases quality of design and construction drawings has led to the consequent increase in productivity. According to personal experience of the participants of the survey for this project, the companies use different tools and methods to achieve the tasks. Hence, there is a lack of standardization in information exchange. As a result, implementation of big and open BIM is low.

It is evident that with new methods, there will be a subsequent change in the role of the project manager in controlling and coordination of a construction project. Additional task, among others to be dealt with includes digital data management, model coordination, managing data exchange and sharing within the participating companies, controlling errors, and coordinating the construction with the digital model. Therefore, additional skills and new process will be required to execute these tasks. Therefore as discussed in chapter 5 and 6, strategic planning for the implementation of BIM is required in terms of team setup, and software and management processes training for the BIM managers according to the resources available. Additional skills such as process innovation, problem solving ability and high technical/software knowledge is expected from the future project managers.

The processes involved in management of a project is changing as BIM-methods are applied. Fundamental approach, and the method of execution of tasks is different as BIM-based methods require new tools to be used and it involves more digital data. Therefore, it is very important to define the requirements, procedure and roles and responsibilities of the participants involved in each task to be executed.

The HOAI\textsuperscript{20} norms followed in Germany as a bible for all remuneration and performance guidelines for Architects and construction companies at every stage of a project does not specifically support the development of BIM-based construction and planning methods as a BIM based project has fundamentally different processes and phases. Most of the companies in construction industry, hence, hesitate to upgrade or change to BIM-based processes as there seems to be no incentive for the same. Upgradation of this remuneration guide is required from the government’s side to support BIM implementation.

\textsuperscript{20} Refer HOAI v. 10.7.2013, BGBl. I S. 2276
Few special factors have been identified through the research regarding the BIM implementation in future projects. There are concerns over lack of proper training provided to the current students with regards to BIM, the software and technical implementation. With the elaborate plans for BIM in future, there is a need of addressing the shortage of trained professionals in the industry. Therefore preparing young graduates and students for the successful implementation of BIM in future seems necessary. A change or addition in the current courses and special training will be required for the same.

7.2 Future Outlook

“The real promise of BIM lies in its application across the entire project team, especially in the area of improved building performance.”—Technology Industry Analyst, Jerry Laiserin

Use of BIM in future projects is logical, and a must, as far as most of the participants of the survey for this thesis are concerned. Better support from the government, and suitable tools are required to achieve fruitful results. Pilot BIM projects in Germany are already being executed and problems are identified. Since the announcement of government’s mandate from 2020 for infrastructure projects, it is beneficial that the implementation of BIM is initiated from now itself, as it will lead to solution of major problems by that time. BIM is a practical approach only by actual implementation, its potential, drawbacks and solutions can be discovered.

Experts are forecasting that it will take five to ten years for BIM based process to be completely implemented in all phases of the construction projects. The major directive being a software that is available on the market to fit to the needs of the planners and other stakeholders. As discussed in chapter 3, the demands of the user are far from being met with current software available on the market. Therefore, cooperation between planners and software companies to develop the best suitable solution for all future project requirement related to BIM would be ideally the best solution.

To conclude, this thesis presents many factors regarding the status of BIM implementation. Although in future, for Germany, BIM will be quite important and would bring much potential to the construction industry by standardizing it and streamlining the processes.
Index A – Interview Questionnaire for Chapter 3

Company: __________________ Company size (employee): __________
Services offered: ___________ BIM-based projects executed: __________

I. Data development and Exchange

1. Do you use BIM-based software in your firm? If yes, which one(s)?
2. Does the technical infrastructure at your firm support the requirements of the BIM software?
3. How great is the acceptance of the BIM software by your employees?
4. Which planning services are offered by your company?
5. How are the data exchanged within the firm?
6. Which types of data are required by you from other companies to generate your data?
7. What are your experiences with errors in design and planning in BIM-based projects?
8. How are the data (such as cost and quantities) prepared for exchange with other participants?
9. Can you identify the main obstacles faced in the data exchange process with other firms?
10. How are the final construction data prepared to be submitted to facility management?

II. Compatibility and interoperability

1. Are the data from other planners compatible with your BIM software?
2. Is it possible to control the data shared by other participants? If yes, how?
   (filter/edit/view/screen)
3. Will it be possible to detect probable loss of information or errors during exchange of data?
4. Which planners/contractors do you work with?
5. What are the problems confronted using BIM-based software?
6. Are there concerns over data protection and sharing of information with other parties?
7. What are your views regarding data ownership and legal aspects regarding BIM data, when the model is editable by multiple participants?
8. How were your experience with cost estimation, 3D simulations and clash detection tools in a BIM-based project?

III. Role definition

1. Do your employees need special training to use the BIM software?
2. Do you require the participation of your employees in an earlier stage of the project for smooth flow of planning/construction process?
3. From which phase do you provide your services in a project?
4. Who is responsible for the data generated by your company?
5. What are the tasks of a BIM manager in your company?
6. Which essential skills a Project Manager must have?
7. What are the advantages of implementing BIM in a project?
8. How do you differentiate the BIM-based construction management processes with the classic construction management processes?
9. Have you structured your team according to the requirements of a BIM-based project?

IV. Communication

1. How are meetings arranged? (face to face, skype, conference)
2. Is it easier to coordinate with the object monitor and planning team on site with BIM?
3. Which languages are spoken in your workplace regarding international projects?
4. How are the language barriers overcome, if any?
5. How are changes/ problems communicated and handled within different parties? (meetings /info via cloud/ e-mail/ mark-ups on the printed plans)
6. How are errors protocolled?
7. How are the important data protected?

V. BIM Implementation and Experiences

1. In your opinion, is interoperability helpful in the implementation of BIM-process?
2. Do you think that the IFC data standards supplements exchange processes between different disciplines and software?
3. Does object oriented modelling help save time during model changes and is better understandable?
4. Are the conflicts avoidable in the design and construction stage when the data are in 3D-5D format during exchange?
5. Is controlling resources such as time, material and people easier and transparent through BIM process?
6. Are the data obtained through BIM model (ex. cost and schedule) more precise as compared to manual process?
7. In your opinion, which role does BIM play in planning and realizing construction projects in future?

VI. BIM Business Case
1. How can the ROI factor be measured for a BIM implemented project?
2. Does the implementation of BIM method give you an advantage over your market competitors?
3. In your opinion, what are the difficulties in implementing BIM in Germany as compared to the USA and the UK?
4. Is HOAI developing at the same pace as BIM technology to be able to compensate the payment structure and the scope of performance of the architects and engineers?
5. Which positive experiences and advantages can you recall regarding BIM project in comparison with the classic project?
6. What are the advantages to the client or customer with regards to implementation of BIM?

VII. BIM Supported Software

1. Can the software you use generate 3D pdf?
2. Is it possible to edit the pre-defined standards and macros?
3. Is it possible to edit the library objects easily?
4. Are the available objects in library sufficient for your planning?
5. Is it possible to generate complex geometric structures with your software?
6. Is clash detection supported by the software you use?
7. Is version control, change history and detailed audit trail possible with this software?
8. Is it possible to control the access and permissions regarding file use?
9. Does the software support walkthroughs and navigation tools such as virtual reality engine?
10. Which data do you share with the project management team?
11. What are the hindrances faced during information exchange with other planners?

Index B– Detailed Analysis of Interviews

The detailed analysis of the results of the interviews were tabularized according to different perspectives relating to the backgrounds of the interviewees. Additional inputs from the perspective of the Project Manager is added for comparison. The data is used from the interview details in Chapter 6 for reference. Since the questionnaires were different, all themes would not be covered from the Project Manager’s view.
Index C – Questionnaire used for Interview Chapter 6

Project Size (sqm): ____________________ Project Cost (ca. Euro): __________

Construction Duration: _______________ Architect: ___________________

Project Management Team Size: _________ Software used: ________________

1. How do you differentiate the BIM-based construction management processes with the classic construction management processes?
2. Which positive experiences and advantages can you recall regarding BIM project in comparison with the classic project?
3. What are the advantages to the client or customer with regards to implementation of BIM?
4. How is controlling resources such as time, material and people executed within the framework of a BIM project?
5. How were your experience with cost estimation, schedule planning (4D, 5D) in this project?
6. How are the final construction data prepared to be submitted to facility management?
7. What are the main problems you faced while working with BIM?
8. Can you identify the main obstacles faced in the data exchange process with other firms?
9. What are the roles and responsibilities of the Project Manager in a BIM based project?
10. Which essential skills a Project Manager must have?
11. Do your team members need special training to use the BIM software?
12. Have you structured your team according to the requirements of a BIM-based project?
13. Concerns over HOAI and performance scope of the Project Manager.
14. How can the ROI factor be measured for a BIM implemented project?
15. In your opinion, which role does BIM play in planning and realizing construction projects in future?
Index D

D.1 List of Figures

Figure 1.1 The research timeline and methodology application for this master thesis project. 11
Figure 1.2 Structured observation research and its deduction 13
Figure 1.3 Chapter sequence and contents of the thesis 14
Figure 2.1 The life cycle of BIM based construction project. Source (JTB World, 2010) 16
Figure 2.2 The four levels of Maturity as defined by the British Standards Institution in 2013. Based on diagram by Borrmann, A., König, M., Koch, C., & Beetz, J. (2015). Copyright holders are Mark Bew and Mervyn Richards (2008) 17
Figure 2.3 Development path of BIM; from little and closed to open and big (iBIM). Based on the diagram by (Borrmann, 2015) 19
Figure 2.4 Object oriented modelling with encoded data; BIM model database including geographical and non-geographical information. Based on the diagram by (Sunesen, 2011) 22
Figure 2.5 definition of what constitutes open BIM by (BuildingSmart, 2014) 25
Figure 2.6 Overview of IFC Data exchange process through IDM/MVD method used by buildingSmart. Diagram based on (Borrmann, 2015). 26
Figure 2.7 : Framework of BIM-Based construction quality model. Based on the model by (Chen & Luo, 2014) 26
Figure 2.8 Workflow of BIM-based construction quality model. Based on the model by (Chen & Luo, 2014) 27
Figure 2.9 Graphical representation of the LOD as defined by AIA. This example shows a steel column and its connection to the underlying component. Source (Borrmann, 2015) 28
Figure 2.10 The hierarchy of development of Standards for BIM by NIBS. Picture Source: NIBS and buildingSmart alliance (NIBS, 2016) 33
Figure 2.11 Information and management processes in a common data environment (CDE) as defined by PAS 1192-2 2013. Source (BSI Group, 2013). Copyright belongs to Mervyn Richards. 35
D.2 List of Tables

Table 2-1 the sample chart for Information delivery manual as suggested by BIM guidelines and Standards Manual - GSA and (Statsbygg, 2013) (Norway)
Table 2-2 the current level of BIM Implementation around the world. Based on the report by Emmanuel Di Giacomo from Autodesk at European BIM Summit at Barcelona (Emmanuel Di Giacomo, Autodesk Inc., 2015) 29


Table 5-1 Specification for clash detection process activities and data requirement 65
Index E: Compact Disc

The Compact Disc submitted with this project contains:

- The complete master thesis document as .pdf
- The process diagrams from chapter 4 and 5 as .pdf
- Survey Analysis Charts as .pdf
Bibliography


Germany | Companies | The BIM Hub. (2016, 02 12). Retrieved from https://thebimhub.com/companies/?&selected_facets=country_exact:Germany


