“Scope and Hurdles for Spreading Building Information Modeling into Indian Project Management Construction Industry.”

Master thesis

International Master of Science in Construction and Real Estate Management
Joint Study Programme of Metropolia UAS and HTW Berlin

Submitted on 20.01.2020 from

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Acknowledgment

The research signifies the outcome of the knowledge I received during the studies at HTW Berlin and Metropolia UAS and past industry experience. I owe my professors for the invaluable support and guidance throughout the course of my studies.

I would like to share my sincere thanks to my supervisors Prof.Dr.-Ing. Roode Liias and Sen. Prof. Eric Pollock for having confidence in my research topic and for the irreplaceable guidance through the course of my research. In addition, I would also like to thank all the professionals who participated in the survey and guided me during the research work.

Lastly, I would like to thank my friends for supporting and sharing their experiences with me and my mom and fiancée for encouraging me to remain positive and strive for the best.

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International Master of Science in Construction and Real Estate Management

Joint Study Programme of Metropolia Helsinki and HTW Berlin

Date: 20.08.2019

Conceptual Formulation

Master Thesis by: Mr. Maan Singh

Student Number: S0562627

Topic: "Scope and Hurdles for Spreading Building Information Modeling into Indian Project Management Construction Industry."

Abstract

Nowadays, the global construction industry seeks various methodologies to make construction processes more efficient and profitable. From experience, literature review and surveys, it appears that project management(PM) firms as well, are interested in computer-aided tools which can help them to organize and monitor their projects and deliver them to on budget and schedule.

In the Indian construction industry, 50% of projects suffer from cost and schedule overruns, This is mainly due to poor transparency in processes and coordination problems (Al-Qershi & Kishore, 2017). Known for helping reduce these problems, benefits presented by the adoption Building Information Modeling (BIM), creates an opportunity for its market growth in the Indian industry. It helps to improve efficient planning, make processes transparent, allow for better coordination, and cost savings solutions. Also, since it integrates design models with attributed construction details, it allows fast and highly accurate calculation of quantities and costs. Real-time progress visualization with 4D BIM and cash flow optimization with 5D BIM

assists better communication of work progress between the project team and project owners.

For this research work, the main focus will be to highlight possible BIM tools from a PM perspective, that can help improve cost and schedule efficiency on Indian projects. It will propose to the Indian construction industry, ways to integrate design, construction and operational phases of buildings through BIM while limiting cost levels to as minimum as possible. The motivation behind this research is an experience with a PM firm that constructed India's tallest residential skyscraper (72 floors). They faced several challenges including but not limited to cost estimation, schedule delays, and clashes in HVAC, MEP and other drawings. With several publications informing on the successful use of BIM in countries such as the United Kingdom, the USA and Finland; and hands-on experience during this master program, it appears BIM could have vast positive impacts in Indian Construction Industry. Also, the Constraints for BIM development in India will also be analyzed to seek solutions.

Scope

- This scientific research will focus on the usage of BIM for project planning and monitoring from project management firm's perspective.
- Research on the current situation of BIM acceptance in India and worldwide and its possible growth in Indian industry.
- Research on implementing BIM strategies to the Construction industry while finding solutions for possible constraints.

Research Objective

- To evaluate the change required by the role of a project manager when implementing BIM methodology as compared to the traditional method.
- Seek possible benefits for different stakeholders concerning project management.

- Analyze possible constraints to adopting and implementing BIM in the Indian market and finding possible solutions.
- Analyzing difficulties and creating a strategy for implementing BIM in a real project.

Research Question

- What changes are required in traditional management processes in order to implement BIM?
- What are possible challenges when adopting BIM in Indian Construction Industry?
- What are the possible benefits to different stakeholders through BIM?
- Is it possible to integrate 3D design with automatic scheduling (4D BIM) and to costing (5D BIM)?

Research Methodology

The following methodology will be adopted for completing this scientific research:

- Before a proposal for practical implementation, a literature review will be done.
- After studying literature, tools such as Revit for smart design and Vico or primavera for scheduling will be analyzed for usage purpose.
- Construction data of a real-life project will be obtained from the Indian project management office. This data will be analyzed for possible BIM Implementation.
- A successful case study will be analyzed for setting up strategy.
- In the end, a possible survey/interview will be conducted to strengthen the research.

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Timeline

The defined time frame for this scientific research is 20 weeks and expected start on 1st of Septermber2019 and handing over date will be 18th of January 2020.

The research progress will be divided into the following pattern:

1. Literature and Data research and collecting project information (visiting India)- 12 weeks
2. Data Processing- 4 weeks
3. Thesis finalization- 4 weeks

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First Supervisor

Roode Hijas

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Expected participating company:

AT Techno Legal Pvt. Ltd. Company (Project Management Company)

Supertech Limited (Developer, India)

BE Billimoria Construction Limited (Contractor)

Abstract

The research attempts to assess the challenges faced by the construction industry in India for the implementation of BIM (Building Information Modeling) Methodology. India being a developing country has a lot of potential in the development of Infrastructure with its increasing Industrial and digital economy. The Architecture, Engineering, and Construction (AEC) industry and public institutions in India face numerous challenges such as cost overrun, time overrun, as well as project quality and coordination issues due to the complexity of its nature. With public and private projects being delayed, there is a demand for the use of a promising solution that can overcome these challenges and increase the productivity of the AEC sector.

Construction project management (CPM) firms play a vital role in efficient and effective project deliverables. On the other hand, the key concept of BIM methodology has relied persistently on construction industries around the world for more than a decade now for its well-known functions towards project success. Therefore, this research work addresses the demonstration of project management processes using BIM methodology as well as to identify the built environment's approach towards BIM growth in the Indian industry. The research focuses on the various hurdles faced by the CPM industry through the analyses of six case studies and a professional survey.

The results concluded that although there are numerous challenges to implement BIM in the Indian construction industry, the Indian government is encouraging the built environment to adopt digital solutions to compensate for the additional costs required on projects. The literature, survey, and case studies analyses conclude that BIM is the future and will serve as an essential tool for managing Indian construction projects. On the other hand, the opportunities and constraints of adopting BIM methodology in the Indian market are successfully addressed and a strategy towards significant growth of BIM industry in India also elaborated in this research work.

Keywords: Building Information Modeling (BIM); AEC industry; Construction Project Management(CPM); BIM future opportunities and constraints; India.

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List of Acronyms

AEC:	Architecture, Engineering, and Construction
AECO:	Architecture, Engineering, Construction, and Operation
BEP:	BIM Execution Plan
BIM:	Building Information Modeling
BOQ:	Bill of quantities
CAD:	Computer-Aided Design
CDE:	Common Data Environment
CM:	Construction Management
COBie:	Construction Operations Building information exchange
CPM:	Construction Project Management
D:	Dimensions
EDMS:	Electronic Document Management System
FM:	Facility Management
IBIMA:	India BIM Association
IFC:	Industry Foundation Class
IPD:	Integrated Project Delivery
LOB:	Line of Balance
LOD:	Level of Development
LPS:	Last Planner System
PM:	Project Management
PPC:	Planned Percentage Complete
SMC:	Solibri Model Checker
VR:	Virtual Reality

1. Introduction

The upcoming subsections give an overview of the BIM (Building Information Modeling) methodology potential to construction processes as well as the opportunities and constraints for the BIM growth in the Indian construction market. The current challenges faced by the Architecture, Engineering, and Construction (AEC) professionals and public institutions over cost overrun, time overrun, and coordination issues also highlighted in the upcoming subsection and briefing of these challenges described in the respective literature section. On the other hand, the following subsections described the motivation behind the research work, aims and objectives, and the research methodology adopted to accomplish the thesis objectives.

1.1 Background and motivation

Nowadays, the global construction industry seeks various methodologies to make construction processes more efficient and profitable. From industry experience, literature reviews during the master programme, it appears that project management(PM) firms as well, are interested in computer-aided tools that can help them to organize and monitor their projects and deliver them to on budget and schedule. On the other hand, the key concept of BIM methodology has been clinging persistently to the construction industry over the globe for more than a decade now and BIM adoption is spreading continuously across the globe through the active involvement of both the public and private sectors in the AEC industry, yet the construction industry is resolutely facing formidable challenges in the appropriate implementation of BIM methodology in countries like India.

According to the latest statistics report presented by Minister of Statistics and Programme Implementation[1], at least 355 Indian projects have faced cost overrun around 3.8 Trillion Indian rupees (20.52% of estimated project cost) and about 552 projects have faced time escalation[1]. With respect to these concerns of project delay and cost overrun, National Institution for Transforming India (NITI) Aayog official said BIM could save up to 20% of the project cost by shorting the construction time[2]. On the other hand, the government set campaigns such as ‘Digital India’ and ‘Make in India’ and the fight against corruption is

[1] (Ministry of Statistics and Programme Implementation, 2019)
[2] (Haidar, 2019)

setting up the impeccable environment for the BIM growth in India. All possible opportunities for BIM acceptance in the Indian market have been briefly discussed in the 'BIM scope in India' section. For the project management perspective, sometimes BIM acronym as Building Information Management could be considered for this research work.

In contrast to BIM future opportunities, there are many challenges analyzed during the literature review, analysis of case studies results and evaluation of professional survey such as Lack of BIM awareness, Initial investment on BIM software and learning processes, unavailability of national BIM standards, guidelines and regulations. Apart from the listed constraints, BIM experts shortage and stakeholders attitude towards new technology acceptance, prepare mindset to change their procedure of managing tasks and fair collaborations are other analyzed barriers against BIM healthy growth.

The motivation behind this research work was the problems faced during the industrial experience in the project management firm while managing various tasks of 72 storey Skyscrapper in India. The project faced lots of issues such as collaboration among stakeholders, quantity take-off, cost overrun, time overrun, and these can be solved through effective usage of BIM methodology learned during the master program about the potential of BIM implementation and its universe success stories.

1.2 Aims and objectives

For this research work, the main focus was to highlight the BIM tools and their functions from the Construction Project Management (CPM) perspective, which can improve the efficiency of the cost and schedule in the Indian construction projects. Moreover, to propose to the Indian construction industry, ways to integrate design, construction and operational phases of buildings through BIM while limiting the additional cost levels to as minimum as possible.

After the synchronization of listed objectives, the following research questions were developed during the conceptual formulation and answered accordingly in the thesis work.

- What changes are required in traditional management processes in order to implement BIM?

- What are the possible challenges when adopting BIM in the Indian Construction Industry?
- What are the possible benefits to different stakeholders through BIM?
- Is it possible to integrate 3D design with automatic scheduling (4D BIM) and to cost (5D BIM)?

1.3 Organization of the thesis

This research work contains eleven sections and these sections are linked to one another in such a way, that it can deliver the desired outcomes effectively. In the second section, the BIM definition and its functions are discussed. The third section described the roles and responsibilities of the construction project management firms in the project. In section four of this research work, the difference between the conventional and BIM methodology is highlighted. Section five has discussed the scope of the BIM and its status in India as well as in the international construction industry. The case studies analysis and evaluation are discussed in section six of this research work. Section seven involves the analysis of the conducted survey. While section eight elaborate on the possible changes of role among involved stakeholders after implementation of the BIM methodology for managing construction activities instead of the conventional approach. Section nine will describe the research questions answers, and sections ten and eleven will illustrate the conclusion and recommendation of the research work.

1.4 Research methodology

A combined approach of the qualitative and quantitative methodology is used for objectively analyzing the potential of BIM functions and construction project management roles and responsibilities. On the other hand, future opportunities and possible constraints of BIM implementation in the Indian construction industry are also highlighted. Based precisely on the pragmatic approach, the relative analysis is divided into three categories as described below.

Initially, the detailed description of BIM methodology and its functions, the CPM firms, roles and responsibilities, the difference between the conventional and BIM methodology,

and BIM implementation scope and status in India and worldwide are described in the literature section.

Secondly, altogether six case studies including the conventional and BIM methodology are investigated from the PM perspective for better evaluation of findings.

Lastly, a professional survey with a variety of questionnaires, and experts opinions are taken out for the empirical validation of the possible results. The questionnaire was distributed through email, LinkedIn, and social networks.

2. Building Information Modeling(BIM)

Before diving into the exploration of the benefits of BIM methodology to the CPM and AEC industry in India, it is essential to have a review of BIM methodology and its processes for effective execution. The upcoming section will illustrate the basic introduction of BIM, the level of specifications and, the benefits and drawbacks of BIM methodology to the construction industry.

2.1 BIM introduction

Building Information Modeling (BIM) is an intelligent model-based process that helps the different stakeholders for handling all necessary data and information at a single point, which helps to plan, design, estimate and manage the building over its lifecycle. As it is cleared from the definition, it is not just a model or software but actually, it's more than a computer-aided design (CAD). Hence it goes beyond traditional drawings by adding information to its individual component as well as putting resources and costing to build each component to that model. BIM should be measured as a developing and using smart models for designing, construction planning and operation of a project[3].

As a BIM model progresses through various phases, new dimensions(D) are encrypted and linked to that model. This information added to a model helps to enhance a greater level of understanding and accuracy in a construction project. After being in for more than two decades, BIM knew worldwide for its multidimensional (nD) features. BIM methodology has evolved from basic 3D (Digital model) to 4D,5D,6D &7D.3D model is developed while adding information (dimensions, materials specification) to each component of a project. When project activities are linked with duration and resources in a model it's called 4D BIM(Scheduling) and it helps to prepare a schedule for a project. Similarly, when each component defines with its cost to build then it helps to prepare an estimate of a project and it is called 5D BIM (Costing). Sometimes costing done first as compared to scheduling for an estimation purpose, hence 4D BIM and 5D BIM are occasionally used interchangeably[4].

[3] (Boukara & Naamane, 2015)
[4] (Kocakaya, Namlı, & Işıkdağ, 2019)

According to a German BIM management company (HOCHTIEF)[5], BIM is a process for optimizing the planning, execution, monitoring, and operation of a project. The "I" in BIM referred to information and can be used by the various stakeholders and M sometimes stands for Management for better and transparent coordination. BIM is a wonderful concept that makes it possible to virtually design a project before its actual construction. As an effect, the stakeholders are able to visualize the building and to evaluate the execution before the actual implementation at the site. Solving coordination, clashes, and other issues at the initial stage of a project can help to save a significant amount of time, efforts and money. Advancement in scheduling, costing and building operations accuracy open up an entire range of new opportunities for BIM methodology[5].

The following diagram shows the functionality of BIM methodology over a project lifecycle. The AEC industry has a new platform to deal with the traditional methodology to solve the issue of planning ahead. In the traditional approach, different project partners put the information to their tasks but were not effectively carry forwarded to the last participants (Facility manager) of a project. Hence, they were facing difficulties while solving any operational or maintenance issues. In BIM, it is obvious that each project participant has to add information to their tasks, but all information added under a single cloud. That's made quite easy to look on a single-mode rather than a big bundle of staggering information. BIM serves the same function as an umbrella as you can see in the below figure that each information carried under an umbrella and helps to streamlines the project delivery[6]. The motive behind BIM methodology is developing a central administration, where as much as possible information related to a project handled. This includes resources, processes, drawings, documentation and much more information that leads the way to project success[7].

[5] (HOCHTIEF ViCon, 2019)
[6] (Dispenza, 2019)
[7] (Egger et al., 2014)

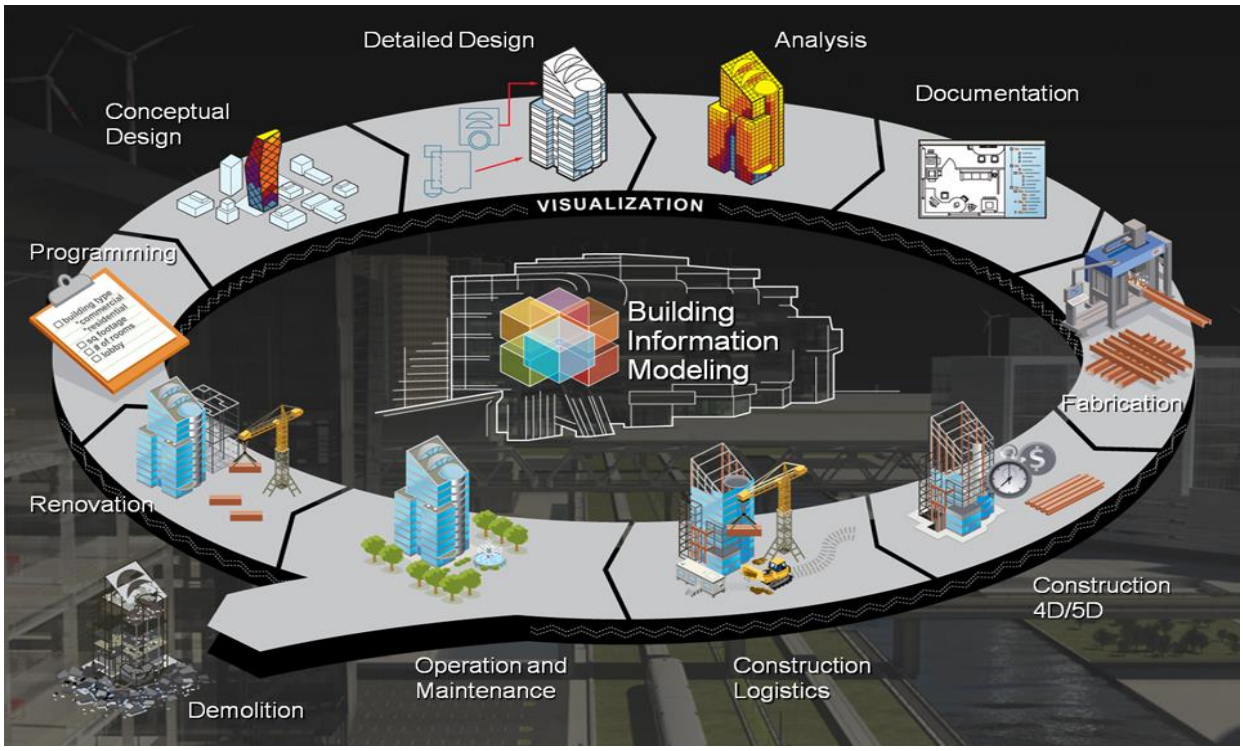


Figure 1: Correlation of BIM during the lifecycle of a project[6].

Another approach is the awareness of little BIM and Big BIM. As specified earlier, to abuse the maximum potential of BIM it is prudent to utilize BIM interdisciplinary all through the project stages and not just for specific exchanges. Little BIM portrays that a solitary individual or one participant links various segments together to store and utilize certain data on its extent of obligations. It very well may be viewed as an island solution. It doesn't provide the full benefit of BIM and called little BIM. A situation where all the stakeholders are connected and the interdisciplinary is given is called Big BIM. This prompts better coordination and allocation of processes and agreements as everyone can see the changes or revision made by any party, resultant in higher transparency and more benefits to individual participants and the whole project[8].

[8] (Borrmann et al., 2015)

2.2 BIM Level of development

Level of development (LOD) in BIM is a set of specifications that enables experts in the AEC Industry to identify, specify and articulate the content of BIM effectively and evidently. With a high level of precision in the content and reliability of LOD specification at different stages in the design, construction and operation processes, different participants can communicate and execute tasks easily. LOD signifies the level of completion of a project model. It signifies the level to which different stakeholders can rely on information linked with an element. The level of detail and level of development are two different terms in BIM methodology. BIM Forum[9] explained the difference in two terminologies as a level of detail explains the details added to a model, on the other hand, LOD describes the degree of completion to which a model is linked with specification and helps different participants to get the information from that model. It can be understood as the level of details is input to a BIM model and LOD can be output used by stakeholders[9].

According to the United BIM forum[10] definition for Level of Development has described below.

Level of Development	**Definition**
LOD100 (Conceptual design)	A basic level model is designed to represent crude information associated with a concept such as a type, height, width, length, volume, location, area, and orientation of elements
LOD200 (Schematic design)	This stage defines a standard model with approximate values for each component. Information such as quantities, site position, shape, floors, and orientation along with other non-geometric information is linked with each of the model's elements.
LOD300 (Detailed Design)	The detailed design level defines accurate models and drawings with detailed assemblies, accurate quantities, precise size, coordinates, and location. The stage helps to create a project model in detail by adding all the information about each element defined with accuracy.
LOD350 (Construction documentation)	This stage defines how different elements interrelate with other elements and arrangements with the help of graphics and standard definitions.

[9] (BIM FORUM, 2013)
[10] (United BIM, 2019)

LOD400 (Fabrication and assembly)	At this stage, all the project elements are defined as precise assemblies with detailed and complete information about muster, detailing and fabrication. Also, details concerning the quantity, size, shape, orientation, site position and non-geometric information are also fed to the model.
LOD500 (As-built)	This stage enables modeling all the components as constructed assemblies- i.e. how they will seem in real life. This stage can define information related to maintenance and operation and various kinds of actual and precise information are attached to the elements.

Table 1: Level of Development with their Definitions[10].

Advantages of LOD

LOD is a dominant communication tool, that supports to organize and implementing information more deliberately in a digital model and exchange information with different participants of a project. Throughout this standardization the coordination, quality, accuracy and efficiency rise and aim to higher success[11]. Some of the following advantages of LOD are listed below:

- Better collaboration and communication among different participants in a project.
- Articulated scope linked with a BIM deliverable.
- Without LOD, a BIM model can be less significant to its full potential.
- If 3D models used without LOD standardization it can cause massive blunders[10].

What can a BIM model define and describe according to LOD level is described in the following table:

Model content	**LOD100**	**LOD200**	**LOD300**	**LOD400**	**LOD500**
3D Model-Based Coordination	Site-level coordination	Major large object coordination	General object-level coordination	Design certainty coordination	N/A
4D scheduling	Project duration and Phasing of	Time-scaled ordered the	Time-scaled ordered the	Fabrication and assembly detail containing construction	N/A

[11] (Mavreli, 2018)

	construction elements	presence of major activities	presence of detailed assemblies	means and methods	
Cost Estimation	Conceptual cost allowance	Estimated cost based on measurement of the general element	Estimated cost based on the measurement of detailed assembly	Committed purchase price of detailed assembly at a buyout	Record cost
Program Compliance	Gross departmental stores	Specific room requirements	FF&ampE, casework, utility connections	N/A	N/A
Sustainable Materials	LEED strategies	Approximate quantities of elements by LEED categories	Precise quantities of materials with calculations of recycled and/or locally purchased materials	Specific manufacturer selections	Purchase documentation
Analysis/Simulation	Strategy and performance criteria developed on volumes and areas	Conceptual design based on Geometry and supposed types	Approximate simulation based on precise building assemblies and engineered systems	Precise simulation based on the specific constructer and detailed system components	Commissioning and recording of restrained performance

Table 2: Capability of a BIM model as per the LOD specification level[10].

2.3 BIM Level and BIM Execution Plan(BEP)

The BIM maturity model defines levels of development with regards to the facility of the construction supply chain to control, operate and exchange information. There are various levels of collective collaboration in a construction project. These are identified as BIM maturity levels. As we progress through the different levels, the collaboration between the

various phases is increasing. Until now, there are four different BIM maturity levels as shown in the following figure and described in detail below[12].

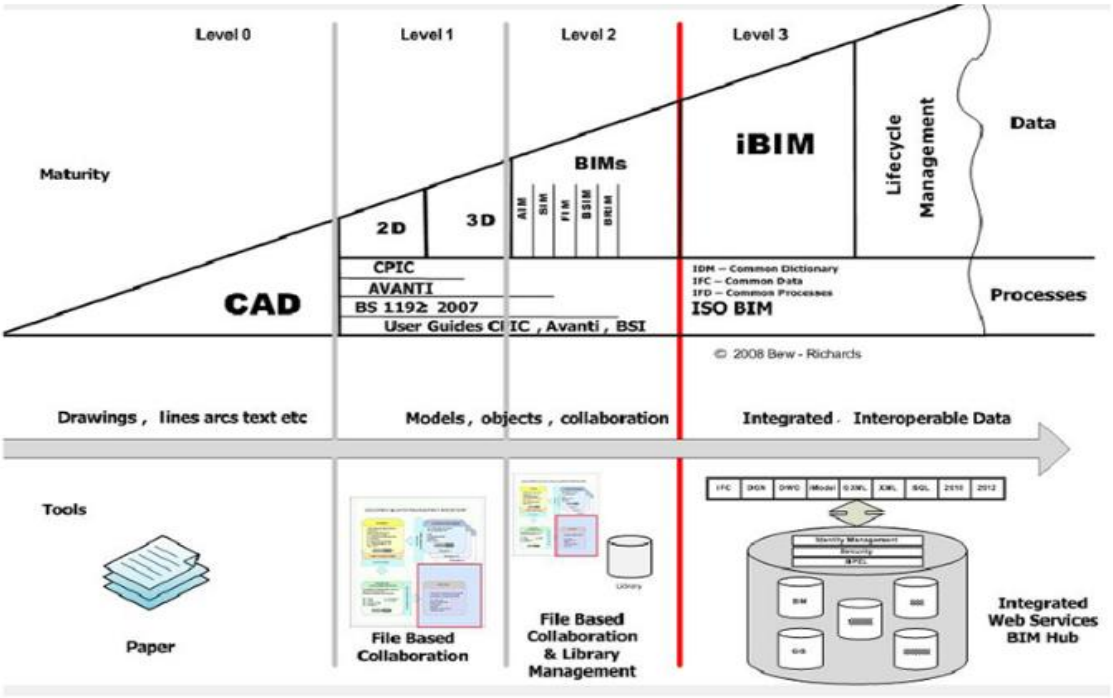


Figure 2: BIM Level ranges from 0 to 3[13].

BIM Level 0(Pre BIM)

It is the simplest form among all BIM level, Level 0 means no collaboration. 2D paper-based CAD drawing is utilized for rough estimation, quantities preparation, and planning) and product information. Electronic sharing of data is passed out from a common data environment, frequently managed by the contractor. As it is clearly seen in the above figure it basically contains text and minimum digitalization.

BIM Level 1(Object-Based Modelling)

This typically comprises a combination of 3D CAD for concept design, and 2D for drafting of statutory support documentation and Production Information. The designer produces a model within all stages of construction and used for 3D visualization of a project. As it is cleared from the above figure the collaboration among different stakeholders is very low.

[12] (Rossana, 2019)
[13] (Tekla Campus, 2019)

The CAD standards are managed and electronic allocation of data is handled by a common data environment (CDE), mostly managed by the contractor. The difference in BIM 0 and BIM 1 are minor in terms of processes and contractual relations[14].

Guidelines to achieve BIM Level 1

For achieving the BIM Level 1 there are some points which you need to take care and these are:

- The roles and responsibilities of all participants should be outlined.
- The standardized naming agreement should be adopted.
- Creation and maintenance of project-related codes and spatial coordination Such as Industry foundation class(IFC).
- Acceptance of CDE of Electronic Document Management System(EDMS) for data sharing between all participants.
- Setting up an appropriate information order that helps CDE and document repository[10].

BIM Level 2(Collaborative BIM)

In this stage, all participants are actively cooperating with others over a model-based collaboration process. Cooperation often occurs over a cloud-based application. This level promotes collaborative functioning by giving each of the parties its own 3D CAD model. Contractual amendments become obligatory and models can be linked to several analysis tools. Each participant work on their own 3D model and information is shared and exchanged through a common format file[15]. For achieving BIM Level 2, It is essential for the company to fulfill all the guidelines of level 1 plus a CAD software that can support common file format systems such as COBie or IFC[10].

BIM Level 3(Integrated BIM-iBIM)

At Level 3, semantically-rich network-based unified models are developed, shared and maintained collaboratively over the project life-cycle. Models in this phase become interdisciplinary nD models, when complex scrutinizes at initial stages of design and

[14] (Kjartansdóttir et al., 2017)
[15] (McPartland, 2014)

construction are permitted. Model deliverables comprise business intelligence, lean construction principles, sustainable policies and whole life-cycle costing of a project. In this stage, major changes are essential in contractual relationships, risk allocation, and procedural courses. A shared interdisciplinary model is essential to provide two-way access to project participants, which will ultimately facilitate Integrated Project Delivery (IPD). The specific details and aspects are yet to be well-defined, but are likely to be positioned around open standards and will need new legal frameworks[14].

BIM Execution Plan (BEP)

When implementing BIM Methodology in a construction project, the project stakeholder should, as soon as possible, make a strategy for how BIM is to be executed. The project management team, mainly who leads the planning process should include other stakeholders in the initial stage for implementing BIM in a project. Penn State University (Kjartansdóttir et al., 2017) (PSU) has described as BIM Execution Planning Procedure, to direct the project stakeholders on how to implement BIM. The guide helps to form a structured procedure for developing BEP. When executing BEP in a project, these four steps need to consider:

- Categorize high-value BIM uses over the various project phases, like in planning, designing, execution, and operational phases.
- Develop the BIM execution process by designing BIM process maps.
- Describe the BIM deliverables through information exchange.
- Create a strategy in the form of contracts, coordination procedures, technology, construction, and quality control and monitoring to support the BEP implementation[14].

Thus, BIM is a tool to accomplish the BEP process, and BEP simply manages the process and roadmap, on the other hand, the software is a set of the toolkit for implementing the BIM methodology in a project[16].

[16] (Hadzaman et al., 2016)

2.4 Benefits and drawbacks of BIM

Eastman et al.[17] assert that although the AEC industry and other stakeholders are being in initial days of BIM use, significant enhancements have already been realized. Hence as a part of the working strategy concerning BIM implantation, it is important to explore the potential benefits to different stakeholders and their drawbacks to deal or overcome it for project success[17].

Benefits of BIM

- **Preconstruction benefits to Owner:**
    1. The concept, design, and feasibility benefit the owner for analyzing whether a project falls under budget or not.
    2. BIM helps to increase building quality and performance[18].

- **Design Benefits:**
    1. BIM helps to develop a more accurate visualization of a model at an early stage.
    2. Low-level of correction required when changes are made to design.
    3. It helps to generate accurate and precise 2D drawings at any stage of design.
    4. An earlier collaboration of various design disciplines.
    5. Extract more accurate cost estimation at initial design state.
    6. Early check against the design intent.
    7. Improve energy efficiency level and sustainability.

[17] (Eastman et al., A Guide to Building Information Modeling for Owners, Managers, Designers,Engineers, and Contractors, 2008)
[18] (Mohammad, 2011)

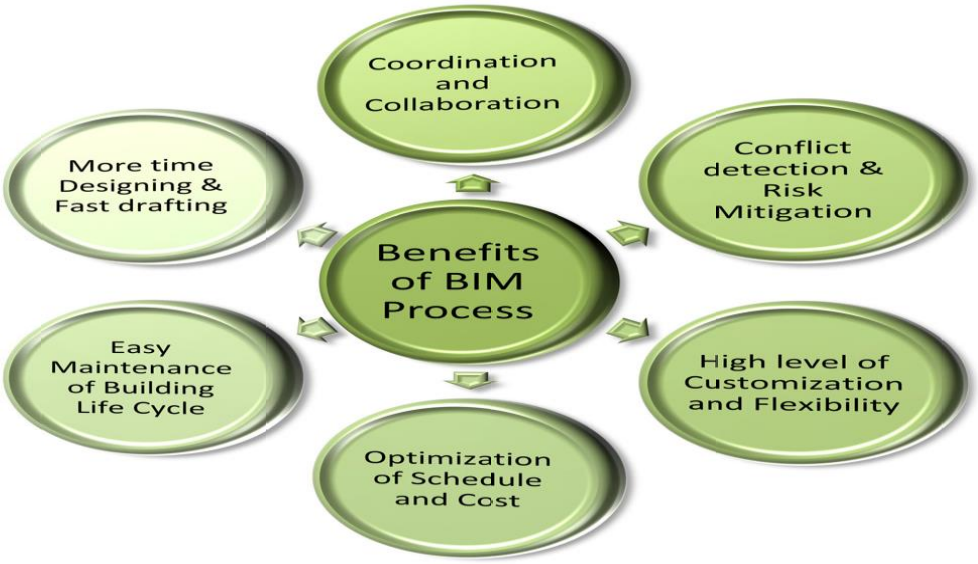


Figure 3: Benefits of BIM Processes[19].

- **Construction and Fabrication benefits**
    1. Synchronize design and construction planning.
    2. Discover design errors and omissions if any before construction execution.
    3. For the fabrications of project elements, a design model can be used directly[20].
    4. While using BIM methodology, a better implementation of Lean construction techniques can be formed.
    5. Synchronize procurement with design and construction.

- **Post-construction benefits**
    1. Better manage and operate facilities at the operational phase of a project.
    2. BIM also acts as operations and maintenance guidebook and helps the facility management team[18].

[19] (Hammad, Rishi, & Yahaya, 2012)
[20] (Chan, Olawumi, & Ho, 2019)

Drawbacks of BIM

- Incompatibility with partners, as BIM is widely known and accepted worldwide still there are companies that don't have the knowledge to deal with BIM, resultant in no use of information.
- The legal implications of using BIM tools have not yet been extensively verified, let alone settled.
- BIM software requires a considerable investment in new technology. The advantages generally make the investment profitable, but only if it is used to its full capacity
- As its trending methodology still need saturation, resultant in limited numbers of experts. Hence additional costs required for education and software.
- Lack of knowledge of BIM tools can cause errors and omission of data resultant in massive project loss[21].

2.5 Summary

After analyzing the above section, it illustrated that the BIM methodology helps to develop an information occupied 3D model for quantity take-off, project scheduling(4D), estimation (5D), sustainability(6D) and, facility management services(7D). Multidimensional(nD) features of BIM-enabled it to be the most adopted technology over the world in the last two decades. Handling all information over a single cloud helps the different stakeholders for better communication and monitoring over the project during the project life-cycle. The BIM level and LOD specifications define the project complexity and model detailing, which enables a better understanding and unique standard of processing. BEP helps to manage processes and create a road map for BIM implementation. At last but not least, it is very important for getting the full potential of BIM that all the stakeholders deal with this methodology in a project rather than using individually or partially.

[21] (Mineer, 2015)

3.Construction project management(CPM)

Project management in construction is not a new concept, It emerged in construction since the 1950s (Peters, 1981)[22]. Formerly, it was used for large projects but currently, it deals with every kind of construction project in some way. The main focus of this organization is to set specific strategies and early planning techniques for avoiding problems before arising and managing all parties to achieve set objectives efficiently and effectively[23]. In this section, an overview of the introduction, construction project management components and its processes will be discussed briefly. The fundamental purpose of this section is to familiarize readers with construction project management roles and responsibilities.

3.1 Introduction

Before digging into the detail about this vast field, it is quite obvious to know about the precise definition which tells mostly about the field itself. Walker[24] (2015) describes the definition of construction project management in an easy and understandable manner that "Construction Project Management is the planning, control, and coordination of a project from conception to completion (including commissioning) on behalf of a client. It is concerned with the identification of the client's objectives in terms of utility, function, quality, time and cost, and the establishment of relationships between resources. The integration, monitoring, and control of the contributions to the project and their output, and the evaluation and selection of alternatives in pursuit of the client's satisfaction with the project outcome are fundamental aspects of Project Management."

According to the Project Management Institute[25](2000), the CPM is the application of knowledge, management skills, tools, and techniques to predetermined project objectives to meet the project requirements. Successful project management is accomplished through various processes such as initiating, setting predetermined objectives, planning,

[22] (Peters, 1981)
[23] (Reiss, 2004)
[24] (Walker, 2015)
[25] (Project Management Institute, 2000)

executing, monitoring, controlling, and handing over. The Project management team manages the activities of the projects, and the task typically involves:

- Competing for the claim: scope, time, budget, risk, safety, quality, and client satisfaction.
- Managing different project participants with different needs and expectations.
- Identified project requirements[25].

According to Peter[22] (1981), almost fifty percent of the project planning is to offer the opportunity and motivation, simply to enable the team to think ahead about the project objectives that they are commissioning. This process creates an opportunity to tackle the problem well before coming into practice. On the other hand, project management coordination helps to deal with generating, reviewing, issuing and spreading the reports/documents and arranging regular meetings among project stakeholders so that the proposed objectives, timing, methods, strategy are made accessible and understood[26]. Evaluation of the findings is critical to improving current performance. Coordination and revision of information and messages, and transmitting to the project stakeholders is also essential to achieve the project goals. Thus, the effectiveness of the project management team to communicate with, evaluate, and respond to the rest of the participants during each stage of the project determines how efficiently the project objectives will be achieved[26].

For decades Men, Materials, Machines, Methods, and Money have been the five (5M's) key tools for construction project management (Clough, Sears, & Sears, 2000)[27]. Effectiveness in the usage of these five 5M's defines project success in the construction industry. Improvement of worker productivity and materials handling should be an important concern to every project management team for cost control and time management concerns. New methodology such as BIM, and Lean, and advance equipment's helped project management teams for implementing better management and achieving higher success towards project delivery. Project management organizations

[26] (Matheu, 2005)
[27] (Clough, Sears, & Sears, 2000)

that don’t support this methodology and new technology suffer a lot while handling a complex and big project, and out of context in the market competition[28].

Atkinson[29] (1999) described the success criteria for project management in terms of cost, time, and quality over project delivery. These three criteria mentioned in the Iron triangle helps to measure the project's success.

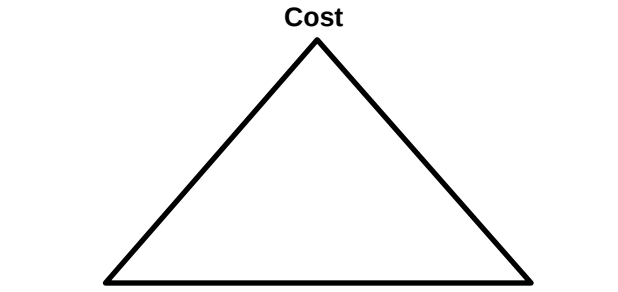


Figure 4: Iron triangle of success criteria for Project Management[29].

There are various actions that have to be taken by a project management team for successful implementation of strategy while keeping in mind the cost, time and quality parameters. These project management actions[30] are listed below:

- Communication system
- Cost estimating
- Preparation of schedule
- Control mechanism
- Feedback capabilities
- Planning effort
- Developing appropriate project processes and organization structure
- Implementing effective strategy method
- Implementing a quality assurance procedure
- Conducting regular meetings and forming a strategy
- Control on contractor and other agency’s work appointed
- Overall managerial actions[30].

[28] (Ilveskoski & Niittymäki, 2015)
[29] (Atkinson, 1999)
[30] (Chan, Scott, & Chan, 2004)

Mostly cost overruns occur through the construction phase, in which various unforeseen factors are considered over the conception/design stages[31]. Time overrun is another big task to control for project management. On the other side, Legislation enforces the required quality for the project to maintain. All these three criteria are always in mind of a project management team from conception to completion of a project. For that, a special skill of time management, cost management, and quality management are crucial for project success. Time overrun cause disputes and claims in a project which are very common nowadays. Apart from this, changes in the decision also result in claims and disputes. All these situations arise in construction project seeks a solution for settling down the issues. In that case, the scope for claim management arises. It is very common in the Indian construction industry to have lots of claims due to improper scheduling, financial issues and changes in the decision as per client wish and drawings faultiness[32]. Hence claim management also becomes an essential part of the project management team.

Here is some Limitation of existing construction project management in terms of accomplishing the functions and requirements:

- Lack of adequate communication resulted in additional expenditure due to reworking.
- Lack of integration within the supply chain causes procurement issues
- Lack of technological awareness and knowledge causes problems while processing applications and time-consuming, such as hard copy and soft copy issue.
- Lack of software integration issues
- Lack of support provided to different stakeholders[26].

3.2 Components of construction project management

There are various tasks over the project phases that need to manage by the project management team. Planning is the first task to accomplish with regard to achieving project objectives[33]. While setting up planning, CPM needs to set specific goals for the project as per client expectations. While project designing with the help of Architect, the CPM firms

[31] (Chan & Kumaraswamy, 1997)
[32] (Abdel-Khalek, Aziz, & Abdellatif, 2019)
[33] (Goubau, 2015)

need to look for legislation project requirements. After a model delivered by an Architect, a precise estimation needs to prepare by the cost management team for avoiding costing issues. Then the role of contract management comes into play for preparing the tender for bidding. Consulting with a client for calling different contractors as per their capability to handle the project is another important task done by the CPM firms. During the start of construction, the project schedule is prepared by the time management team. The project communication team helps in coordination among different stakeholders to manage different project processes. The project quality team holds the responsibility of managing project quality as per standards in all construction activities. While a risk management team manages and tackle the different construction risks[34]. Procurement management takes care of all purchasing, invoices, and handling of documents. On the other hand, the site management team looks for safety and logistics planning to avoid hazardous situations. A list of grouped members[35] or component of CPM to manages all tasks have been illustrated in the following figure.

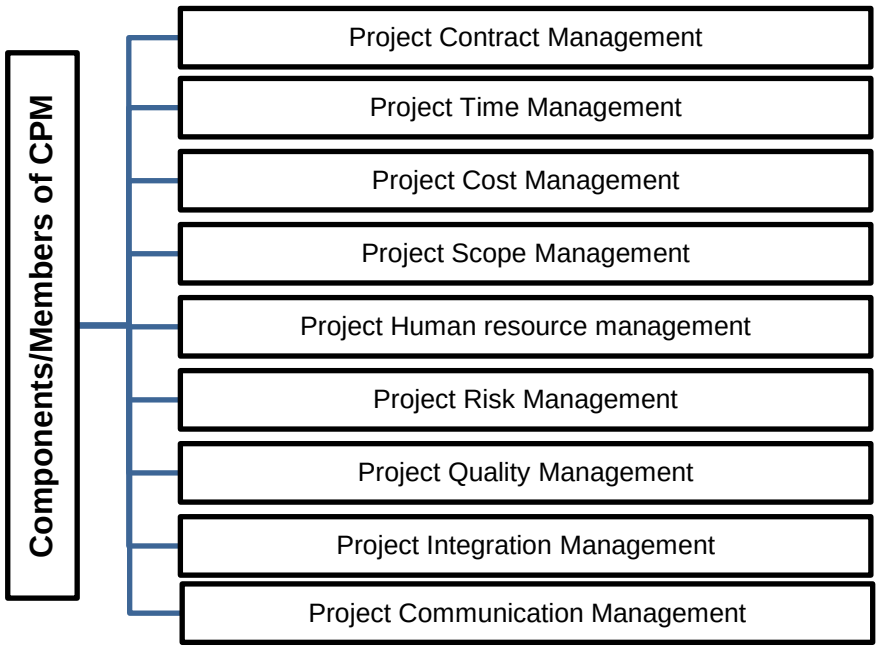


Figure 5: Components/members of Construction Project Management[35].

[34] (Wong, 2019)
[35] (Nikumbh & Pimplikar, 2014)

3.3 Processes of construction project management

All the components of CPM have their individual processes. These processes have been briefly described in the PMBOK book by Project management institute(2000)[25]. An overview of the CPM member's processes will be discussed in this sub-section. All these processes help to integrate the project activities from conception to completion of a project. These processes have been listed in the following figure.

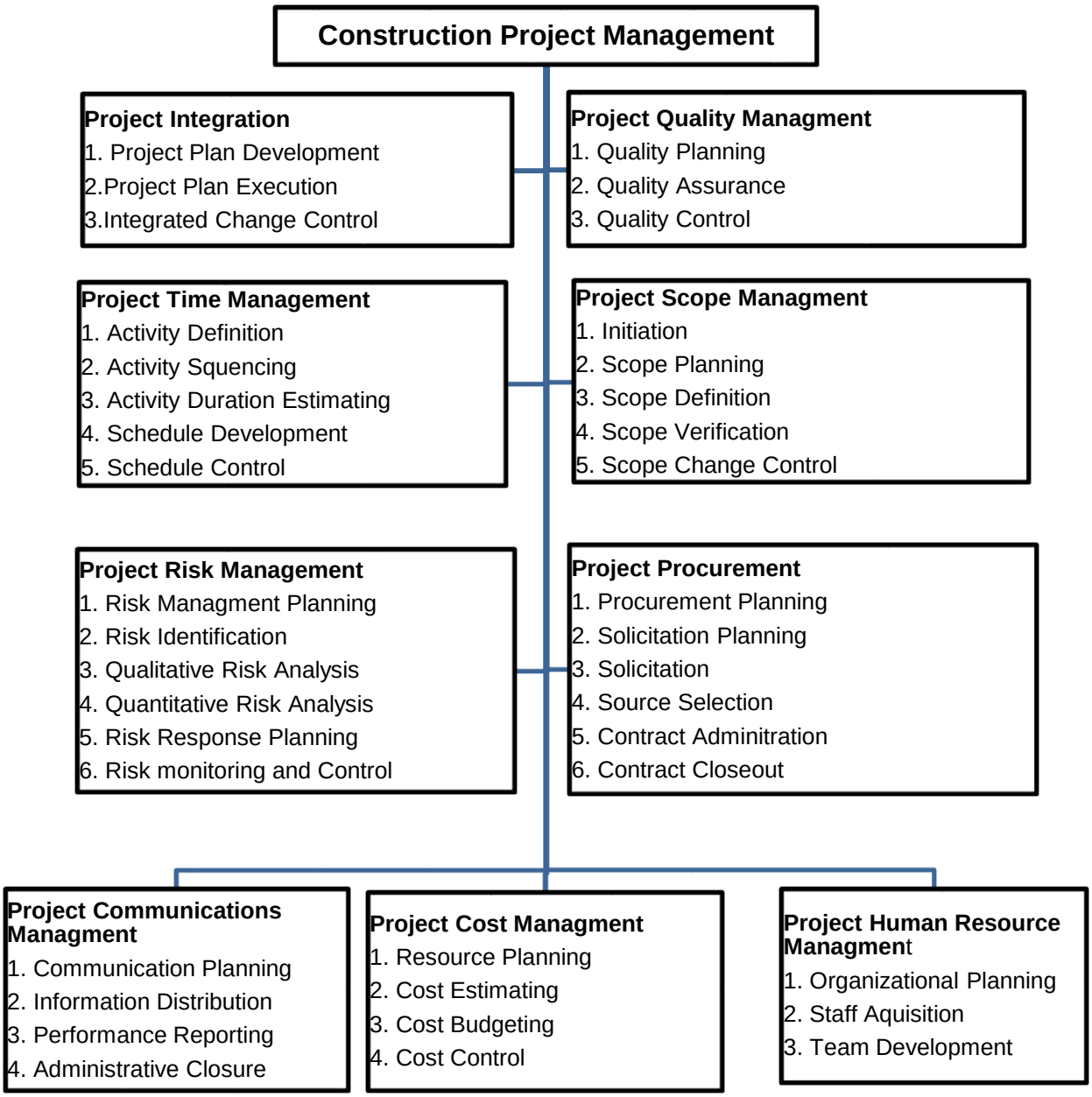


Figure 6: Overview of CPM members and their processes (Project Management Institute, 2000)[25].

According to Project Management Institute[36](2013), the CPM is accomplished through the various applications and integration of the 47 relatively grouped processes carried out by project management, further these processes are categorized into five significant process groups[36]. These resultant five process groups are defined as:

- Initiating
- Planning
- Implementing
- Monitoring and Controlling
- Handing over

Managing a construction project generally includes, but is not limited to:

- Identifying the roles, requirements, and scope of the project.
- Addressing the different needs, concerns, and expectations of the participants in planning and executing the project activities.
- Setting up strategy, keep communicating and maintaining coordination among participants that are active, effective, and cooperative in nature;
- Managing different participants towards project requirements, and delivering project deliverables towards set goals;
- Balancing the competing project constraints, which include, but are not limited to project scope, quality assurance, costing, scheduling, resources, and project risks[36].

The specific project characteristics like objectives, scope, type, and circumstances can influence the processes on which the project management organization needs to take care of. For that, it is quite essential before commissioning real construction to identify the main project activities to be undertaken for project success and to avoid cost overrun, time overrun, and quality issues[37].

[36] (Project Management Institute, 2013)
[37] (ISO, 2017)

3.4 Summary

After the literature review of this section, it concluded that there is no unique solution to what the knowledge field is important for managing a project successfully. Every project is unique in itself, hence requires special attention for achieving objectives. Although, some of the management strategies and knowledge needed to manage construction projects are unique or almost unique, on the other hand, some projects require a lot of effort to manage a project. A professionally occupied project management team helps to manage the project deliveries through appropriate methodology and strategies. Knowledge of managing construction projects by project management are resultant of general management and technology management.

It is quite difficult to achieve project objectives and to avoid cost overrun, time overrun and quality issues in a construction project. Secondly, managing unbiased coordination among all the stakeholders, and their requirements and expectations are the second important task handled by the project management team. Defining goals as per client expectations and bringing into reality through proper planning, execution, controlling, and monitoring the project activities is another important task for the CPM. Nowadays, it is in the trend to construct the skyscrapers and complex projects consist of thousands of processes, hence it requires a professional project management team who has the special knowledge of new technologies and methodology for efficient and effective execution of project deliveries.

4. BIM methodology vs Conventional methodology in CPM

The methods and processes in the construction projects that have traditionally been used by CPM for the project deliverables have always had various handicaps that are now somehow solved with the implementation of the BIM methodology. By defining, the various construction processes into different dimensions(nD) such as 2D,3D,4D,5D, etc., can help to distinguish both methodologies. The conventional methodology in CPM focuses the project in a unique approach in its reference, but in an entirely detached way in terms of methods, processes, and a single database[38]. The conventional methodology approach of Design-Bid-Build, separate the role of all stakeholders during various phases. in other words, it obstructs the cooperative involvement of construction participants like construction managers and general contractors during the design phase[39].

It can be easily understood through the following figure that each stakeholder coordinates direct to the process involved member-only, and other members have no updating in conventional methodology, resultant in opaque and sometimes unnecessary processing. On the other hand, BIM helps to develop a single cloud space that can carry all the information, resultant in more transparency in a process as well as merging the same information-carrying through all stakeholders. Through BIM methodology, not only the process related members but also all the project participants can visualize the updates or changes within a fraction of the second[14].

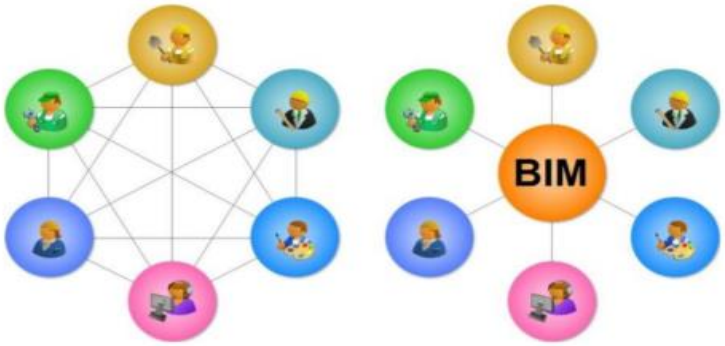


Figure 7: Conventional process versus the BIM process[14].

[38] (Granero, 2017)
[39] (Heregunsel, 2011)

Section 2 of this thesis work describes the functionality, usage, and potential benefits of BIM methodology and section 3 defines the role of CPM and its conventional approach of handling the construction project. A literature review of the preceding two chapters helps to differentiate between the conventional methodology and BIM methodology executed by the CPM firms and has been illustrated in the following table.

Exemplary use	CPM with the use of Conventional Methodology	CPM with the use of BIM methodology
2D (Planes)	A 2D plane has no correlation with other project sections, which means they are designed separately, resultant if any change or revision has to made in any section then other dependent sections need to review carefully by the project management team.	Through this methodology, the task for the project management team gets a bit easier as the 2D planes are automatically generated from a 3D model in which every component is interlinked, resultant in an automatic update on dependent sections.
3D (Visualization)	The 3D model allows the project management team to visualize the project volumetrically, it means in terms of information and interrelation between the elements, it doesn't compose any information. Hence requires a lot of effort by the CPM team for combing the information manually.	3D visualization is another benefit that can be extracted from the BIM methodology. BIM model possesses all the information about its elements. Hence gathering information about the materials and quantities is quite easy to extract.
Quantity take-off	As the model is not linked with any material specification in this methodology, Project management needs to calculate all the quantities manually. Resultant in the chance of errors while measuring quantities is more and extra time-consuming.	All the materials specifications are fed into a model while designed by the designers, hence it requires very little time to extract these quantities more precisely by a project management team.

Estimation(5D)	Estimation is yet another difficult and time-consuming task for the project management team because there is not any involvement of designers while calculating the costing of elements. On the other hand, if any revision in materials specification is required for keeping the project in budget then it is quite difficult to calculate revised costing as it needs to done manually.	In this case, it is also quite easy for the project management team because all the hard work is done while designing a model and putting the elements information by designers. Hence more accurate estimation can be done with no time and if requires any modification in materials it is also easy for preparing the new estimation for finalizing the model elements specifications.
Scheduling(4D)	In this methodology, firstly the quantities are prepared manually by project management and then in scheduling software, these quantities and their resources with production rates are inserted manually which requires a lot of time. On the other hand, the real-time visualization in the model is not available hence it is quite hard for CPM to explain the project progress to the client and other customers. Additionally, if any changes are made to model quantities, entire new scheduling needs to revise carefully because there is no linkage of schedule with the model.	By linkage of resources and activities duration to BIM models helps to visualize the real-time construction project through the model itself. Hence it is quite easy for the CPM team to explain the project progress. On the other hand, any changes in the activity quantity help update the entire scheduling automatically because of the integration of the model with its processes and duration. This extraordinary feature of BIM helps in controlling and monitoring construction activities more precisely.
Energy Simulation(6D)	Energy simulation and sustainability analysis of project elements are not done intensively by CPM, these tasks are carried by experts and planners, and only report analysis reviews by the project management team.	Implementing BIM can also help, CPM firms to perform energy simulation and other sustainability checks with the help of energy simulation software like Revit, ArchiCAD, etc. Hence CPM firm has more control over the sustainability of the project through BIM acceptance.

Facility Management Services (7D)	As all the documentation is done manually, there always some coordination issues regarding drawings and services to the facility management team.	All the information is stored in a single cloud and in the digital model which is very helpful for the facility management team to extract the exact information requires for operational purposes.
Clash Detection	This is another important task that needs assistance from the project management team. Firstly, all the hard copies of architectural, structural, and other services drawings printed out for inspection by the project management team. All the sections, plans are checked carefully to avoid the omission of clashes that can cost a lot after occurring in real construction. Even though there still chances of omitting some clashes because of carelessness or some other reason, resultant in claims, disputes, and a money loss for redoing the work. Hence it requires special attention from the project management team.	Another important feature of BIM implementation to detect clashes among all services within the model itself. Hence a lot of time, papers, and manpower can be saved for this process. On the other hand, it is more accurate than manual inspection, which means no accidental clashes among all activities at construction. But for this feature, it is important that the BIM model should be designed in software that can extract (IFC) files, which can be viewed for clash detection in Solibri model checker.
Documentation	Mainly documentations are recorded manually, resultant in heavy storage, and unnecessary data collections that can mislead the processes progress. Hence it quite difficult to manage documentation in large and complex projects.	Mainly information is linked in the BIM model and in a single cloud, Hence any revision and updates can be seen by all participants, resultant in less trouble while maintaining coordination and managing documentation.
Coordination with Stakeholders	As all the processes are not linked with each other's, resultant in less transparency among processes. Hence coordination issues arise quite often, and quite difficult to manage all the stakeholder's requirements and	BIM implementation enables more transparency among all the processes resultant in fewer coordination issues. It also helps the CPM team to meet the client and other stakeholders requirements and expectations.

	expectations by the project management team.	
Software and tools	Successful implementation of the project can be achieved with little knowledge of new technology and software but requiring more manpower, time because managing all the processes manually.	Special skills required by the project management team for the successful implementation of BIM in a project. It requires extra expenses for managing BIM software. While using it to its full potential, BIM helps to save money, time as well as raise status in the AEC industry.

Table 3: CPM processes with conventional methodology vs. BIM methodology.

It can be seen from the followed table that the role and approach of CPM firms for managing various tasks in the project will change, even their attitude towards strategy implementation also changes in BIM methodology but the tasks and responsibilities somehow will always be the same as it was in conventional methodology accepted by CPM. On the other hand, it requires initial training and additional expenditure on BIM technology for getting overall benefit from the project processes. BIM methodology not only beneficial for the only CPM but can be beneficial for all the stakeholders and project itself in terms of quality, cost, and sustainability if it is used to its maximum potential. It would be recommended to CPM firms that see BIM methodology as an expenditure with overall savings rather than see it as a cost. The successful implementation of BIM methodology helps in all directions for achieving project objectives, hence it is a very useful tool in this era for the CPM firms to remain on the client's first choices in this competitive world[40].

[40] (Yalcinkaya & Arditi, 2013)

5. Implementation of BIM in India

The objective of this research work is to elaborate on the real potential of BIM methodology in the Indian construction industry. In chapter second, the potential impact that BIM can bring into the AEC industry was elaborated. In chapter third, the role and responsibilities of construction project management have been exploited in a project. Now it is crucial to research the standards, constraints, status of BIM methodology in India to form a linkage with previous sections to approach towards achieving the thesis objectives. Hence this section highlights the available, and significant research information about the BIM implementation in the Indian construction industry. The first subsection describes the status of BIM implementation in India as well as worldwide. The second subsection illustrates the BIM trend in India, then the BIM standards and constraints are discussed in the following subsections.

5.1 Status of BIM implementation

Although BIM methodology has been adopted by the AEC industry in many developing countries since the last two decades, the Indian AEC industry seems to be behind for implementing BIM methodology appropriately in construction procedures. In order to recommend a strategy to the Indian AEC industry for the successful implementation of BIM technology in construction processes, this research highlights the current state of BIM knowledge in the Indian industry as well as the problems faced by the AEC firms to implement this high potential technology to their construction environment. For that, it is quite essential to review the current status of BIM implementation in India, and at which level it is adopted so far as compared to the rest of the world[41].

5.1.1 BIM in India

This research work will reveal how the AEC industry, real state, and infrastructure developers in India are adopting, executing and deriving value from BIM. Expecting over 70 percent of the built environment projects required in India is yet to be built[42]. This expected development for urbanization requires a high volume of construction projects in the coming years emphasizes the significance of increased collaboration in the public and

[41] (Nanajkar & Gao, 2014)
[42] (Sawhney, 2014)

private sector to meet its ambitious objectives in a sustainable way. While many countries around the world are already implementing Level 2 BIM, emerging countries like India are still struggling while implementing BIM to its full potential and mostly used in the designing phase, not in construction and Facility Management (FM)[43].

In India, some major companies are offering BIM services to overseas companies like 3D BIM services, Virtual modeling, Quantity take-off, and much more. These services at comparable low pricing make India a primary destination for BIM outsourcing at the Global level. As far as BIM implementation in India is restricted to only design not passed forward to construction and FM activities. Recent initiatives established by the Indian government, like Make in India and the urbanization approach, are serving to grow the Architecture, Engineering, Construction, and Operation (AECO) firms, however, legal action for implementing BIM services from the government has not been laid in place yet[44].

Recently constructed major public projects in India using BIM methodology are:

- Amritsar Rapid Transit, Punjab: An infrastructure project consisting of various activities like 3D modeling, 4D scheduling, planning, and construction was carried through BIM technology.
- Bangalore Airport, Karnataka: Autodesk BIM 360 was executed for designing and planning.
- Nagpur Metro Rail Corporation, Maharashtra: Implementing 5D BIM technology.
- Delhi Metro Rail, Delhi: Implementing 4D BIM for underground track construction[44].
- Power plant, ‘Vidharbha’.
- Navi Mumbai International Airport[45].

Apart from the abovementioned public projects, there are various private projects currently implementing BIM technology in India. In India, the surveys and statistics about the BIM implementation are rare. On the other hand, there is no official information about BIM usage in governmental statistics. This indicates that BIM methodology still has little

[43] (Paul, 2018)
[44] (Sharma, 2018)
[45] (Amarnath CB, 2017)

acceptance nationally. Therefore, the research work concentrates on evaluating the two major surveys including expert interviews conducted by RICS[42], school of the built environment and India BIM Association(IBIMA) [45] to reach about the current status of BIM technology in India.

The first survey was conducted by RICS, school of the built environment in 2014 with the help of a survey tool called Survey Monkey, they were able to manage responses from 365 people nationwide from the AEC industry. Apart from the survey, they have done interviews with 40 experts in the Indian major cities. Then the data collected from the survey and through interviews were carefully analyzed through experts for better evaluation. These 405 respondents belong from different disciplines such as BIM consultants, architects, construction management(CM), contractors, developers, etc. as shown in the below figures with their working experiences[42].

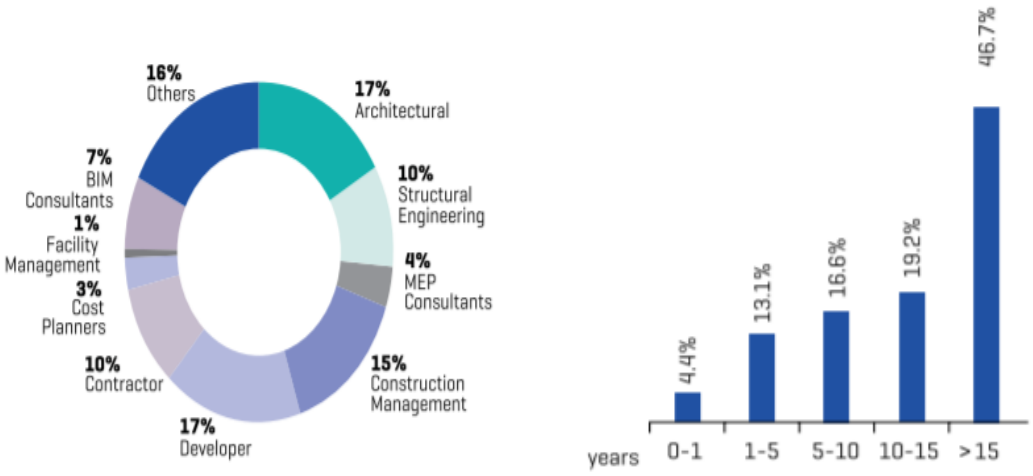


Figure 8: Profile of respondents and their experiences in the AEC industry[42].

The above figures demonstrate that more than 83% of respondents possess at least 5 years of experience in their respective disciplines. The biggest group in respondents was from architectural, developers, CM, and structural engineering firms among other disciplines. On the key questions of BIM implementation in the organization, 22% of participants reported that they are actively using BIM in their processes while 27% reported they are aware of BIM technology and actively considering usage.

On the other hand, 43% of respondents claimed BIM awareness but not sure about BIM implementation in their workflow as they are more confident to deal with their conventional approach of handling processes. Surprisingly, only 8% of respondents were not aware of BIM usage. The survey elaborates that BIM usage is getting acceptance day by day in their respective disciplines. Almost one-fifth of respondents started using BIM in their processes since last year, while almost half of respondents claiming BIM usage in their organization for the last five years. On the other hand, 34.6% of respondents having more than 5 years of BIM experience. Some respondents are not using BIM only on the national level but also serving Global services[42].

On questioning about projects done using BIM technology, 26.9% of respondents finish under 10% of their projects using BIM services. While 23.1% claimed that 10-30% of projects were managed using BIM. On the other hand,17.9% of respondents believed that they handed over 30-60% projects using BIM services, surprisingly one-third of respondents believed that they used BIM methodology in half of their projects. On asking at which stage BIM usage in project phases, 48% of respondents use BIM methodology for concept and schematic design, and 80% use BIM for design development. Surprisingly 60% BIM accepted in construction processes. On the other hand, 36% BIM usage for procurement and tendering processes, and only 12% is used for facility operations. The survey states about BIM software usage is well. It describes 79.2% Autodesk Revit usage for BIM services. Autodesk Naviswork is another popular BIM software with 40.9% usage followed by Sketchup with 37.7% usage for BIM services. Apart from listed above that Graphisoft ArchiCAD, Bentley Microstation, Trimble Tekla are other software used for BIM services[42].

The second survey was conducted by IBIMA in 2017 to analyze the hurdles for diffusing BIM technology to the Indian construction industry. A total of 140 respondents from 26 different locations on the national as well as international level have successfully participated in the survey. Apart from India, other respondents currently working with BIM organizations in developed countries such as Hong Kong, Singapore, Australia, Dubai, Qatar, and Abu Dhabi. Here also the biggest group in respondents was from design (46%), developers (23%), CM (12.6%), structural engineering, government organization firms

among other disciplines. One-third of respondents claimed that their organizations involved in more than 20 BIM projects, while almost 40% of respondents have involvement in less than 5 BIM projects. Rest involved in between these numbers in terms of dealing with BIM projects. On asking about the BIM-related employees' strength in their respective organizations, almost half of respondents stated that their strength of BIM employees in the organization is more than twenty, while one third have strength less than five employees. 54% of respondents used BIM technology for design and visualization while only 14% integrate with time and scheduling[45].

After evaluating the surveys conducted by two recognized BIM organizations, there are some points to highlight. First of all, these surveys evaluations were based on 100-400 participants' reviews hence cannot be assumed Universally valid but somehow it can believe that the result lies in between the figures mentioned as both surveys shows similar kind of results. Secondly, there are still many questions about coordination problems, stakeholder's mindset, problems while adopting BIM technology, are still needs to address for better evaluation of BIM acceptance in the Indian market. The future looks promising for BIM acceptance with bright construction scope in India, and more acceptance of BIM technology in the last decade. It seems, in the next 5 years BIM can impact Indian construction considerably as it did in the other developed countries like America, Australia, United Kingdom, Scandinavian countries, etc.

5.1.2 Worldwide

BIM adoption is spreading continuously across the globe through the active involvement of both the public and private sectors in the AEC industry. The public sector plays an important role in adoption, imposing BIM standards for encouraging BIM growth in the AEC industry. On the other hand, currently, no comprehensive steps for BIM adoption are set in the Indian public sector resultant in less acceptance as compared to other countries. This subsection highlights the status in four different regions- the United States, Asia, Europe, Australia, and their efforts in public sectors for successful BIM implementation[46]. Developed countries across these four regions have understood the need and benefits of

[46] (Cheng & Lu, 2015)

BIM methodology in the construction industry, hence encouraging the AEC industry for BIM adoption to its full potential for sustainable usage and better collaboration[47].

The United States stands top among other countries for implementing BIM technology and setting up BIM strategies and national BIM standards at various levels. From national organizations (public and private sectors) to public universities all actively contributing to BIM implementations. In 2006, the United States Army Corps of Engineers(USACE) established the first road Map for BIM implementation. While the General Service Administration(GSA) set a goal to use the IFC file for better design quality, coordination, and construction delivery. In 2009, the Veterans Affairs(VA) also mandated BIM usage for all major construction, and rehabilitation projects carrying budget over $10 Million. In 2014, the National Institute of Building Sciences(NIBS) presented Construction Operations Building information exchange (COBie) for better collaboration and information exchange among stakeholders. Till 2015, there were 47(17 from government organizations and 34 from nonprofit public organizations) BIM standards imposed by public sectors at state and national levels[46].

The following table illustrates the BIM standards and guidelines established by public sectors at the organization or country-level in four mentioned regions and their timeframe for establishment. The United States stands top across other regions with the publication of 47 standards and guidelines followed by Europe with 34 BIM standards published. On the other hand, the Australian public sector established eight standards until 2015. While BIM implementation across the Asian countries getting more acceptance day by day. The table illustrates the involvement of Indian public agencies while setting up BIM standards, and encouragement for BIM growth is still missing. There are several studies that illustrate the stark contrast of BIM adoption across many countries. BIM adoption in the United States is 71%, 61% in Australia[48], 62% in the UK[49], 36% in Europe, and 25% Middle-East[47]. On the other hand, BIM adoption in India is 10-18%[42].

[47] (Wu, Li, & Wang, 2017)
[48] (McGRAW HILL CONSTRUCTION, 2014)
[49] (NBS, 2017)

Region	Country/Organization	Year	Nos of standards published by public sectors		
			Gov. Org.	Nonprofit Org.	Total
The United States	Nationwide	2007-2015	9	15	24
	Statewide and citywide	2009-2013	8		8
	University-wide	2009-2013		15	15
	Sub-total		17	30	47
Europe	United Kingdom	2007-2015	3	15	18
	Norway	2008-2013	4	2	6
	Finland	2007-2013	2	1	3
	Denmark	2007		4	4
	Sweden	2009		1	1
	Netherland	2013			2
	Sub-total		9	23	34
Asia	Singapore	2008-2013	12		12
	Korea	2009-2011	5	1	6
	Japan	2012-2013		3	3
	Mainland China	2013-2015	4		4
	Taiwan	2010-2014		4	4
	Hong Kong	2009-2014	4	2	6
	Sub-total		25	10	35
Australia	Nationwide	2009-2015	3	5	8

Table 4: BIM standards/guidelines in different regions across the world[46].

BIM strategies and implementation issues in BIM adopted Countries

In any nation, while adopting a new technology the public sector plays a vital role in its growth such as for BIM methodology. As mentioned in the followed paragraph the developing nation's public organizations provide encouragement and set standards/guidelines for BIM growth. There are many countries that are using BIM at some level but still not aware of their full potential usage. While in the US, organizations facing problems for analyzing the level of development and maturity map criteria[46]. On the other hand, there is inadequate understanding and evidence of BIM maturity tools in UK

construction available. This maturity tool maybe not fit to purpose hence a duplicate work can be done from start in other organizations in the same project[50]. Six major roles of public organizations for BIM adoption has mentioned in the below figure and which is vital for accepting BIM methodology.

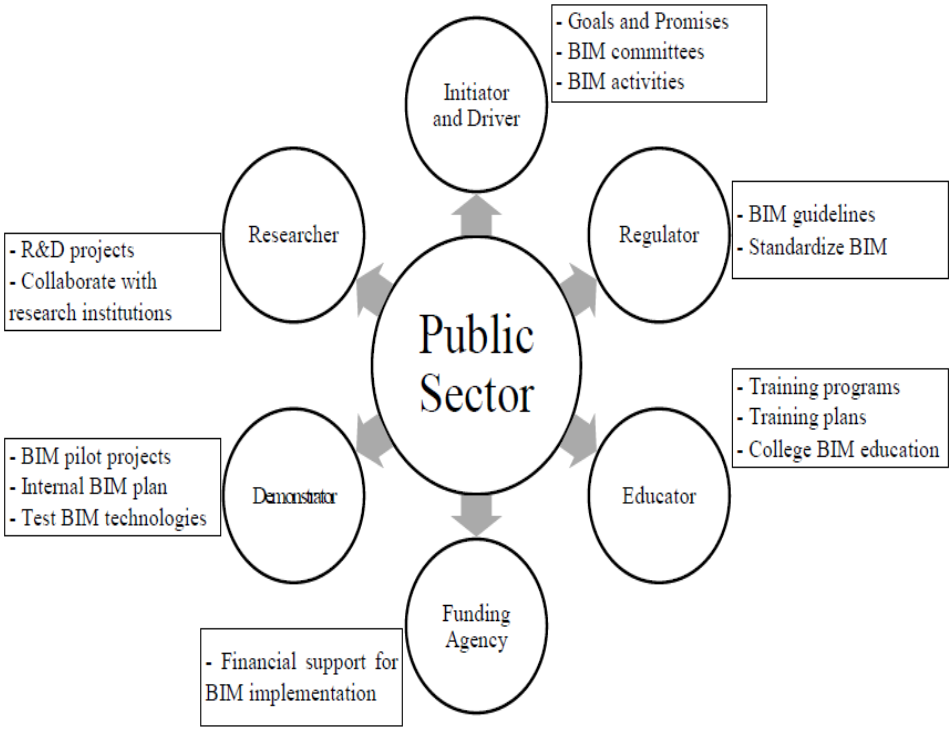


Figure 9: Roles of Public organizations for BIM adoption[46].

Factors while considering BIM adoption in various countries

There are many factors that can influence the usage of BIM and can restrict its acceptance. These factors can affect the decision making but after overcoming these issues BIM adopted countries have seen the benefits of BIM technology and looking to utilize the full potential of BIM technology for high project life cycle savings, better quality, avoiding coordination issues in a sustainable way[50].

[50] (University Cambridge, 2019)

Factors	Constructs	Definition	Issues/Problems	Strategies to overcome issues
Technological factors	Complexity	When new technology is relatively complex to understand and use	The full potential of BIM is unclear	Consistency with existing beliefs, needs, and values
	Compatibility	At which level the innovation is consistent with its existing needs, belief, and values	BIM software is complex to use	Availability of BIM software, guidelines on trial basis
	Trailability	At what extent the experimentation trail is available for BIM innovation so its benefits can be analyzed	BIM usage is a complex process	Encouraging attitude towards BIM
			Lack of process standardization	
Organizational factors	Top management support	The supportive climate and resources available from Top management help to adopt new technology	High setup cost	Compatibility with existing beliefs, values, and practices
	Perceived costs	It is related to setup cost and system usage related costs. The less perceived cost can help for more acceptance towards innovation	High training and maintenance cost	Top management support
	Expertise	Experts help to adopt any new technology and allow to grow	Lack of awareness	
			long time required for using to full potential	
			Non-availability of BIM expertise	
Environmental factors	Trade partner readiness	Good partner relationship helps for accepting new technology for coordination and collaboration	Lack of government encouragements and incentives	BIM readiness by project consultants
	Client requirement	Owner willingness and innovativeness means a lot for adopting any new technology	Lack of BIM knowledge within stakeholders	Existing sustainable regulations helps to BIM adoption
	Regulatory support	standards and guidelines help to understand and work with the technology more faster	clients do not want to spend money on BIM	

Table 5: Factors affecting BIM adoption and its problems and solutions[51].

5.2 Scope of BIM in India

The goal set by the Indian government to provide housing and sustainable infrastructure facilities to the public until 2022. This encourages the high demand in Indian society for planning, design, and construction in the coming years. On the other hand, 'Make in India' and 'Digital India' campaign set by the Indian government supports BIM technology to grow in the AEC industry for better quality, coordination, and less corruption through

[51] (Ahuja et al., Factors influencing BIM adoption in emerging markets – the case of India, 2018)

digitalization. International companies such as Graphisoft and RIPL are trying to spread BIM software and its training to deal with BIM methodology in the Indian construction industry for creating a positive BIM environment. With a small investment over the BIM training and Archicad software, just .05% of project costs can resultant saving up to 5-7% of the project cost[52]. With the government stabilization and rising economy encourages the international firms to set their industries to the Indian market which also inspires the AEC industry to deal with internationally accepted technology[53].

According to the latest statistics report presented by Minister of Statistics and Programme Implementation[1], at least 355 Indian projects have faced cost overrun around 3,880 Billion Indian rupees around 20.52% of original project cost and about 552 projects have faced time escalation. With respect to these concerns of project delay and cost overrun, National Institution for Transforming India (NITI) Aayog official said BIM could save up to 20% of the project cost by shorting the construction time. NITI Aayog the government 'think tank' in addition to implementing BIM technology for government upcoming housing projects they also considering this technology to be adopted by all other ministers for other infrastructural projects such as National highways, airports, railways stations, and metro stations[2]. While Mr., Sunil MK, Head of the AEC at Autodesk India during an interview with the economic times stated (Haidar, 2019) "Even though BIM acceptance in the Indian industry is growing over the years but much more needs to be done for the healthy growth of world accepted technology. BIM has the capability to manage large and complex projects more effectively through cost and time reduction and reduces the negative impact on the environment beforehand."

The status of BIM implementation discussed in the above subsection also indicates the steady growth in BIM acceptance in the last few years. on the other hand, the two surveys conducted by the recognized institutes also highlight the story that how BIM is getting famous among the AEC firms. After analyzing both surveys it can be concluded that the BIM usage is more adopted during design, planning phases and still struggling its way to construction (4D BIM & 5D BIM), coordination, and information exchange. BIM usage in

[52] (REPL, 2019)
[53] (Geospatial World, 2016)

the design and planning is resultant of globally offered services to the Indian consultants, and struggle in further processes is resultant of the unwillingness of the client's interest in paying more for design and lack of expertise at the construction level. Even though BIM is getting more acceptance in public projects mentioned in the above sub-section. All this information, future construction demand, and public sector involvement in BIM technology make future promising for the BIM industry in India. As BIM acceptance is flourishing it is evident that BIM technology will soon be a substitute to the CAD systems[54].

5.3 Construction standards for BIM in India

BIM methodology has received a different level of acceptance across the globe. In the United States, the United Kingdom, and Singapore like countries not only accepted but also mandated BIM usage in public, and on large scale projects. The GSA in the US has mandated for planners to design the BIM model for spatial validation in 2007[55]. Subsection 5.1.2, describes that the US has established 47 BIM standards/guidelines for BIM usage. While selected four regions for BIM status highlights 124 BIM standards and guidelines already have been in use to grow the BIM industry. On the other hand, the BIM industry in India has not yet supported by the Indian government[56]. The missing encouragement from the public sectors highlights the rare acceptance of BIM technology in India as compared to other developing countries.

Indian Building Information Modelling Association(IBIMA) is the first non-profit registered organization in India that encourages the AECO firms to understand and work with the BIM environment. The IBIMA serves, advocate, supports the BIM interested organization on the behalf of Indian BIM community[57]. The mission is to aware of the AEC firms, and clients about BIM technology and its real potential that can enhance the project quality by avoiding time overrun cost overrun and coordination issues.

For the bright future of the BIM industry in the Indian market is it essential for the Indian government to review the BIM methodology success in developing countries and its

[54] (Isac & C K, 2019)
[55] (Kumar & Mukherjee, 2009)
[56] (Ahuja et al., Adoption of BIM by architectural firms in India: technology–organization–environment perspective, 2016)
[57] (India Building Information Modelling Association(IBIMA), 2019)

contribution towards digitalization and development. This can help the Indian public sector to understand the real potential of BIM technology. Through the BIM analysis over the developing countries in section 5.1.2, it can be believed that establishing the BIM standards/guidelines can convince people to use BIM in their processes to overcome corruption and claim issues.

5.4 Constraints while adopting BIM methodology in the Indian construction industry

Conventional processes in the Indian construction industry are in use for decades, hence it is not easy for any new technology to come in action without facing any barriers. To adopt new technology in industrial usage it takes a long time as well need to face multiple barriers and need to validate the potential benefits to each individual project participants. These constraints and challenges can be any of any type but in this research are categorizes them into four major groups such as technological constraints, economical constraints, legal constraints, and social constraints.

5.4.1 Technological constraints

Technological aspects categorize into the first barrier to implement the BIM methodology into the industry. Whenever a new technology enters the market it has to face many technological constraints such as hardware issues, software availability, and knowledge to deal with before getting industrial acceptance. Mostly project stakeholders are used to working with conventional tools and data transfer through digitalization is rare. Secondly, incompatibility and inconsistency in the transmission of information are other technological barriers that need to resolve[58]. The shortage of BIM experts and guidelines into the market also restricting BIM usage. Due to high complexity in BIM methodology, an omission or modification of data can change automatically all other linked information's into the project, hence self-belief and assurance of the data accuracy also affect the decision of accepting BIM technology into the project. Lack of experience while working with this advanced innovation can cause enormous mistakes resultant in heavy losses. BIM is known for multidimensional (nD) features of the design, planning, scheduling (4D), costing(5D), and much more but at the same time as they are linked to each other sequences hence any

[58] (Migilinskas et al., 2013)

lack ness can be resultant of the inefficient result. A complete change in workflow also scares users to adopt any new technology[59].

Another approach to persuading project participants to use BIM methodology is the accessibility of run-time examples of projects executed using BIM technology. If project participants and firms have access to analyze a real sample of BIM-implemented project, their belief to execute their processes using BIM technology will increase[60].

5.4.2 Economic constraints

In addition to technical constraints here is another categorized barrier defined as economic constraints, which also identified as one of the biggest barriers for BIM success. While implementing the BIM technology into a company or in specific projects, it requires a lot of encouragement from a company to invest a considerable amount of money for software, hardware, and training a team requires a lot of time. The expenditure at the start without getting initial BIM benefits measured as the real challenge for bringing BIM into use. The money spent on BIM methodology at the start should be weighed against potential benefits[61]. The BIM communities, BIM project executed analysis, and public organizations should come forward to set strategies to encourage clients for adopting BIM methodology and looking benefits in the long run[62].

While understanding the Indian market there are another two challenges that can also be identified under economic constraints such as small-scale projects, and corruption. In the first case when the projects are small then BIM has seemed like a not profitable method as it can unbalance the project budget and its return on investment can also be less[63]. Corruption is the second threat especially in India for BIM growth in the public sector as BIM enforces processes and project data to run through in a digitalized and transparent way. Hence chances for corruption in the form of fake quantities, bidding prices, and claimed issues can be squeezed to at large extent. But India's prime minister campaign

[59] (Knight, 2013)
[60] (Sardroud et al., 2018)
[61] (Lymath, 2014)
[62] (The B1M, 2015)
[63] (Kushwaha, 2016)

of ‘Digital India’, a battle against corruption already started in 2015[64], and BIM can be used as a real weapon against corruption in public projects to overcome corruption issues. On the other hand, it is quite hard for adopting BIM technology for medium and small-sized organizations because of initial high investments, while market competitions and latest technologies developing high pressures to these small firms for keeping themselves in the market. As these investment problems are really not affecting big companies public sector should encourage and help small firms financially to adopt new technologies for overcoming time overrun, cost overrun, and dispute issues[65].

5.4.3 Social constraints

While considering BIM implementation in the AEC industry another constraint that needs to highlight is social constraints. Society and professionals' approach towards adopting a new technology that can change the entire scenario of processing their tasks can be another challenge to project participants. BIM has shown its full potential only if it adopted by all participants and used effectively for collaboration and coordination. Collaboration between project participants through BIM technology indicates involvement in terms of cost, planning, effectiveness, and efficiency. This can be achieved only if users are ready to adopt new technology and society is ready to set BIM awareness strategies through training programs conducted at university or national level organizations[66].

Section 5.1.1 has described the current status of BIM in India as well as professionals' opinions on BIM adoption through two conducted surveys by recognized institutes, it seemed BIM adoption highly influenced through personal attitude and their opinion on BIM adoption. Many professionals in the mentioned surveys have experience over 15 years and confident to deal with the 2D drawings and paper-based methodology for coordination and collaboration purposes. Hence it is quite obvious for them to change their working procedure and come into digitalization from nowhere in the short term

[64] (Ministry of Electronics & Information Technology Government of India, 2015)
[65] (Yoshino & Hesary, 2016)
[66] (ZIGURAT GLOBAL INSTITUTE OF TECHNOLOGY, 2018)

workload[67]. Another factor of less acceptance is a shortage of BIM experts and BIM findings at the national level which can encourage people to use advanced technology.

BIM behavioral risks that can be identified under coordination issues, collaboration issues, and efficiency level of participants among all participants can arise hurdles in project success hence should be mentioned within contractual issues[60].

5.4.4 Legal constraints

The last categorize constraint but not least is termed as Legal constraint which can influence the decision of BIM adoption. As discussed in section 5.1.2, BIM is mandated in many countries over public projects as well as private projects over a certain budget. Hence if it enforces by law for project approval then BIM adoption is quite obvious to use and helps the BIM industry to grow. On the other hand, public bodies need solid proof that BIM can serve the essential requirements set by the government under available facilities. But these guidelines and standards as mentioned in section 5.1.1 are currently missing in India resultant in less acceptance of BIM technology.

A recent survey conducted in the AEC industry reveals that around 40% of BIM participants[60] are not aware of BIM standards forms of contract resultant in custom manuscripts in their project contracts and uncleared parties' roles in BIM uses. BIM adopted countries have set BIM agenda contracts in their project contracts for creating more transparency in BIM uses. Lack of BIM standards and unclear legal liabilities[67], responsibilities of inaccuracies, and license problems[68] are other big challenges for BIM acceptance.

[67] (MEGANATHAN & NANDHINI, 2018)
[68] (Liu et al., 2015)

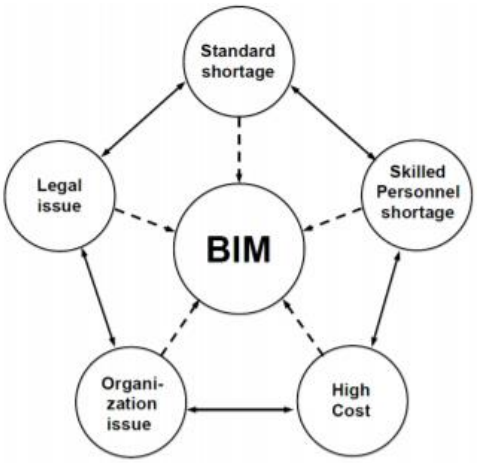


Figure 10: Relationship between BIM constraints[68].

5.5 Summary

After analyzing the above section about BIM status and possible constraints for BIM growth in India there are various points to discuss. Currently, the BIM impact on the Indian construction industry is rare and struggling for its acceptance. Most of the BIM projects are using BIM methodology for design and planning purposes not carried forwarded to construction and operation purposes. After analyzing BIM success in other countries, BIM can be a useful tool only if it is adopted by all project participants for coordination and collaborations of project data. Both surveys mentioned in section 5.1.1 describe the opinion of BIM experts in the Indian industry and their BIM adoption growth makes future promising for BIM acceptance. While large construction requirements for urbanization and mentioned in public agenda and digital campaign set by Indian prime minister also encourage BIM communities to show up their potential.

The standards and guidelines set up by BIM adopted countries for BIM growth are still missing in India. While various constraints such as technological, legal, economic, and social mentioned in the 5.4 subsections are the real challenges for BIM acceptance. Lack of experts, high initial investment, short term workload, and professional attitude towards the adoption of new technology gives tough competitions for BIM adoption. Public sector initiative for encouraging people for BIM uses is another issue. Indian government agenda against corruption, digitalization, and sustainability create opportunities for BIM growth in India.

6. Case studies

In this section 6 case studies are chosen to analyze the impact of conventional technology and BIM implementation on construction projects with regards to project management tasks for project success. The first case study will highlight the failure of the conventional project delivery method on a high-rise Indian residential project. The second and third case studies will analyze the potential benefits of BIM methodology to the construction project management team towards project success. Lastly, case studies based on the BIM implementation during the master program will be analyzed for better evaluation of research data.

6.1 North Eye, India (Conventional methodology)

Project description

The project consists of 66 floors and one of the tallest residential buildings in India. It is located in Noida sector 74 near to India's capital New Delhi. The estimated project cost was 84 Million Indian rupees and started in July 2011. Supertech Limited was the developer of the skyscraper, and B.E. Billiomoria was the contractor. AT Techno Legal Combine Limited was the project management consultancy who was mainly controlling and monitoring project progress on behalf of the client. The project completion duration was estimated for 5 years and should be completed in 2016. Unfortunately, it is currently on the 50th floor means already facing time overrun and cost overrun issues. The project processes were carried out through a conventional methodology resultant of high complexity in managing tasks[69].

Software used

The 3D model and 2D drawings were designed using AutoCAD. The bar chart in primavera and excel was used for scheduling and costing purposes. The project coordination was done through paper and via emails. The quantities were prepared manually with the help of 2D drawings. The clash detection among various drawings was done through manual processes by inspecting all drawings[69].

[69] (Garg, 2019)

Methodology

Bill of quantities (BOQ) prepared through the architectural drawings and accordingly scheduled project completion period and costing for bidding were prepared. All the contractors were hired accordingly to continuing the project. The contract type was the unit price contract. The financer of the project was the government bank and payment clearance was done on every floor completion[69].

Figure 11: North Eye, North India's Skyscraper[70] and project current status July,2019[69].

[70] (Supertech Limited, 2017)

Challenges

The challenges faced by the project management team during the project life cycle has been described by the interviewee while asking in an interview. The first challenge was to prepare the BOQ for almost 2000 activities in such a complex project on the basis of 2D drawings. The cost estimation was prepared with the help of Delhi Analysis of Rate(DAR) and problems while managing complex costing manually for each activity were too high. The safety analysis and energy analysis were other big hurdles to manage. After preparing the cost estimation convincing lender for loan approval was another big task which took 6 months and the payment method was set on every floor completion. The type of contract was unit rate contract hence the contractor has no concerns with total project loan approval as they will get money every month after submitting the bill to the client. The clash detection and preparing Bar Bending Schedule(BBS) manually consumed a lot of time and manpower, and coordinating to consultants regarding revisions was another difficult task to manage[71].

For the first 3 years, the project was going as per planning and has no issues regarding its progress and money. After that half of the project was finished but the quantities and costing were reached to 70-75%. The client was facing around 40% negative cash flow which affects the project progress resultant project currently facing cost overrun issues, time overrun and claims from the contractor for machinery available at the site and from customers for not handing over[71]. A list of problems faced while managing a project with a conventional approach was discussed in the following table.

Project issues	Explanation	Possible solutions
Quantity take-off	The quantities prepared manually using 2D drawings with respect to the quantities consumed at the site was 25% less, resulting in dispute among client and other stakeholders.	BIM 3D model claimed high accuracy in Quantity takes off.
Costing	The quantities prepared were less than actual, hence the project is facing financial issues to continue the project.	BIM-based costing also offered more accuracy.

[71] (Singh D. , 2019)

Scheduling	The project schedule was prepared through the bar chart for such a complex project hence many concurrent activities were running parallel resultant in hindrances in progress and claims arisen from subcontractors.	Location-based Vico software help to manage concurrent activities.
Clash detection	2D drawings from all consultants were inspected manually to check the clashes resultant in a lot of manpower and time consumed.	Solibri model checker through IFC files helps to identify clashes more quickly and accurately.
Coordination issues	The coordination was mainly done through paper or via emails hence any revision in drawings or other important information sometimes not reached to other stakeholders because of the communication gap.	More transparency in processes through BIM methodology avoid coordination issues.
Project progress	The manual dates for floor completion were added in the progress report to show to clients and customers, any kind of visual method of planned and actual progress was not available resultant in difficulties while understanding.	Synchro software helps to visualize the real progress vs planned through BIM model.
Claims for a project delay	Project completion prolongs by 4 years and still counting, resultant in claimed arose from customers and contractors.	Because of transparency in processes, hence makes it easy to manage claims.

Table 6: Project issues, explanation, and possible solutions[71].

6.2 Metro rail system of Chennai (Phase 1), India (BIM methodology)

The phase 1 of the Chennai metro rail project consisted of 54.1Km rail track with multiple metro stations and two corridors. One metro station was chosen for BIM implementation, due to confidentiality reasons the real name was not revealed, hence in this report, the project name is called Alpha metro project consisted of three elevated floors with the interference of the tunnel. The total cost of the project was 72.5 Billion India rupees with the planned duration of 1360 days started in 2012[72].

[72] (Mahalingam, Yadav, & Jarjana, 2015)

The project was initially started with the last planner system (LPS) to maintain the planned percentage complete (PPC) without BIM methodology. The LPS involves a collaborative planning approach to create 4 weeks' advance schedule with respect to the master schedule to manage the tasks by avoiding possible constraints. The progress was checked each week based on PPC report and solutions for possible constraints were discussed. However, the PPC level was only 45% of planned for the first 4 months because of multiple reasons such as a breakdown of crane one day and reinforcement threatening issue. One of the challenges the site team facing was pouring concrete in the metro station because of less space availability[72].

In the next meeting, the BIM consultant came to look for issues concerns regarding project progress. The same consultant worked in the Nagpur metro station and have demonstrated BIM benefits to the project team. After attending the weekly meeting, they requested the client to propose a BIM model for simulation and visualization of planned versus actual progress to monitor the progress more efficiently. The first model was prepared to visualize the logistic methodology of excavating the disposing muck in an efficient way to get more access to the site[72].

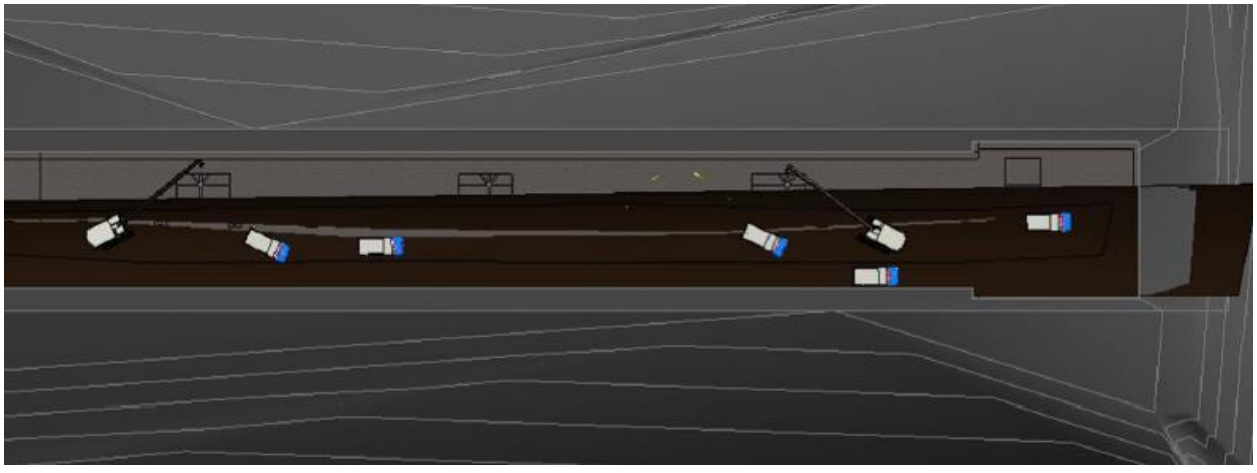


Figure 12: Simulating excavation and muck disposal[72].

After briefing the first model and its function in the project weekly meeting, the project team was interested to get more project information from BIM methodology. They

requested to prepare BOQ and costing and project schedules to work efficiently and effectively. After 6 months, more participant was attending weekly meetings and discussing possible constraints and looking at possible forthcoming solutions[72].

In the meeting mainly six root causes for the project delay were discussed as follows: machinery failure, material shortage due to unavailability, labor productivity, coordination, alignment of project activities, quality issues of rework, and unforeseen problems. Out of these issues, coordination and alignment of activities were the major challenges to solve which contains almost one-third of all root causes. After implementing BIM methodology the processes being capable to share information more effectively and efficiently and the problem of trust and coordination through active participation of stakeholders solved this issue and drop down its causes to below 10%[72].

Furthermore, the PPC matrix used for measuring the efficiency of the LPS system was significantly improved after adopting BIM technology. Where the PPC level at the start of the project was 45% only after implementing BIM it reached 65% within 4 months of BIM adoption[72].

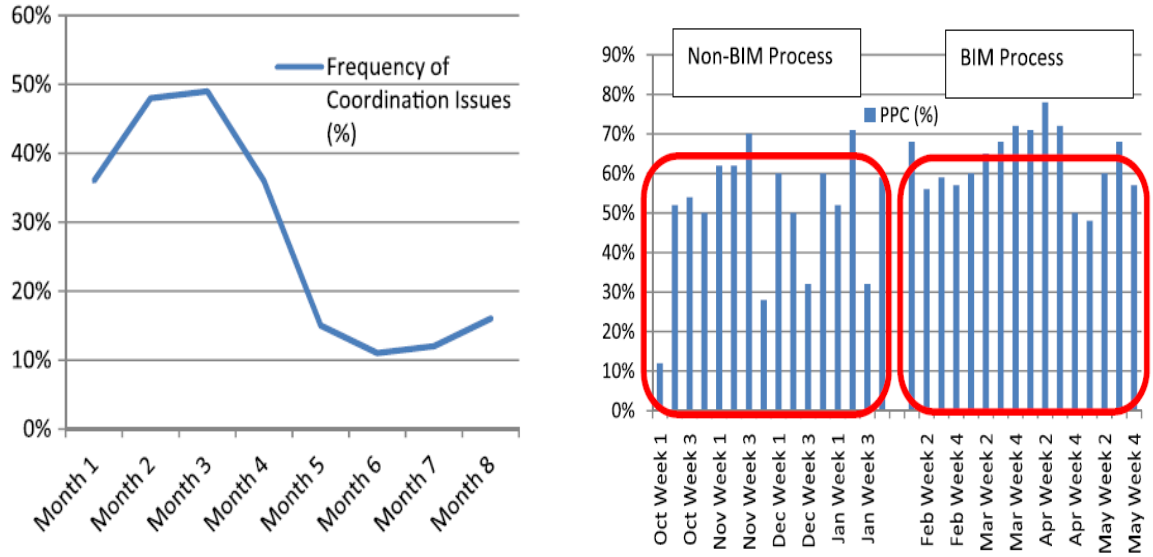


Figure 13:Frequency of coordination based root cause Planned Percentage Complete trend on the project[72].

Based on the stakeholder's interest in monitoring the progress of the project with respect to planned cost and time, a system was suggested by the BIM consultant in which planned versus actual progress with respect to actual progress can be visualized in the same window. The Python tool was used to simulation the required information. The expectation of using this model to monitor the weekly site situation and avoid possible constraints through effective collaboration[72].

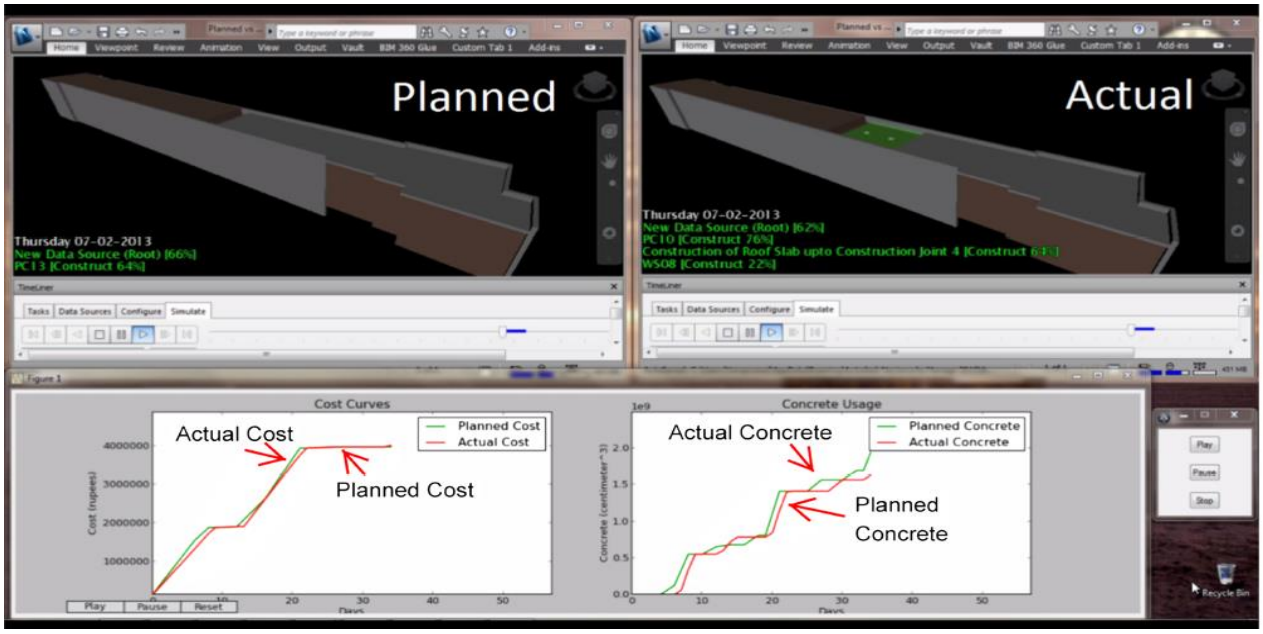


Figure 14: Python simulation tool for comparing planned vs actual progress[72].

Findings

Before implementing the BIM methodology, the project was struggling in coordination, planned project completion and monitoring issues. While these issues significantly controlled through BIM adoption. However, BIM was not the first choice at the start of the project but later on, this technology has shown its potential at various processes and all project stakeholders were impressed by its effective and efficient working approach.

6.3 Commercial Retail Centre, India (BIM methodology)

A commercial retail center project having a gross built-up area of 35,000m2 was designed and executed with the help of BIM methodology in India. Both the client and contractor were agreed to implement BIM methodology from the design stage Hence, BIM consultant was hired at the early stage. BIM Execution Plan (BEP) was prepared during the contractual stage for defining the roles and responsibilities of each stakeholder for better collaboration in project phases[73].

Preconstruction Phase

Initially, all 2D drawings were prepared by respective stakeholders in compliance with Level 1 BIM. Then BIM consultant using Revit software prepared 3D model with maturity level 300 from approved 2D drawings. After using the maturity model a virtual reality (VR) model was designed for better visualization. A Common Data Environment (CDE) was formed to enable real-time discussion and better coordination resultant in more transparency in processes, improved information sharing, and reduction in rework issues through avoiding duplicity of efforts. Clashes among the drawings were deducted and managed through Walkthroughs before going to the execution phase. Revit model helped to extract quantities for preparing BOQ and cost estimation. Naviswork was used to simulate the real-time construction progress by importing schedule file prepared with the help of Microsoft Project (MSP). Through the simulation, the project management team and other involved stakeholders manage to finalize the project duration[73].

Construction Phase

Walkthroughs helped contractors for planning and managing logistics issues such as material placing, labor hut, and equipment installation issues for avoiding possible safety hazards and enhancing productivity in processes at the site. COBie data was used for facility management purposes. A list of BIM capabilities with respect to project phases has been elaborated in the following figure[73].

---

[73] (Singhal & Ahuja, 2018)

Project Phases	BIM Capabilities	Worker safety	Increased team productivity	Improved communication	Reduced project schedule	Reduced life-cycle cost	Better risk management	Waste minimization	Improved quality construction	Improved team dynamics	Improved Customer satisfaction
Preconstruction Phase	Design Coordination	x	√	√	√	√	√	√	√	√	√
	3D Visualization	√	√	√	x	x	√	√	√	√	√
	Quantity take-off	x	√	√	√	√	√	√	√	√	√
	4D Scheduling	√	√	√	x	√	√	√	√	√	√
Construction Phase	4D scheduling and monitoring	√	√	√	x	x	√	√	√	√	√
	Cost tracking	x	x	√	x	√	√	√	x	x	√
	Safety Management	√	√	√	x	x	√	√	√	√	√
	Collaboration and coordination	√	√	√	√	√	√	√	√	√	√

Table 7: BIM capabilities during various project processes[73].

6.4 Case studies with BIM methodology during the master program

In this subsection, three case studies based on BIM methodology elaborate on the BIM functions implemented in three different arbitrary projects during the master's studies program. The first case study describes the BEP features with detailed design during preconstruction phase of a primary school in Peshawar city, Pakistan[74], and second will highlight the scheduling features of BIM methodology in a small housing project in Helsinki[75], and last cast study also discusses the 4D and 5D features of BIM technology in a hotel project located in Germany (Pedro et al., 2019)[76].

[74] (Singh, Malhotra, & Rose, 2018)
[75] (Beyer et al., 2018)
[76] (Pedro et al., 2019)

6.4.1 Primary school project, Peshawar (Pakistan)

The primary school consisted of 2 floors with a gross built-up area of 911m^2 and the budgeted cost was around 20 million Pakistani rupees. The planned duration for the completion of the project was calculated for 15 months. The client of the school was 'Khyber Pakhtoonkhwa', a government firm. For the successful implementation of BIM methodology, the BIM team has developed the BEP file along with detailed design for setting up the strategy. The 3D architectural and structural models were developed using ArchiCAD and Tekla structures software. While two-way data exchange was formed using IFC files for detecting clashes through Solibri Model Checker (SMC). Through the utilization of model, scheduling, cost estimation, and COBie data report were prepared. The 3D model of the project and the 2D generated plan as shown in the following figures[74].

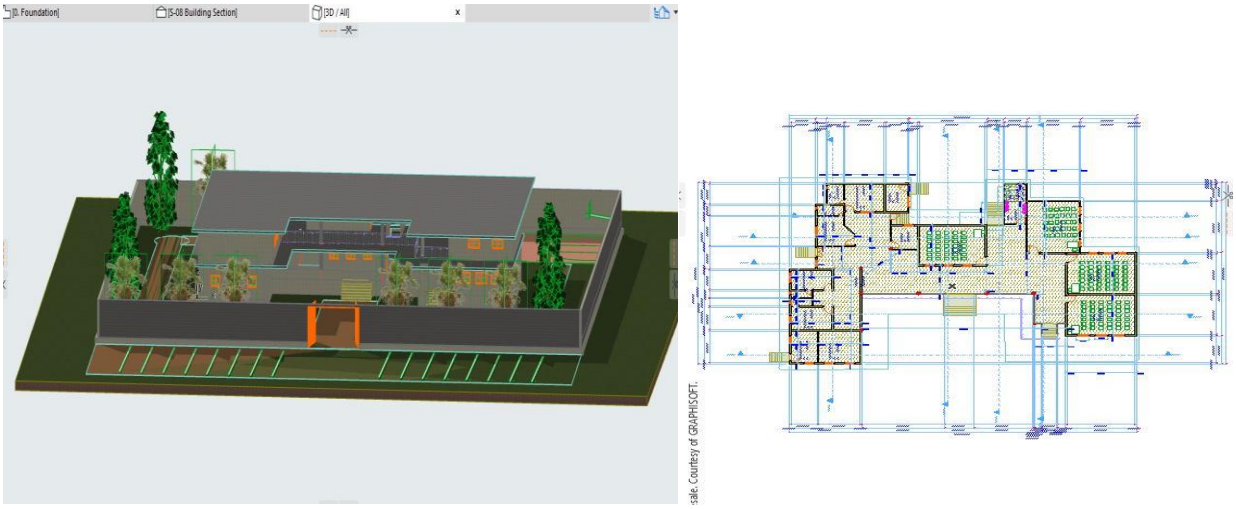


Figure 15: Primary school 3D architectural model and generated 2D plan[74].

The materials information was added in the model while designing for the automatic quantity take-off helped to prepare the project BOQ. All the 2D plans and sections were exported from the models for better communication with the site team. As the model was developed with materials information any changes in the model automatically revised the quantity, hence more accuracy in preparing quantities with respect to the conventional approach of calculating quantities using 2d drawings. In the below figures, IFC files generated from the architectural model and structural models highlight the detected clashes among both models which were rectified before implementing them into the site[74].

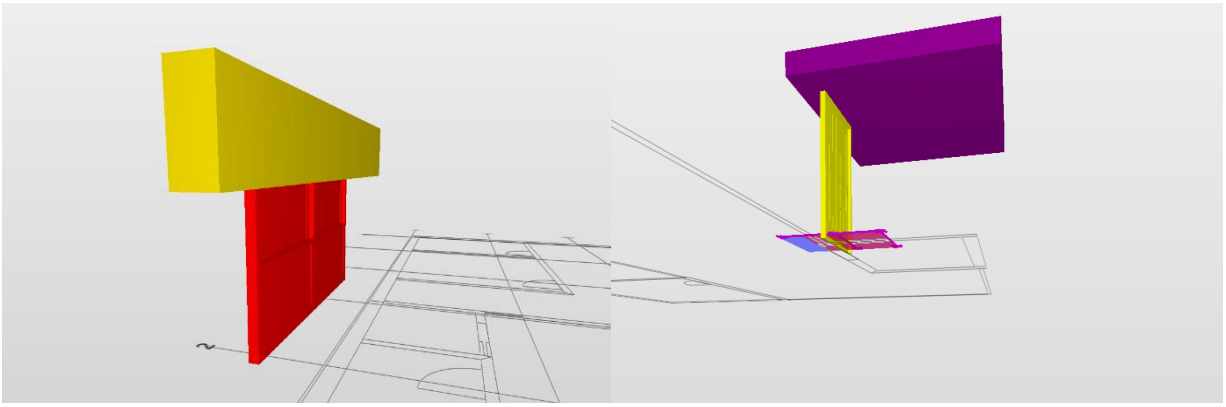


Figure 16: Clashes deducted among the project components using the SMC software[74].

After fixing all the clashes, good for construction (GFC) drawings were sent to the construction team for execution purposes. While BIM models helped the planning team for site utilization and 3D coordination among other involved stakeholders. The phase Planning(4D), costing(5D), cash flow processes were performed using Vico software for controlling and monitoring project execution activities. The COBie spreadsheet was used by the facility manager during project operational phase for better facility management[74].

	A	B	C	D	E	
1	Assembly-AssemblyType	Category-Connection	Category-Coordinate	Category-Document	Category-Element	
2	Excluded	Control	Point	Certificates	21-01 00 00 Substructure	11-11 00 00 Assembly Facility
3	Fixed	Flow	Line-end-one	Client Requirements	21-01 10 Foundations	11-11 11 00 Convention and Exhibition Facility
4	Included	Return	Line-end-two	Closeout Submittals	21-01 10 10 Standard Foundations	11-11 11 11 Convention Center
5	Layer	Supply	Box-lowerleft	Contract Drawings	21-01 10 10 10 Wall Foundations	11-11 11 17 Conference Facility
6	Mix	Structural	Box-upperright	Contract Drawings	21-01 10 10 30 Column Foundations	11-11 14 00 Meeting Facility
7	Optional			Contract Modifications	21-01 10 10 90 Standard Foundation Supplementary Components	11-11 14 11 Club or Organization Building
8				Contract Specifications	21-01 10 20 Special Foundations	11-11 14 14 Ceremonial Hall
9				Design Data	21-01 10 20 10 Driven Piles	11-11 21 00 Entertainment Assembly Facility
10				Design Review Comment	21-01 10 20 15 Bored Piles	11-11 21 11 Cinema
11				Manufacturer Field Reports	21-01 10 20 20 Caissons	11-11 21 17 Performing Arts Facility
12				Manufacturer Instructions	21-01 10 20 30 Special Foundation Walls	11-11 21 17 11 Auditorium and Theater Facility
13				Operation and Maintenance	21-01 10 20 40 Foundation Anchors	11-11 21 17 14 Outdoor Theater
14				Preconstruction Submittals	21-01 10 20 50 Underpinning	11-11 21 21 Casino
15				Product Data	21-01 10 20 60 Raft Foundations	11-11 21 22 Theme Park
16				Punch List Items	21-01 10 20 70 Pile Caps	11-11 21 23 Fair or Circus Ground
17				Request for Information	21-01 10 20 80 Grade Beams	11-11 21 24 Race Track
18				Requests for Information	21-01 20 Subgrade Enclosures	11-11 21 24 11 Horse Racing Track
19				Samples	21-01 20 10 Walls for Subgrade Enclosures	11-11 21 24 14 Dog Racing Track
20				Shop Drawings	21-01 20 10 10 Subgrade Enclosure Wall Construction	11-11 21 24 17 Automobile Racing Track
21				Specifications	21-01 20 10 20 Subgrade Enclosure Wall Interior Skin	11-11 21 27 Arena
22				Test Reports	21-01 20 10 90 Subgrade Enclosure Wall Supplementary Components	11-12 00 00 Education Facility
23					21-01 40 Slabs-On-Grade	11-12 11 00 Daycare or Preschool Facility
24					21-01 40 10 Standard Slabs-on-Grade	11-12 11 11 Daycare Facility

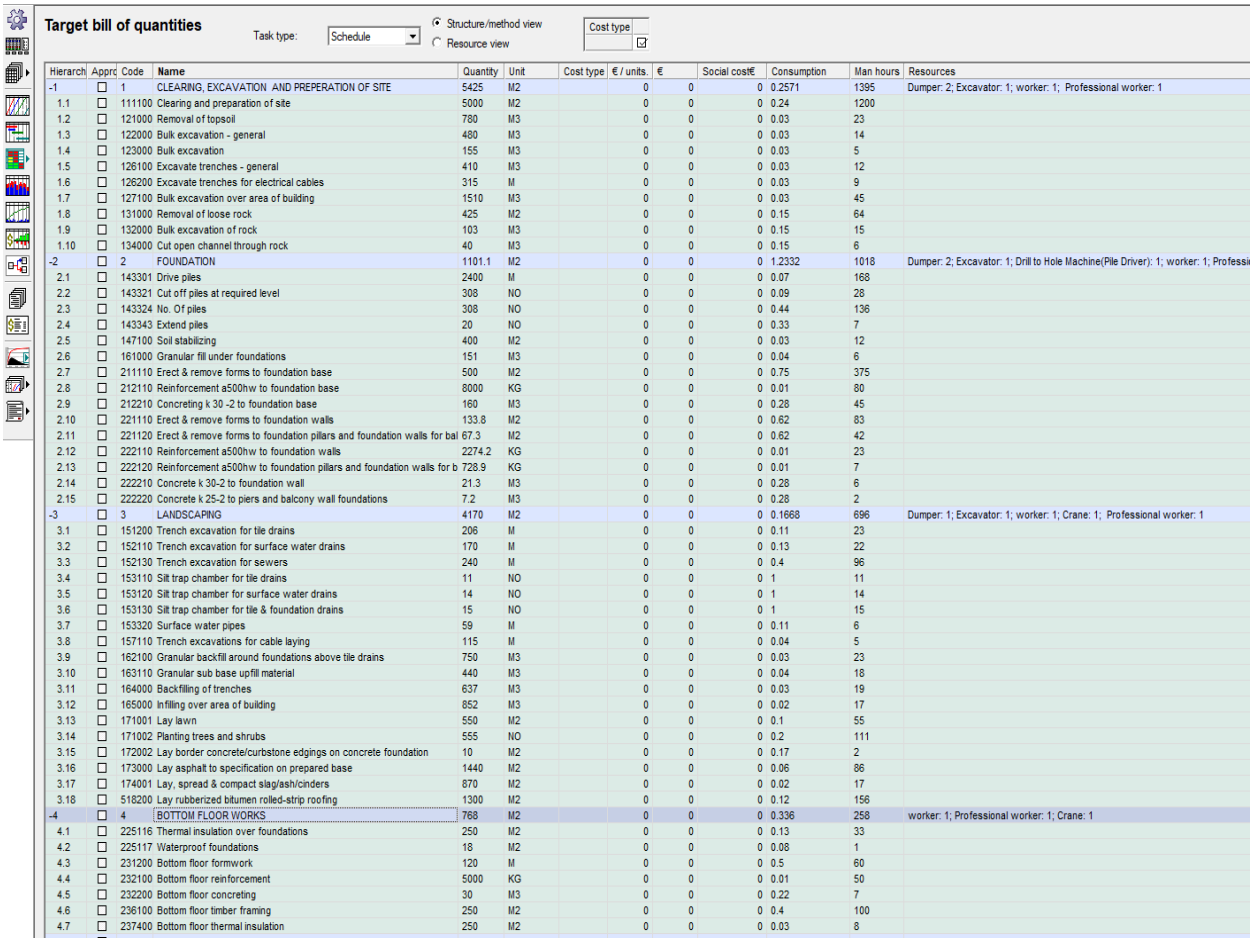
... Assembly | Connection | Spare | Resource | Job | Impact | Document | Attribute | Coordinate | Issue | PickLists

Listo 100%

Figure 17: COBie Spreadsheet for facility management uses[74].

6.4.2 Housing project, Helsinki

The project consisted of two buildings of 4 floors and a pitched roof in Helsinki, Finland. The appointed task was to prepare project planning and scheduling to control and monitor the project progress accordingly. Firstly, Work Break Down (WBS) structure and BOQ were prepared for the given activities. After defining the resources for each activity through Vico schedule planner software, the construction time was calculated 11 months for both buildings. All the individual activities squeezed and synchronized into 16 major activities in a logical manner for better understanding and monitoring of project progress. The following figure highlights the prepared BOQ including resources and duration of each activity[75].



Target bill of quantities

Task type: Schedule — Structure/method view / Resource view — Cost type

Hierarch	Apprc	Code	Name	Quantity	Unit	Cost type	€ / units.	€	Social cost€	Consumption	Man hours	Resources
-1	☐	1	CLEARING, EXCAVATION AND PREPERATION OF SITE	5425	M2		0	0	0	0.2571	1395	Dumper: 2; Excavator: 1; worker: 1; Professional worker: 1
1.1	☐	111100	Clearing and preparation of site	5000	M2		0	0	0	0.24	1200	
1.2	☐	121000	Removal of topsoil	780	M3		0	0	0	0.03	23	
1.3	☐	122000	Bulk excavation - general	480	M3		0	0	0	0.03	14	
1.4	☐	123000	Bulk excavation	155	M3		0	0	0	0.03	5	
1.5	☐	126100	Excavate trenches - general	410	M3		0	0	0	0.03	12	
1.6	☐	126200	Excavate trenches for electrical cables	315	M		0	0	0	0.03	9	
1.7	☐	127100	Bulk excavation over area of building	1510	M3		0	0	0	0.03	45	
1.8	☐	131000	Removal of loose rock	425	M2		0	0	0	0.15	64	
1.9	☐	132000	Bulk excavation of rock	103	M3		0	0	0	0.15	15	
1.10	☐	134000	Cut open channel through rock	40	M3		0	0	0	0.15	6	
-2	☐	2	FOUNDATION	1101.1	M2		0	0	0	1.2332	1018	Dumper: 2; Excavator: 1; Drill to Hole Machine(Pile Driver): 1; worker: 1; Professi
2.1	☐	143301	Drive piles	2400	M		0	0	0	0.07	168	
2.2	☐	143321	Cut off piles at required level	308	NO		0	0	0	0.09	28	
2.3	☐	143324	No. Of piles	308	NO		0	0	0	0.44	136	
2.4	☐	143343	Extend piles	20	NO		0	0	0	0.33	7	
2.5	☐	147100	Soil stabilizing	400	M2		0	0	0	0.03	12	
2.6	☐	161000	Granular fill under foundations	151	M3		0	0	0	0.04	6	
2.7	☐	211110	Erect & remove forms to foundation base	500	M2		0	0	0	0.75	375	
2.8	☐	212110	Reinforcement a500hw to foundation base	8000	KG		0	0	0	0.01	80	
2.9	☐	212210	Concreting k 30 -2 to foundation base	160	M3		0	0	0	0.28	45	
2.10	☐	221110	Erect & remove forms to foundation walls	133.8	M2		0	0	0	0.62	83	
2.11	☐	221120	Erect & remove forms to foundation pillars and foundation walls for bal	67.3	M2		0	0	0	0.62	42	
2.12	☐	222110	Reinforcement a500hw to foundation walls	2274.2	KG		0	0	0	0.01	23	
2.13	☐	222120	Reinforcement a500hw to foundation pillars and foundation walls for b	728.9	KG		0	0	0	0.01	7	
2.14	☐	222210	Concrete k 30-2 to foundation wall	21.3	M3		0	0	0	0.28	6	
2.15	☐	222220	Concrete k 25-2 to piers and balcony wall foundations	7.2	M3		0	0	0	0.28	2	
-3	☐	3	LANDSCAPING	4170	M2		0	0	0	0.1668	696	Dumper: 1; Excavator: 1; worker: 1; Crane: 1; Professional worker: 1
3.1	☐	151200	Trench excavation for tile drains	206	M		0	0	0	0.11	23	
3.2	☐	152110	Trench excavation for surface water drains	170	M		0	0	0	0.13	22	
3.3	☐	152130	Trench excavation for sewers	240	M		0	0	0	0.4	96	
3.4	☐	153110	Silt trap chamber for tile drains	11	NO		0	0	0	1	11	
3.5	☐	153120	Silt trap chamber for surface water drains	14	NO		0	0	0	1	14	
3.6	☐	153130	Silt trap chamber for tile & foundation drains	15	NO		0	0	0	1	15	
3.7	☐	153320	Surface water pipes	59	M		0	0	0	0.11	6	
3.8	☐	157110	Trench excavations for cable laying	115	M		0	0	0	0.04	5	
3.9	☐	162100	Granular backfill around foundations above tile drains	750	M3		0	0	0	0.03	23	
3.10	☐	163110	Granular sub base upfill material	440	M3		0	0	0	0.04	18	
3.11	☐	164000	Backfilling of trenches	637	M3		0	0	0	0.03	19	
3.12	☐	165000	Infilling over area of building	852	M3		0	0	0	0.02	17	
3.13	☐	171001	Lay lawn	550	M2		0	0	0	0.1	55	
3.14	☐	171002	Planting trees and shrubs	555	NO		0	0	0	0.2	111	
3.15	☐	172002	Lay border concrete/curbstone edgings on concrete foundation	10	M2		0	0	0	0.17	2	
3.16	☐	173000	Lay asphalt to specification on prepared base	1440	M2		0	0	0	0.06	86	
3.17	☐	174001	Lay, spread & compact slag/ash/cinders	870	M2		0	0	0	0.02	17	
3.18	☐	518200	Lay rubberized bitumen rolled-strip roofing	1300	M2		0	0	0	0.12	156	
-4	☐	4	BOTTOM FLOOR WORKS	768	M2		0	0	0	0.336	258	worker: 1; Professional worker: 1; Crane: 1
4.1	☐	225116	Thermal insulation over foundations	250	M2		0	0	0	0.13	33	
4.2	☐	225117	Waterproof foundations	18	M2		0	0	0	0.08	1	
4.3	☐	231200	Bottom floor formwork	120	M		0	0	0	0.5	60	
4.4	☐	232100	Bottom floor reinforcement	5000	KG		0	0	0	0.01	50	
4.5	☐	232200	Bottom floor concreting	30	M3		0	0	0	0.22	7	
4.6	☐	236100	Bottom floor timber framing	250	M2		0	0	0	0.4	100	
4.7	☐	237400	Bottom floor thermal insulation	250	M2		0	0	0	0.03	8	

Figure 18: BOQ of housing project with resources and activity duration[75].

After finalizing the BOQ and durations for each activity the master schedule was prepared in Vico software. This software basically works on a location-based system hence it provided a clear picture of clashes among concurrent activities resultant in better controlling and monitoring. The conventional approach of preparing schedules through the Gantt chart was the easiest way for understanding and progress but the main drawback was not indicating the exact status of each activity with respect to parallel activities. The below figures described the problems and solutions within the schedule chart[75].

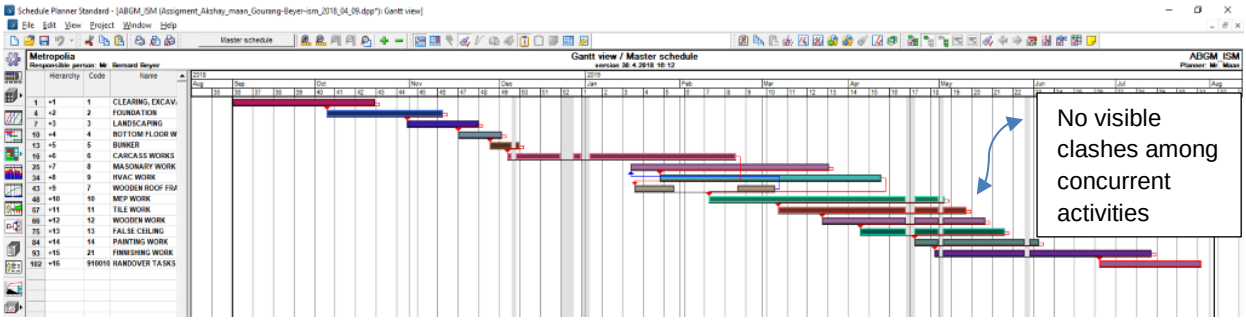


Figure 19: Gantt chart after finalizing the project shcedule[75].

Above mentioned Gantt chart was extracted from the Vico software for the construction team to manage construction activities. Although Line of Balance(LOB) diagram in the location-based methodology described a clear picture among all parallel activities which was shown in the below figure[75].

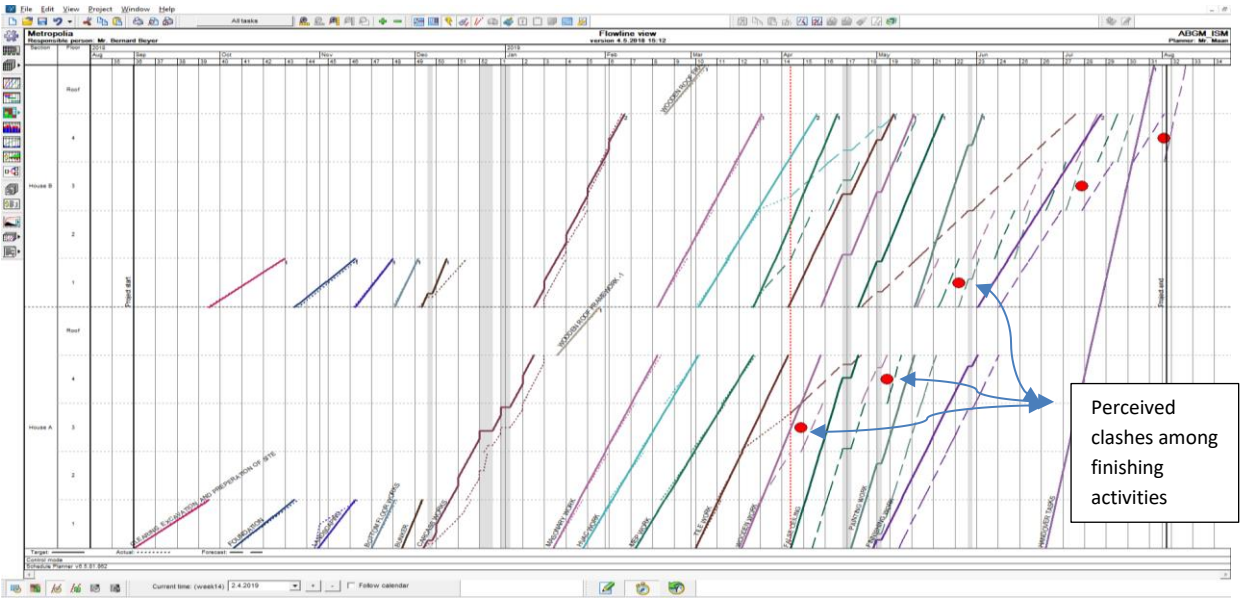


Figure 20: LOB diagram in control mode for visualizing clashes among activities[75].

The red dotes highlighted the possible clashes among interior activities which were rectified later on before finalizing the schedule for execution. The dotted lines describe the delay in other activities because of clashes. This feature of controlling and monitoring made planning more efficient and economical and have more influence over the project execution. The actual progress at any point can be visualized with respect to planning. After rectification of the master schedule, the combined diagram of LOB and Gantt chart was displayed in the below figure which was sent to the execution team[75].

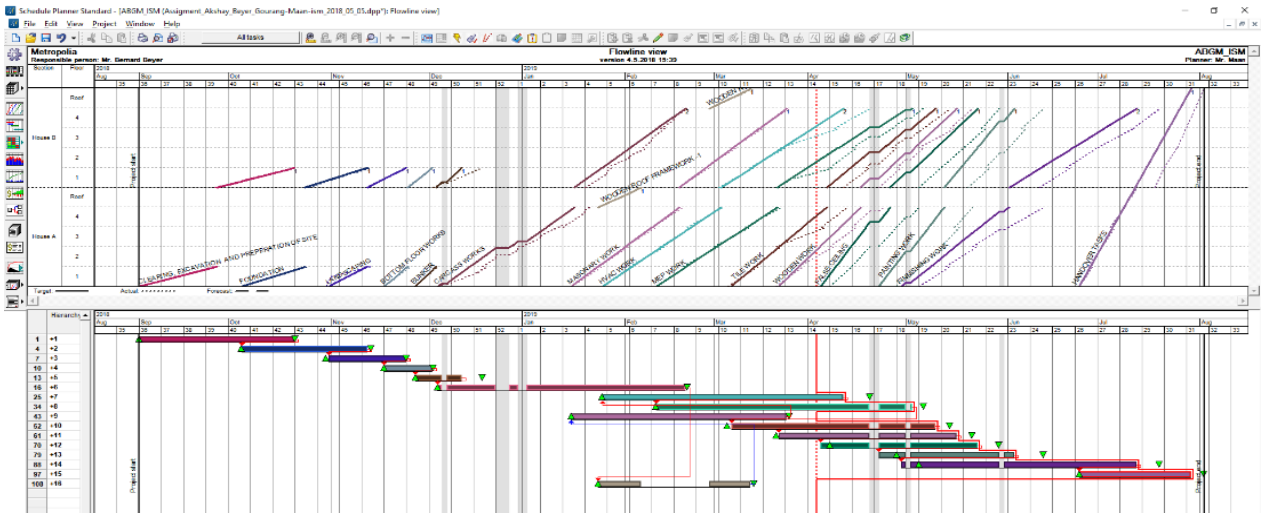


Figure 21: Finalized master schedule for construction activities[75].

Findings

The above case study described the influence of modern methodology to deal with project planning and monitoring concerns in a more efficient and economical way. The challenges faced through the conventional methodology of managing construction execution progress and detect clashes among concurrent activities in the planning phase were solved here in this case study.

6.4.3 SEAZ Hotel, Germany

The hotel project consisted of 11 floors including one-floor basement parking in one of the German cities. The task was to prepare BOQ, prepare execution plan, scheduling, costing and managing cash flow through the conventional methodology and modern methodology. The ground floor involved shops, café, restaurant, and hotel reception. The upper floors were designed for guest rooms and the hotel was fully air-conditioned. After preparing the BOQ, the total cost calculated through DIN276 was 8.3 Million euros and the time for completion was 3 years[76]. The floor plan and section were shown in the below figures.

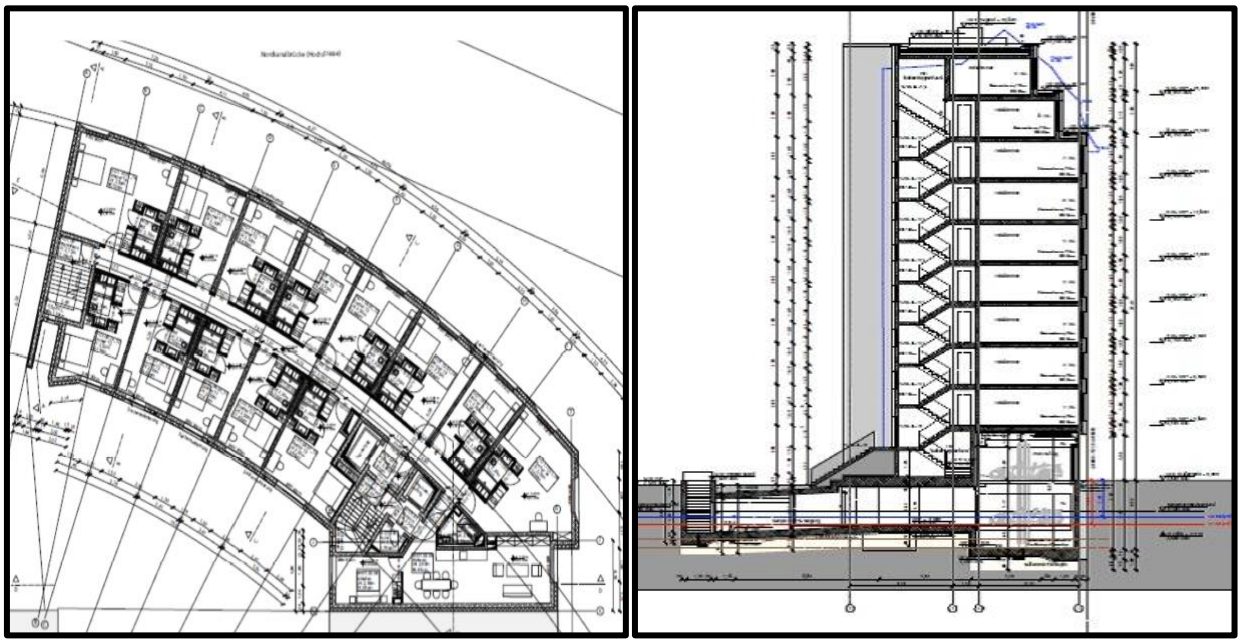


Figure 22: SEAZ hotel floor plan and section[76].

The procedure adopted for formulating BOQ, and scheduling was the same as mentioned in subsection 6.4.1, and 6.4.2, hence this case study elaborates more about monitoring cash flow through resources, and activities reallocation. This case study highlighted the comparison between conventional and modern approaches to managing scheduling and cash flow, installments payment issues. Resultant a better understanding of managing project execution was developed[76].

In the conventional approach, the project schedule was prepared without utilizing free float and space buffer among construction processes resultant in substantial congestion and more resources involvement during interior activities and project cash flow came out minus 79%. Due to congestion in interior activities mostly claimed because of delay were occurred consequential penalty raised negative cash flow to -94%. The below figures describe the irregularity among activities and negative cash flow sheet[76].

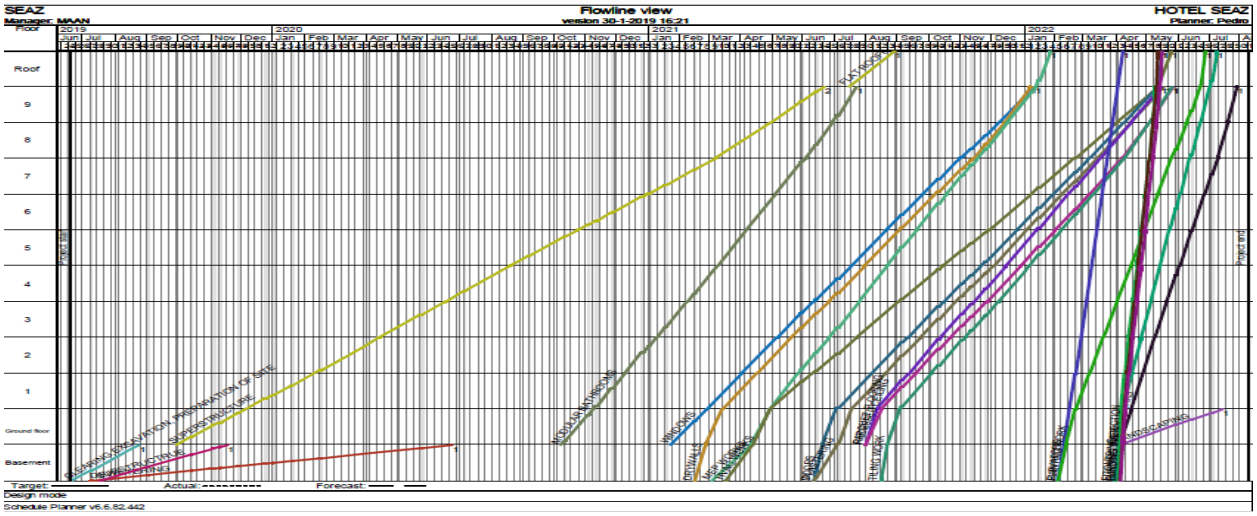


Figure 23: Line of balance prepared through a conventional methodology[76].

Month	Income	Outcome		Cashflow
		C. Claims	Outcome	
jun-19	€ 2.496.673	€ -	€ 6.515	€ 2.490.158
jul-19	€ -	€ -	€ 57.458	€ 2.432.700
ago-19	€ -	€ -	€ 99.055	€ 2.333.644
sep-19	€ -	€ -	€ 82.676	€ 2.250.968
oct-19	€ -	€ -	€ 191.718	€ 2.059.250
nov-19	€ 2.330.228	€ -	€ 153.234	€ 4.236.244
dic-19	€ -	€ -	€ 108.277	€ 4.127.967
ene-20	€ -	€ -	€ 108.277	€ 4.019.691
feb-20	€ -	€ -	€ 101.291	€ 3.918.399
mar-20	€ -	€ -	€ 108.277	€ 3.810.123
abr-20	€ -	€ -	€ 104.784	€ 3.705.339
may-20	€ -	€ -	€ 108.277	€ 3.597.062
jun-20	€ -	€ -	€ 104.334	€ 3.492.727
jul-20	€ -	€ -	€ 106.286	€ 3.386.442
ago-20	€ -	€ -	€ 106.286	€ 3.280.156
sep-20	€ -	€ -	€ 102.857	€ 3.177.299
oct-20	€ -	€ -	€ 120.470	€ 3.056.828
nov-20	€ -	€ -	€ 132.882	€ 2.923.947
dic-20	€ -	€ -	€ 184.939	€ 2.739.008
ene-21	€ -	€ -	€ 186.839	€ 2.552.168
feb-21	€ -	€ -	€ 195.571	€ 2.356.598
mar-21	€ -	€ -	€ 372.325	€ 1.984.273
abr-21	€ -	€ -	€ 451.303	€ 1.532.970
may-21	€ -	€ -	€ 530.391	€ 1.002.579
jun-21	€ -	€ -	€ 482.425	€ 520.154
jul-21	€ -	€ -	€ 438.590	€ 81.564
ago-21	€ 466.046	€ -	€ 442.552	€ 105.058
sep-21	€ -	€ -	€ 391.923	-€ 286.865
oct-21	€ -	€ -	€ 404.987	-€ 691.852
nov-21	€ -	€ -	€ 393.238	-€ 1.085.090
dic-21	€ 349.534	€ -	€ 487.601	-€ 1.223.157
ene-22	€ 1.106.858	€ 83.631	€ 503.588	-€ 703.517
feb-22	€ 174.767	€ -	€ 277.573	-€ 806.323
mar-22	€ -	€ -	€ 297.115	-€ 1.103.439
abr-22	€ 407.790	€ -	€ 335.239	-€ 1.030.888
may-22	€ 990.347	€ 102.267	€ 43.090	-€ 185.897
jun-22	€ -	€ 4.796	€ -	-€ 190.694
jul-22	€ -	€ 60.613	€ -	-€ 251.306
ago-22	€ -	€ 14.791	€ -	-€ 266.097
	€ 8.322.243	€ 266.097	€ 8.322.243	-€ 7.825.127
				-94%

Figure 24: Cash flow sheet in conventional methodology[76].

During the optimization phase, the aim was to drag the negative cash flow up to 20% hence relocation of activities through utilizing space buffer and manpower was the possible solution. After the analysis of conventional schedule drawbacks, the first step was decided to divide the whole building into two sections for better controlling and monitoring of construction activities. Then the synchronization of resources was done, and more resources were allotted in the middle phase of construction with respect to the end phase. Through the utilization of space buffer in construction activities, more time was allotted for interior activities resultant in no clashes among interior activities. The following figures define the optimized LOB diagram and optimized cash flow sheet which was reduced to minus -15% through optimization[76].

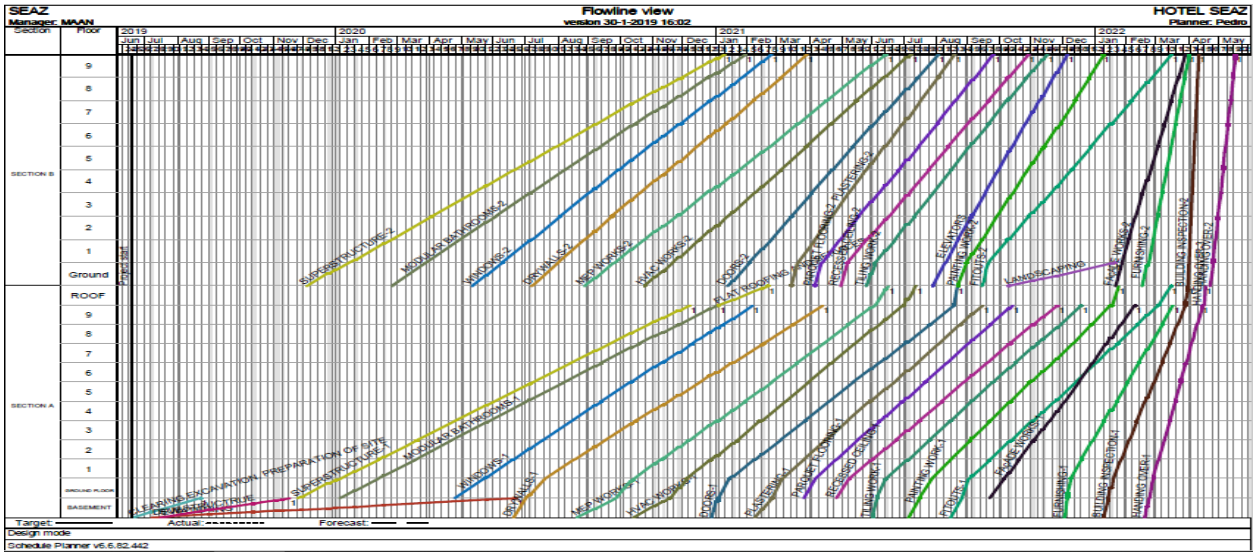


Figure 25: Optimized LOB diagram resultant of a modern approach[76].

Month	Total Income	Total Outcome		Cashflow
		C. Claims	Outcome	
jun-19	€ 2.496.673	€ -	€ 6.515	€ 2.490.158
jul-19	€ -	€ -	€ 57.458	€ 2.432.700
ago-19	€ -	€ -	€ 99.055	€ 2.333.644
sep-19	€ -	€ -	€ 82.676	€ 2.250.968
oct-19	€ -	€ -	€ 85.432	€ 2.165.536
nov-19	€ 2.330.228	€ -	€ 71.347	€ 4.424.416
dic-19	€ -	€ -	€ 164.515	€ 4.259.901
ene-20	€ -	€ -	€ 177.158	€ 4.082.743
feb-20	€ -	€ -	€ 166.996	€ 3.915.747
mar-20	€ -	€ -	€ 178.513	€ 3.737.234
abr-20	€ -	€ -	€ 173.362	€ 3.563.872
may-20	€ -	€ -	€ 181.654	€ 3.382.217
jun-20	€ -	€ -	€ 200.178	€ 3.182.040
jul-20	€ -	€ -	€ 249.647	€ 2.932.393
ago-20	€ -	€ -	€ 300.934	€ 2.631.459
sep-20	€ -	€ -	€ 381.468	€ 2.249.991
oct-20	€ -	€ -	€ 446.637	€ 1.803.353
nov-20	€ -	€ -	€ 474.033	€ 1.329.321

Month	Total Income	Total Outcome		Cashflow
		C. Claims	Outcome	
dic-20	€ -	€ -	€ 490.232	€ 839.088
ene-21	€ 29.128	€ -	€ 419.934	€ 448.282
feb-21	€ 1.106.858	€ -	€ 313.446	€ 1.241.695
mar-21	€ 116.511	€ -	€ 334.092	€ 1.024.114
abr-21	€ 87.384	€ -	€ 382.906	€ 728.591
may-21	€ 87.384	€ -	€ 425.353	€ 390.622
jun-21	€ 592.266	€ -	€ 377.993	€ 604.895
jul-21	€ 97.093	€ -	€ 264.812	€ 437.176
ago-21	€ 126.221	€ -	€ 255.692	€ 307.705
sep-21	€ 203.895	€ -	€ 285.235	€ 226.365
oct-21	€ 184.476	€ -	€ 289.957	€ 120.885
nov-21	€ 38.837	€ -	€ 224.834	-€ 65.111
dic-21	€ 155.349	€ -	€ 207.070	-€ 116.833
ene-22	€ 116.511	€ -	€ 183.308	-€ 183.629
feb-22	€ 116.511	€ -	€ 166.869	-€ 233.986
mar-22	€ 29.128	€ -	€ 170.497	-€ 375.355
abr-22	€ 116.511	€ -	€ 21.748	-€ 280.591
may-22	€ 291.279	€ -	€ 10.687	€ 0
	€ 8.322.243	€ -	€ 8.322.243	-€ 1.255.506
				-15%

Figure 26: Optimized cash flow sheet[76].

6.5 Evaluation of case studies

The above section has described the complications and challenges faced by the project management team for managing tasks through the conventional approach. While BIM methodology had significantly solved these issues and made project planning, controlling, and coordination among stakeholders more efficient and effective. The subsections 6.1 and 6.4.3 have described the issues such as cost overrun, time overrun, coordination, claims, and negative cash flow and payment delivery issues occurred through the conventional approach of managing a construction project. While the inefficient ways of utilizing resources and space buffer among activities were other concerns to be noticed.

On the other hand, subsections 6.2,6.3,6.4.1, and 6.4.2 have shown the potential benefits of BIM methodology for effective and efficient project delivery and solved most off the problems faced while implementing the conventional methodology. Although one team effort for managing all the activities was not possible hence every stakeholder has to contribute equally towards project success. The real-time monitoring and controlling had significantly capitalized the available resources and space buffer over the project duration and reduced negative cash flow considerably.

7. Survey analysis for the validation of findings

To validate the findings of the literature review and the analysis conducted through case studies, it was essential to obtain the insight professionals review about the BIM implementation from the AEC industry. For that, the survey was structured accordingly into three categories to deliver the current, relevant and empirical data through various questions. An online website ‘Google form’ was used to form the questionnaire. A small paragraph about the introduction of BIM methodology and thesis objective was introduced during the formation of the questionnaire for better clarification about the survey theme. The subsections describe the survey objectives, survey analysis, and evaluation of survey analysis.

7.1 Objectives of the survey

The literature review and case studies have shown the growth of BIM adoption in the Indian construction industry over the past few years. Although BIM is still facing many challenges for its market growth and BIM experts are seeking opportunities for positive growth in the coming years. To encourage professionals and government bodies BIM still needs to verify its potential in the Indian environment as it has shown in the UK, USA and Scandinavian like nations. The first objective of the survey is to evaluate that the BIM methodology ensures better coordination and implementation of project processes with maximum control over project progress. Secondly, to identify the experts opinions about the potential benefits of BIM and problems faced while implementing BIM methodology. Thirdly, to analyze the major barriers and possible opportunities for BIM growth into the Indian construction industry. In last, to identify the key factors that can contribute to significant growth of BIM methodology into coming years and when it can overtake the conventional approach of managing construction projects.

Survey structure formation

The above-listed objectives can be evaluated through the synchronized formation of the questionnaire. For this, three categories of the questionnaire were formed while conducting the survey. The first category was prepared to fetch information about personal information of professionals such as profession, experience, and organization type and strength. The five questions were prepared for gathering personal information. This will

help to identify the active participants' profession and their industry experience. The second category including fifteen questions highlights the BIM-related questions such as BIM benefits, barriers, comparison with conventional methodology and future opportunities, and need for BIM growth into the Indian construction industry. The third category through four questions describes the professionals' opinion about BIM implementation problems, scope, and hurdles for BIM acceptance within. The first and second categories are multiple-choice while the third category allows adding comments and opinions.

Selection Criteria

There are many agencies involved in the construction industry, hence quite difficult to address the opinion of all members. The survey mainly conducted for analyzing the BIM role for project management firms hence 7 main target groups are selected which have a major influence on PM firms. These target groups are defined as architectural, structural, project management, contractor, developer, BIM consultant, and public authorities. The other profession option was added to the remaining participant. The participant selected from the recognized academic profession, the AEC professionals and BIM experts who have the industry knowledge and more influence over the market. Students or other professions with no construction experience has been restricted for better evaluation of experts opinion. To maintain the anonymity of the survey and to encourage participants, personal information such as the name of participant, organization, and active project details were not asked. Furthermore, the questionnaire was drafted in an intuitive, explicit, and logical manner to keep the discontinuation rate to the minimum.

7.2 Survey analysis

This subsection described the finding through opinion percentages of active participants and diagrams fetched from the survey website for better clarification and evaluation of the result. The analysis sorted the same as categories formed during questionnaire formation. First category about personal info, second about BIM implementation and third about personal opinions, comments on BIM scope and hurdles. After finalizing the survey content, it was sent to all professional experts through email, LinkedIn, and social

networks for gathering more empirical information. Altogether 41 participants actively participated in the conducted survey over a period of 10 days.

7.2.1 Personal information related questionnaire

In figure 27, the variety of active participants has illustrated. A total of 40 participants respondent to this question out of this exact 50% belong to project management firms that addressed the right direction of the survey about the BIM role in project management. The architectural firms were the second among active participants with a 15% contribution. The third leading respondent belongs to contractor firms with 12.5%. A total of 7.5% from other professions apart from target groups also responded to the conducted survey. The respondents from BIM consultants, developers, and public authorities had the least percentage among other participants.

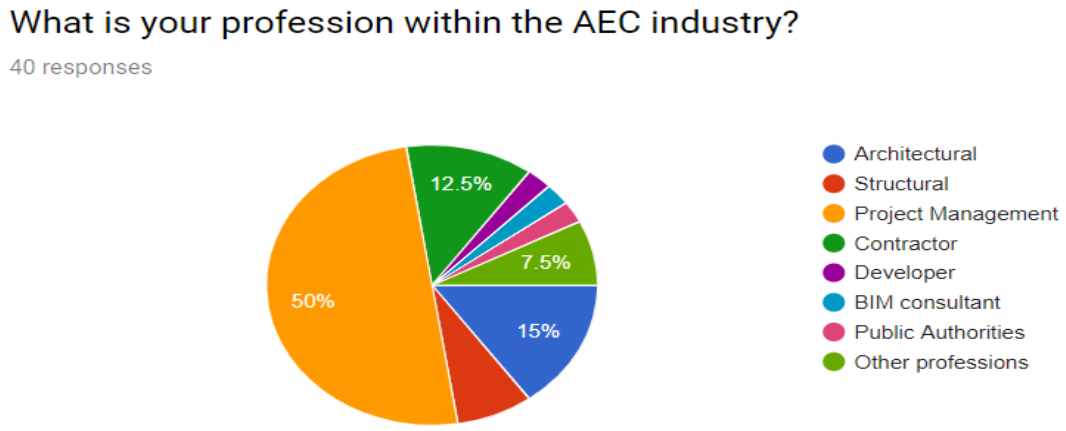


Figure 27: Professional background of respondents.

Figure 28 described the role of involved participants. Almost every respondent anyhow serves the specific role related to the project lifecycle resultant of more specific reviews generated from each designated person. The respondent serves the role of general manager, BIM coordinator, project manager, construction inspector and other reputed designated employee from the AEC industry. Although, the list of active participants was not enough for better evaluation but can be reliant because of industry experience and well-reputed posts in recognized firms.

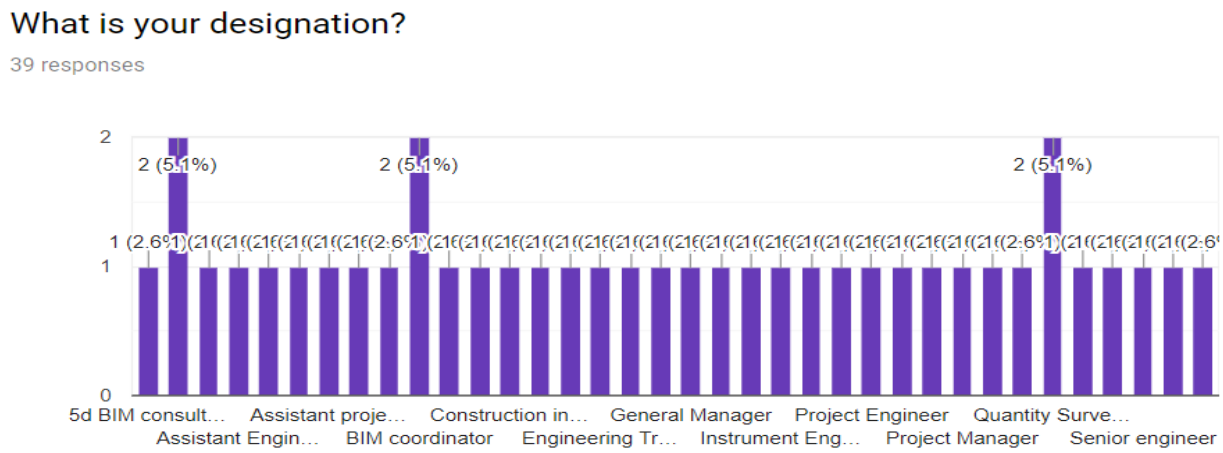


Figure 28: Respondents designation within the organization.

On asking about the experience, 45% of respondents stated that they possess experience between 5-10 years. While 37.5% of participants have less than 5 years of experience. On the other hand, 17.5% of respondents have more than 11 years of industry experience and can be believed that they know the market situation very well. Figure 29 illustrated the exact figure of experience claimed by respondents.

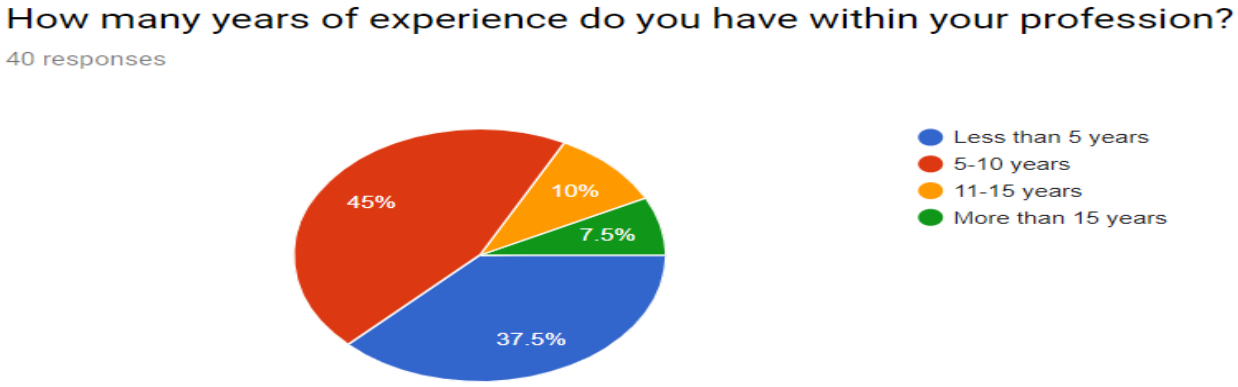


Figure 29: Respondents experience in their respective professions.

On asking about the staff strength of the respondent's organization an optional question, 39 respondents responded to this question, and almost 44% of participants believed that their employees strength is more than 500. These figures indicate the popularity of these firms among the Indian industry and it might belong to contractor firms mainly. On the other hand, 23.1% of respondents claimed that their staff strength is less than 50, an

indication towards architectural, BIM, and PM firms. While 20.5% of respondents stated that they possess 101-500 employees in their organization. They can be a mixture of all organizations. As seen in the following figure, almost 13% claimed their employee's strength between 50-100.

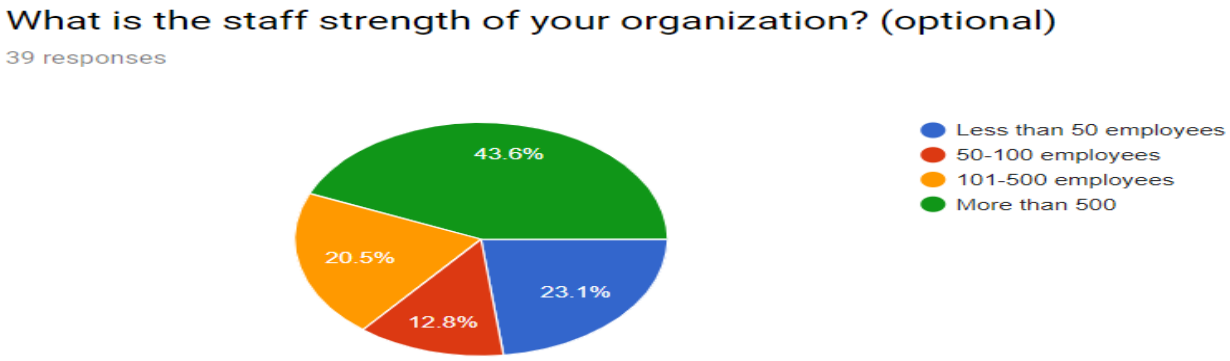


Figure 30: Respondents employee's strengths in their organizations.

The below figure illustrated the number of projects undertaken by the respondent's organization at present. This was also an optional question but surprisingly 38 respondents replied to this question. It seems almost one-third of participants organization managing more than 5-10 projects while one-fourth organization is handling less than 5 projects. On the other hand, almost half of the respondents claimed that their organization is managing more than 11 construction projects currently.

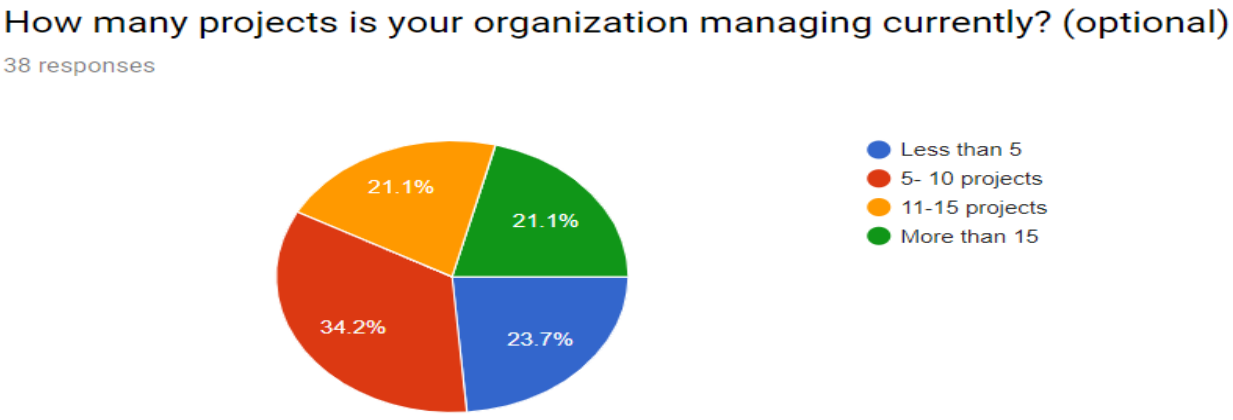


Figure 31: Respondents organization managing construction projects in present.

7.2.2 BIM implementation related questionnaire

This subsection highlighted the current status of BIM and its usage and scope and hurdles towards BIM growth in the Indian industry. The response gathered about each question are discussed below for more clarification about expert's attitudes towards BIM implementation and future needs for BIM growth. The first two questions are related to personal and organizational experiences towards BIM methodology. Third and fourth questions dealt with respondent opinions about BIM software expenses and comparison with the conventional methodology of managing construction projects. Fifth and sixth and seventh questions are related to BIM benefits and stakeholder's role change while implementing BIM methodology. The project management company's relation with BIM was discussed in eighth questions while the ninth question was related to stakeholder's attitudes towards BIM acceptance. The remaining questions described the future BIM scope and necessities required for overtaking the conventional approach of managing projects.

All participants responded to BIM related questions as shown in the following figure. Almost half of the respondents claimed working knowledge of BIM methodology in their profession although most of the respondents stated this knowledge is limited to the design phase at present. While 31.7% of respondents believed that they possess a basic understanding of BIM methodology. On the other hand, 14.6% of participants don't have any clue about this world adopted technology while 7.3% of respondents claimed that they possess BIM Level 2 knowledge.

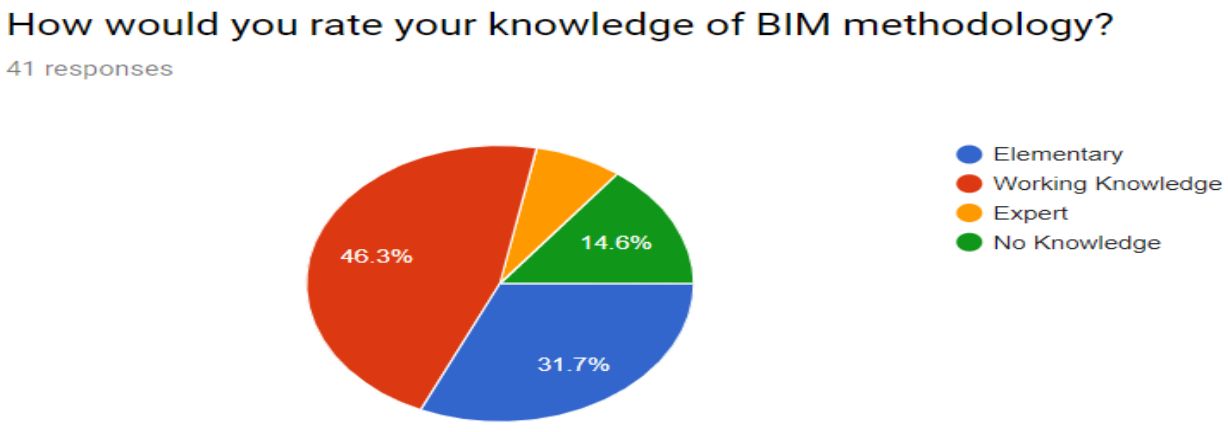


Figure 32: Respondents knowledge of BIM methodology.

The below diagram illustrated the percentage of BIM adopted organizations respondent in India. Surprisingly almost 44% of respondents claimed that they adopted BIM implementation in their projects. While the percentage of respondents stated that they don't use this methodology at all. On the other hand, 12.2% were not about BIM adoption in their organization. While asking on a telephonic interview about the BIM usage, companies such as Afcon infrastructures Ltd., Takenaka India Pvt. Ltd., Architectural firms described most of the BIM usage were implemented until design level for better visualization for client satisfaction and not forwarded to construction phase because of less demand and marginally high fees.

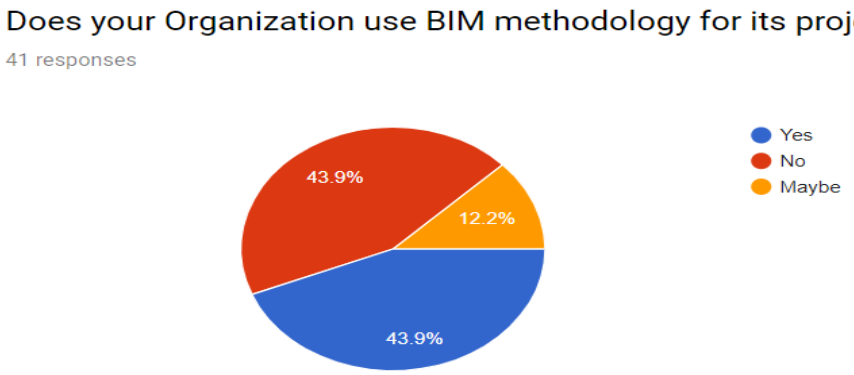


Figure 33: Respondents claim about BIM usage in their organizations.

In figure 34 the respondents described their opinions about BIM software expenses and time required for training. Around half of respondent believed purchasing license of BIM software is quite expensive in country like India where people don't want to invest more in design phase and also time required to train staff for BIM usage is also high and difficult to provide in such a competitive market where most of the tasks need to finish in short period of time. On the other hand, one-fourth of respondents claimed using BIM software is neither expensive if utilizes over the project lifecycle nor more time required for learning. While one-fourth of respondents stated that they were not aware of BIM software.

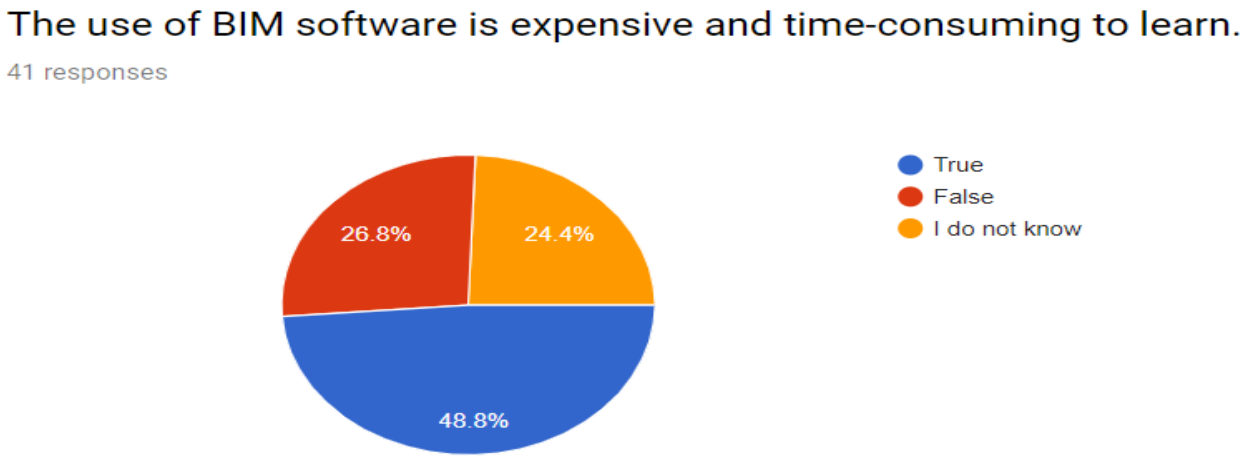


Figure 34: Respondents opinions about BIM software expenses and time-consuming to learn.

On asking about the BIM effectiveness to manage time, cost and coordination issues, 85.4% of participants believed that BIM has the potential to manage these issues effectively even though fair efforts from involved stakeholders, better planning, and well knowledge about BIM tools required as stated through comments. While only one participant claimed that BIM doesn't have the capability to resolve the above-mentioned issues. On the other hand, 12.2% of respondents don't have any clue about BIM effectiveness.

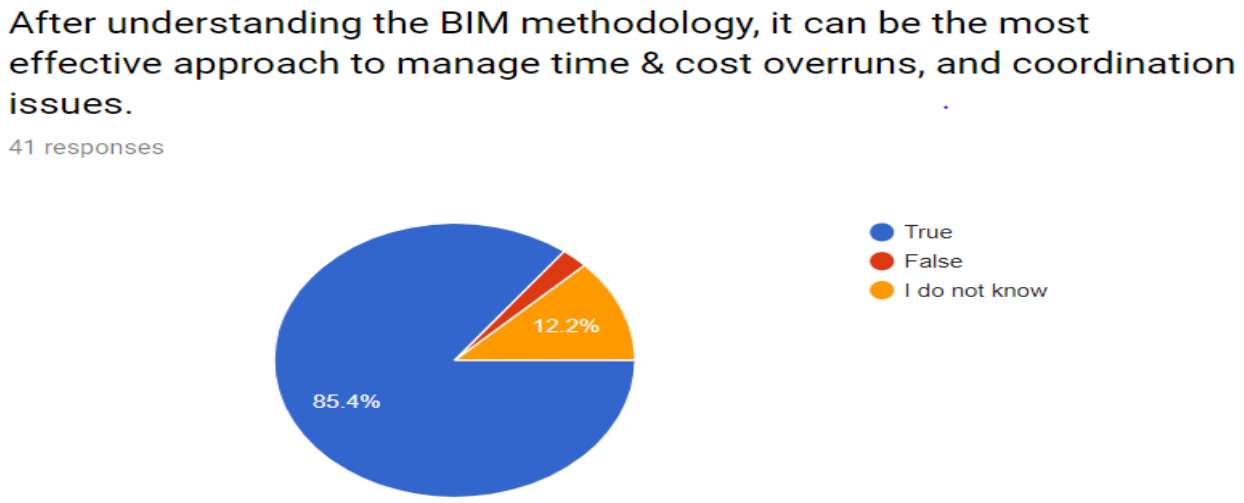


Figure 35: Respondents review toward BIM effectiveness to resolve cost, time and coordination issues.

The following chart describes the respondents assessment of the BIM benefits to PM firms. Altogether 75.6% of participants believed that BIM methodology helps PM firms for

managing tasks such as clash detection, planning, quantity-take off, costing, scheduling, coordination, collaboration, and better controlling and monitoring of construction processes. While one-fourth of respondents stated BIM helps PM firms in planning, costing, quantity take-off, coordination, and collaboration only. While most of the respondents believed that clash detection was not considered as potential benefits to PM firms.

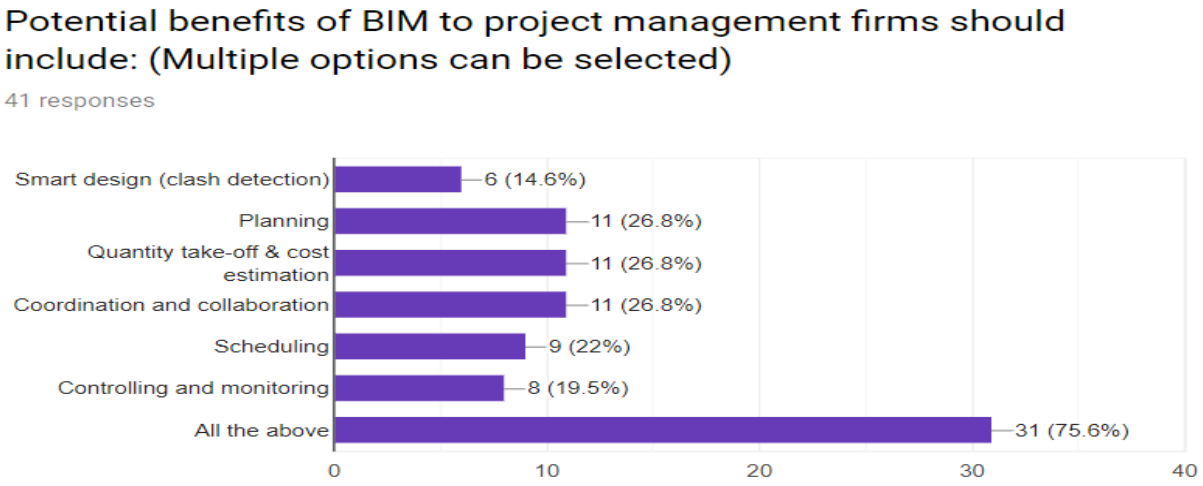


Figure 36: Respondents assessment towards potential benefits of BIM methodology to PM firms.

On asking about the change of role and procedures of managing tasks while using BIM methodology with respect to conventional approach of handling tasks, 70.7% of respondents believed that yes the role of each involved stakeholders change while implementing BIM methodology such as managing 3D model for project progress visualization instead of using huge numbers of bar chart sheets to explain the progress while generating quantities and costing automatically from the smart model rather than preparing manually. On the other hand, 10% of respondents don't think the role change significantly with the adoption of this new technology. While nearly 20% of respondents were not sure about changes with BIM adoption.

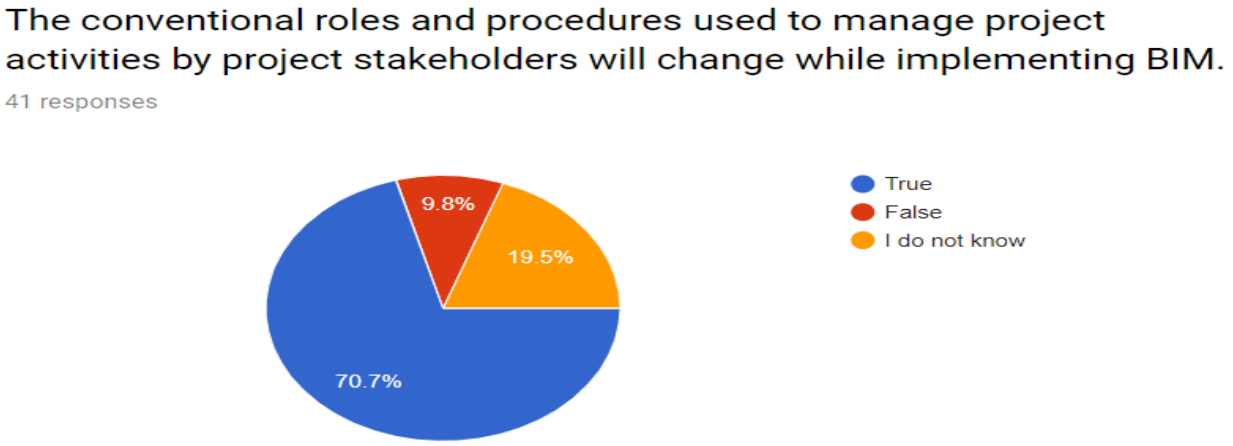


Figure 37: Respondents review for the change of stakeholders role with BIM adoption.

The following diagram showed the majority (78%) of respondents believed that BIM can be more beneficial for the entire construction industry in terms of productivity, quality and reduction in claims and coordination issues. On the other hand, marginally (2.4%) respondents don't think about any remarkable benefits. While almost 20% of respondents were not sure about significant benefits to the Indian construction industry. A majority of people were agreed with this statement of BIM benefits to the construction industry that indicates the built trust in BIM methodology over a period of time and after visualizing BIM benefits over the UK, USA, and European countries.

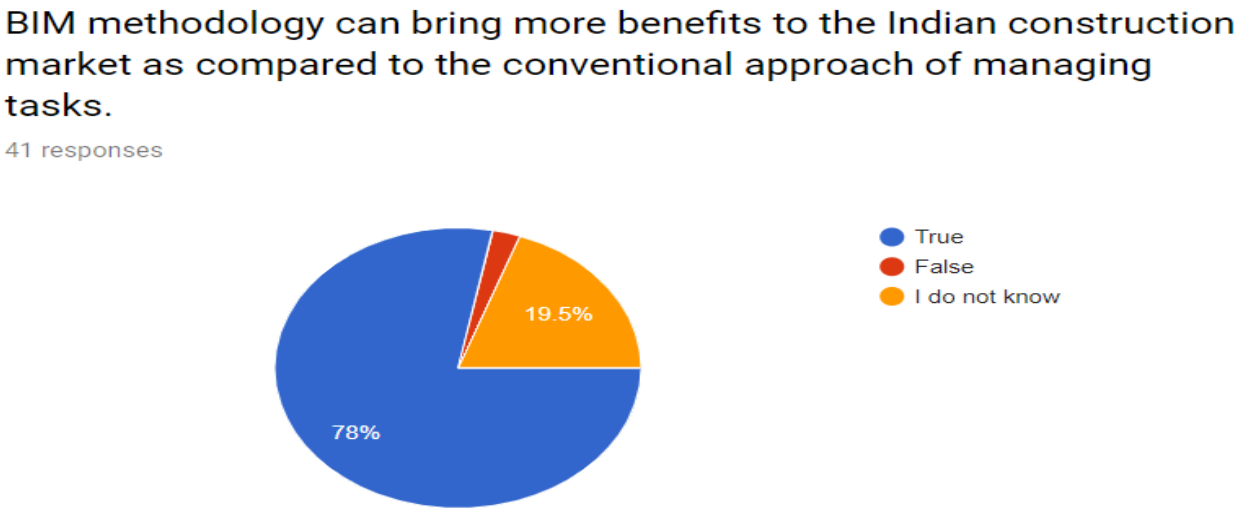


Figure 38: Respondents responses towards BIM benefits to the Indian construction industry.

On asking about the project deliverable, almost 83% of respondents believed that PM firms can deliver the project more effectively through the BIM methodology as compared to the conventional methodology of managing project activities. While 2.4% of respondents were not agreed to this statement. On the other hand, 14.6% of respondents were not sure about the stated comment.

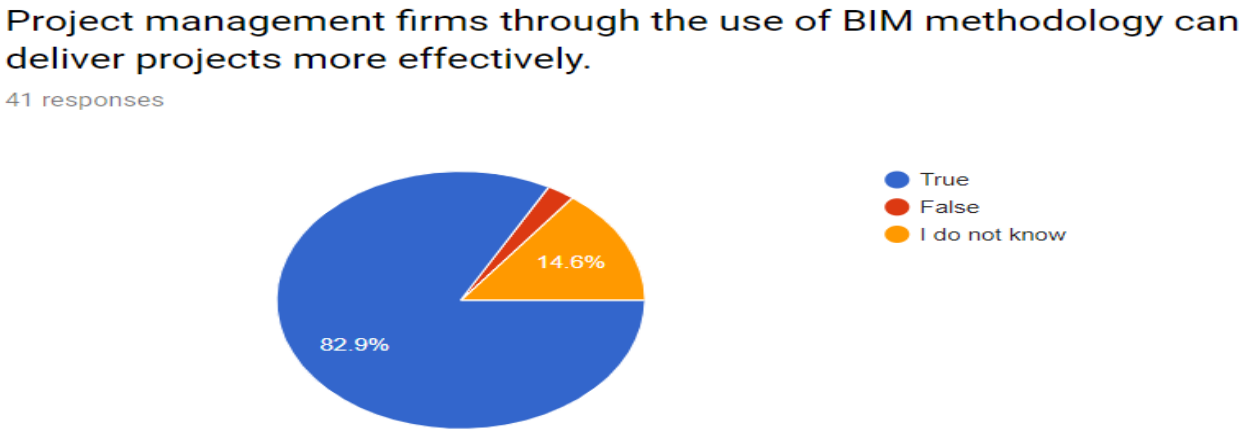


Figure 39: Respondents opinions towards efficient project deliverable through BIM usage.

The next question was related to identifying the biggest challenges towards BIM growth in reply to that 78% of respondents were agreed the stakeholder's attitudes towards BIM adoption were one of the biggest challenges to overcome. While almost 10% of respondents don't believe the stated statement. On the other hand, 12.2% of participants were not sure about the stakeholder's attitude can be a considerable challenge or not for BIM growth in the Indian industry.

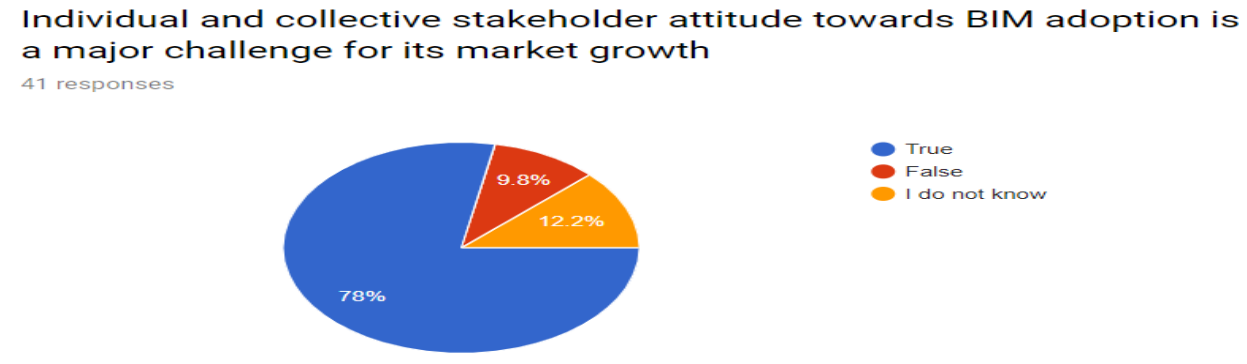


Figure 40: Respondents response toward major challenges for BIM adoption.

The next four questions were asked to look at the future opportunities and requirements for the healthy growth of BIM adoption in India. The below diagram illustrated the responses towards BIM adoption at a bigger level in the coming years. Altogether 53.7% of respondents have faith in the healthy progress of BIM adoption in the coming 5-10 years where they believed most of the projects will be carried over through BIM methodology replacing the traditional approach. While almost 30% of respondents stated it will come sooner than the next 5 years period. On the other hand, 14.6% of respondents stated BIM adoption over the construction market will take more than 10 years due to inadequate standards, regulations, and guidelines available so far.

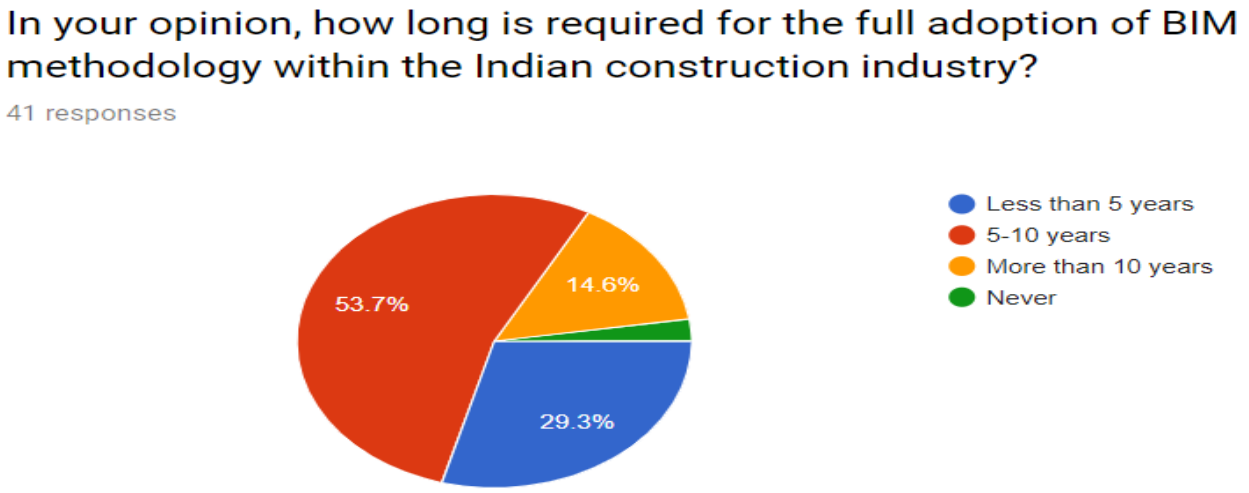


Figure 41: Respondents thought about BIM scope in the coming years.

On asking about the future choices of AEC professionals between conventional methodology or BIM methodology, almost three-quarters of participants believed that BIM will be the first choice in the coming years for the AEC industry to manage projects. While 7.3% of respondents don't think that BIM will overtake the conventional approach of managing construction projects. On the other hand, 17.1% of respondents were not whether BIM overtake the conventional methodology or not.

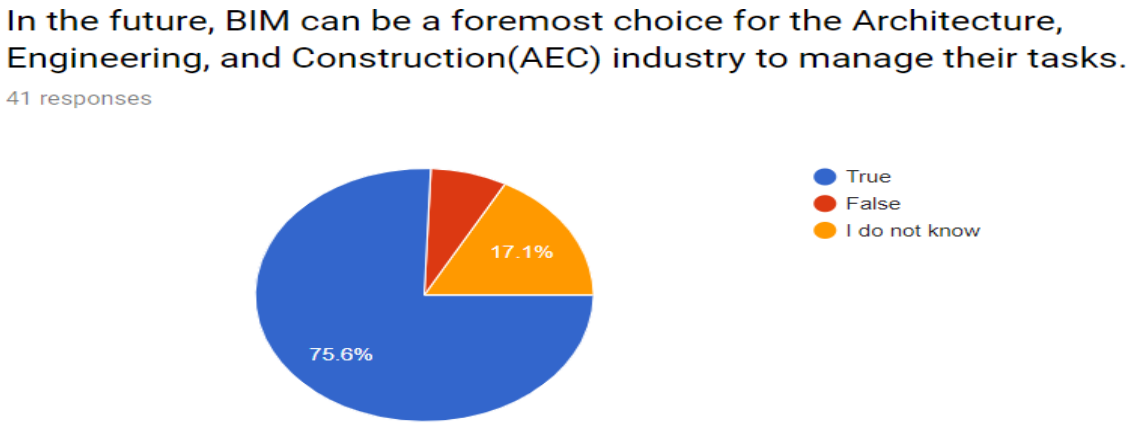


Figure 42: Respondents choice of BIM adoption over conventional methodology.

The below diagram illustrated the role of government bodies for the BIM growth in the Indian construction industry. Almost 90% of respondents believed government bodies, as well as training institutes, should come forward to encourage people for BIM adoption through spreading awareness about BIM benefits as well as setting BIM guidelines, regulations and standards for better clarification and building trust among stakeholders.

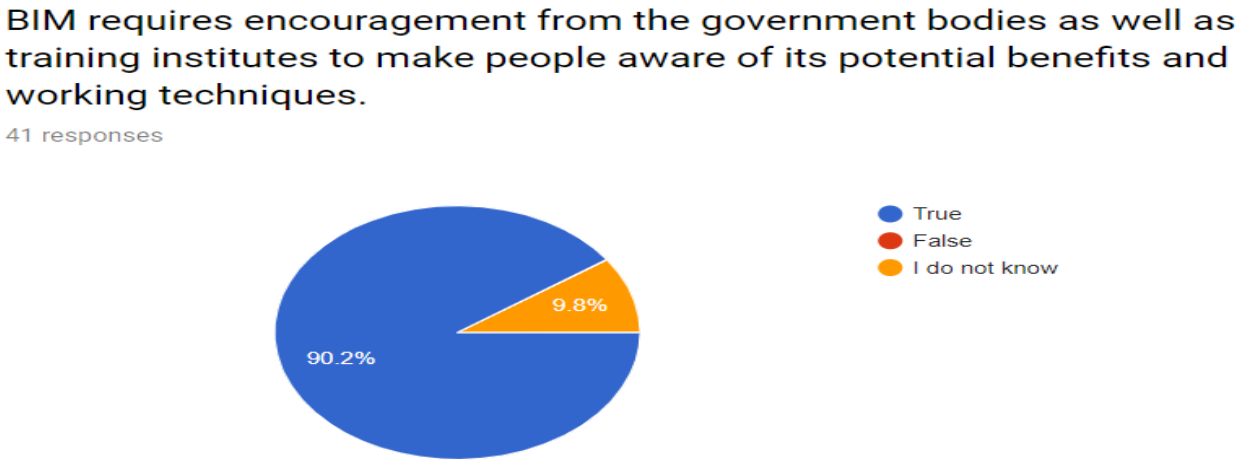


Figure 43: Public bodies' role in BIM adoption by setting up awareness among people.

The last question of this subsection highlighted the possible opportunity for BIM growth in the coming years due to the urbanization campaign requires more construction in the future. Altogether 78% of respondents believed more construction required in the coming years for the fulfillment of urbanization will bring lots of opportunities for BIM growth. More complex projects nowadays are setting up the perfect conditions for BIM acceptance.

While 7.3% of respondents don't believe in that statement. On the other hand, 14.6% of respondents were not sure about this possible opportunity for BIM growth.

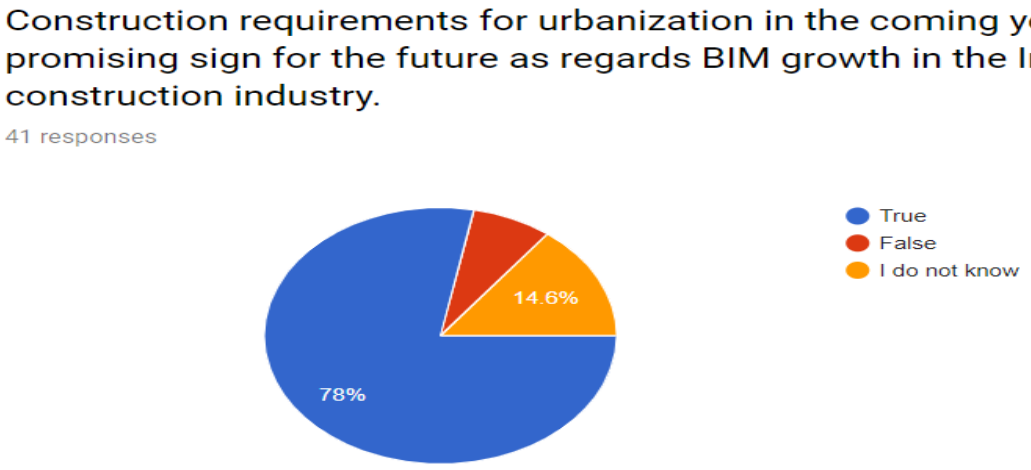


Figure 44: Future construction requirements create opportunities for the possible growth of the BIM industry.

7.2.3 Respondents comments and opinions

The last category of the conducted survey was to gather respondent's opinions and comments towards their BIM knowledge and BIM barriers and opportunities towards BIM acceptance in the Indian construction industry. In this phase, four questions were asked for better clarification about BIM scope in India. The first question was asked about BIM Level uses by their organization to manage projects. Altogether 36 respondents have given their opinions towards these questions. The five respondents claimed that they were implementing up to Level 2 BIM in their organization for managing tasks such as 3D model preparation, scheduling, cost estimation, and collaboration among stakeholders. While three respondents stated that they were using BIM between Level1and 2 in their organization for visualization, cost estimation, and quantity take-off sheets. The twelve respondents stated they are the initial state of BIM usage and just prepared a 3D model for better visualization and to prepare project planning. While five participants stated their organization is considering implementing BIM in their future projects. On the other hand, eleven participants stated they were not interested to adopt BIM methodology.

The second question was related to BIM implementation. Altogether 37 professionals gave their valuable opinions about the BIM methodology. Some of the respondents claimed BIM as a tool requires time, purpose-specific and training to learn for effective

usage. Some respondents believed that most stakeholders don't know much about BIM, so the traditional always caters rather than BIM approach. Hence in order to develop a healthy environment for BIM growth, one needs to inculcate training and applicability of tools at undergraduate level education. They believed this approach will create awareness and scale up the usage of BIM in the Indian industry in the coming years. Some of the respondents stated it develop more transparency among stakeholder's resultant in a more cost-effective approach. While some of the respondents claimed it is quite manageable during the design phase but difficult to implement in the construction phase. In last, some professionals suggested it should be mandatory in all governmental projects and need to include in the educational curriculum.

On asking about the BIM benefits to respondent's organization and to their country, some participants claimed BIM reduces rework, improve productivity, and reduces conflicts and changes during execution. One respondent stated BIM is a one-point solution to his organization for managing tasks. While one respondent claimed it reduces data loss, safe, efficient. One respondent stated BIM help his organization to manage complex projects effectively. One stated it reduces man-hours and efficient for documentation preparation. It enables virtual decisions making during the preconstruction phase claimed by one respondent. Some of the professionals stated all three aspects (time, cost, and quality) in the project enhanced positively and significantly through BIM. They believed countries (especially in the global south) can meet their developmental needs in the built environment through BIM methodology. While sustainability aspects in several dimensions also fostered through BIM implementation.

Through the literature review, and case studies analysis many factors and barriers were figured out but it was essential to ask professional opinions about BIM future opportunities and barriers for the healthy growth of the BIM industry. Altogether 34 respondents have given their opinions about BIM opportunities and hurdles in India. After collecting the empiric data, many respondents stated the major reason for little BIM acceptance was lack of awareness, expertise shortage, co-effectiveness of small projects, resistance to change, lack of cooperation between stakeholders. While some believed BIM, the potential is huge but the Indian construction industry is not mature to change their way of

working and totally dependent on digitalization. Other respondents claimed cost and knowledge of usage of BIM software are striking points to resist to accept new methodology. While some respondents believed rapid urbanization in India demands remarkable expansion in the built environment which requires a large amount of construction in India, big companies with huge projects already started this methodology with some foreign agencies for better training about BIM software. They believed BIM has huge future possibilities in India but at the same time the biggest challenge to meet the skill required for using BIM to its full potential.

7.3 Evaluation of conducted survey

This subsection has summarized the findings of empirical data received from the industry experts through this conducted survey. Even though there were a limited number of respondents had participated in the survey but luckily, all respondents were professional from the recognized academic and industrial background. Top persons from the Autodesk, IBIMA community, Afcon Ltd. and Takenaka Ltd. giant construction firms who hold the knowledge of BIM, as well as the Indian construction industry, had participated in the conducted survey.

The conducted survey has almost the same findings as discussed in subsection 5.1, where two big surveys in India about BIM were analyzed. Even though this survey was addressed to project management firms hence it cannot be seen as representative for the entire industry. Almost half of the participants belong to the project management firms while half of the respondents have a working knowledge of BIM methodology and almost 50% of respondents stated their organization possesses more than 500 employees.

Most people stated they were implementing BIM to design level and still struggling to implement in the construction phase. While many are willing and highly motivated to adopt this new technology. Most respondents stated Lack of BIM awareness, no initiative taken from the public bodies and institutes to encourage people for BIM adoption are the current challenge for little BIM acceptance. With comparison to analyzed surveys in subsection 5.1, more participants stated they possess working and elementary knowledge of BIM methodology which highlights the increase in BIM awareness over time. With more stability in the Indian government and campaigns set by the Indian governments towards

urbanization, digitalization and fight against corruption encourage the BIM industry to grow. Most respondents believed BIM should be encouraged through undergraduate studies, government initiatives such as setting up regulations, guidelines for building trust among the stakeholders and providing more clarification for setting up a strategy for BIM adoption. Almost every respondent believed BIM has the capability to deal with time, cost, quality, and coordination issues. Some respondents stated it should be mandated in all governmental projects to enforce people for BIM adoption.

8. Implementation of BIM methodology in the CPM industry

The above sections described the essentials of BIM methodology, project management, BIM implementation status, and the conducted survey helped to gather empirical data for better evaluation of the successful growth of modern technology. The above case studies highlighted the current challenges faced by project management firms towards project delivery processes while implementing the conventional approach, and their expectations towards BIM methodology. The upcoming subsections will highlight the possible usage of BIM adoption in India and consequently will elaborate on the possible changes in the stakeholder's role while implementing BIM methodology in construction processes. For this, all the information gathered in the previous sections, and relevant data will be capitalized to identifying aspects and fields of action required for successful implementation[77].

8.1 Changes in the stakeholder's role

While implementing the conventional methodology, procedures and roles for managing construction projects were well defined. Each stakeholder has had its well-established strategies and methodology for coordination and task execution. The transition from the conventional to modern methodology requires a shift of stakeholder's mindset to adopt changes in current procedures of managing tasks and collaboration processes. It also essential for each stakeholder to have an impartial and open collaborative approach towards the implication of new technology for effective usage[78].

BIM coordination

The project where the implementation of BIM is decided to adopt should possess a clear and well-framed structure for responsibilities and tasks done through BIM methodology to achieve better transparency among stakeholder's collaboration. Howard and Björk explained the necessity to change construction processes rather than just introducing new technology while implementing BIM methodology[79]. The first step is to define the responsibility of each planner with respect to their BIM generated model.

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[77] (Blömer, 2016)
[78] (Sebastian , Haak , & Vos, BIM Application for Integrated Design and Engineering in Small-Scale Housing Development: A Pilot Project in The Netherlands , 2009)
[79] (Howard & Björk, 2008)

The task to ensure the quality of an individual model to its planning discipline with BIM management. The model developed while adding non-geometric information can allocate failures among other models and help to find a unique solution[80]. The BEP resolves the coordination and collaboration issues at the contractual stage. Although it's inevitable to define the project detailed information in terms of BIM usage before the project started because of project size and scope of the project varies from project to project. Within a project, BIM coordinator has to play a crucial role in the successful implementation of BIM methodology on the behalf of the client's requirements for following guidelines and standards to maintain quality work. BIM coordinator is also responsible for setting strategy, data security, and regular meeting set up for better collaboration[81].

Stakeholders Involvement

The attitude towards acceptance of a new methodology is an essential factor for effective BIM usage. Most of the information and strategies are made during the designing and planning phase. In the traditional method, Architectural firms develop their designs on them as per client's requirements and have no fair collaboration with other project participants such as contractors, MEP consultant resultant more discrepancy arises during construction phases. Lack of materials and processes information made more confusion during execution and prolong the construction time. Hence it should be essential that each stakeholder should participate during the planning and designing phase for suggesting possible future obstructions and solutions before making final planning. Sharing of information should be transparent and BIM training to indulged staff should be provided before implementing BIM methodology. The project management firms need to participate actively with all stakeholders and clients for avoiding coordination issues[81].

BIM Management

In coordination with client and project management, the BIM coordinator defines the project-specific practices, BIM levels and presents BIM maturity map within the project scope during the contractual practices for effective implementation. BIM coordinator has to clear BIM processes and about new technology, data production, and procession. One

[80] (Eadie et al., 2015)
[81] (Borrmann et al., 2015)

of the major hurdles is to manage multiple models from different disciplines to develop a unique model possessing all information to avoid rework and mistakes that can mislead the project progress. After doing research about BIM status in India, unfortunately, there is currently missing information about BIM coordinator roles and scope of work as defined in UK and USA guidelines. Hence BIM coordinator and project management firms need to put more effort into successful implementation. The literature review and case studies and this section define five critical factors (POWER) for successful BIM integration in project processes and collaboration[82]. These factors are defined as

P- Product information sharing

O- Organizational roles synergy

W- Work processes coordination

E- Environment among stakeholders effort

R- Reference data consolidation[82].

The characterization of BIM roles in a BIM implemented project are described below.

Characterization of New BIM roles			
Stakeholders	**Within a multidisciplinary team**	**Within an organization**	**Used nomenclature**
Architect and BIM Coordinator	Overseeing BIM workflows and system; Ensuring that protocols are being implemented; design and setting up processes.	Overseeing Organizational BIM workflows and systems; setting up and maintaining organizational standards for BIM.	BIM coordinator
BIM manager	N/A	N/A	BIM manager
Architect and BIM manager	Setting up BEP plans and BIM standards	Implementation and business development around BIM.	BIM manager
`Client, Virtual design construction (VDC)coordinator, civil and structural engineer	Basic Management of drawing production.	software adaption; Model navigation and revision	BIM manager

[82] (Sebastian, Changing roles of the clients, architects and contractors through BIM, 2011)

Architect, PM, and VDC-BIM coordinator	N/A	N/A	BIM manager
Architect and BIM Coordinator	Driving BIM collaboration among involved stakeholders	Development of organizational standards and workflow around BIM; Alignment of work processes	BIM coordinator

Table 8: Characterization of a new BIM role[83].

8.2 Potential benefits to the CPM industry

The increasing acceptance of BIM can be understood with the conjunction of new PM's outlines, such as BEP and IPD processes which increase the need for better coordination and collaboration among all stakeholders (Eastman et al., BIM Handbook: A Guide to Building Information Modeling for Owners, Managers, Designers, Engineers and Contractors, 2011)[84]. BIM methodology offers various usage to all stakeholders within a project over its life-cycle such as BIM offers better visualization of the scope of work and project needs to client, design team ensures better model analysis thorough BIM, PM firms able to prepare planning and manage it more effectively and economically. During the construction phase, the contractor has more clarification over project requirements and it enables construction easy and shortens, while the facility team uses BIM for operational purposes and decommissioning phases[85].

- 3D Model integrated with non-geometric information helps to prepare quantity take-off more accurately and quickly.
- While using 4D and 5D BIM integrated Model, the PM firms immediately update the schedule and budget after any changes occur resultant in better organization of time and cost frame.
- BIM helps to optimize the client's satisfaction towards project progress.
- Less time required for time and cost estimation with more accuracy through BIM.

[83] (Akintola , Venkatachalam, & Root, 2017)
[84] (Eastman et al., BIM Handbook: A Guide to Building Information Modeling for Owners, Managers, Designers, Engineers and Contractors, 2011)
[85] (Grilo & Goncalves, 2010)

- 5D BIM ensures the PM team to keep budget reins tight which helps to increase the overall profit.
- Better coordination during preconstruction ensures minimum changes during the construction phase[86].
- Clash detection and 3D visualization ensure better quality and reduce rework.
- BIM helps to achieve better collaboration among different stakeholders.

According to PMBOK, the success criteria with the influence of BIM are described below.

PMBOK Knowledge area	Influence of BIM	Criterion	BIM Benefits
Integration Management	Development of the project charter and PM plan in sync with the BEP; develop integrated change control with BIM	Coordination	Improvement
Scope Management	Integrate BEP with scope definition; develop a scope control mechanism	Scope	More clarification
Time Management	Incorporate standard processes and practices of 4D simulation, phasing, and prototyping; the interface of the project schedule and the BIM implementation plan	Time	Reduction or control
Cost Management	Incorporate standard processes and practices of quantity take-off, estimating; link cost assemblies with model objects to generate estimates	Cost	Reduction or control
Quality Management	The interface of a model quality management plan with the overall project quality plan	Quality	Increase or control
Human Resource Management	Coordination and communication protocols, training, and competency mapping about BIM	Organization	Improvement
Communication Management	Collaboration, coordination and communication protocols	Communication	Improvement
Risk Management	Accuracy and certainty in time, cost, and other project parameters	Risk	Negative risk reduction
Procurement Management	Supply chain integration, quantity take-off, estimating	Procurement	Help
Stakeholder Management	Visualization, collaboration & information sharing	Information sharing	More satisfaction

Table 9: BIM benefits to project processes as per the PMBOK knowledge area[87].

[86] (Fazli et al., 2014)
[87] (Bryde , Broquetas , & Marc, 2013)

8.3 Summary

This section illustrated the change of stakeholder's role while implementing BIM and described the potential benefits to the project management team. The above PMBOK table highlighted the BIM usage to different disciplines within the PM firms as all of these management works mainly handled by PM firms in India. Although, each stakeholder needs to collaborate in teamwork with fair efforts and attitude. It is not only the responsibility to manage and encourage all project-related disciplines other also have to show their interest and understand their responsibility. BIM coordinator is the key pillar for successful BIM implementation in the project. All the participants need to trust each other's work for enhancing communication. For a better understanding of BIM processes, the clients need to organize proper training for the better and secure result. The described benefits in subsection 8.2 and case studies can be achieved only if BIM uses to its full potential with the highest precision and special attention.

9. Research questions answers

This section illustrates the solution of research questions developed during the formation of conceptual formulation and as mentioned in subsection 1.2 to obtain the objective of this scientific research. With the help of the literature review, analysis of case studies, and professional survey, all the research questions with their solutions are mentioned below.

Question 1 What changes are required in traditional management processes in order to implement BIM?

The traditional(conventional) methodology manages project processes through lots of manual and paperwork, while BIM methodology enables project processes handling through digitalization. In the conventional approach, where the quantities and estimation were prepared manually through 2D drawings requires a lot of effort, time and still have chances to omit mistakes while preparing estimation and quantity take-off. While BIM methodology permits quantity take-off and cost estimation automatically through the information-rich 3D model. For project scheduling, the bar chart was the most used options for managing construction activities in the conventional approach resultant of more clashes among concurrent activities. While BIM empowers the real-time progress visualization through software like Vico office that helps to prepare the location-based schedules which detect the concurrent activities clashes before implementing into execution and enables the project progress smoother and more efficient. On the other hand, BIM methodology offers one-point solutions where all the involved stakeholders can coordinate effectively and more transparency among processes is built but these benefits were missing in the conventional approach of managing tasks. The rest of the changes in processes such as clashes detection, collaboration strategy, energy analysis, and maintenance processes have been briefly discussed in the subsections 6.3 and 8.2.

Question 2 What are the possible challenges when adopting BIM in the Indian construction industry?

Through the literature review, case studies and professional survey, various challenges for healthy BIM growth have been identified. A list of possible constraints is listed below and the detailed briefing about these constraints was listed in subsection 5.4,6.2 and 7.3.

- **Technological constraints:** Hardware issues, software availability, lack of BIM knowledge.
- **Economic constraints:** Software expenses, training expenses and time to learn. The expenditure at the start without getting initial BIM benefits measured as the real challenge for bringing BIM into use.
- **Social constraints:** Society and professional's attitude towards the adoption of new technology measured as one of the major challenges towards BIM growth. Efforts required from professionals to change their working procedure also makes harsh conditions for BIM adoption. Encouragement of BIM adoption from government bodies and training institute is still a bigger challenge.
- **Legal constraints:** Unavailability of BIM standards, guidelines, and regulation in India sets difficult conditions for BIM growth. On the other hand, limited BIM benefited projects sample to build trust among stakeholders is currently missing.

Question 3 What are the possible benefits to different stakeholders through BIM?

There are various benefits discovered through this research work and are listed below.

- 3D Model integrated with non-geometric information helps to prepare quantity take-off more accurately and quickly.
- While using 4D and 5D BIM integrated Model, the PM firms immediately update the schedule and budget after any changes occur resultant in better organization of time and cost frame.
- BIM helps to optimize the client's satisfaction towards project progress.
- Less time required for time estimation and cost estimation with more accuracy through BIM.
- 5D BIM ensures the PM team to keep budget reins tight which helps to increase the overall profit.
- Better coordination during preconstruction ensures minimum changes during the construction phase.
- Clash detection and 3D visualization ensure better quality and reduce rework.
- BIM helps to achieve better collaboration among different stakeholders.

The other benefits and detailed descriptions were described in subsection 8.3.

Question 4 Is it possible to integrate 3D design with automatic scheduling (4D BIM) and to cost (5D BIM)?

The literature review and followed case studies have shown the integration potential of BIM methodology. A BIM model can not only be integrated with 4D BIM or 5D BIM but also possible to integrate with 6D BIM and 7D BIM services. Although some manual efforts always exist such as to link the cost information and resources with a 3D model that helps to extract the IFC files from the 3D model. Then the IFC files imported to the Vico office for 4D and 5D BIM services. But if any changes made to the model then the same procedure needs to revise again. A brief description of 4D and 5D BIM is demonstrated in the case study section of this research work.

10. Conclusion

The aim of the research was to demonstrate the project management processes in construction projects using BIM methodology as well to assess the built environment approach towards BIM growth in the Indian industry. The research was able to uncover the BIM potential from a project management perspective and able to set up a strategy for effective BIM usage towards project success. Moreover, BIM provides a framework through BIM execution plan for the successful project delivery by ensuring the effective involvement of all the stakeholders. Mostly huge and complex projects in India are managed by project management firms, BIM is the most suitable tool for the project management firms to manage construction projects effectively and efficiently.

The construction sector in India will continue to perform a significant role in the country's infrastructure and industrial development that is being driven by the nation’s economic growth, urbanization. Other future opportunities in India as well as worldwide status, international standards/guidelines, regulations and strategies to encourage people towards BIM adoption are briefly described in section 5 of this research work.

Through a comprehensive literature review, case studies analyses and survey evaluations, various points about BIM methodology as well as the conventional approach of managing the construction processes and construction market trends were figured out in the research work such as, the conventional methodology that fundamentally deals with more manual and paperwork hence arises the transparency issues, quantities preparation, schedule formation, and coordination among stakeholders were the most commons problems faced by the involved parties especially in the complex projects. While BIM is globally adopted technology for its well-defined functions of managing above-listed processes more effectively and efficiently. All changes required in stakeholder procedures while implementing BIM methodology to manage tasks were highlighted in section 8 of this research work such as collaboration on a smart model, information transfer procedure, BIM execution plan. Almost 50% of respondents in the conducted survey believed that BIM is growing in the Indian market and will become the most popular choice for the AEC professional in the coming years to manage complex projects. Even though BIM still in its

early phases of managing project design and planning yet struggles to find its way in construction activities for showing its full potential.

It is important to keep in mind that the built environment approach towards adopting new technology will face various possible opportunities and constraints that are mentioned in this research work. These opportunities are campaigns set by Indian government such as ‘Make in India’, ‘Digital India’, a continuous rise in urbanization over the past ten years, and fight against corruption through developing more transparency in processes- all of which create a healthy environment for BIM growth. BIM standards and regulations set by countries like the USA, UK, and Scandinavia towards BIM implementation and its potential benefits encourage the AEC professionals in India to adopt the world encouraged technology for the built environment tasks. On the other hand, lack of BIM awareness, BIM software expenses, training expenses and time to train, BIM experts shortage, training missing during undergraduate studies, absence of regulations and guidelines/standards set by government to encourage industry people, society attitudes towards accepting a new technology are some identify major challenges among others listed in research questions answers and in section 5 of this research work that needs to be overcome before a significant growth of BIM industry in India can be achieved.

11. Recommendations

This research efficiently utilizes a combined qualitative and quantitative methodology using literature, case studies, and professional survey to carefully analyze the potential impact of specific BIM functionalities on the various phases of the life cycle. Although BIM is getting attention and acceptance in the Indian construction industry over a decade now, it is a long way until it will be completely implemented. For the significant growth of the BIM industry in India and to enhance the project processes these are followings recommendations that need to be considered for future research:

- Education and training at universities and organizations should be encouraged towards BIM functions and their effectiveness in project deliverables.
- Currently, limited case studies related to BIM Implementation are available in India hence more publications on BIM related case studies are required to analyze the BIM impact on project success in the Indian environment. These can be useful for setting up an effective strategy and attitude towards BIM acceptance.
- The government should encourage people towards BIM acceptance through developing BIM standards, guidelines and regulations seeing examples from BIM adopted nations such as the USA, UK, and Scandinavian countries.
- Amidst the BIM hype in the Indian AEC market, the stakeholders need to be educated about BIM use cases and strategies. This can help the consultants and clients to work on common grounds and really reap benefits out of BIM implementation strategies.
- BIM is used up to design level and most of the unexploited potential still exists hence motivation and positive attitude from the client are highly recommended to explore the potential benefits from the BIM methodology over the project lifecycle.
- Project management firms and researchers need to explore the integration functions of BIM methodology with 4D BIM,5D BIM, 6D BIM, and 7D BIM while considering the BIM potential over the project lifecycle.

Declaration of Authorship

I hereby declare that the attached Master's thesis was completed independently and without the prohibited assistance of third parties, and that no sources or assistance were used other than those listed. All passages whose content or wording originates from another publication have been marked as such. Neither this thesis nor any variant of it has previously been submitted to an examining authority or published.

Berlin,15/01/2020

Location, Date

Signature of the student

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