DEVELOPMENT OF A STANDARDIZED INTEGRATED BIM APPROACH FOR A VILLA PROJECT

PROJECT REPORT

Submitted by

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of

Master of Technology

in

Structural Engineering & Construction Management

DEPARTMENT OF CIVIL ENGINEERING

T.K.M. College of Engineering, Kollam

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DECLARATION

I, undersigned, hereby declare that the project report “DEVELOPMENT OF A STANDARDIZED INTEGRATED BIM APPROACH FOR A VILLA PROJECT”, submitted for partial fulfillment of the requirements for the award of degree of Master of Technology of the APJ Abdul Kalam Technological University, Kerala, is a bonafide work done by me under supervision of Dr. Seema K. Nayar. This submission represents my ideas in my own words and where ideas or words of others have been included, I have adequately and accurately cited and referenced the original sources. I also declare that I have adhered to ethics of academic honesty and integrity and have not misrepresented or fabricated any data or idea or fact or source in my submission. I understand that any violation of the above will be a cause for disciplinary action by the institute and/or the University and can also evoke penal action from the sources which have thus not been properly cited or from whom proper permission has not been obtained. This report has not previously formed the basis for the award of any degree, diploma or similar title of any other University.

Kollam

12/09/2022 Jasmin Jabbar

DEPARTMENT OF CIVIL ENGINEERING

T.K.M. COLLEGE OF ENGINEERING, KOLLAM

CERTIFICATE

This is to certify that the report entitled **"DEVELOPMENT OF A STANDARDIZED INTEGRATED BIM APPROACH FOR A VILLA PROJECT"** submitted by **JASMIN JABBAR, TKM20CESC12** during **2021-2022** to the APJ Abdul Kalam Technological University in partial fulfillment of the requirements for the award of the Degree of Master of Technology in Structural Engineering and Construction Management of Civil Engineering is a bonafide record of the project work carried out by her under my guidance and supervision. This report, in any form, has not been submitted to any other University or Institute for any purpose.

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ABSTRACT

The process of managing a construction project is difficult and time-consuming. Since the jobs associated with a project are diverse and complex, involving numerous stakeholders in various phases, successful project management is not easy. Moreover, reliance on manual labour and the reluctance to adopt automation in planning and design, make management of projects difficult. However, there is ample scope of information technology in construction industry and within the context of sustainable development, the expectations associated with efficient project management has increased multi-fold.

Building Information Modelling (BIM) offers great support in project management, together with advanced technologies as knowledge systems.BIM is a progressive intelligent 3D model-based process that gives Architecture, Engineering and Construction (AEC) professionals the insight to plan, design and manage more efficiently. In an attempt to simplify the efforts of the industry and to tap the potential of the technology, this study proposes an integrated BIM approach for a double-storeyed villa so as to develop a complete integrated 4D/5D BIM workflow. The dominant aim of this study is to standardize the BIM metadata with the help of a BEP (BIM Execution Plan), which is limited to 5D.The management tool used in this work is Bexel Manager. This work also proposes the standardization of a workflow template in order to replicate similar projects in future, leading to less rework and more of optimization and customization of digital workflows.

With the intention of keeping the project as close to the industry and using authentic data, the labour productivity was determined through a questionnaire survey. The output quantity per work hour was examined from 30 responses from the industry. To calculate the productivity criteria and schedule the project, this output quantity was employed as an input. Autodesk Revit was used to create the villa's 3D model. Primavera P6 was used to construct the 4D/5D model after analysing the quantity take-off and Bill of Quantities (BOQ). A clash-free model was created once the 3D model's clashes were identified. As a result, the cost disparity was discovered and a template of the same was standardized. After that, the properties required to create a flawless BIM model were standardised in accordance with LOD 300 in the BIMForum's ISO 19650 series, in the form of a template. The constructed villa model underwent a property check, and a report was simulatively generated. Then a template defining the quantity take-off structure was created for the typical villa project and was standardized.

Comparably, all the activities required for a villa project was sorted and standardized. Also, as a part of deriving the creation template, the methodology of the project was generated in two levels of cost item. As a result, the entire workflow of a double-storeyed villa has been standardized and the schedule has been generated effortlessly. This template can be used to develop the workflow/schedule of any residential building smoothly. Ultimately, the standardized workflow has been suggested to experts in construction industry, which comprised of project managers, engineers and supervisors, and the feedback was recorded and simulated. The upshot showed that the integrated BIM approach was significantly and considerably excelling the traditional mode of project management.

Keywords– Building Information Modelling (BIM), workflow, quantity take-off, standardization, productivity standard, BIMForum, property check, clash detection.

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ABBREVIATIONS

PM	Project Management
BIM	Building Information Modelling
LOD	Level of Development
MEP	Mechanical, Electrical and Plumbing
WF	Workflow
wh	Work hours
wd	Work days
BCF	BIM Collaboration Format
BXF	BIM Exchange Format
IFC	International Foundation Class
CM	Construction Management
CMAA	Construction Management Association of America
AEC	Architecture Engineering and Construction
OL	Organizational Learning
LOB	Line of Balance

CHAPTER 1

INTRODUCTION

1.1 GENERAL

Construction Management (CM) is a truly professional service that incorporates specialized project management methodologies to administer the planning, design, and construction of a project from its beginning to end. The purpose of construction management is to manage a project's time/delivery, cost and quality—referred to as project management triangle or "triple constraints". The Construction Management Association of America (CMAA) states the most common responsibilities of a Construction Manager fall into the following 7 categories: Project Management Planning, Cost Management, Time Management, Quality Management, Contract Administration, Safety Management, and CM Professional Practice. These are often delayed due to several reasons - commonly communications issues, design errors, changes in scope, supply chain issues, build failures and some unforeseen risks. Hence, construction project management is a very complicated process. The obstacles in project management can be encountered to a great extent by switching the traditional approach of project management to Digital Project Management which uses Building Information Modelling (BIM).

Building Information Modelling (BIM) is one of the most optimistic recent developments in the Architecture Engineering and Construction (AEC) industry. BIM presents a digital envision containing the precise geometry and apposite data required to support the design, obtainment, fabrication and construction activities in the form of 3D oriented CAD *(Ahuja t al., 2020).* Building information modelling according to the "ISO 19650 series" is about getting benefit through better specification and delivery of just the right amount of information concerning the design, construction and management of buildings and infrastructure, using appropriate technology tools. This helps deliver the efficiencies and savings envisaged by the UK Government and others. Figure 1.1 shows the components of BIM. The standard is about good practice throughout the whole project and asset management team. It applies throughout the whole life cycle of an asset, including construction, refurbishment, operation, decommissioning, and it applies to all types of asset in the built environment – buildings, infrastructure, and the systems and components within them.

Figure 1.1 Components of BIM *(Ahuja t al., 2020)*

BIM is indeed an additional model for a project's engineering information database, storing all of the architectural designs with the geometric information and the corresponding high-tech information for all the works. There are numerous anterior studies that have examined BIM detriments and benefits in construction. Benefits recognized during the construction phase of a project include less rework, lesser requests for information and changes in orders, customer satisfaction through envision, improved productivity in scheduling, effective and faster construction management with easier exchange of information, accuracy in cost estimation and visualizing safety analysis. Numerous recent studies relative to information system development present the application of the proposed system integrated with BIM in construction. One among them is the BEXEL Manager.

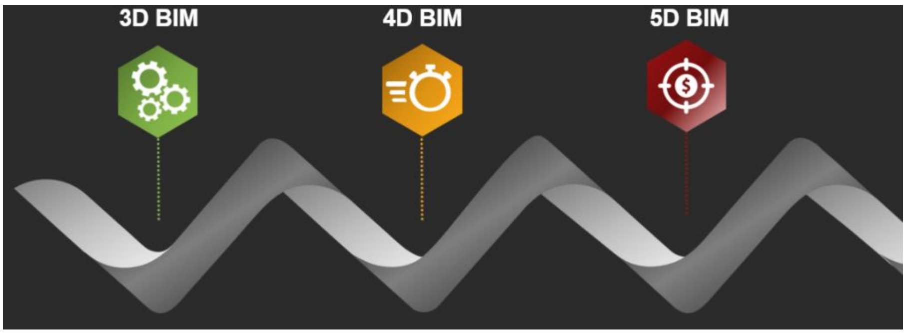


Figure 1.2 BIM parameters *(Liu et al., 2015)*

Nearly 50% of the construction industry is using BIM today. BIM models cover a wealth of building. This is because the BIM covers 4-dimensional and 5-dimensional models which adds on to the 3-dimensional geometry of the building. Figure 1.2 shows the parameters of BIM. 3D refers to the geometry of the building considered, 4D refers to the time plus the geometry and 5D refers to the cost in addition to the geometry. While technological revolution is quickly forging ahead, the construction sector is falling far behind – with productivity levels straggling behind every other industry sector in India. The government is already recognising this with a number of initiatives launched last year aiming to help the sector adopt new innovations to indulge in more of information technology and increase productivity levels.

However, many construction businesses scuffle to implement new technology so it’s not startling that a global report from McKinsey Globe Institute recognised construction as the second least digitalised sector in the world. Although the construction sector may rate there is not much benefit in implementing technologically innovative changes in a physical environment, clutching digital technology delivers multiple secondary benefits in construction. These benefits include more efficient usage of materials, improved health and safety of labours, safer working environments and a more efficient recruitment process.

1.2 SIGNIFICANCE OF THE STUDY

Construction Project management is a time-consuming and difficult procedure. Numerous parties are significantly involved at various stages of construction. Using several solutions for various issues is part of the traditional project management methodology. As a result, details regarding a project are dispersed throughout various construction activity levels. However, the final outcome would make it difficult for the stakeholders to enforce and carry out any plans. By introducing Digital Project Management to the sector, this might be improved. BIM (Building Information Modelling), Digital Twin, CDE (Common Desktop Environment), and other tools are used in digital project management.

Figure 1.3 represents the most commonly used BIM tools. BIM is the newest and most popular of these advancements. Conflicts in building design are supported by BIM, as are clash detection, cost estimation, quantity take-off, etc.

However, stakeholders' biggest difficulties are interoperability-related. These problems involve the ability of software and hardware components to allow the construction of various component combinations within or between organisations in order to enable various capabilities. Figure 1.4 represents the BIM roles in construction project management.

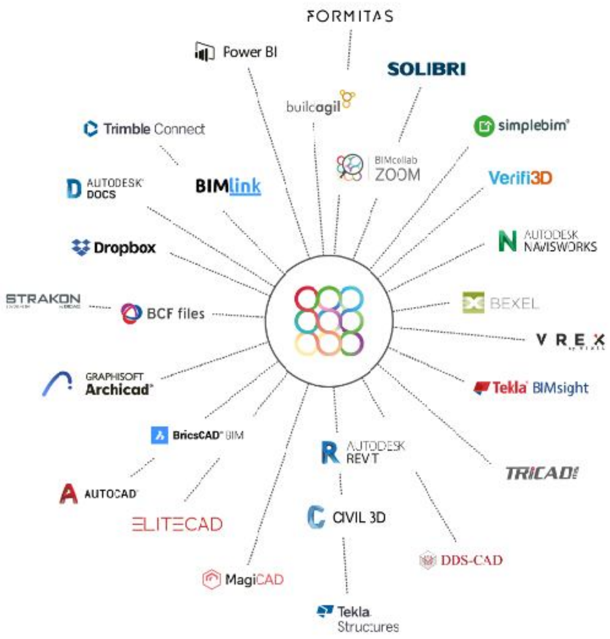


Figure 1.3 BIM Tools

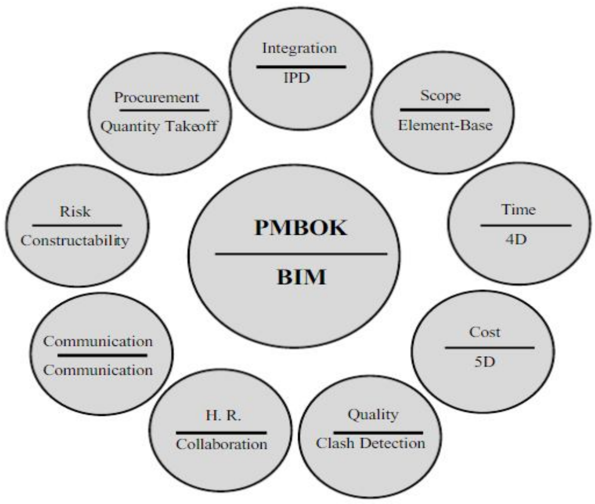


Figure 1.4 BIM Roles in Construction Project Management

Therefore, different management software is used to handle the execution of each task. The project team faces a significant challenge as a result of the need for extensive software training. Consequently, an integrated BIM strategy may be more beneficial. Figure 1.5 explains the Integrated Bim Approach.

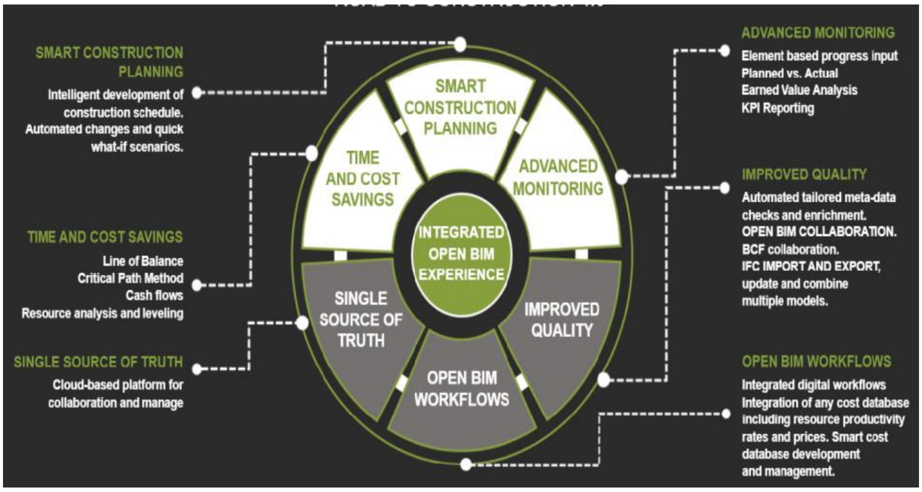


Figure 1.5 Integrated BIM Approach *(Mesaros et al.,2020)*

1.3 NEED OF THE STUDY

Project management is a labour-intensive and inefficient procedure that heavily relies on human labour. Therefore, the building business needs to adopt information technology more frequently. However, the level of automation in the construction sector needs to be increased somewhat. The fact that BIM is information-poor and that the majority of its tools are difficult to use is one of its biggest flaws. Consequently, a management solution that is more user-friendly and streamlined is needed. Repetition of the same task is monotonous as well. Therefore, there is a need for template standardisation so that identical projects can be created with minimal duplication of effort. It improves the simplicity of copying models to buildings with comparable genres, enabling the replication of projects of a similar nature.

CHAPTER 2

LITERATURE REVIEW

2.1 GENERAL

Researchers have identified the need to incorporate BIM into the industry to equip all the stakeholders with an adequate understanding of BIM concepts and they identified that engineers with BIM skills help to achieve the successful uptake of BIM within the AEC industry. A number of studies have been carried out targeting the benefits, challenges and opportunities of BIM. Studies that were of prior importance were that of implementing and evaluating construction performance in the mere cases of productivity, supply chain management and its potential in Indian Construction industry. The resistance to the change in the traditional project planning scenario has also been studied by most of the researchers. Some of the predominant papers on BIM is discussed below.

Bhuvanesh et al. (2020) analyzed the importance of implementation of BIM concept in Indian construction and management industry by awareness of BIM, implementation, and utilities in the building structure and established industry in India. The expediency of effectuating BIM was to upgrade the part of the building structure, and MEP systems. The results show that BIM creates competency and also helps users to get several benefits. It gives back the feature that customer of all levels realizes BIM to allocate them work greater, but rate reduction is feasible to be realized by professional users. The high rated professional conveniences are: perceptible access to construction information, enables easy conflict resolutions, helps to schedule the construction process. Moreover, BIM needs a significant alteration in traditional project delivery methods by changing the authority of every individual in the organization in India. To accomplish satisfaction from BIM to the whole stretch, each collaborator of the construction industry needs to incorporate it. The barriers like interoperability, allowable issues, deficiency of recommendations or protocol, cost, etc. can be conquered.

Ahuja et al. (2020) studied the adoption of BIM in emerging markets. According to them, factors responsible for the adoption of BIM are studied in the context of Indian architectural firms. The mechanisms of diffusion of BIM were analyzed through a questionnaire survey based on the Technology–Organization–Environment (TOE) framework which broadly categorizes the influencing factors along these three dimensions. Data were collected through a web-based questionnaire survey. The study found that full potential of BIM has been explored but not realized by many in the Indian construction sector. Findings of the study are analyzed and compared with other emerging and developed markets. Based on the survey results, recommendations for increasing the BIM adoption are provided. Further studies and learnings from mature markets can help Indian construction sector develop effective BIM implementation strategies.

Mesaros et al. (2020) analyzed the use of BIM technology and its impact on productivity in construction project management. BIM technology has a real impact on productivity as one of KPIs in construction project management. Implementation of BIM technology meant a resistance to change by employees and it must by done the teaching process in new system. In spite of this, research confirmed increasing productivity was seen on the next time when the resistance to change barrier was defeated. It was confirmed by experimentation on employees. The results show that BIM technology has a real impact on productivity as one of the KPIs in construction project management.

Wong et al. (2020) presented the findings obtained through a quantitative structured close-ended survey questionnaire distributed among BIM-pioneering construction companies in terms of the three factors of the project, organization, and individual. The results suggest that BIM factors related to the individual supervision category have the highest positive impact, while the Individual (Labour) factor has the most negative impact on labour productivity. The study concludes by recommending the incorporation of BIM in the Individual (Supervision) category to improve the low construction productivity. A practical recommendation was done for building regulatory bodies is to develop comprehensive credential training programs with the greater utilization of BIM-related design and construction management to diminish the negative impact of Individual (Labour) factors and thus improve labour productivity in the construction sector.

Arif et al. (2020) presented a low cost and easily adaptable real-time construction activities' productivity tracking framework. The framework focuses on gathering progress data through construction face survey and thereafter processes it through Dynamo programming to generate data-driven as-built model of an under-construction project on a BIM platform. The framework was implemented to track the real-time productivity and progress of three bulk construction activities; concreting in columns, concreting in slab and placement of block masonry on the construction sites. Based on tracking the productivity for columns was found to be well above (faster) than the budgeted productivity, but slower than calibrated productivity for both progress updates. In case of concreting for slab, the actual productivity was found to be slower than both budgeted and calibrated productivity, for both progress updates. For block masonry, the actual productivity was found slower than both budgeted and calibrated productivity.

Moumita et al. (2019) presented an integrated framework based on 4D BIM and GIS to support CSCM (Certificate in Supply Chain Management). The framework consists of three layers, namely (1) data storage and retrieval layer, (2) analysis layer, and (3) application layer. The framework supported decision making for the three common tasks in CSCM are: (1) supplier selection, (2) determination of the number of deliveries, and (3) allocation of consolidation centres. With data from 4D BIM and GIS, the three CSCM tasks are formulated mathematically and solved to support decision making. The results of the study indicated that selection of suppliers needs to consider both the delivery distance and unit price. The combined effect due to the delivery distance and unit price needs to be considered in selecting the optimal supplier. Second, the number of material deliveries has impacts on the total cost of the supply chain. The proposed framework enhances CSCM using the data inputs and analysis functions in BIM and GIS. With application of BIM increasing in the construction industry, data in BIM nowadays are capable
of providing information for the analysis functions.

Kim et al. (2017) proposed a framework for developing a productivity and safety monitoring system using BIM. It was based on a study comprising of interviews and a questionnaire-based survey. It used BIM to integrate buildable design, prevention and control of hazards, and safety assessment. The study illustrated a development of IPASS (Industrial Project Approval and Self-Certification System) capable of generating productivity and safety scores for construction projects by analysing BIM model information. Finally, they concluded that BIM can be used to monitor productivity and safety as a project progresses, and help to enhance performance under the two parameters.

Park et al. (2017) analyzed daily construction labour productivity using a BIM 3D model and associated properties. The result was based on the process of 3D BIM modelling, quantity take-off, and productivity baseline initialization, acquisition, and analysis. The results show that it is possible to represent productivity using visual progress via a 3D BIM model. This study is limited to BIM-based productivity analysis regarding formwork construction, and further studies based on this information are needed.

Lee et al. (2017) analysed for a unique case where two towers, A and B, of a hospital project deployed two different design coordination strategies in a 2D and BIM mixed-construction environment. The tower A strategy coordinated designs using drawings as the main source of information and confirmed them using BIM (BIM-assisted coordination), whereas the tower B strategy coordinated designs using BIM and confirmed them using drawings (BIM-led coordination). The coordination productivity was 228% faster for tower B than for tower A. The frequency of design changes was much lower for tower B (0.42 times/drawing) than for tower A (2.13 times/drawing). As a result, the design coordination for tower A was delayed by 9.3 months, whereas tower B was completed rapidly and without any delay. A social network analysis revealed that the BIM-led coordination was supported by the relatively even distribution of information, the reduced control of a mechanical, electrical and plumbing (MEP) engineer over a project, and higher accessibility to the information for every project participant. The main contribution of this study is that it explains what causes the differences and why it is important to choose the BIM-led design coordination strategy, even if it will be more challenging to persuade project participants to join a BIM-led coordination process than a BIM-assisted coordination process.

Lin et al. (2016) presented the BIM based Defect Management system that incorporates BIM and web technologies to improve the effectiveness and convenience of Quality Inspection and Defect Management of building projects. The system also provides for synchronous communication between a construction jobsite and a jobsite office. Applied for defect management, the BIMDM system shows potential for creating new practices for the construction quality inspection and defect management in a BIM visualization environment. The real-time sharing of defect data integrated with BIM technology between a construction jobsite and a jobsite office in the BIMDM system may reduce redundancies, decrease poor performance, and deter a lack of common understanding among participants. The proposed system has shown promising results and a great potential for use in equipment and facilities defect management in construction building.

Shang et al. (2016) studied the issues of low construction productivity, and focused on how the use of Organizational Learning (OL) in labour efficiency initiatives, BIM, Buildable Design Appraisal System (BDAS), and Constructability Appraisal System (CAS) can lead to productivity increase in construction. They also analysed the motivating factors and hindrances to OL in the Indian context. It was concluded that OL leads to increased construction productivity, and that the increased practice of OL leads to a greater increase in construction productivity. Also, the OL implicit in BIM, BDAS, and CAS also leads to increased construction productivity. It was further found that a decrease in construction time results from OL in WTU, BIM, BDAS, and CAS, while a decrease in construction cost results from organizational learning in BIM and BDAS. This study assisted industry professionals to understand the importance of OL in construction, by showing enhanced productivity rates through OL in labour efficiency, BIM, BDAS, and CAS.

Poirier et al. (2015) attempted to quantify the impact of BIM on labour productivity. An action-research was carried out with a small mechanical contractor to measure the productivity on labours. Labour productivity for areas where BIM and prefabrication were used is compared to where it was not. And the findings demonstrated a 75% to 240% increase in labour productivity for modelled and prefabricated areas.

Ofori et al. (2015) examined the utilisation of BIM in the construction industry, and the possibility of deriving further benefits from the potential of BIM to improve productivity in the industry . A series of interviews was carried out and an online questionnaire-based survey was undertaken to investigate the views of practitioners on the current state of productivity and BIM application in the construction industry, and explore the potential of BIM to help in the efforts to improve productivity on construction projects. The findings suggest that the framework set up by in the industry using BIM has laid the necessary foundation which improved the productivity in terms of manpower and equipment. It contributed to the provision of a collaboration tool for all project participants, reduction in manual efforts, time and cost savings, and identification of possible conflicts and risks that would have arisen.

Hussein et al. (2015) proposed a BIM-based integrated approach for detailed construction scheduling under resource constraints. This capitalized on the benefits of rich building information in BIM and the capability of DES to mimic the construction operation logic and investigate the allocation of available resources among activities. Furthermore, a prototype scheduling system for panellized LGS construction has been developed as an Autodesk Revit add-on which is able to produce MS Project-based schedules in order to facilitate communication among project stakeholders and support project management on site. The scheduling system was generally able to produce expected schedules for panel construction, and assists project managers in effectively planning on-site assembly work by reducing the human error in scheduling for panellized construction.

Azhar et al. (2011) studied the current trends, benefits, possible risks, and future challenges of BIM for the AEC (Architecture, Engineering and Construction) industry. The result of the study showed that the construction industry has long sought techniques to decrease project cost, increase productivity and quality, and reduce project delivery time using BIM. They concluded that the increasing use of BIM will enhance collaboration and reduce fragmentation in the AEC industry and eventually lead to improved performance and reduced project costs.

Kulkarni et al. (2021) practiced a cutting-edge method for remotely managing and designing projects in BIM. According to the poll, BIM has the ability to improve decision-making and communication amongst trades in the building industry by integrating and communicating construction data more effectively. BIM is an important tool for updating the information flow throughout a project, just like it was the first time. Although BIM continues to improve the efficiency of its tools, present procedures enable a BIM-enabled user to carry out duties rather effectively. The study focused more precisely on the implementation of the model to help planning and scheduling of a business in India. BIM helps to save time and money across the whole lifespan of a building, not only during its design and construction but also in the post-construction stage. BIM is mostly a human activity that leads to significant process improvements; it is not just software.

Razali et al. (2019) demonstrated how BIM is used all the way through a project's life cycle. Additionally, it was noted that although BIM deployment in the AEC sector is still in its infancy, it is drawing quick attention. To be sure, there is still a long way to go because "the formal standards on BIM, such as the Industry Foundation Class (IFC) are complicated and have not got the resources for quick development and promotion that their promise warranted. BIM is quickly becoming a cutting-edge method of digitally organising and creating projects. Every stage of the building process may benefit from BIM to the fullest extent possible. Teamwork among team members ought to improve as the rate of BIM adoption rises, resulting in a decrease in project costs, time savings, customer satisfaction, and increased performance. In the AEC sector, BIM introduces a novel idea that improves communication amongst project stakeholders. This partnership has the potential to increase efficiency and cohesion among stakeholders who frequently view one another as competitors in the AEC sector.

Pellicer et al. (2019) demonstrated that there are numerous gaps in the research on BIM's applications in structural engineering; additional work has to be done to develop this area of study. The promise of BIM for structural engineering has been eclipsed by BIM-related concerns, such as implementation hurdles on projects. As a result, prior studies have ignored the technical structural engineering problems that can be handled with the use of BIM. In addition, the existing study on the subject is dispersed and isolated. The isolation also applies to institutions, active researchers, and research subjects. The results of this study show the necessity for a new evaluation and definition of these trends. With the aforementioned in mind, structural engineering and BIM future work must focus on bringing in structural engineering concerns to be addressed and handled through the use of BIM capabilities.

Nadeem et al. (2021) investigated whether there are BIM departments (their types and functionalities), coordination meetings for clash resolution, strategies to improve clash detection, and data security measures during collaborative design. This involved reviewing current regulatory documents regarding BIM technology, interviewing industry professionals, and conducting surveys among construction companies and design organisations. Investigations were also conducted into the dissemination of project conflict-related work among team members and the information exchange that goes along with it. In BIM tools, the primary causes of conflict incidence and the locations of clash occurrence were investigated. The inferences that can be made are that even in the absence of a legislative standard, BIM-enabled collision detection is employed. The use of various file formats, lack of time during the design stage, lack of object model information and the complexity of the modelled objects are the primary causes of conflicts in the BIM tools of the AECO sector of India. But the responsible party that created regulation papers relating BIM technology saw the aforementioned motives as secondary.

Aziz et al. (2022) summarised that project quality enhancement, lifecycle data storage and management, collaboration optimization, and planning and schedule management optimization are all benefits of BIM deployments in green building construction. Furthermore, it can be deduced from the discussion and analysis of the studied BIM capabilities that BIM may contribute significantly to the pre-construction, construction, and post-construction phases of green building projects. Despite the enormous above-mentioned benefits of BIM, there are still some challenges when utilising BIM in the construction phase of green buildings. These challenges include non-uniform data formats, a lack of interaction, uncertain ownership, a lack of BIM training, and BIM adoption reluctance. Additionally, this study outlined the difficulties and potential directions for BIM capabilities in green buildings to inspire other academics to find solutions.

Dasandara et al. (2022) conducted expert interviews to identify the relevancy of KPIs (key performance indicators) that are discovered through literature review to the Sri Lankan context, and the expert survey was conducted to identify their level of importance. Findings showed that in order for FM services in hotel buildings in Sri Lanka to successfully satisfy the demands of the customers, a PM system with pertinent KPIs (key performance indicators) may be highlighted as a vital necessity. As a result, the current study identifies the (KPIs) that may be used to gauge how well FM (Facility Management) services are performing in hotel buildings. The study suggests using a suitable PM system with established KPIs by relevant industry practitioners to improve the performance of fm services in hotel structures in Sri Lanka and effectively meet the final objectives.

2.2 SUMMARY OF THE LITERATURE REVIEW

This review is of the best practices in AEC (Architecture, Engineering and Construction) universities supported the foundation for integration of BIM into construction education. Research studies also highlighted that some countries have already prepared to deal with the integration while others have yet to start this integration process into CM (Construction Management) programs. However, in India, studies on the status of BIM implementation in academia and in the construction industry are not very common. BIM education is lacking in formal and informal settings. Universities across India are facing a serious lack of focus on overall construction engineering and management skills and education. It believed that 60-70% of Civil Engineering graduates join construction firms and rest to the other domains such as design and consulting firms. Therefore, there is a need to introduce BIM education at university level so that when the students join professional organizations, it will be easy for them to apply BIM on projects. Researchers have highlighted the strong points of introducing and integrating BIM into the CM curriculum in the engineering universities. They have concluded that BIM is a helpful teaching tool for construction estimation and quantity take-off skills and highly contribute to design comprehension skills and understanding of construction materials, methods, and processes.

CHAPTER 3
OBJECTIVES AND SCOPE

3.1 OBJECTIVES OF THE STUDY

The objectives of the study are:

- To derive the labour productivity standards
- To develop a complete integrated 4D/5D BIM workflow for a villa project
- To create a complete clash free model
- To create a cost breakdown structure/BOQ
- To standardize the BIM metadata with the help of a BEP (BIM Execution Plan)
- To create a 4D/5D BIM model using rule based scheduling
- To compare the traditional workflow and the integrated 4D/5D BIM workflow
- To conduct a feedback survey from experts to identify the effectiveness of the templates

3.2 SCOPE OF THE STUDY

A double-storeyed villa project was chosen for modelling and analysis. The management solution utilised in this study to integrate the BIM technique for project delivery is BEXEL Manager. Only the constructions taking place under Indian conditions is covered by the workflow standardisation of the template. Additionally, the villa may only be modelled in 4D or 5D when time, money, and geometry are taken into account. Facility management (6D) is not taken into account in this work. Additionally, LOD (Level of Development) 300 is the referenced industry standard for this project.

3.3 BACKGROUND OF THE PROJECT

The selected villa project is located in the Thrissur district in Kerala. The villa, which has a plinth area of 1830 square feet, takes up 48.05 percent of the 4.57 cents site designated for a single residence. The project consists of a total of 29 identical villas that are all located in the same area of the Puthenchira Grama Panchayat. The area is contoured as a water-logged area and so the foundation assigned is pile foundation. This is an ongoing project where the construction of just a single villa is complete. The rest of the 28 villas are still in the planning stage. The two-dimensional model of the villa is depicted in Figure 3.1. The finished villa (no. 28) is shaded in Figure 3.2, which depicts the layout of the full villa project.

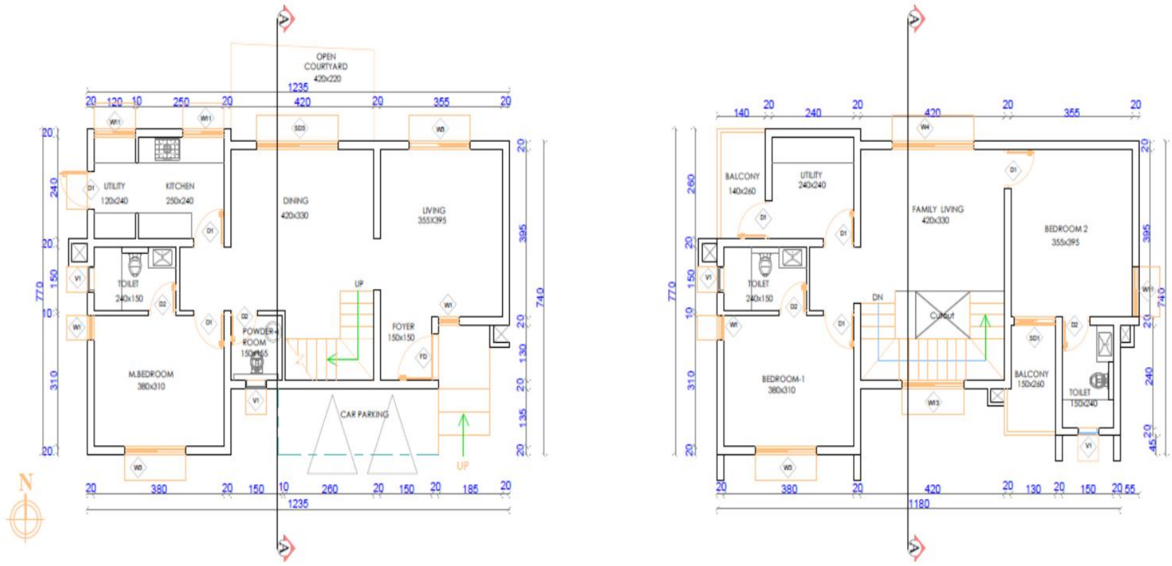


Figure 3. 1 Two-dimensional Model of the Villa

Figure 3.2 Layout of the Villa Project

3.4 RELEVANCE OF THE PROJECT

This is a solely industry-oriented project in which all the details pertaining to the project are collected from Asset Homes, an authorised builder in Kerala. The details provided included the complete layout of the project, the 2D model (CAD drawing) of the villa and the schedule of the entire project. This formed the input base of the project where the processing of these inputs relied exclusively on academics in which the optimization of the work was carried out through BIM. The academic output is to be referred back to the industry to assess the effectiveness of the result obtained.

CHAPTER 4

METHODOLOGY

4.1 GENERAL

This chapter deals with the methodology of the work and the predominant specifications of the software used in this study. The flow diagram of the methodology is given in Figure 4.1.

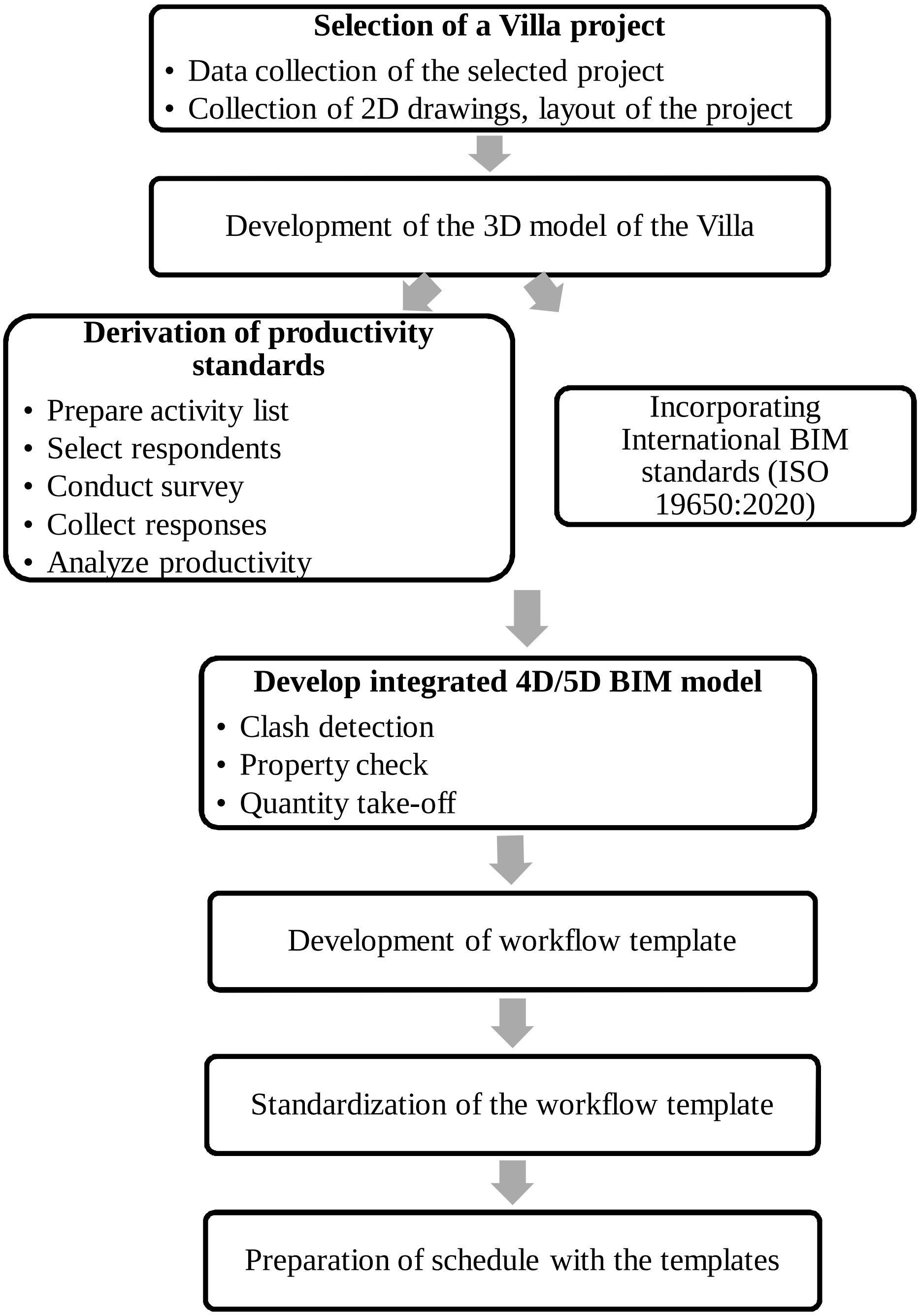


Figure 4.1 Flow Diagram of Methodology of Work

In order to define the productivity requirements for the study, a questionnaire survey was done on experienced builders was conducted given a list of all the tasks necessary to construct a double-storeyed villa. The responses were collected and sorted, which indicated the crew size and composition (number of assistants and skilled workers) needed for each task. In order to implement a flawless schedule, this output was used as a BEXEL Manager input. The specifics of an average villa project in Thrissur have also been gathered and quantified. The standard three-dimensional model of the villa has been created using Revit. According to the BIM forum, the properties of the model's elements are to be standardised with reference to ISO 19650, and this particular 3D model was checked for any clashes between its elements. The quantity take-off was done. The 4D/5D model was created using the ISO 19650 international BIM standard code, and the productivity standards were then encoded into it. The following stage involved creating the workflow template needed for a typical villa project. Standardizing the complete workflow template in accordance with ISO 19650 is the last stage.

4.2 BEXEL MANAGER

The integration of BIM was brought about by a recently developed software named "BEXEL Manager" in the year 2020. BEXEL Manager platform changes the perspective of integrated project management allowing full optimization and customization of digital workflows. The salient features of this particular software are:

- Easy clash detection
- Quantity take-off
- Provides property check with custom breakdown tool
- Creates 4D and 5D simulation within 3 minutes
- Advanced scheduling by creating zone and methodology
- Easy cost comparison
- BIM collaboration
- Advanced interoperability
- Creating and exporting selection sets using BCF manager
- Easy data exchange with other software
- BIM analysis workflow

4.2.1 *Clash Detection*

A software module called clash detection enables clash analysis amongst the various model components. Conflicts between structural elements and MEP elements or within MEP systems, are the most frequent and dangerous. In order to complete the project without many issues with quality, delays, or additional expenditures, clash detection is crucial at every stage. An illustration would be potential collisions between structural elements and installation systems or between components of different installation systems, etc. Job provides a clash analysis between the various model components, which includes a list of all the collisions that take place between the components of the groups that are chosen. According to BEP, the conflict matrix and clash detection rules are the primary inputs for clash detection. For each category in clash matrix all disciplines shall develop rules for clashing groups, defining type of clash and set exact distances for soft clashes (clearance tolerance). The clash report is usually generated through BCF Manager.

4.2.2 *Quantity Take-Off*

The Quantity Take-off palette is a platform for calculating the number of individual groups of elements directly from the geometry of the 3D model. It can also be referred to as a detailed measurement of materials and labour essential to complete a construction project. They are developed by a quantity-surveyor during the pre-construction phase. This process includes splitting the project down into smaller and more feasible units that are easier to estimate. These measurements are useful to structure a bid on the scope of construction. Quantity-surveyors evaluate the drawings and specifications of the models to find these quantities. With BIM, quantity take-off can be organised automatically provided that the type of materials, their quantity and price are accounted in the model. One of the major issues faced by construction projects is that they often run overtime and over budget and one of the reasons is inaccuracy in quantity take-off and estimates.

4.2.3 *Property check*

There are certain element properties which are essential for a perfect BIM model. The model has to be checked whether it has been developed in accordance with BEP. The properties could be the dimensions of the elements, the reinforcement details, the nomenclatures, the description about the element, the assembly code, etc. These properties can be further gathered under property sets, the required phases and their specific value type. The property set defines the parameter set under which the properties can be categorised. The sets are mainly attributed as analytical properties, construction, identity data, constraints, phases, structural, text and asset information. The value type that could be defined can be in the form of numerals, length, area, mass, volume or even in the form of Boolean. For example, in the case of a wall element, the parameter/property 'length', can be defined under the property set 'dimension', and under value type 'length' (mm, cm, m) and it comes under the 'concept design phase' in which this particular property is required. These properties can be constituted as per the required LOD.

4.2.3.1 Level of Development (LOD)

A BIM model contains a large amount of elements. Those elements possess a large amount of information required to represent several aspects of the building/model. There could be an involvement of several parties in a project, the building consultants, the clients, the contractors, subcontractors, etc. Therefore, it is commentative to ascertain how they are going to formalize the project, the quantity of information to be included, the feasibility of information, and what they expect from other models. This should be assigned for each project stage, without compromising specific deliverables needed for intended BIM model uses. To tackle these issues, a common standard/framework/language about development and reliability of information in projects is essential that could make coopetition easier. Every stakeholder could then use the same standard so that they can understand each other in proper clarity. The standard should not compromise the depth of information to be included in the elements concocting the model and the adequate usage and application of that particular information (which sometimes is intentionally incorporated in models, and often unintentionally). This language/standard is LOD. It is a language, that ladle out to know what to expect, and the amount of assurance about the properties, features and specifications of a given element. There are a series of LOD elements, namely, LOD 100, LOD 200, LOD 300, LOD 350, LOD 400 and LOD 500. The specifications of LOD's are explained in Figure 4.2.

The BIMForum as per ISO 19650 interprets that:

a. LOD 100 model elements are not geometric representations. The information attached to the model elements shows just the existence of components but not its shape, size or precise location. The information derived from LOD 100 elements must be considered approximate.

b. LOD 200 model elements are generic placeholders. They may be recognizable as the components they represent, or they may be volumes for space reservation. The information derived from LOD 200 elements must be considered approximate.

c. In LOD 300 models, the quantity, size, shape, location and orientation of the element as designed can be measured directly from the model without referring top non-modelled information such as notes or dimension call-outs. The project origin is defined and the element is located accurately with respect to the project origin.

d. In LOD 350 models, the parts necessary for the coordination of the element with nearby or attached elements are modelled. These items includes supports and connections. The quantity, size, shape, location and orientation of the element as designed can be measured directly from the model without referring top non-modelled information such as notes or dimension call-outs.

e. LOD 400 model elements are graphically represented as a specific system in terms of size, shape, location, quantity, and orientation with detailing, fabrication, assembly, and installation information. Non-graphic information are also attached to the model.

f. LOD 500 elements are modelled as constructed assemblies for the purpose of maintenance and operations. In addition to accuracy in size, shape, location, quantity, and orientation, non-geometric information is attached to modelled elements.

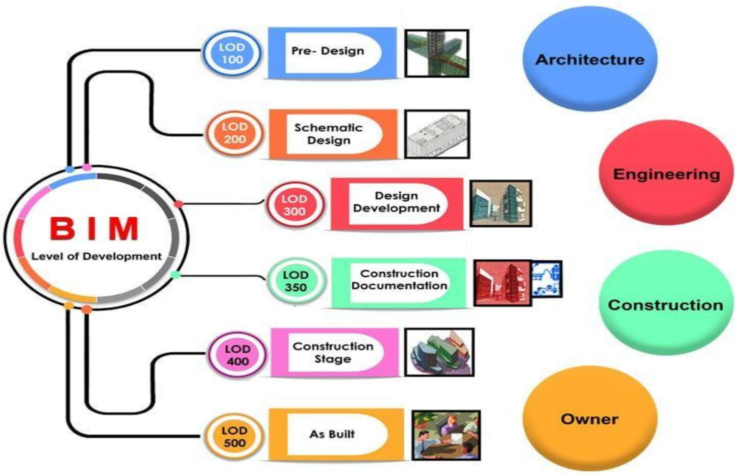


Figure 4.2 Level of Develeopment (LOD)

4.2.3.2 Phases of Project

The phases of a project as per ISO 19650 can also be referred to as the hierarchical flow of information.

- LOD 100 - Concept Design
- LOD 200 - Schematic Design
- LOD 300 - Detailed Design
- LOD 350 - Construction Documentation
- LOD 400 - Fabrication & Assembly
- LOD 500 - As-Built

a. Concept Design phase: In this phase, the two-dimensional drawings of the building are developed, particularly with no details.

b. Design Development phase: In this phase, the 2D model is converted to 3D model using a modelling software, and the detailing is provided. At this stage, the GFC (Good for Construction) drawings are derived.

c. Issue for Construction phase: In this phase, a perfect 3D model with details is developed with very few or no errors.

d. As-built phase: This is the final stage of a construction phase which is carried out as soon as the construction process is over and handing over the key to the client is done. In this phase, there would be a wide range of differences in drawings/model, from the GFC drawings obtained in the design development phase can be seen. The model developed in this phase reflects the exact copy of the constructed building.

e. Facility Management phase: This is an extremely detailed stage, where the digital representation of the entire building is derived. The purpose of this representation is to recognize, any chances of maintenance to be done in the future, to know the storage capacity of the building, the heating capacity, the electrical consumption of a room, etc.

4.2.4 *Classification Item and Cost Editor Item*

Creating a 4D/5D BIM model can be done in various ways with the help of Schedule and Cost Editor for the creation of classification optimal for the project. There are two workflows that are enabled by the software. The first one integrates cost and schedule into one with no need for manual connection. In this case, the schedule is automatically created using Creation Templates. This enables the ability to use created methodology afterwards on a similar project, since the fact that schedule tasks are already linked to cost items in the BIM model and grants significant reduction in workload for a quantity-surveyor. The second workflow consists of importing a schedule from scratch in a traditional way by creating tasks and relations and linking tasks of manually created/imported schedule with the elements of the BIM model.

4.2.5 *Intelligent/Advanced Scheduling (Creating Zone and Methodology)*

Since it allows for simultaneous creation of a 4D/5D BIM model and a 4D/5D animation, better schedule optimization, and a highly automated workflow, the advanced method of creating schedules, which is based on Methodology and Zones definition, enables users to create complex, detailed schedules for large-scale construction projects with a vast array of tasks and relationships. The order (sequence) in which the works are completed is essentially represented by the creation approach. Cost classification serves as the foundation for methodology since it presents, describes, and quantifies every type of work done on a project. The user can specify the order of construction tasks and the relationships between various work kinds using the Creation approach.

As a straightforward illustration, the Methodology user specifies that foundation work is only carried out when excavation and other preparatory work are finished, and that superstructure work is carried out following foundation completion. Therefore, it is essentially the same construction logic that every project manager and planner employs. In this instance, Planner is using the Creation Methodology to "teach" an automatic scheduling engine the logic of the construction process.

And construction zones, which are essentially areas where work is distributed spatially. Buildings (if the project consists of more than one Building), Storeys (vertical distribution), and Construction Sequence - Phases are used to disperse the construction work (horizontal distribution). When creating activities and relationships for an automatically generated schedule, an intelligent scheduling engine uses a creation template that combines construction methodologies and construction zones.

4.2.6 *Easy Data Exchange with Other Software (BCF Manager)*

Regardless of the programme being used, BCF Manager review enables participants in a project to exchange files in the form of BCF formats. Simply, the transmitted BCF file can be opened in another piece of software. If the model is derived from the same source IFC (Issued for Construction) model and all participants software tools support the open BCF format, sharing reports in the BCF format between various participants using different software tools is only conceivable.

CHAPTER 5

DEVELOPMENT OF TEMPLATE

5.1 GENERAL

This chapter deals with the results of survey, the 3D, 4D and 5D modelling of the villa which contributes to the input of developing the templates.

5.2 SURVEY RESULTS

A questionnaire, consisting of all the activities required particularly for a villa project was circulated among various efficient and experienced project engineers employed at various reputed construction companies across Kerala. The questionnaire was shared through online mode. The questionnaire is attached in Appendix B. The survey responses from thirty authorised personnel (industry-oriented) were collected to determine the labour productivity per work day of each activity that stands essential for a double-storeyed villa. The survey respondents were chosen based on their experience in the field of civil engineering (shown in Figure 5.1) and the responses were examined considering their experience as well. The average productivity was computed to obtain the schedule of the project.

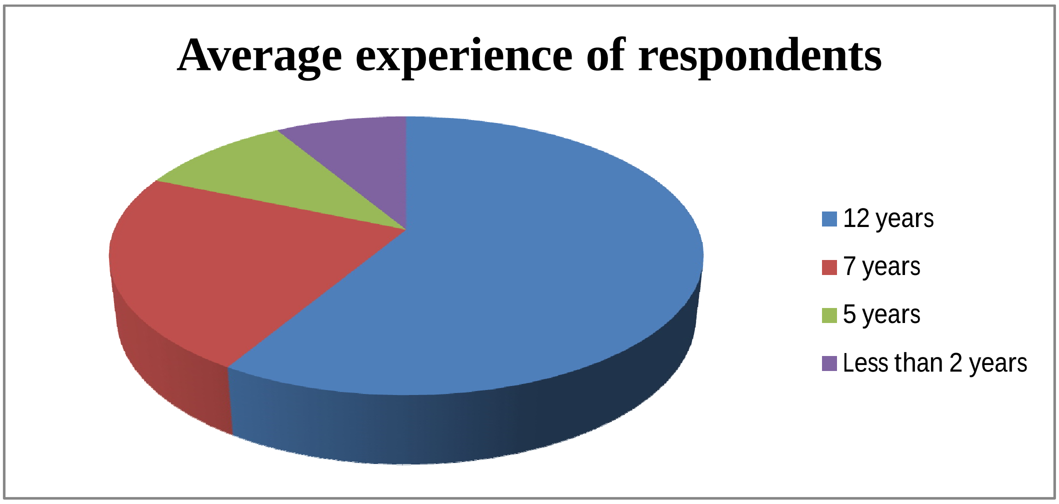


Figure 5.1 Average experience of respondents

The productivity was measured in such a way that, the labours required to carry out a single piece of work (in units) is accounted. Table 5.1 represents the average productivity measured from 30 responses. The mean of the 30 responses were calculated and computed as the daily output of the labours.

Table 5.1 Survey Results

Sl. no.	Activity	Average productivity	Unit
1	Site clearance	136	m^2
2	Setting out	46.67	m^2
3	Excavation	18	m^3
4	Footing for pillars	1.2	m^3
5	Pile foundation work	1	m^3
6	Setting up main door frame and other room door frames	0.75	Nos.
7	Brick masonry until window frame base	0.5	m^3
8	Setting up window frames	1	Nos.
9	Shuttering and rebar placement for lintel beam	4.5	m^2
10	Concreting lintel beam	0.431	m^3
11	Brick masonry until beams if needed	0.5	m^3
12	Setting up kitchen ventilators for exhaust fans or bathroom ventilators	3	Nos.
13	Formwork for roof slab	8.33	m^2
14	Bar bending work for beams and roof	0.25	ton
15	Electric pipes setup inside roof	22.5	m
16	Concreting of slab	1.667	m^3
17	Curing on roof top	-	
18	Laying electric conduits in the walls and setting up electric boxes	11.25	m
19	Plumbing work for kitchen and bathroom	11.25	m
20	Setup kitchen platform and sink	1	Nos.
21	Tiles laying in bathroom and kitchen for walls	6.67	m^2
22	Plastering	18.67	m^2
23	Water-proofing for wall	40	m^2
24	Fixing window and door shutters	3.33	m^2
25	Flooring	4	m^2
26	Sanitary fittings	-	
27	Painting	50.91	m^2
28	Electric work	-	
29	External wall paint coating	40	m^2
30	Laying electric service wire from pole to meter board	-	
31	Fixing meters in panel board	-	
32	Digging pit for power earth	-	
33	Motor & connection to tank	-	
34	Laying sewage lines to pit	6.25	m
35	Compound wall construction	3	m

36	Construction of parapet wall	1.875	m
37	Fixing of false ceiling	10.25	m

5.3 THREE-DIMENSIONAL MODEL OF THE VILLA

The three-dimensional model of the villa was developed using Autodesk Revit. The model was developed assigning all the elements in the dimensions provided for the model with suitable categories, family names, types, and with appropriate naming conventions in multiple levels of construction. Architects, engineers, and contractors frequently utilise the BIM programme Revit to produce a single model that can be used by all trades and disciplines to accomplish their job. Autodesk Revit was not meant to replace BIM; it was made to assist it. While Revit is a design and documentation solution that supports all phases and disciplines in a building project, AutoCAD is a generic drawing programme with wide use. All data inputs, including CAD, are coordinated using Revit, which also generates federated project outputs. The same company frequently use both systems, with BIM and CAD professionals working on various project components. With the help of the Revit programme, one may perform virtual modelling, or acquire a model of the building or infrastructure before it is constructed on-site. Users of the Revit programme may build intelligent models with data saved in them, thanks to the tools in the software that are particularly made to enable BIM. If utilised appropriately, these technologies may assist the user in avoiding rework, reducing costs, identifying issues before construction takes place on-site, avoiding delays, etc.

5.3.1 Architectural Model of the Villa

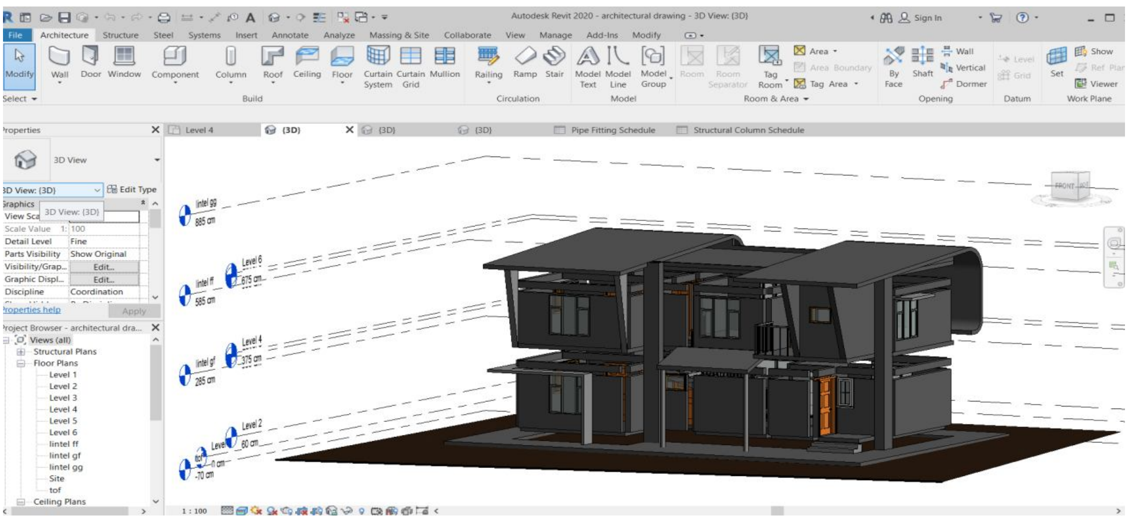


Figure 5.2 Architectural Model of the Villa

The architectural model was developed incorporating all the architectural features as suggested by the builders. Figure 5.2 represents the architectural model of the Villa.

5.3.2 Structural Model of the Villa

The structural model of the villa consists of the foundation, pile cap, column footing, beams, lintels and columns. Figure 5.3 shows the structural model of the villa. Since, the area is water-logged, as the depth of water-table is low, the building is supported by eighteen piles and therefore eighteen beams and columns.

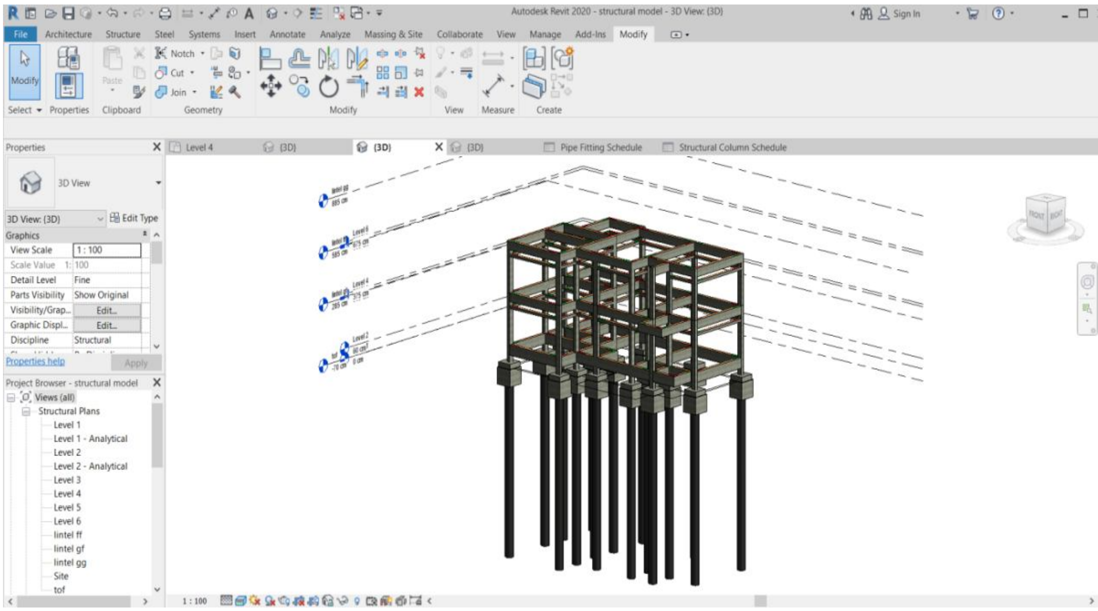


Figure 5.3 Structural Model of the Villa

5.3.3 MEP(Mechanical, Electrical, Plumbing) Model of the Villa

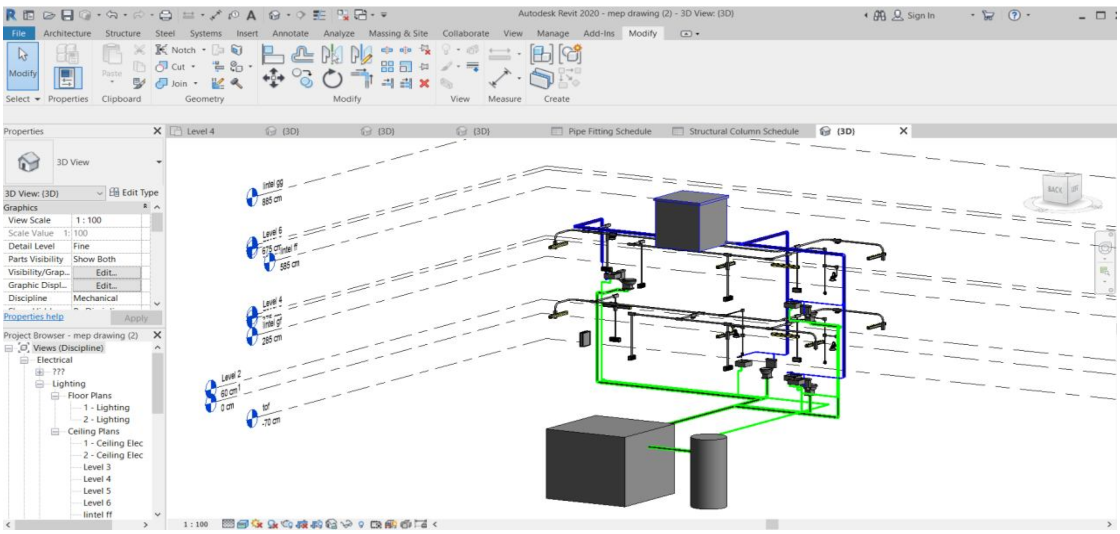


Figure 5.4 MEP Model of the Villa

The MEP model consists of the electrical lines, plumbing lines and the fixtures of the same. Figure 5.4 depicts the MEP model of the Villa.

5.3.4 Integrated Three-Dimensional BIM Model

This model was formed by linking/integrating the three isolated 3D models (architectural, structural and the MEP model). This model represents the '3D BIM model'(Figure 5.5).

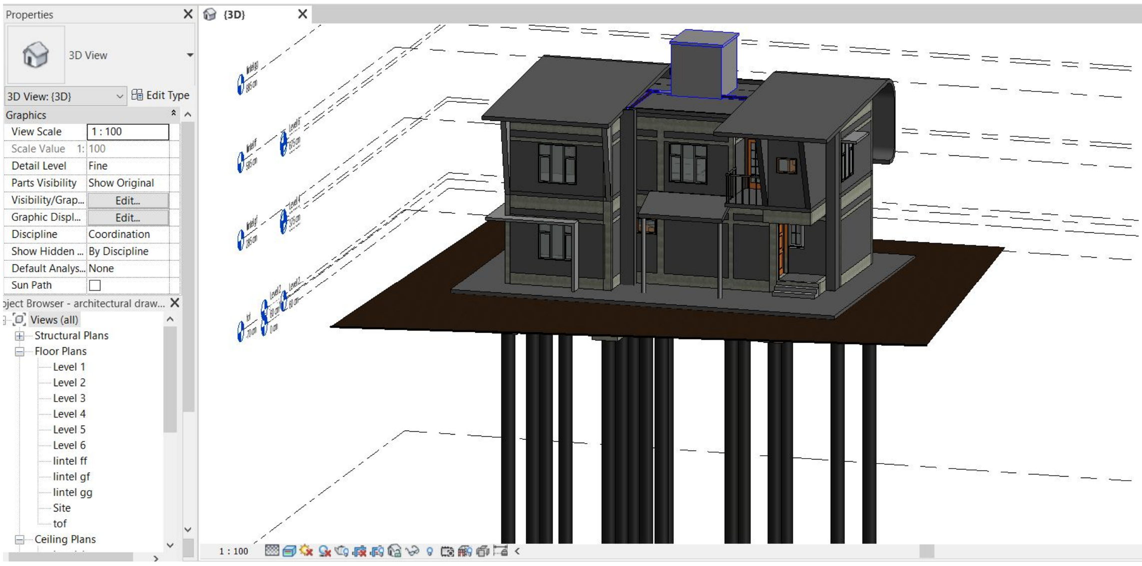


Figure 5.5 Integrated 3D BIM Model

5.3.5 Three-Dimensional Layout of the Project

The 3D layout of the entire project comprising of 29 villas were modelled which is depicted in Figure 5.6.

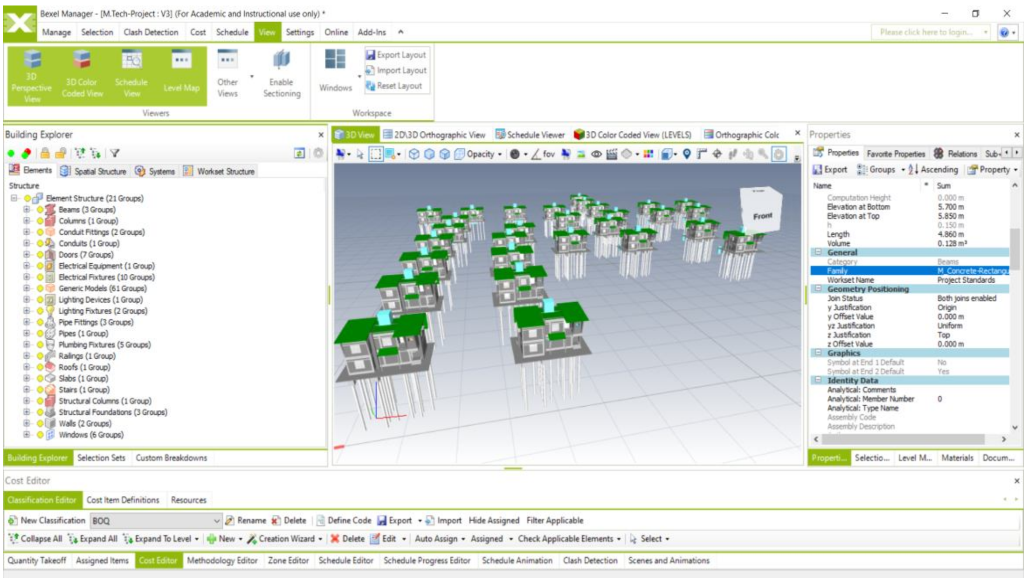


Figure 5.6 3D Layout of the Project

5.4 4D/5D BIM MODEL OF THE VILLA

The 4D/5D BIM model was developed using PRIMAVERA P6. Figure 5.7 depicts the 4D/5D model of the villa. The Bill of Quantities was recorded referring the information from the 3D model. As a result, the total budgeted cost of the developed 3D model was obtained. As per the 4D/5D model developed, the whole project would cost about Rs.12,78,74,760.80.

TKM Project — Classic Schedule Layout

Activity ID	Predecessor	Activity Name	Original Duration	Remaining Duration	Schedule % Complete	Start	Finish	Resources	Budgeted Labor Cost	Budgeted Material Cost	Budgeted Total Cost
TKM Project			1209	1209	0%	28-Sep-22	08-Aug-26		Rs7,052,200.00	Rs120,822,560.80	Rs127,874,760.80
A1010	A1000	Statutory Approvals	71	71	0%	30-Sep-22*	22-Dec-22	Project engineer, Project manager	Rs67,500.00	Rs0.00	Rs67,500.00
A1000		Stone Laying /Agreement	2	2	0%	28-Sep-22	30-Sep-22	Project engineer, Project manager, Worke	Rs360,000.00	Rs0.00	Rs360,000.00
Construction			1136	1136	0%	22-Dec-22	08-Aug-26		Rs6,624,700.00	Rs120,822,560.80	Rs127,447,260.80
Substructure			60	60	0%	22-Dec-22	02-Mar-23		Rs1,043,100.00	Rs3,800,364.74	Rs4,843,464.74
A1130	A1120	Pile Cap	15	15	0%	26-Jan-23	13-Feb-23	CEMENT, Admixture, M-Sand, Metal 2, Worl	Rs278,400.00	Rs2,653,023.24	Rs2,931,423.24
A1140	A1130	Column Footing	15	15	0%	13-Feb-23*	02-Mar-23	CEMENT, Admixture, M-Sand, Metal 2, Worl	Rs278,400.00	Rs656,661.50	Rs935,061.50
A1120	A1000	Pile Work	30	30	0%	22-Dec-22*	26-Jan-23	Metal, Sand, CEMENT, Steel, Project engin	Rs486,300.00	Rs490,680.00	Rs976,980.00
Super Structure			180	180	0%	02-Mar-23	28-Sep-23		Rs3,629,200.00	Rs15,468,865.06	Rs19,098,065.06
Ground Floor			90	90	0%	02-Mar-23	15-Jun-23		Rs1,435,500.00	Rs5,399,224.06	Rs6,834,724.06
A1180	A1170	Wall 20 Cm	30	30	0%	24-Apr-23*	29-May-2	Block 1, CEMENT, M-Sand 2, Worker, Mas	Rs278,400.00	Rs2,171,450.40	Rs2,449,850.40
A1190	A1180	Wall 10 cm	5	5	0%	29-May-23*	03-Jun-23	Block 2, CEMENT, M-Sand 2, Worker, Mas	Rs278,400.00	Rs293,219.00	Rs571,619.00
A1150	A1140	Plinth Beam	10	10	0%	02-Mar-23*	14-Mar-23	CEMENT, Admixture, M-Sand, Metal 2, Worl	Rs217,500.00	Rs1,172,277.44	Rs1,389,777.44
A1160	A1150	Columns	15	15	0%	14-Mar-23*	31-Mar-23	CEMENT, Admixture, M-Sand, Metal 2, Worl	Rs191,400.00	Rs721,449.82	Rs912,849.82
A1170	A1160	Beam	20	20	0%	31-Mar-23*	24-Apr-23	CEMENT, Admixture, M-Sand, Metal 2, Worl	Rs252,300.00	Rs843,946.69	Rs1,096,246.69
A1200	A1190	Lintel	10	10	0%	03-Jun-23*	15-Jun-23	CEMENT, M-Sand, Metal 2, Worker, Mason	Rs217,500.00	Rs196,880.71	Rs414,380.71
First Floor			90	90	0%	15-Jun-23	28-Sep-23		Rs2,193,700.00	Rs10,069,641.00	Rs12,263,341.00
A1240	A1230	Wall 20 cm	25	25	0%	14-Jul-23*	12-Aug-23	Block 1, CEMENT, M-Sand 2, Mason, Worl	Rs278,400.00	Rs2,330,039.80	Rs2,608,439.80
A1280	A1270	parapet	5	5	0%	11-Sep-23*	16-Sep-23	Block 2, CEMENT, M-Sand 2, supervisor, W	Rs217,500.00	Rs179,742.00	Rs397,242.00
A1250	A1240	Wall 10 Cm	3	3	0%	12-Aug-23*	16-Aug-23	Block 2, CEMENT, M-Sand 2, Worker, Mas	Rs278,400.00	Rs185,223.00	Rs463,623.00
A1220	A1210	Columns	10	10	0%	21-Jun-23*	03-Jul-23	CEMENT, Admixture, M-Sand, Metal 2, Masc	Rs191,400.00	Rs413,853.78	Rs605,253.78
A1270	A1260	Roof	12	12	0%	28-Aug-23*	11-Sep-23	CEMENT, Admixture, M-Sand, Metal 2, Masc	Rs278,400.00	Rs4,153,631.43	Rs4,432,031.43
A1210	A1200	Floor Slab	5	5	0%	15-Jun-23*	21-Jun-23	CEMENT, Admixture, M-Sand, Metal 2, Proje	Rs227,500.00	Rs1,654,123.75	Rs1,881,623.75
A1230	A1220	Beam	10	10	0%	03-Jul-23*	14-Jul-23	CEMENT, Admixture, M-Sand, Metal 2, Worl	Rs217,500.00	Rs805,099.45	Rs1,022,599.45
A1260	A1250	Lintel	10	10	0%	16-Aug-23*	28-Aug-23	CEMENT, M-Sand, Metal 2, supervisor, Wor	Rs252,300.00	Rs247,761.79	Rs500,061.79
A1290	A1280	Sunshade	10	10	0%	16-Sep-23*	28-Sep-23	CEMENT, P-Sand, Mason, Worker, superv	Rs252,300.00	Rs100,166.00	Rs352,466.00
Plastering			180	180	0%	28-Sep-23	25-Apr-24		Rs556,800.00	Rs1,312,598.00	Rs1,869,398.00
A1300	A1290	Internal	90	90	0%	28-Sep-23*	11-Jan-24	CEMENT, P-Sand, supervisor, Worker, Mas	Rs278,400.00	Rs712,414.00	Rs990,814.00
A1310	A1300	External	90	90	0%	11-Jan-24*	25-Apr-24	P-Sand, CEMENT, Mason, Worker, superv	Rs278,400.00	Rs600,184.00	Rs878,584.00
Electrical			180	180	0%	25-Apr-24	21-Nov-24		Rs217,500.00	Rs710,442.00	Rs927,942.00
A1320	A1310	Complete Electrical Works	180	180	0%	25-Apr-24*	21-Nov-24	Conduit, Wire, Metal Box, FAN, Socket, Swi	Rs217,500.00	Rs710,442.00	Rs927,942.00
Plumbing			180	180	0%	25-Apr-24	21-Nov-24		Rs217,500.00	Rs2,472,453.00	Rs2,689,953.00
A1330	A1310	Complete Plumbing Works	180	180	0%	25-Apr-24*	21-Nov-24	15 mm pipe, Tap, Wash Basin, Kitchen sink	Rs217,500.00	Rs2,472,453.00	Rs2,689,953.00
Waterproofing Works			45	45	0%	21-Nov-24	13-Jan-25		Rs217,500.00	Rs928,000.00	Rs1,145,500.00
A1340	A1320, A	Complete waterproofing works	45	45	0%	21-Nov-24*	13-Jan-25	Chemical, supervisor, Worker, Mason	Rs217,500.00	Rs928,000.00	Rs1,145,500.00
Putty and Paint Works			180	180	0%	13-Jan-25	11-Aug-25		Rs174,000.00	Rs2,164,038.00	Rs2,338,038.00
A1350	A1340	Internal and External	180	180	0%	13-Jan-25*	11-Aug-25	Putty, Cement PRimer 1, Emulsion1, Primer	Rs174,000.00	Rs2,164,038.00	Rs2,338,038.00
Flooring and Cladding			120	120	0%	11-Aug-25	29-Dec-25		Rs164,400.00	Rs91,927,680.00	Rs92,092,080.00
A1360	A1350	Complete Flooring and Claddir	120	120	0%	11-Aug-25*	29-Dec-25	Vertified Tile, supervisor, Worker, Mason	Rs164,400.00	Rs91,927,680.00	Rs92,092,080.00
Joinery and Fixture Works			60	60	0%	29-Dec-25	09-Mar-26		Rs121,800.00	Rs2,038,120.00	Rs2,159,920.00
A1370	A1360	Complete Joinery and Fixture I	60	60	0%	29-Dec-25*	09-Mar-26	Wood Teak, Door Handle, Hinges, Worker	Rs121,800.00	Rs2,038,120.00	Rs2,159,920.00
Final Finishes			131	131	0%	09-Mar-26	08-Aug-26		Rs282,900.00	Rs0.00	Rs282,900.00
A1400	A1390	Handing Over	1	1	0%	07-Aug-26*	08-Aug-26	Project manager, Project engineer	Rs4,500.00	Rs0.00	Rs4,500.00
A1390	A1380	Final Cleaning and Snag Worl	30	30	0%	03-Jul-26*	07-Aug-26	Worker	Rs78,300.00	Rs0.00	Rs78,300.00
A1380	A1370	Internal and External	100	100	0%	09-Mar-26*	03-Jul-26	Worker, Mason	Rs200,100.00	Rs0.00	Rs200,100.00

Figure 5.7 4D/5D Model of the Villa

CHAPTER 6

RESULTS AND DISCUSSION

6.1 GENERAL

This chapter deals with the outcome of the entire work of developing the templates and standardization of the same. Also, this chapter reflects the interpretation of the templates so standardized, with the help of a feedback survey collected from civil engineering experts from the industry. Figure 6.1 represents a glance of the entire work done, in just one instance.

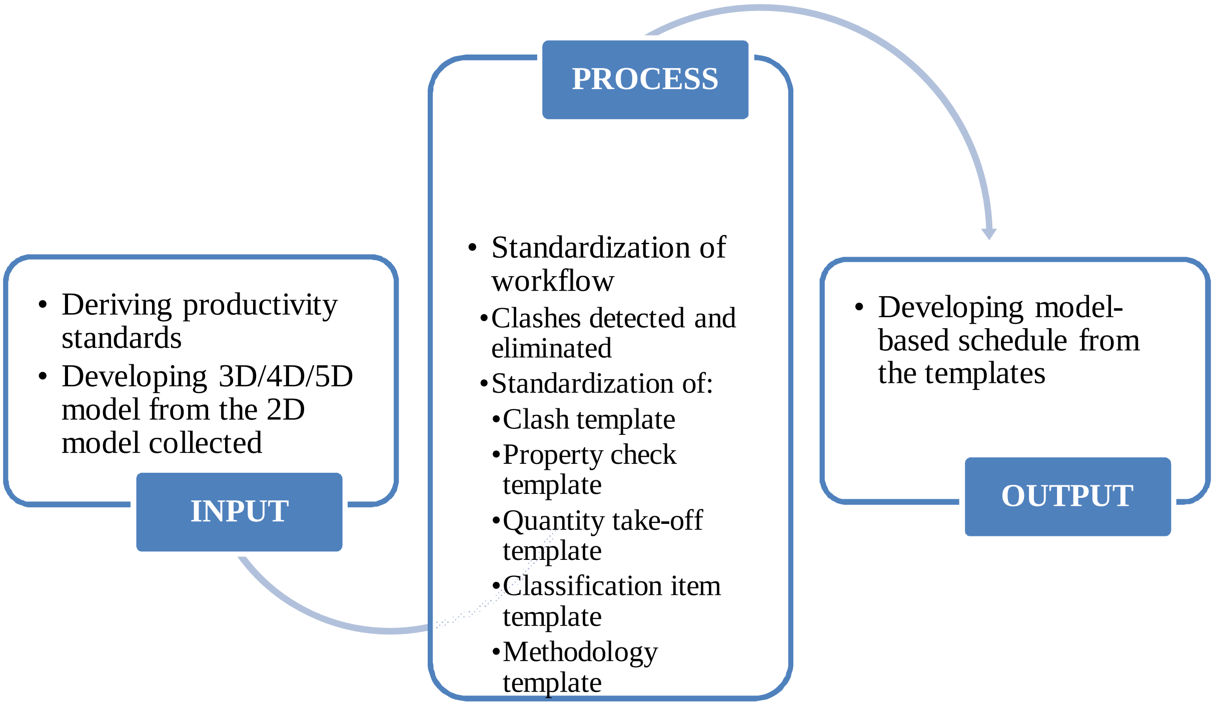


Figure 6.1 Flow of Work

6.2 STANDARDIZATION OF WORKFLOW

6.2.1 Detection of Clashes in the Model

A crucial step in the integrated BIM modelling process is clash detection. BIM modelling entails building a thorough master model that incorporates design models from several engineering design disciplines. By detecting conflicts between various models early in the design process, clash detection through BIM aids in project acceleration by assisting architects and contractors in removing the possibility of multi-level design changes that could lead to budget overruns and delays in project completion.

The model was examined prior to the clash detection method, and any issues relating to structural element collisions were forwarded to the designers. According to BEP, Clash Matrix served as the primary input for clash detection. Figure 6.2 represents the disciplines intersecting within Clash matrix for Clash detection job creation.

All disciplines for conflicting groups were defined for each category in the collision matrix, defining the type of clash and assigning precise distances for gentle clashes. Distance is an important parameter for defining clash detection status. So, a tolerance of 0.1 meter was enabled. This was because at tolerance of zero, even the intersection of walls would be read as clashes. Certain tolerances allow minor overlaps that are not important. In an excel spreadsheet, different disciplines and its categories were intersected to detect clashes among them.

		Architecture												Structure					
	Components	Ceilings	Curtain Panels	Curtain wall mullions	Doors	Floors	Railings	Ramps	Roofs	Speciality Equipment	Stairs	Walls	Windows	Columns	Foundations	Floors	Framing	Trusses	Walls
Architecture	Ceilings																		
	Curtain Panels	H																	
	Curtain wall mullions	H	N/A																
	Doors	N/A	H	N/A															
	Floors	N/A	N/A	N/A	H														
	Railings	N/A	N/A	N/A	H	N/A													
	Ramps	N/A	N/A	N/A	H	N/A	N/A												
	Roofs	N/A	H	H	H	N/A	N/A	N/A											
	Speciality Equipment	H	H	H	H	H	H	H	N/A										
	Stairs	N/A	H	H	N/A	N/A	N/A	N/A	N/A	H									
	Walls	N/A	N/A	H	N/A	N/A	N/A	N/A	H	H	H								
	Windows	N/A	N/A	N/A	N/A	H	H	H	H	H	H	N/A							
Structure	Columns	N/A	H	H	H	N/A	H	H	N/A	H	H	N/A	H						
	Foundations	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A					
	Floors	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A				
	Framing	H	H	H	H	N/A	N/A	H	N/A	H	H	H	N/A	N/A	N/A	H			
	Trusses	H	H	H	H	N/A	N/A	H	N/A	H	H	H	N/A	N/A	N/A	H	H		
	Walls	N/A	H	H	H	H	H	H	H	H	H	H	H	N/A	N/A	N/A	H	H	
HVAC	Air Terminals	N/A	H	H	H	N/A	N/A	N/A	N/A	H	H	H	H	H	N/A	N/A	H	H	H
	Ducts/Acce/Fittings	C-50	H	H	H	H	N/A	N/A	H	H	H	C-50	H	C-50	N/A	H	H	C-50	C-50
	Mechanical Equipment	C-50	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H
	Pipes & fittings	C-50	H	H	H	N/A	N/A	N/A	C-50	H	H	C-50	H	H	N/A	N/A	H	H	C-50

Figure 6.2 Intersecting Disciplines within Clash Matrix for Clash Detection Job Creation

Then, the clash detection groups, which were defined in the excel sheet was prepared depending on the model status. The Selection Sets were then assigned. The Smart Selection Sets were referred to the element attributes by distributing the elements correctly into worksets and categories. Finally, the command to run clash detection was given. When the analysis was complete, a completion notice popped up, projecting the number of clashes.

Figure 6.3 shows the Clash Detection analysis completion window. The process of detecting clashes is explained in Figure 6.4.

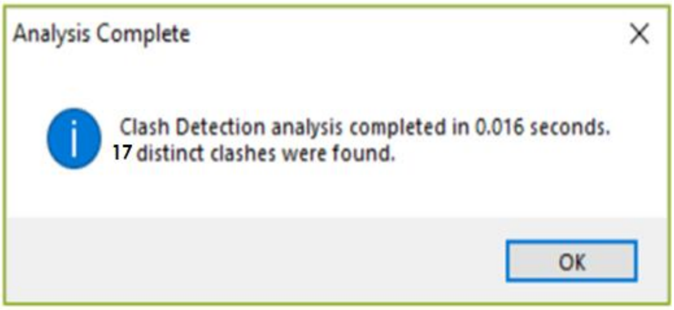


Figure 6.3 Clash Detection Analysis Completion Notice

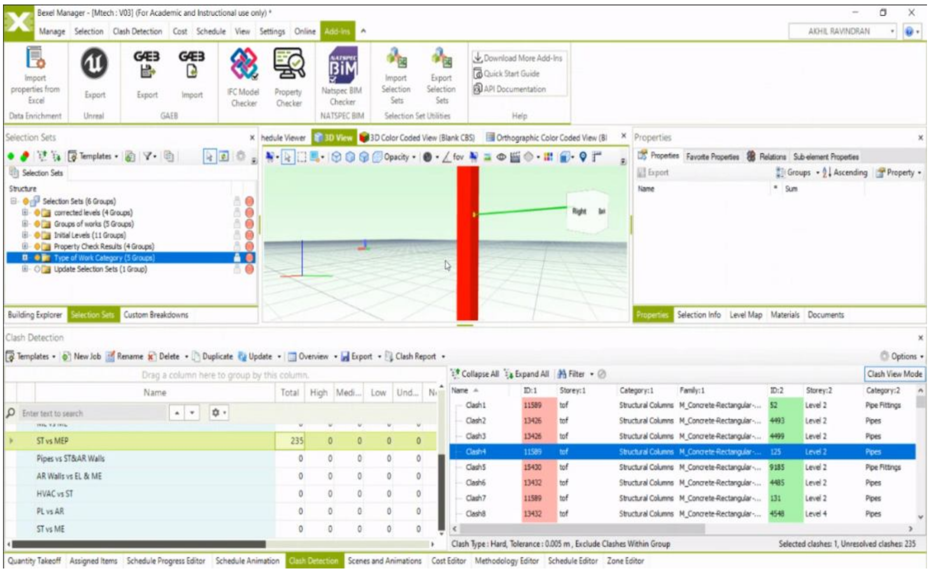


Figure 6.4 Process of Detecting Clash

A total of seventeen clashes were detected. It often happens that individual clashes are interconnected, because they arise from the same problem or as resolved in the same way. Figure 6.5 - 6.14 represents the images of the seventeen detected clashes. Such clashes were combined into one group of clashes. All the clashes considered can be grouped under hard clash category. These could be the clashes between the structural elements, structural and architectural elements and finally between structural and MEP elements. The considered clashes were assumed at a tolerance of 0.1 meters.

The clashes encountered in this particular 3D model of the villa is shown in Table 6.1.

Table 6.1 Number of Clashes with Elements of Clash

No. of clashes	Clashes between
1	10 cm ground floor wall and Kitchen floor terminal sink
1	Structural column and Pipe fitting
1	Car porch column and Roof slab
1	Bathroom ceiling and Staircase
1	20 cm ground floor wall and Structural column
5	Slab and 10 cm Wall (extra covering works)
1	20 cm first floor wall and Structural column
1	Beam and Electrical conduit
4	Ground floor slab and Plinth beam
1	Beam and Structural column
Total = 17	

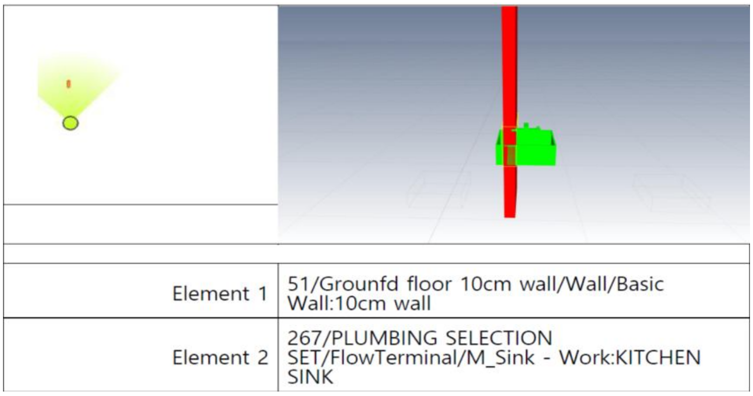


Figure 6.5 Clash Detected between AR Wall and MEP

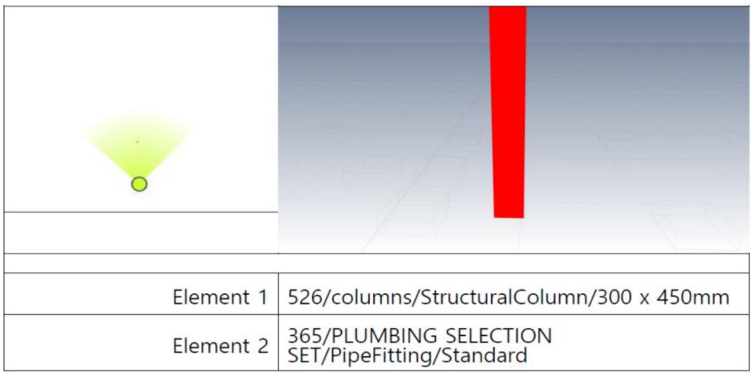
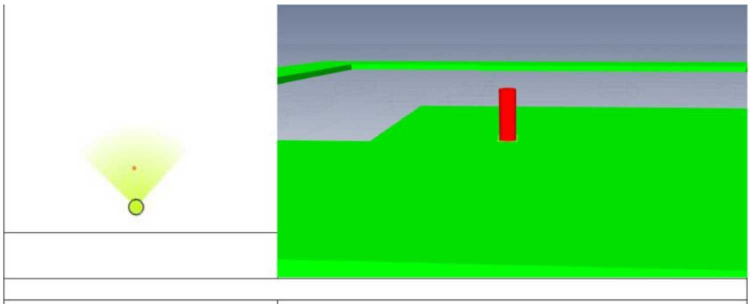
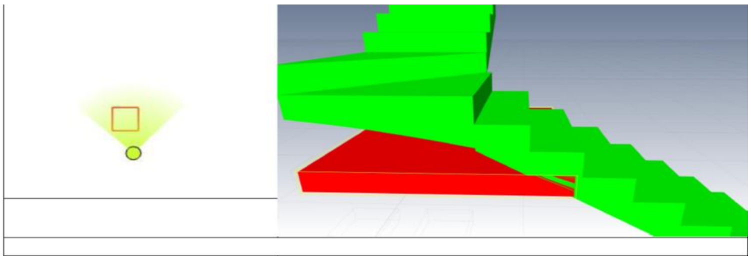


Figure 6.6 Clash Detected between ST Column and MEP



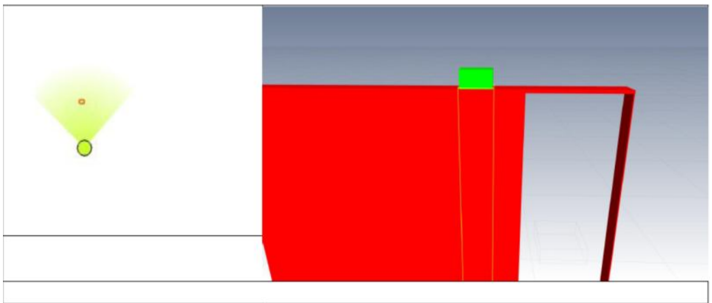
Element 1	208/car porch/Column/152mm Diameter
Element 2	10/outside slab/Slab/Floor:Generic 150mm

Figure 6.7 Clash Detected between AR Column and Slab



Element 1	250/Bathroom Ceiling/Roof/Basic Roof:Generic - 400mm
Element 2	245/stair/Stairs/Cast-In-Place Stair:Stair

Figure 6.8 Clash Detected between AR Roof and Stairs



Element 1	35/Grounfd floor 20cm wall/Wall/Basic Wall:Generic - 200mm
Element 2	534/columns/StructuralColumn/300 x 450mm

Figure 6.9 Clash Detected between AR Wall and ST Column

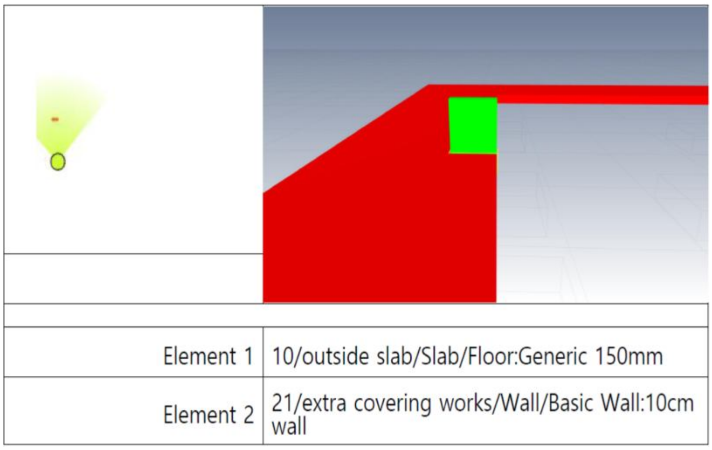


Figure 6.10 Clash Detected between AR Wall and Slab

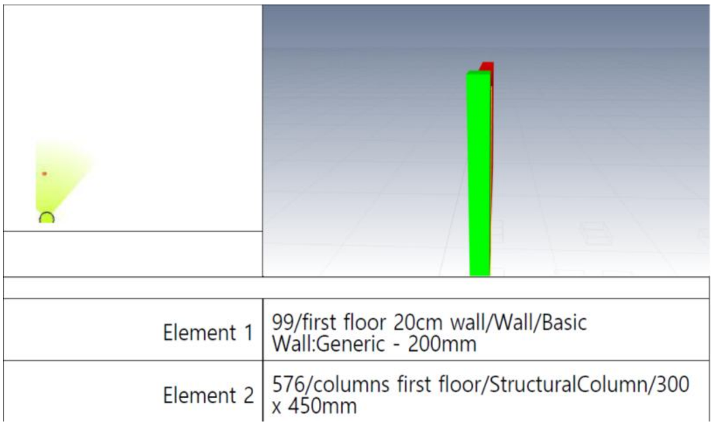


Figure 6.11 Clash Detected between AR Wall and ST Column

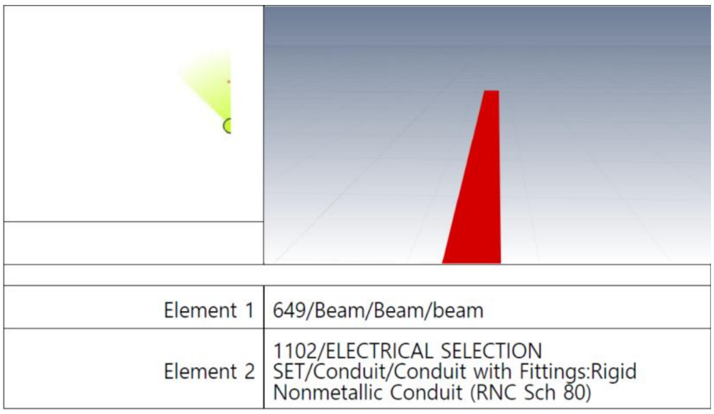
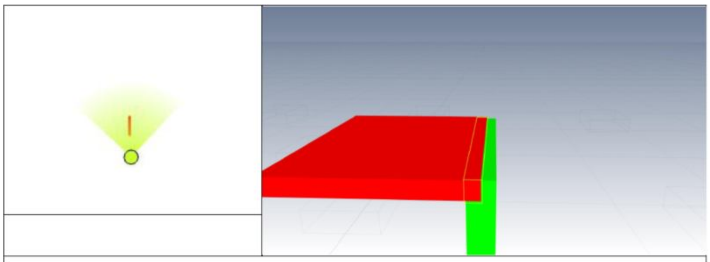
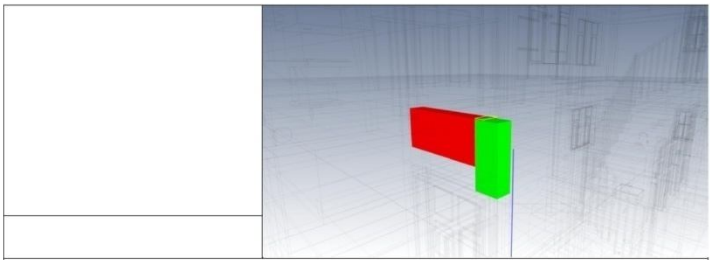


Figure 6.12 Clash Detected between ST Beam and MEP



Element 1	889/floor slab ground floor/Slab/Floor:Generic 150mm
Element 2	615/Plinth Beam/Beam/M_Concrete-Rectangular Beam:300 x 600mm

Figure 6.13 Clash Detected between Slab and ST Beam



Element 1	651/Beam/Beam/beam
Element 2	540/columns/StructuralColumn/300 x 450mm

Figure 6.14 Clashes Detected between Beam and ST Column

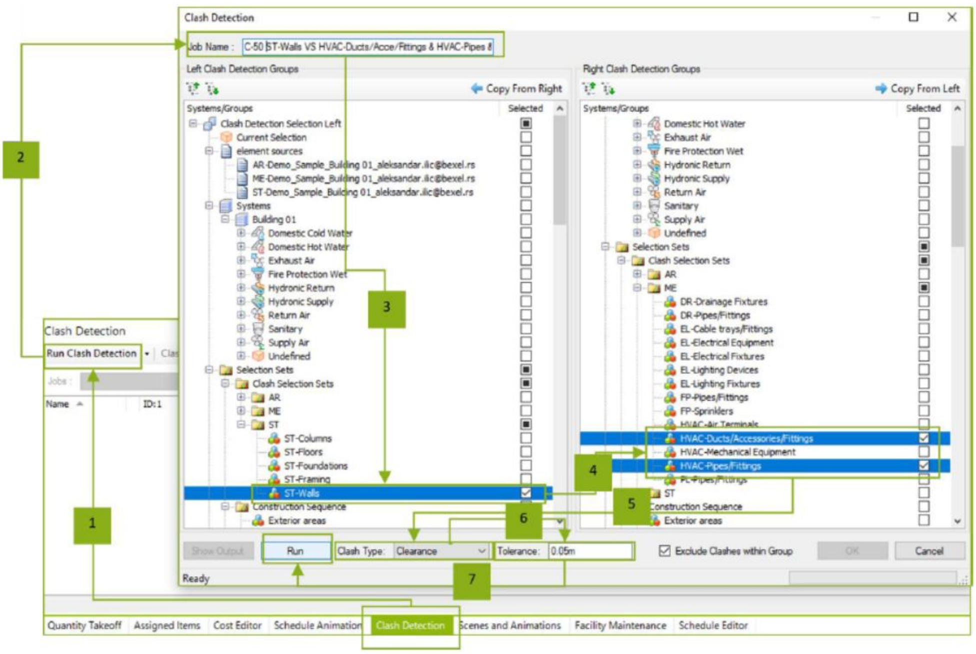


Figure 6.15 The Process of Creating Clash Detection Job

The result was an organized overview of Clash Detection job with comments and adjusted views ready to be sent to designers to eliminate collisions, depicted in Figure 6.15. In the clash detection list, the information about the level for each element with its level map was defined. The clash list was in the form of a priority list, categorising the clashes as high, medium and low. At the end of the clash analysis, the clash report was formulated in a PDF format. The clashes were studied properly and the model was rectified by resizing the clashed elements, using the level maps that accurately spotted the location of clashes. The 3D model was made clash free using this procedure. Then the 4D/5D model was rectified reducing the cost for the extra quantities. The 4D/5D clash free model of the Villa is shown in Figure 6.16.

TKM Project				Classic Schedule Layout					13-Jun-22
Activity ID	Activity Name	Original Duration	Remaining Duration	Schedule % Complete	Start	Finish	Budgeted Labor Cost	Budgeted Material Cost	Budgeted Total Cost
TKM-7 TKM Project		1209	1209	0%	28-Sep-22	08-Aug-26	Rs.7,052,200.00	Rs.116,546,164.05	Rs.123,598,364.05
A1000	Stone Laying / Agreement	2	2	0%	28-Sep-22	30-Sep-22	Rs.360,000.00	Rs.0.00	Rs.360,000.00
A1010	Statutory Approvals	71	71	0%	30-Sep-22*	22-Dec-22	Rs.67,500.00	Rs.0.00	Rs.67,500.00
TKM-7.1 Construction		1136	1136	0%	22-Dec-22	08-Aug-26	Rs.6,624,700.00	Rs.116,546,164.05	Rs.123,170,864.05
TKM-7.1.1 Substructure		60	60	0%	22-Dec-22	02-Mar-23	Rs.1,043,100.00	Rs.3,637,161.00	Rs.4,680,261.00
A1120	Pile Work	30	30	0%	22-Dec-22*	26-Jan-23	Rs.486,300.00	Rs.327,476.26	Rs.813,776.26
A1130	Pile Cap	15	15	0%	26-Jan-23	13-Feb-23	Rs.278,400.00	Rs.2,653,023.24	Rs.2,931,423.24
A1140	Column Footing	15	15	0%	13-Feb-23*	02-Mar-23	Rs.278,400.00	Rs.656,661.50	Rs.935,061.50
TKM-7.1.2 Super Structure		180	180	0%	02-Mar-23	28-Sep-23	Rs.3,629,200.00	Rs.11,355,672.05	Rs.14,984,872.05
TKM-7.1.2.1 Ground Floor		90	90	0%	02-Mar-23	15-Jun-23	Rs.1,435,500.00	Rs.4,268,336.30	Rs.5,703,836.30
A1150	Plinth Beam	10	10	0%	02-Mar-23*	14-Mar-23	Rs.217,500.00	Rs.634,057.48	Rs.851,557.48
A1160	Columns	15	15	0%	14-Mar-23*	31-Mar-23	Rs.191,400.00	Rs.512,951.34	Rs.704,351.34
A1170	Beam	20	20	0%	31-Mar-23*	24-Apr-23	Rs.252,300.00	Rs.531,182.46	Rs.783,482.46
A1180	Wall 20 Cm	30	30	0%	24-Apr-23*	29-May-23	Rs.278,400.00	Rs.2,171,450.40	Rs.2,449,850.40
A1190	Wall 10 cm	5	5	0%	29-May-23*	03-Jun-23	Rs.278,400.00	Rs.293,219.00	Rs.571,619.00
A1200	Lintel	10	10	0%	03-Jun-23*	15-Jun-23	Rs.217,500.00	Rs.125,475.62	Rs.342,975.62
TKM-7.1.2.2 First Floor		90	90	0%	15-Jun-23	28-Sep-23	Rs.2,193,700.00	Rs.7,087,335.75	Rs.9,281,035.75
A1210	Floor Slab	5	5	0%	15-Jun-23*	21-Jun-23	Rs.227,500.00	Rs.999,257.09	Rs.1,226,757.09
A1220	Columns	10	10	0%	21-Jun-23*	03-Jul-23	Rs.191,400.00	Rs.352,567.61	Rs.543,967.61
A1230	Beam	10	10	0%	03-Jul-23*	14-Jul-23	Rs.217,500.00	Rs.510,927.11	Rs.728,427.11
A1240	Wall 20 cm	25	25	0%	14-Jul-23*	12-Aug-23	Rs.278,400.00	Rs.2,330,039.80	Rs.2,608,439.80
A1250	Wall 10 Cm	3	3	0%	12-Aug-23*	16-Aug-23	Rs.278,400.00	Rs.185,223.00	Rs.463,623.00
A1260	Lintel	10	10	0%	16-Aug-23*	28-Aug-23	Rs.252,300.00	Rs.152,005.54	Rs.404,305.54
A1270	Roof	12	12	0%	28-Aug-23*	11-Sep-23	Rs.278,400.00	Rs.2,302,526.03	Rs.2,580,926.03
A1280	parapet	5	5	0%	11-Sep-23*	16-Sep-23	Rs.217,500.00	Rs.179,742.00	Rs.397,242.00
A1290	Sunshade	10	10	0%	16-Sep-23*	28-Sep-23	Rs.252,300.00	Rs.75,047.58	Rs.327,347.58
TKM-7.1.3 Plastering		180	180	0%	28-Sep-23	25-Apr-24	Rs.556,800.00	Rs.1,312,598.00	Rs.1,869,398.00
A1300	Internal	90	90	0%	28-Sep-23*	11-Jan-24	Rs.278,400.00	Rs.712,414.00	Rs.990,814.00
A1310	External	90	90	0%	11-Jan-24*	25-Apr-24	Rs.278,400.00	Rs.600,184.00	Rs.878,584.00
TKM-7.1.6 Electrical		180	180	0%	25-Apr-24	21-Nov-24	Rs.217,500.00	Rs.710,442.00	Rs.927,942.00
A1320	Complete Electrical Works	180	180	0%	25-Apr-24*	21-Nov-24	Rs.217,500.00	Rs.710,442.00	Rs.927,942.00
TKM-7.1.7 Plumbing		180	180	0%	25-Apr-24	21-Nov-24	Rs.217,500.00	Rs.2,472,453.00	Rs.2,689,953.00

Figure 6.16 4D/5D Clash Free Model of the Villa

As per the 4D/5D model re-developed, the whole project cost reduced to Rs.12,35,98,364.05. The difference in cost amounted to a total of Rs.42,76,396.75. This extra cost is to be referred to the builders associated with the Villa Project, so that they can re-route the design of the model to be clash free and to eliminate the wasteful activities.

6.2.2 Standardization of Clash Template

As described earlier, clashes form a major problem in construction sequencing resulting in wastage of resources and thereby increase in construction cost. So, clashes have to be detected at the design stage itself. But it becomes very difficult when clashes are to be detected for a huge project. Therefore, it becomes really helpful if these clashes can be detected with the help of a standard template.

Job Name	Left Clash Detection Group	Right Clash Detection Group	Clash Type	Tolerance	Exclude Clash
AR Walls vs EL	Type of Work Category\Architectural Works\Architectural Walls	Type of Work Category\Electrical Works\Electrical Equipment	Containment	0.050000	TRUE
		Type of Work Category\Electrical Works\Electrical Fixtures			
		Type of Work Category\Electrical Works\Lighting Devices			
		Type of Work Category\Electrical Works\Lighting Fixtures			
		Type of Work Category\Electrical Works\Cable Tray Fittings			
		Type of Work Category\Electrical Works\Cable Trays			
		Type of Work Category\Electrical Works\Conduits			
		Type of Work Category\Electrical Works\Conduit Fittings			
ST vs ST	Type of Work Category\Structural Works\Structural Foundations	Type of Work Category\Structural Works\Structural Columns	Duplicate	0.000000	TRUE
	Type of Work Category\Structural Works\Structural Columns	Type of Work Category\Structural Works\Structural Rebar			
	Type of Work Category\Structural Works\Structural Rebar	Type of Work Category\Structural Works\Structural Beams			
	Type of Work Category\Structural Works\Structural Beams	Type of Work Category\Structural Works\Structural Slabs			
	Type of Work Category\Structural Works\Structural Slabs	Type of Work Category\Structural Works\Structural Walls			
AR vs AR	Type of Work Category\Architectural Works\Architectural Beams	Type of Work Category\Architectural Works\Architectural Slabs	Duplicate	0.000000	TRUE
	Type of Work Category\Architectural Works\Architectural Slabs	Type of Work Category\Architectural Works\Architectural Walls			
	Type of Work Category\Architectural Works\Stairs	Type of Work Category\Architectural Works\Curtain Walls			
	Type of Work Category\Architectural Works\Doors	Type of Work Category\Architectural Works\Doors			
	Type of Work Category\Architectural Works\Windows	Type of Work Category\Architectural Works\Ceilings			
	Type of Work Category\Architectural Works\Architectural Walls	Type of Work Category\Architectural Works\Furniture			
	Type of Work Category\Architectural Works\Curtain Walls	Type of Work Category\Architectural Works\Curtain Panels			
	Type of Work Category\Architectural Works\Curtain Panels	Type of Work Category\Architectural Works\Railings			
	Type of Work Category\Architectural Works\Curtain Wall Mullions	Type of Work Category\Architectural Works\Stairs			
	Type of Work Category\Architectural Works\Railings	Type of Work Category\Architectural Works\Curtain Wall Mullions			
	Type of Work Category\Architectural Works\Ceilings	Type of Work Category\Architectural Works\Windows			
PL vs PL	Type of Work Category\Plumbing Works\Pipes	Type of Work Category\Plumbing Works\Pipe Fittings	Duplicate	0.000000	TRUE
	Type of Work Category\Plumbing Works\Pipe Fittings	Type of Work Category\Plumbing Works\Plumbing Fixtures			
	Type of Work Category\Plumbing Works\Plumbing Fixtures	Type of Work Category\Plumbing Works\Sprinklers			
EL vs EL	Type of Work Category\Electrical Works\Electrical Equipment	Type of Work Category\Electrical Works\Electrical Fixtures	Duplicate	0.000000	TRUE
	Type of Work Category\Electrical Works\Electrical Fixtures	Type of Work Category\Electrical Works\Lighting Fixtures			
	Type of Work Category\Electrical Works\Lighting Devices	Type of Work Category\Electrical Works\Cable Trays			
	Type of Work Category\Electrical Works\Lighting Fixtures	Type of Work Category\Electrical Works\Conduit Fittings			
ME vs ME	Type of Work Category\Mechanical Works\Duct Fittings	Type of Work Category\Mechanical Works\Ducts	Duplicate	0.000000	TRUE
	Type of Work Category\Mechanical Works\Ducts	Type of Work Category\Mechanical Works\Flex Ducts			
	Type of Work Category\Mechanical Works\Flex Ducts	Type of Work Category\Mechanical Works\Mechanical Equipments			
	Type of Work Category\Mechanical Works\Mechanical Equipments	Type of Work Category\Mechanical Works\Air Terminals			
ST vs MEP	Groups of works\Structural Works	Groups of works\MEP Works	Hard	0.005000	TRUE
Pipes vs ST&AR Walls	Type of Work Category\Plumbing Works\Pipes	Type of Work Category\Structural Works\Structural Walls	Containment	0.050000	TRUE
		Type of Work Category\Architectural Works\Architectural Walls			
AR Walls vs EL & ME	Type of Work Category\Architectural Works\Architectural Walls	Type of Work Category\Electrical Works\Electrical Equipment	Clearance	0.500000	TRUE
		Type of Work Category\Electrical Works\Electrical Fixtures			
		Type of Work Category\Electrical Works\Lighting Devices			
		Type of Work Category\Electrical Works\Lighting Fixtures			
		Type of Work Category\Electrical Works\Cable Tray Fittings			
		Type of Work Category\Electrical Works\Cable Trays			
		Type of Work Category\Electrical Works\Conduits			
		Type of Work Category\Mechanical Works\Mechanical Equipments			
		Type of Work Category\Electrical Works\Conduit Fittings			
		Type of Work Category\Mechanical Works\Air Terminals			
		Type of Work Category\Mechanical Works\Duct Fittings			
		Type of Work Category\Mechanical Works\Ducts			
		Type of Work Category\Mechanical Works\Flex Ducts			
HVAC vs ST	Type of Work Category\Mechanical Works\Duct Fittings	Type of Work Category\Structural Works\Structural Foundations	Hard	0.000000	TRUE
	Type of Work Category\Mechanical Works\Ducts	Type of Work Category\Structural Works\Structural Rebar			
	Type of Work Category\Mechanical Works\Flex Ducts	Type of Work Category\Structural Works\Structural Slabs			
	Type of Work Category\Mechanical Works\Mechanical Equipments	Type of Work Category\Structural Works\Structural Beams			
	Type of Work Category\Mechanical Works\Air Terminals	Type of Work Category\Structural Works\Structural Walls			
		Type of Work Category\Structural Works\Structural Columns			
PL vs AR	Type of Work Category\Plumbing Works\Pipes	Type of Work Category\Architectural Works\Architectural Beams	Hard	0.000000	TRUE
	Type of Work Category\Plumbing Works\Pipe Fittings	Type of Work Category\Architectural Works\Doors			
	Type of Work Category\Plumbing Works\Plumbing Fixtures	Type of Work Category\Architectural Works\Curtain Wall Mullions			
ST vs ME	Type of Work Category\Mechanical Works\Duct Fittings	Type of Work Category\Structural Works\Structural Foundations	Hard	0.000000	TRUE
	Type of Work Category\Mechanical Works\Ducts	Type of Work Category\Structural Works\Structural Columns			
	Type of Work Category\Mechanical Works\Flex Ducts	Type of Work Category\Structural Works\Structural Rebar			
	Type of Work Category\Mechanical Works\Mechanical Equipments	Type of Work Category\Structural Works\Structural Beams			
	Type of Work Category\Mechanical Works\Air Terminals	Type of Work Category\Structural Works\Structural Slabs			
		Type of Work Category\Structural Works\Structural Walls			

Figure 6.17 Standardized Clash Template

This template is based on assumptions in the type/discipline of clashes. There are mainly 10 important clashes that has to be governed, namely, architectural vs electrical, structural vs structural, architectural vs architectural, plumbing vs plumbing, electrical vs electrical, mechanical vs mechanical, structural vs MEP, HVAC vs structural, plumbing vs architectural and structural vs mechanical. These are the clashes that cannot be ignored at any cost. The elements for the standard clash template are retrieved from the selection set. Figure 6.17 represents the standardized template for clashes. These selection sets are prepared on the basis of how to detect the clash. As such the element clashes in the entire project can be detected within just 2 seconds by importing/referring to this standard template.

6.2.3 *Standardization of Property Check Template*

Geometric and semantic information are both included in BIM models. The level of abstraction varies from rough models to intricately modelled technical building components. BIM has so far been created and utilised during the design and construction stages of a building's lifetime. BIM models must offer a trustworthy data base of the as-built and, correspondingly, the as-is scenario in order to effectively use the benefits of BIM for the operation and refurbishment phases. However, many homes have not yet been built or planned using BIM, and occasionally digital planning information isn't even accessible. As a result, the real world must be used to generate the digital model.

1	Category	Property Naming Pattern	Example (Not required)
2	Beams	^[A-Z]{2}-([A-Z][a-z]*)(_[A-Z][a-z]*)*-[0-9]+x[0-9]+[a-z]{2}$	ST-Concrete_Rectangular_Beam-600x900mm
3	Conduit Fittings	^[A-Z]{2}-([A-Z][a-z]*)(_[A-Z][a-z]*)*$	EL-Conduit_Body_Type_L_Aluminum
4	Conduits	^[A-Z]{2}-([A-Z][a-z]*)(_([A-Z][a-z]*)|((\([A-Z]+(_[a-zA-Z0-9])+\))*))*$	EL-Rigid_Nonmetallic_Conduit_(RNC_Sch_80)
5	Electrical Equipment	^[A-Z]{2}-([A-Z][a-z]*)(_[A-Z][a-z]*)*-[0-9]+x[0-9]+[a-z]{2}$	EL-Circuit_Breaker_Switchboard-762x965mm
6	Electrical Fixtures	^[A-Z]{2}-([A-Z][a-z]*)(_[A-Z][a-z]*)*-([A-Z][a-z]*)$	EL-Duplex_Receptacle-Plain
7	Lighting Devices	^[A-Z]{2}-([A-Z][a-z]*)(_[A-Z][a-z]*)*-[A-Z][a-z]*(_[A-Z][a-z]*)*$	EL-Lighting_Switches-Single_Pole
8	Lighting Fixtures	^EL-.*$	EL-Pendant_Light_Linear_2_Lamp-277V_2400mm
9	Pipe Fittings	^PL-.*$	PL-Transition_Generic-Standard
10	Pipes	^PL-.*$	PL-Opening Cut
11	Plumbing Fixtures	^PL-.*$	PL-Lavatory_Wall_Mounted-Public-485x355mm
12	Railings	^[A-Z]{2}-.*$	AR-Guardrail_Pipe
13	Roofs	^[A-Z]{2}-([A-Z][a-z]*)(_[A-Z][a-z]*)*-.*$	AR-Roof-100mm
14	Slabs	^[A-Z]{2}-([A-Z][a-z]*)(_[A-Z][a-z]*)*-[0-9]+[a-z]{2}$	AR-Floor_finish-100mm
15	Stairs	^AR-Stair$	AR-Stair
16	Structural Columns	^ST-.*$	ST-Concrete_Round_Column - ST-Round_Column-300mm
17	Structural Foundations	^ST-.*$	ST-Pile_Steel_Pipe-Diameter-500mm
18	Doors	^AR-.*$	AR-Double_Glass_1 - AR-Double_glass-1830x2134mm
19	Windows	^[A-Z]{2}-([A-Z][a-z]*)(_[A-Z][a-z]*)*-[0-9]+x[0-9]+[a-z]{2}$	AR-Square_Opening-600x500mm

Figure 6.18 Standardized Naming Conventions

Figure 6.18 shows the standardized naming conventions of the elements required for a perfect BIM model. There are certain properties which should be incorporated in the model to form a perfect BIM model. It becomes difficult to check each and every element property in a model in accordance to the BEP. This particular issue has been rectified by standardizing a Property Checker Template, which forms all the properties of every element that are essential in a perfect BIM model. The standardization of the template was done by referring the BIMForum as per the ISO 19650 series. Properties of the LOD 300 of the BIMForum was assumed in this project. As a part of the property check, appropriate naming conventions were initially standardized. Appropriate naming conventions as per LOD 300 of the BIMForum was assigned to eighteen selected elements which form an essential part of a typical double-storeyed villa.

Ensuring that a project, procedure, etc. is described using the same term, description, or acronym is what it is, to put it simply. Using standard property names makes it simpler to recognise the building properties and keeps them organized. It becomes easy to locate properties or names of elements more quickly if consistently organised in universally accepted naming conventions. Additionally, it will make it simpler for others to navigate a work in a shared or collaborative group file-sharing environment.

1	Parameter Name	Pset	Value Type	Phase
2	Analytical: Length	Analytical Properties	Length	Issue for Construction
3	Analytical: Physical Material Asset	Analytical Properties	Text	Issue for Construction
4	End Level Offset	Constraints	Length	Design Development
5	Reference Level Elevation	Constraints	Length	Design Development
6	Start Level Offset	Constraints	Length	Design Development
7	End Extension (Construction)	Construction	Length	Issue for Construction
8	End Offset	Construction	Length	Issue for Construction
9	Start Offset	Construction	Length	Issue for Construction
10	Depth	Dimensions	Length	Concept Design
11	Length	Dimensions	Length	Concept Design
12	Reinforcement	Dimensions	Mass	Design Development
13	Specific Weight	Dimensions	Mass	Design Development
14	Volume	Dimensions	Volume	Concept Design
15	Assembly Code	Identity Data	Text	Design Development
16	Join Status	Geometry Positioning	Numeric	Issue for Construction
17	Comments	Identity Data	Text	Design Development
18	Cost	Identity Data	Numeric	Design Development
19	Description	Identity Data	Text	Design Development
20	Fire Rating	Identity Data	Text	Design Development
21	Model	Identity Data	Text	Design Development
22	Phase Created	Phases	Text	Issue for Construction
23	Camber Size	Structural	Text	Issue for Construction
24	Cut Length	Structural	Length	Issue for Construction
25	Estimated Reinforcement Volume	Structural	Volume	Issue for Construction
26	Number of studs	Structural	Text	Issue for Construction
27	Structural Usage	Structural	Numeric	Issue for Construction
28	Construction Sequence	Text	Text	Design Development
29	Maintenance	Asset Information	Boolean	FM
30	ReqInspection	Asset Information	Boolean	FM
31	ProductionYear	Asset Information	Text	FM
32	DateFirstUsed	Asset Information	Text	FM
33	WarrantyEndDate	Asset Information	Text	FM
34	Manufacturer	Asset Information	Text	FM

Help / Project Information / Project Naming Conventions / Property Naming Conventions / Pick Lists / **Beams**

Figure 6.19 Standardized Properties of a Beam

Then, the properties of all the eighteen elements that are essential to form a standard BIM model was standardized. Figure 6.19 represents the standardized template of properties required for a beam. The template thus standardized consisted of the name of essential BIM properties, the property set to which it belongs, the value type of the property, and finally the phases in which that particular property is required. This template was used to analyze the element properties of the Villa model. The properties of the developed Villa was analyzed to check the effectiveness of the standard template.

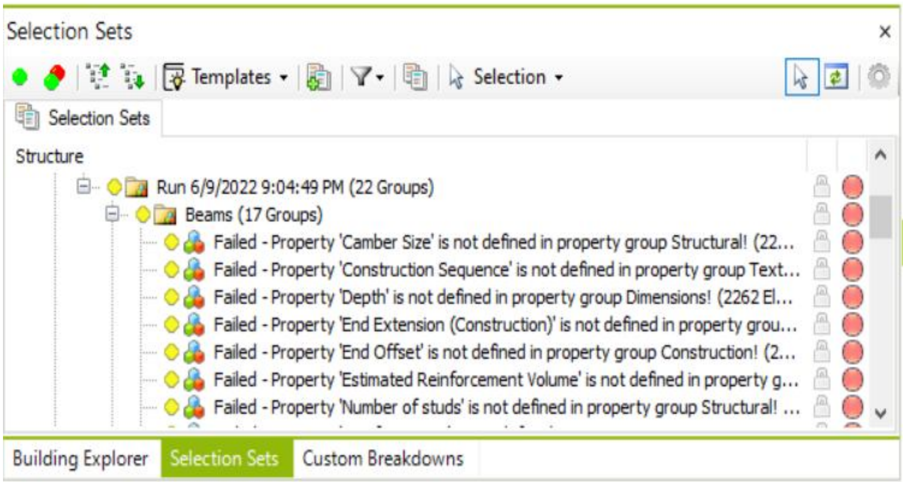


Figure 6.20 Example of Failed Properties (Beam)

The 3D model that has been developed was overviewed at the start of the property check. The model was then checked to see whether it has been developed in accordance with the BEP. In this way, it was analyzed whether the elements have all the properties as specified in the BEP.

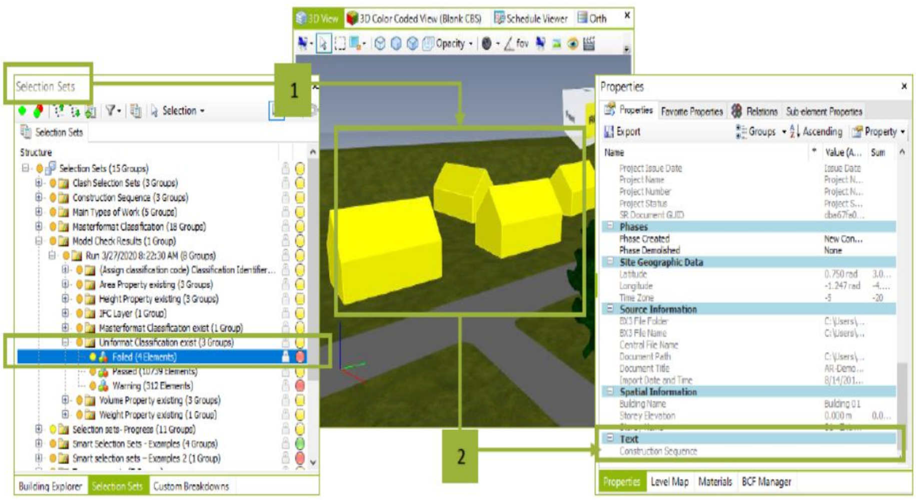


Figure 6.21 Results of Property Check Analyzed With Add-In

When the villa model was checked closely for it's properties using the standard template, the software has analyzed and showed that some of the element properties have failed to run. The properties that failed to match the beam element properties are shown in Figure 6.20 and the results of property check analyzed with add-in is represented in Figure 6.21. The data check analysis of the property check of the Villa was generated through Power BI and the following simulation was obtained.

Users of the Power BI service may see dashboards, reports, and Power BI applications via a web browser. Power BI apps are a form of content that mix connected dashboards and reports. Data Connection, Data Relationships, Power Query, Power Pivot Access, Cost of Power BI, Custom Visualizations, Power BI Question and Answers, and Report Sharing are the primary aspects of Power BI. The reports are in the form of data check analysis which makes it easier to check data pertaining to different categories.

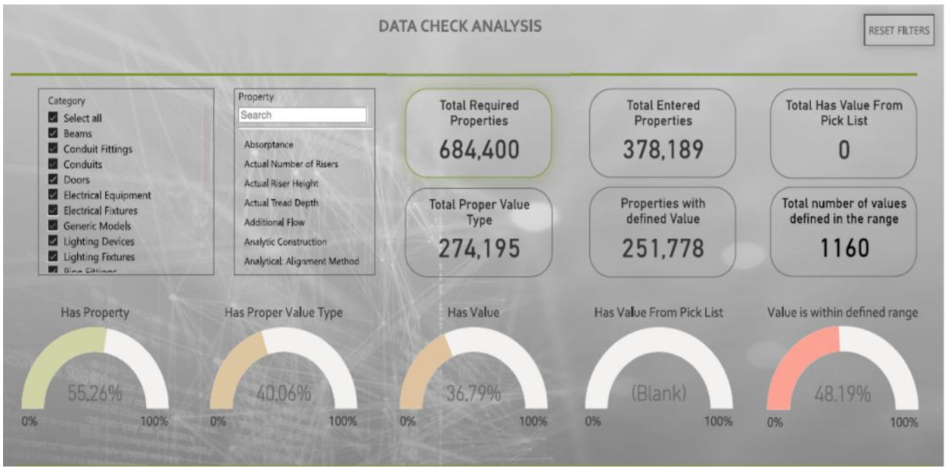


Figure 6.22 Data Check Analysis Exported using Power BI

The data check analysis depicted in Figure 6.22, showed that the total number of element properties required to form a perfect BIM model as per the standard template was 6,84,400 and that of the villa model was just 3,78,189. This difference in properties spotted the unmatched or the missing properties in the villa model.

By doing so, it was checked, why certain elements that should have the selected property, do not have it. It was identified that some properties of the Villa model that have failed to match the standard was misspelled, few other properties were inappropriate in content, some other properties were missing in the model and the nomenclatures of the rest were inappropriate. Figure 6.20 shows an example of the failed properties of a beam which were essential to form a perfect BIM model and Figure 6.21 shows the results of Property Check analyzed with add-in.

It was identified that, all the twenty-seven properties are essential to form a perfect BIM beam model as per LOD 300. As such, all the eighteen elements in the model were checked for it's properties. Thus, the result of the property check of the villa model was derived. The report was generated by exporting it to Power BI. Figure 6.23 shows the data check analysis of property check of the Wall as the element. As such, the data check analysis of all the elements has been done with reference to the standardized property template. The matching properties /the properties in sync with the 3D model can also be determined in percentage (Has property %). Also, the value type percentage can be derived from Power BI.

Data Check Analysis

Category / Property	Properties	Has Property	Has Property %	Has Value	Has Value %	Has Proper Value Type	Has Proper Value Type %	Has Value From Pick List	Has Value From Pick List %	Value is within defined range	Value is within defined range %
Walls	**1,07,532**	**65,714**	**61.11**	**38,831**	**36.11**	**50,779**	**47.22**	**0**	**0.00**	**0**	**0.00**
Absorptance	2,987	2,987	100.00	2,987	100.00	2,987	100.00	0	0.00	0	0.00
Analytical: Alignment Method	2,987	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Analytical: Area	2,987	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Analytical: Perimeter	2,987	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Area	2,987	2,987	100.00	2,987	100.00	2,987	100.00	0	0.00	0	0.00
Assembly Code	2,987	2,987	100.00	0	0.00	0	0.00	0	0.00	0	0.00
Base Offset	2,987	2,987	100.00	2,987	100.00	2,987	100.00	0	0.00	0	0.00
Comments	2,987	2,987	100.00	0	0.00	0	0.00	0	0.00	0	0.00
Construction Sequence	2,987	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Cost	2,987	2,987	100.00	2,987	100.00	2,987	100.00	0	0.00	0	0.00
DateFirstUsed	2,987	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Description	2,987	2,987	100.00	0	0.00	0	0.00	0	0.00	0	0.00
Fire Rating	2,987	2,987	100.00	0	0.00	0	0.00	0	0.00	0	0.00
Heat Transfer Coefficient (U)	2,987	2,987	100.00	2,987	100.00	2,987	100.00	0	0.00	0	0.00
Length	2,987	2,987	100.00	2,987	100.00	2,987	100.00	0	0.00	0	0.00
Maintenance	2,987	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Manufacturer	2,987	2,987	100.00	0	0.00	0	0.00	0	0.00	0	0.00
Total	**1,07,532**	**65,714**	**61.11**	**38,831**	**36.11**	**50,779**	**47.22**	**0**	**0.00**	**0**	**0.00**

BEXELMANAGER

Figure 6.23 Data Check Analysis of Property Check of Walls

6.2.4 Standardization of Quantity Take-off Template

In the construction industry, the phrase "quantity take-off" has been used for a very long time to describe an essential step in the planning process. To properly manage data during quantity takeoff, a highly specialised skill set is needed. This important early-stage project step can make or break success. The entire construction process can become inefficient as a result of poor quantity takeoffs, which can under- or overestimate construction expenses. Any project may suffer if necessary material quantities and reasonable price ranges are ignored or duplicated. Accuracy and completeness are crucial for successful data collecting in the construction industry.

The quantity take-off for the villa project has been done by analyzing the model. The process of carrying out quantity take-off for the Villa project has been shown in Figure 6.24.

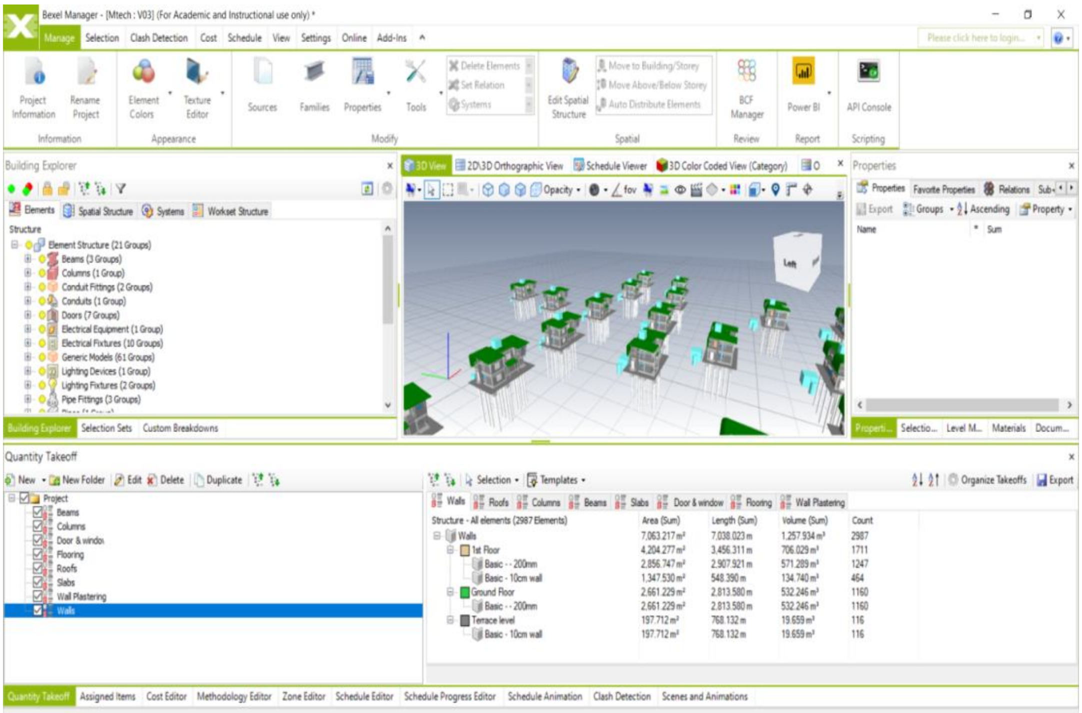


Figure 6.24 Process of Carrying Out Quantity Take-Off for the Villa Project

The quantity take-off template has been standardized in the form of a structure. This structure is in BXF (BIM Exchange File Format) Format and so it can be imported and used by builders dealing with similar projects so that the scheduling can be done with ease.

The BXF - BIM Exchange File proprietary file format from SrinSoft enables smooth file exchange across animation, conceptual design, and mechanical design software. It's an intelligent tool that allows you to import the correct geometry and meta-data into any software programme. In contrast to other intermediate file formats, BXF enables the user to select particular components and assemblies as well as the characteristics of corresponding pieces. BXF maintains the corresponding model hierarchy while producing 3D geometry.

The process of carrying out quantity take-off for the villa project has been shown in Figure 6.24.

Structure - All elements (899 Elements)	Count (Value)	Sill Height (Sum) (Unit)	Sill Height (Sum) (V
Doors	**377**	**m**	**0.00**
1st Floor	203	m	0.00
M_Door-Interior-Double-Full Glass-Wood - 1500 x 2100mm	29	m	0.00
M_Door-Interior-Single-6_Panel-Wood - 80 x 190	87	m	0.00
M_Door-Interior-Single-6_Panel-Wood - 90 x190	87	m	0.00
Ground Floor	174	m	0.00
M_Door-Interior-Single-6_Panel-Wood - 110 x210	29	m	0.00
M_Door-Interior-Single-6_Panel-Wood - 80 x 180	29	m	0.00
M_Door-Interior-Single-6_Panel-Wood - 80 x 210	29	m	0.00
M_Door-Interior-Single-6_Panel-Wood - 900 x 2100mm	87	m	0.00
Windows	**522**	**m**	**427.75**
1st Floor	261	m	186.18
M_Fixed - 80 x 60	58	m	75.40
M_Window-Awning-Triple-Horizontal - 100 x 100	29	m	22.33
M_Window-Casement-Multi-Sash-Horizontal - 1800 x 1350mm	29	m	15.95
M_Window-Casement-Single_Right - 50 x 100	29	m	26.10
M_Window-Casement-Triple-Side-Transom - 150 x150	116	m	46.40
Ground Floor	261	m	241.57
M_Fixed - 80 x 60	58	m	86.71
M_Window-Awning-Triple-Horizontal - 100 x 100	58	m	59.16
M_Window-Casement-Single_Right - 50 x 100	58	m	60.90
M_Window-Casement-Triple-Side-Transom - 150 x150	58	m	34.80
M_Window-Casement-Triple-Side-Transom - 240 x210	29	m	0.00

Structure - All elements (2262 Elements)	b (Sum) (Unit)	b (Sum) (Value)	Volume (Sum) (Unit)	Volume (Sum) (Value)	Length (Sum) (Unit)	Length (Sum) (Value)
Beams	**m**	**452.40**	**m^3**	**614.24**	**m**	**8,559.68**
1st Floor	m	179.80	m^3	202.37	m	3,324.89
M_Concrete-Rectangular Beam - beam	m	98.60	m^3	160.11	m	1,782.92
M_Concrete-Rectangular Beam - lintel	m	81.20	m^3	42.27	m	1,541.97
Ground Floor	m	179.80	m^3	262.98	m	3,582.08
M_Concrete-Rectangular Beam - 300 x 600mm	m	110.20	m^3	221.78	m	2,052.91
M_Concrete-Rectangular Beam - lintel	m	69.60	m^3	41.20	m	1,529.17
Terrace level	m	92.80	m^3	148.89	m	1,652.71
M_Concrete-Rectangular Beam - beam	m	92.80	m^3	148.89	m	1,652.71

Structure - All elements (87 Elements)	Thickness (Sum) (Unit)	Thickness (Sum) (Value)	Area (Sum) (Unit)	Area (Sum) (Value)
Slabs	**m**	**13.05**	**m^2**	**6,425.41**
1st Floor	m	4.35	m^2	2,169.10
Generic 150mm	m	4.35	m^2	2,169.10
Ground Floor	m	8.70	m^2	4,256.31
Generic 150mm	m	8.70	m^2	4,256.31

Structure - All elements (145 Elements)	Thickness (Sum) (Unit)	Thickness (Sum) (Value)	Area (Sum) (Unit)	Area (Sum) (Value)
Roofs	**m**	**21.75**	**m^2**	**5,753.47**
1st Floor	m	4.35	m^2	154.11
Generic - 400mm	m	4.35	m^2	154.11
Ground Floor	m	4.35	m^2	76.56
Generic - 400mm	m	4.35	m^2	76.56
Terrace level	m	13.05	m^2	5,522.80
Generic - 400mm	m	13.05	m^2	5,522.80

Structure - All elements (58 Elements)	Volume (Sum) (Unit)	Volume (Sum) (Value)	Length (Sum) (Unit)	Length (Sum) (Value)
Columns	**m^3**	**3.22**	**m**	**177.41**
Ground Floor	m^3	3.22	m	177.41
M_Round Column - 152mm Diameter	m^3	3.22	m	177.41

Structure - All elements (1566 Elements)	Area (Sum) (Unit)	Area (Sum) (Value)	Depth (Sum) (Unit)	Depth (Sum) (Value)	Diameter (Sum) (	Diameter (Sum) (Value)	Length (Sum) (Uni	Length (Sum) (Valu	Volume (Sum	Volume (Sum) (Value
Structural Foundations	**m^2**	**1,047.30**					**m**	**991.80**	**m^3**	**1,673.66**
TOF	m^2	1,047.30					m	991.80	m^3	1,673.66
M_Footing-Rectangular - column footing	m^2	422.82					m	469.80	m^3	126.85
M_Pile Cap-1 Pile - 1000 x 1000 x 900mm	m^2	522.00					m	522.00	m^3	522.00
M_Pile-Steel Pipe - 600mm Diameter	m^2	102.48	m	5,220.00	m	261.00	m	0.00	m^3	1,024.82

Structure - All elements (2987 Elements)	Area (Sum	Area (Sum) (Value)	Length (Su	Length (Sum) (Valu	Volume (Sum) (Unit	Volume (Sum) (V	Count (Value)
Walls	**m^2**	**7,063.22**	**m**	**7,038.02**	**m^3**	**1,257.93**	**2987**
1st Floor	m^2	4,204.28	m	3,456.31	m^3	706.03	1711
Basic - - 200mm	m^2	2,856.75	m	2,907.92	m^3	571.29	1247
Basic - 10cm wall	m^2	1,347.53	m	548.39	m^3	134.74	464
Ground Floor	m^2	2,661.23	m	2,813.58	m^3	532.25	1160
Basic - - 200mm	m^2	2,661.23	m	2,813.58	m^3	532.25	1160
Terrace level	m^2	197.71	m	768.13	m^3	19.66	116
Basic - 10cm wall	m^2	197.71	m	768.13	m^3	19.66	116

Figure 6.25 Standardized Quantity Take-Off Template

The structure as to how the quantity take-off for a similar project can be carried out is depicted in Figure 6.25.

6.2.5 Standardization of Classification Item/Cost Item Template

A standard structure/template for classification item has been prepared with all the pertaining cost items. This structure can be used as the standard list of activities required for a similar villa project with comparable costs met with each activities. These costs can also be considered standard as per Indian conditions. Also, the resources required for each activity are standardized. This particular template can be used in order to schedule a massive project with a few clicks. The template has been standardized with the required properties as per LOD 300.

With the use of this template it becomes easier to define or justify the activities that are necessary to be contented while planning a similar project. The whole lot is carried out keeping that one aspect in mind/ considering that only the magnitude of elements changes and not the elements as a whole. In the template, the cost pertaining to materials required to carry out each activity has also been elaborated as per Indian conditions as of now.

Figure 6.26 represents the standardized activity/classification item template.

Code	Name	Cost Items Count	Unit Cost	Daily Output	Quantity Type
Enter text to search					
BIM based Cost	BIM based Cost	36			
A	Approvals	2			
A.a	Stone laying/ Agreement		₹ 8,100.00	1	Numeric
A.b	Statutory approvals		₹ 4,500.00	1	Numeric
B	Earthwork	1			
B.1	Earth filling inside the basement including watering, proper consolidation etc. complete		₹ 33,963.00	3	Volume
C	Piling	3			
C.1	Pile Cap		₹ 6,328.50	1	Volume
C.2	Plinth Beam		₹ 6,328.50	1	Volume
C.3	Pile foundation		₹ 4,979.58	1	Numeric
D	PCC, RCC & Reinforcement works	8			
D.1	RCC Works	7			
D.1.01	Lintel		₹ 6,811.98	1	Volume
D.1.02	Sunshade		₹ 6,328.50	1	Volume
D.1.03	Column		₹ 8,971.85	1	Volume
D.1.04	Beam		₹ 8,971.85	1	Volume
D.1.05	Roof Slab		₹ 8,971.85	1	Volume
D.1.06	Staircase		₹ 6,871.85	1	Volume
D.1.07	Slab		₹ 6,871.85	1	Volume
D.2	PCC for Foundation	1			
D.2.01	Providing and laying PCC 1:4:8, using 20 to 40mm nominal size stone aggregate for foundation bed as a base course, machine mixed and placed properly in level and manually compacted with hand rammers including cost and conveyance of all materials, all labour charges, shuttering, curing, all lead & lift etc.		₹ 4,808.00	1	Volume
E	Block work masonry	2			
E.1	20cm wall		₹ 4,828.42	3	Volume
E.2	10 cm wall		₹ 4,302.91	3	Volume

F	Plastering	4			
F.1	Plastering with C.M 1:5, 12mm thick, one coat floated hard and trowelled smooth to the internal walls including cost and conveyance of all materials, all labour charges, scaffolding charges, watering, curing, proper hacking in concrete surface etc. complete		₹ 2,504.00	1	Area
F.2	Plastering with C.M 1:4, (15mm thick) , first layer 6mm thick and a second layer 9mm thick to the external surface of walls (including the curved portions) including cost and conveyance of all materials, all labour charges, scaffolding charges, watering, curing, proper hacking in concrete surface etc.		₹ 2,511.00	1	Area
F.3	Plastering with C.M 1:4, 9mm thick, one coat floated hard and trowelled smooth to the underside of slabs and exposed beams including cost and conveyance of all materials, all labour charges, scaffolding charges, watering, curing, proper hacking in concrete surface etc.		₹ 2,290.00	1	Area
F.4	Protection Plastering with C.M 1:4, upto 25mm thick and finished with one coat floated hard and trowelled smooth for all open terrace, roof top and sunken slabs, including cost and conveyance of all materials, all labour charges, scaffolding charges, watering, curing, proper hacking in concrete surface etc.		₹ 4,131.00	1	Area
G	Flooring Works	2			
G.1	Flooring		₹ 3,600.00	1	Area
G.2	GF Plinth area		₹ 3,308.00	1	Volume
H	Grill/ handrail/Counter works	3			
H.1	Handrail - Staircase	1			
H.1.01	Handrail		₹ 3,000.00	1	Length
H.2	Handrail - Balcony	1			
H.2.01	Handrail outer		₹ 5,100.00	1	Length
H.3	False Ceiling Works	1			
H.3.01	False ceiling work - Toilet		₹ 63,193.17	1	Area
I	Wood works	9			
I.1	Door	4			
I.1.01	MD		₹ 61,250.00	1	Numeric
I.1.02	D1 (External)		₹ 53,226.00	1	Numeric
I.1.03	D2 & D3		₹ 22,359.72	1	Numeric
I.1.04	D2*-Toilet		₹ 10,729.81	1	Numeric
I.2	Wooden joinery work for windows and ventilator	5			
I.2.01	W2		₹ 5,461.00	1	Area
I.2.02	W3		₹ 76,880.00	1	Area
I.2.03	W1		₹ 26,887.00	1	Area
I.2.04	KW2		₹ 26,093.00	1	Area
I.2.05	V		₹ 10,857.00	1	Area
J	Painting works	0			
K	Flooring	2			
K.1	Trimix Flooring		₹ 9,608.00	1	Area
K.2	Water proofing works in toilets,roof top		₹ 11,107.09	1	Area

Figure 6.26 Standardized Activity/Classification Item Template

6.2.6 Standardization of Methodology Template

Methodology is based on a certain classification and can be used on various similar projects unlike the zones that are based more on a certain project and consist from selection sets, buildings, levels etc. Methodology is typically created on two levels. Uniformat (as the most common) for physical-based work item segregation and Masterformat (as the most common but also numerous other national classification standards) for material-based work items segregation. These two classification systems are complementary. This is typically defined in cost classification structure so in Methodology, user only has to define proper work sequence between these sub-groups of works. On the first level it will define sequence and relations between groups of works (defined in Uniformat classification). In reality, in Bexel Manager user is able to define this sequence by simple linking “chapters” or Classification items from cost classification and defining type of relation between tasks.

After proper sequence and the relations are defined between groups of works (Uniformat classification) and within every group (Masterformat classification) there is complete methodology ready for Creation Template definition. Within construction methodology, it is possible to define construction sequence on only one level without defining second level relations. In this case automatically generated schedule will be less detailed and less precise but still accurate and practical for progress tracking and planning. Created Methodology can be edited, copied or deleted after it is created. Created Methodology could also be transferred between projects through Bexel Manager exchange process so user is able to re-use once created Methodology on future projects. The methodology to carry out the schedule for the typical villa project has also been standardized in two levels. This methodology template can be used to prepare the schedule for any such project. Figure 6.27 and 6.28 represents the standardized methodology template of the first and second level respectively.

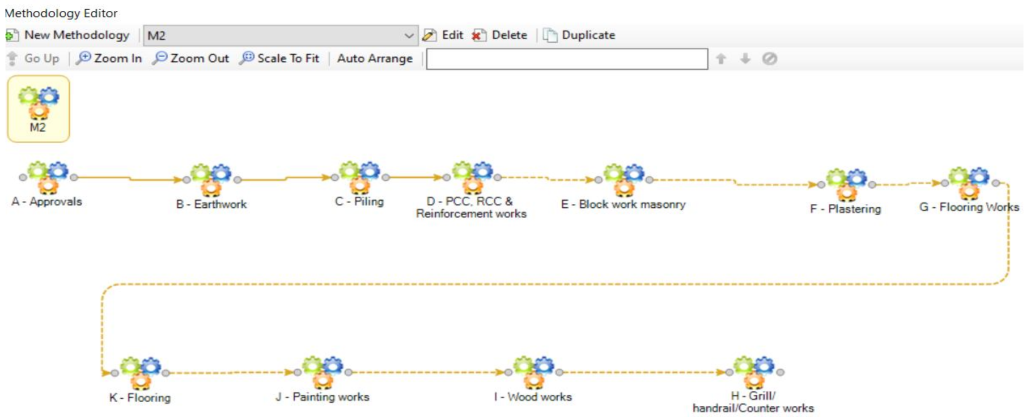
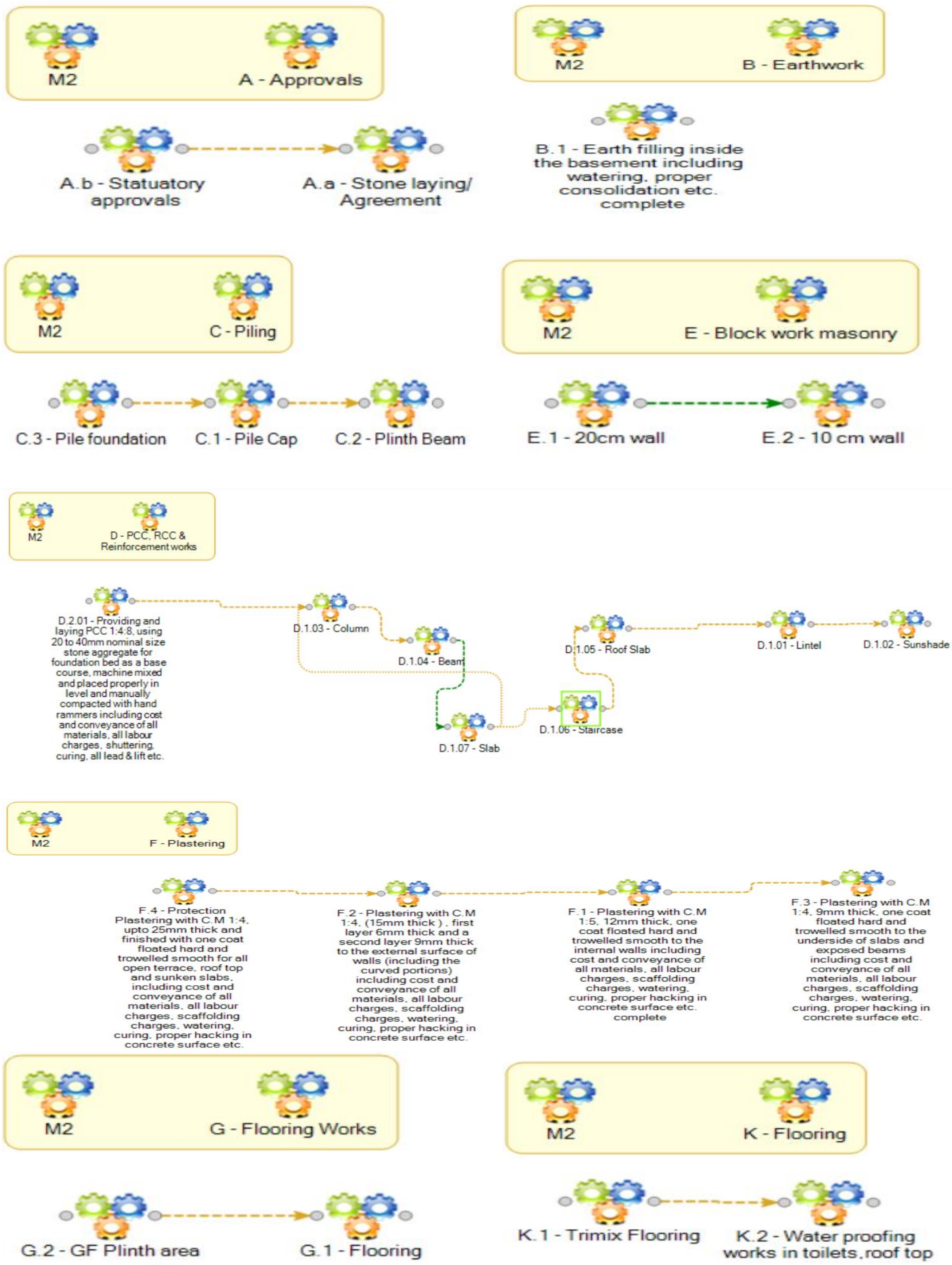


Figure 6.27 Standardized Methodology Template (First Level)


M2
A - Approvals
A.b - Statuatory approvals
A.a - Stone laying/ Agreement
M2
B - Earthwork
B.1 - Earth filling inside the basement including watering, proper consolidation etc. complete
M2
C - Piling
C.3 - Pile foundation
C.1 - Pile Cap
C.2 - Plinth Beam
M2
E - Block work masonry
E.1 - 20cm wall
E.2 - 10 cm wall
M2
D - PCC, RCC & Reinforcement works
D.2.01 - Providing and laying PCC 1:4:8, using 20 to 40mm nominal size stone aggregate for foundation bed as a base course, machine mixed and placed properly in level and manually compacted with hand rammers including cost and conveyance of all materials, all labour charges, shuttering, curing, all lead & lift etc.
D.1.03 - Column
D.1.04 - Beam
D.1.07 - Slab
D.1.06 - Staircase
D.1.05 - Roof Slab
D.1.01 - Lintel
D.1.02 - Sunshade
M2
F - Plastering
F.4 - Protection Plastering with C.M 1:4, upto 25mm thick and finished with one coat floated hard and trowelled smooth for all open terrace, roof top and sunken slabs, including cost and conveyance of all materials, all labour charges, scaffolding charges, watering, curing, proper hacking in concrete surface etc.
F.2 - Plastering with C.M 1:4, (15mm thick) , first layer 6mm thick and a second layer 9mm thick to the external surface of walls (including the curved portions) including cost and conveyance of all materials, all labour charges, scaffolding charges, watering, curing, proper hacking in concrete surface etc.
F.1 - Plastering with C.M 1:5, 12mm thick, one coat floated hard and trowelled smooth to the internal walls including cost and conveyance of all materials, all labour charges, scaffolding charges, watering, curing, proper hacking in concrete surface etc. complete
F.3 - Plastering with C.M 1:4, 9mm thick, one coat floated hard and trowelled smooth to the underside of slabs and exposed beams including cost and conveyance of all materials, all labour charges, scaffolding charges, watering, curing, proper hacking in concrete surface etc.
M2
G - Flooring Works
G.2 - GF Plinth area
G.1 - Flooring
M2
K - Flooring
K.1 - Trimix Flooring
K.2 - Water proofing works in toilets, roof top

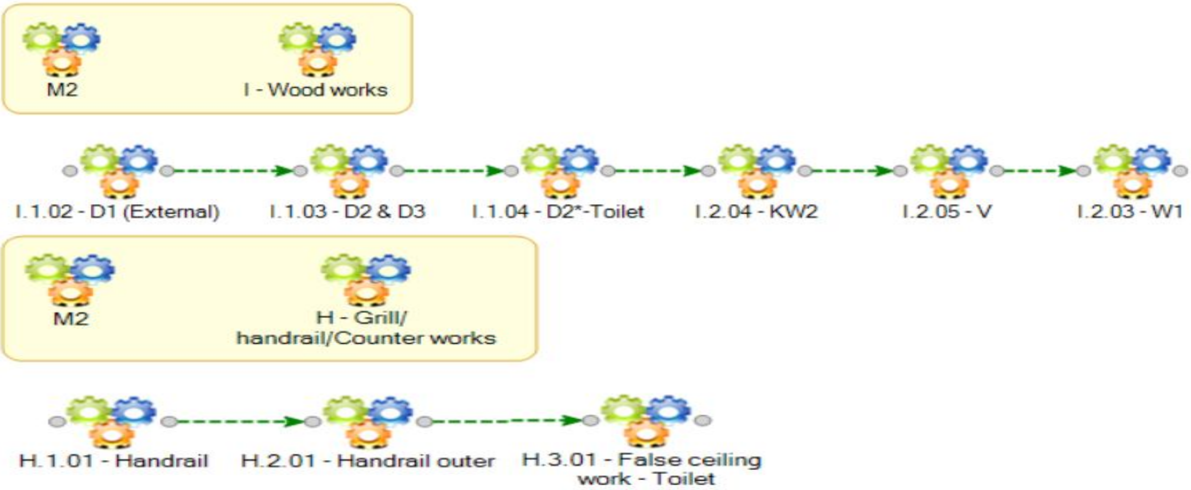


Figure 6.28 Standardized Methodology Template (Second Level)

6.2.7 *Scheduling of the Villa*

Automatically created schedule is organized as a series of tasks of uniform duration set by user (most commonly one working week). Majority of schedule is perfectly balanced and optimized but on most projects, it will certainly require some additional optimization effort by planner. In order to clearly analyze performance of created schedule, construction planner is able to check schedule in classic Gantt diagram, LOB (Line of Balance) flow line diagram (according to which automatically generated schedule is optimized) and Logic diagram. The Planner is also able to check some basic performance parameters of created schedule.

This could be also done for every task or parent task in schedule, so user is able to analyze project performance by any parameter for every single task in schedule.

After the creation of Methodologies, Zones and finally assembled Creation template, then a new schedule is formed which will be created based on Creation template. Intelligent scheduling engine could be also used for creation of schedules optimized in a different way using Zones and Methodologies in different order, or grouping elements only by Zones through Creation Rule command.

These alternative workflows would give less optimized schedules and will require additional manual adjustments but are legitimate way for partial automation of traditional schedule creation process. Creation of schedule based on methodology is depicted in Figure 6.29.

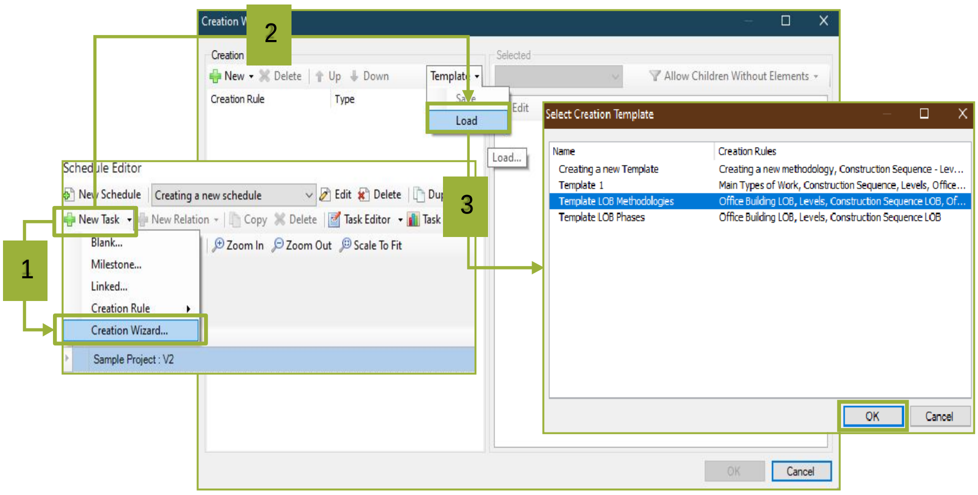


Figure 6.29 Creation of Schedule based on Methodology

The schedule was derived completely from the BIM model within a short span. The cost has been standardized as an excel template, the zone and methodology has been standardized as a Bexel template. So for similar projects builders can rely on these templates and within a few clicks these templates can be imported to their project and the schedule can be generated with ease and greater efficiency.

Scheduling is the most hectic and time-consuming task in project planning. It makes certain that everyone is aware of the tasks, dependencies, and deadlines. draws attention to problems and situations, such as a shortage of resources, finds links between tasks, monitors development and spots problems early. The main aim of standardizing the workflows specifically for clash, quantity take-off, properties, activities etc., is to derive the scheduling in no time and on real-time basis.

Since, the schedule has been derived from the BIM model, the total duration required for the construction of the entire villa project was calculated automatically from the model directly by recognizing the quantities in the model. Therefore, the so obtained schedule showed a drastic change over the manually prepared schedule.

The schedule was derived from the model (automatic/intelligent scheduling), which showed the required duration as per the quantities calculated by the software in days and also in work hours (wh). The schedule derived from the BIM model is depicted in Figure 6.30.

Name	Duration (Days)	Duration	Start Date	Finish Date
Mtech : V03	570 wd	4560 wh	09/28/2022 09h	07/23/2024 17h
A - Approvals	73 wd	584 wh	09/28/2022 09h	12/21/2022 17h
C - Piling	55 wd	440 wh	09/28/2022 09h	11/30/2022 17h
C.3 - Pile foundation	30 wd	240 wh	09/28/2022 09h	11/01/2022 17h
TOF	30 wd	240 wh	09/28/2022 09h	11/01/2022 17h
C.1 - Pile Cap	15 wd	120 wh	11/02/2022 09h	11/18/2022 17h
TOF	15 wd	120 wh	11/02/2022 09h	11/18/2022 17h
C.2 - Plinth Beam	10 wd	80 wh	11/19/2022 09h	11/30/2022 17h
TOF	10 wd	80 wh	11/19/2022 09h	11/30/2022 17h
D - PCC, RCC & Reinforcement work:	46 wd	361 wh	02/03/2023 09h	03/28/2023 10h
D.2.01 - Providing and laying PCC 1	15 wd	120 wh	02/03/2023 09h	02/20/2023 17h
TOF	15 wd	120 wh	02/03/2023 09h	02/20/2023 17h
D.1.02 - Sunshade	10 wd	80 wh	02/21/2023 09h	03/03/2023 17h
Ground Floor	10 wd	80 wh	02/21/2023 09h	03/03/2023 17h
D.1.03 - Column	15 wd	120 wh	02/21/2023 09h	03/09/2023 17h
Ground Floor	15 wd	120 wh	02/21/2023 09h	03/09/2023 17h
D.1.06 - Staircase	15 wd	120 wh	02/21/2023 09h	03/09/2023 17h
Ground Floor	15 wd	120 wh	02/21/2023 09h	03/09/2023 17h
D.1.01 - Lintel	20 wd	160 wh	02/21/2023 09h	03/15/2023 17h
Ground Floor	10 wd	80 wh	02/21/2023 09h	03/03/2023 17h
1st Floor	10 wd	80 wh	03/04/2023 09h	03/15/2023 17h
D.1.07 - Slab	25 wd	200 wh	02/21/2023 09h	03/21/2023 17h
Ground Floor	5 wd	40 wh	02/21/2023 09h	02/25/2023 17h
1st Floor	5 wd	40 wh	03/16/2023 09h	03/21/2023 17h
D.1.05 - Roof Slab	30 wd	240 wh	02/21/2023 09h	03/27/2023 17h
Ground Floor	5 wd	40 wh	02/21/2023 09h	02/25/2023 17h
1st Floor	12 wd	96 wh	02/27/2023 09h	03/11/2023 17h
Terrace level	5 wd	40 wh	03/22/2023 09h	03/27/2023 17h
D.1.04 - Beam	31 wd	241 wh	02/21/2023 09h	03/28/2023 10h
Ground Floor	20 wd	160 wh	02/21/2023 09h	03/15/2023 17h
1st Floor	10 wd	80 wh	03/16/2023 09h	03/27/2023 17h
Terrace level	1 wd	1 wh	03/28/2023 09h	03/28/2023 10h
E - Block work masonry	55 wd	440 wh	12/01/2022 09h	02/02/2023 17h
E.2 - 10 cm wall	33 wd	264 wh	12/01/2022 09h	01/07/2023 17h
1st Floor	5 wd	40 wh	12/01/2022 09h	12/06/2022 17h
Terrace level	3 wd	24 wh	01/05/2023 09h	01/07/2023 17h
E.1 - 20cm wall	55 wd	440 wh	12/01/2022 09h	02/02/2023 17h
Ground Floor	30 wd	240 wh	12/01/2022 09h	01/04/2023 17h
1st Floor	25 wd	200 wh	01/05/2023 09h	02/02/2023 17h
F - Plastering	61 wd	480 wh	03/28/2023 10h	06/06/2023 10h
F.1 - Plastering with C.M 1:5, 12mn	61 wd	480 wh	03/28/2023 10h	06/06/2023 10h
Ground Floor	21 wd	160 wh	03/28/2023 10h	04/20/2023 10h
1st Floor	21 wd	160 wh	04/20/2023 10h	05/13/2023 10h
Terrace level	21 wd	160 wh	05/13/2023 10h	06/06/2023 10h
F.3 - Plastering with C.M 1:4, 9mm	61 wd	480 wh	03/28/2023 10h	06/06/2023 10h
Ground Floor	21 wd	160 wh	03/28/2023 10h	04/20/2023 10h
1st Floor	21 wd	160 wh	04/20/2023 10h	05/13/2023 10h
Terrace level	21 wd	160 wh	05/13/2023 10h	06/06/2023 10h
F.4 - Protection Plastering with C.N	61 wd	480 wh	03/28/2023 10h	06/06/2023 10h
Ground Floor	21 wd	160 wh	03/28/2023 10h	04/20/2023 10h
1st Floor	21 wd	160 wh	04/20/2023 10h	05/13/2023 10h
Terrace level	21 wd	160 wh	05/13/2023 10h	06/06/2023 10h

G - Flooring Works	121 wd	960 wh	06/06/2023 10h	10/24/2023 10h
G.2 - GF Plinth area	16 wd	120 wh	06/06/2023 10h	06/23/2023 10h
Ground Floor	16 wd	120 wh	06/06/2023 10h	06/23/2023 10h
G.1 - Flooring	121 wd	960 wh	06/06/2023 10h	10/24/2023 10h
Ground Floor	61 wd	480 wh	06/06/2023 10h	08/15/2023 10h
1st Floor	61 wd	480 wh	08/15/2023 10h	10/24/2023 10h
H - Grill/ handrail/Counter works	60 wd	479 wh	05/15/2024 10h	07/23/2024 17h
H.1.01 - Handrail	60 wd	479 wh	05/15/2024 10h	07/23/2024 17h
1st Floor	60 wd	479 wh	05/15/2024 10h	07/23/2024 17h
H.2.01 - Handrail outer	60 wd	479 wh	05/15/2024 10h	07/23/2024 17h
1st Floor	60 wd	479 wh	05/15/2024 10h	07/23/2024 17h
I - Wood works	11 wd	80 wh	05/03/2024 10h	05/15/2024 10h
I.1.01 - MD	6 wd	40 wh	05/03/2024 10h	05/09/2024 10h
Ground Floor	6 wd	40 wh	05/03/2024 10h	05/09/2024 10h
I.1.02 - D1 (External)	11 wd	80 wh	05/03/2024 10h	05/15/2024 10h
Ground Floor	6 wd	40 wh	05/03/2024 10h	05/09/2024 10h
1st Floor	6 wd	40 wh	05/09/2024 10h	05/15/2024 10h
I.1.03 - D2 & D3	11 wd	80 wh	05/03/2024 10h	05/15/2024 10h
Ground Floor	6 wd	40 wh	05/03/2024 10h	05/09/2024 10h
1st Floor	6 wd	40 wh	05/09/2024 10h	05/15/2024 10h
I.1.04 - D2*-Toilet	11 wd	80 wh	05/03/2024 10h	05/15/2024 10h
Ground Floor	6 wd	40 wh	05/03/2024 10h	05/09/2024 10h
1st Floor	6 wd	40 wh	05/09/2024 10h	05/15/2024 10h
I.2.01 - W2	11 wd	80 wh	05/03/2024 10h	05/15/2024 10h
Ground Floor	6 wd	40 wh	05/03/2024 10h	05/09/2024 10h
1st Floor	6 wd	40 wh	05/09/2024 10h	05/15/2024 10h
I.2.02 - W3	11 wd	80 wh	05/03/2024 10h	05/15/2024 10h
Ground Floor	6 wd	40 wh	05/03/2024 10h	05/09/2024 10h
1st Floor	6 wd	40 wh	05/09/2024 10h	05/15/2024 10h
I.2.03 - W1	11 wd	80 wh	05/03/2024 10h	05/15/2024 10h
Ground Floor	6 wd	40 wh	05/03/2024 10h	05/09/2024 10h
1st Floor	6 wd	40 wh	05/09/2024 10h	05/15/2024 10h
I.2.04 - KW2	11 wd	80 wh	05/03/2024 10h	05/15/2024 10h
Ground Floor	6 wd	40 wh	05/03/2024 10h	05/09/2024 10h
1st Floor	6 wd	40 wh	05/09/2024 10h	05/15/2024 10h
I.2.05 - V	11 wd	80 wh	05/03/2024 10h	05/15/2024 10h
Ground Floor	6 wd	40 wh	05/03/2024 10h	05/09/2024 10h
1st Floor	6 wd	40 wh	05/09/2024 10h	05/15/2024 10h
J - Painting works	180 wd	1440 wh	09/28/2022 09h	04/25/2023 17h
K - Flooring	166 wd	1320 wh	10/24/2023 10h	05/03/2024 10h
K.1 - Trimix Flooring	121 wd	960 wh	10/24/2023 10h	03/12/2024 10h
1st Floor	121 wd	960 wh	10/24/2023 10h	03/12/2024 10h
K.2 - Water proofing works in toile	46 wd	360 wh	03/12/2024 10h	05/03/2024 10h
Terrace level	46 wd	360 wh	03/12/2024 10h	05/03/2024 10h
L - Finishes	131 wd	1048 wh	09/28/2022 09h	02/27/2023 17h

Figure 6.30 Schedule Derived from the BIM Model

After scheduling the entire villa project, the reports reflecting the total project cost has been derived using Power BI. The cost obtained as a result was found to coincide with that generated manually, cost-effectively and with less time. Figure 6.31 represents the report of the total project cost derived from Power BI, where the material cost and labour cost have also been detected. Also, it shows the costs met with each activity in the form of a pie-chart. The pie-chart manifests that the highest cost activity is met at the time of paving the PCC (Plain Cement Concrete) and RCC (Reinforced Cement Concrete) works.

Figure 6.31 Power BI Report of the Total Project Cost

6.2.8 Task Report

In Task Report, the user is able to see charts representing cost, material, labour and equipment distribution during project execution. Planner can easily identify anomalies in resource use and adjust schedule in order to optimize it. This could be also done for every task or parent task in schedule, therefore the user is able to analyze project performance by any parameter for every single task in schedule. As per the report, the highest cost was reflected in the month of May 2024.

The task report was generated for the villa project (Figure 6.32), and the costs for every month was identified. This enables the planner to control the excess flow of cash across the project by reducing the wastage of resources and plan accordingly.

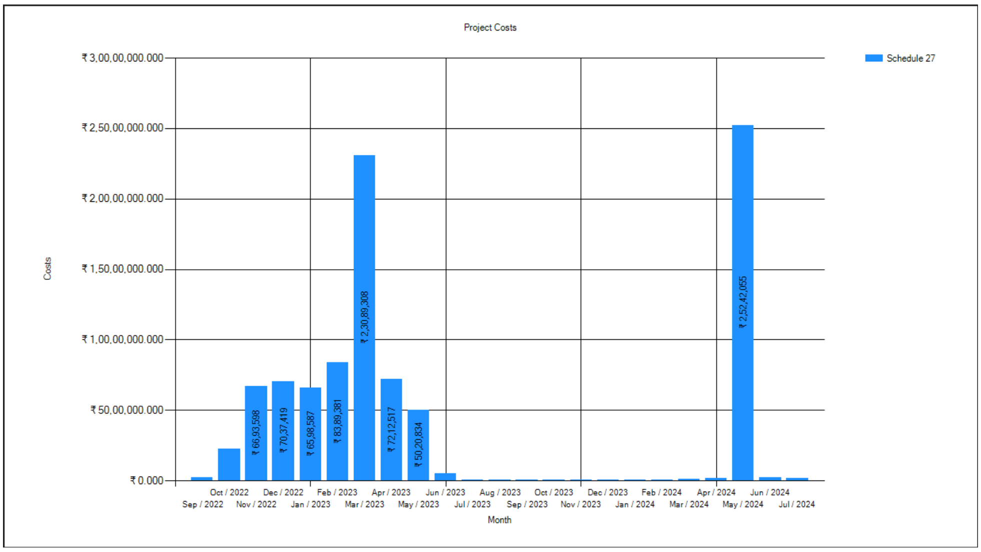


Figure 6.32 Task Report of the Project Cost

As a part of generating the task report, the cumulative cost curve was also obtained. The curve was obtained as an S-curve. Figure 6.33 represents the cumulative cost curve/ S-curve obtained for the project. An S-curve is a mathematical graph that represents the aggregate data for a project. This information can be the project cost or the number of person-hours against time. The curve is termed an S-curve because of the graph's S-shape. The different stages in an S-curve can be justified as: infancy stage, rapid growth stage, maturity stage and decline stage.

The S-curve obtained claims that the growth of the project in the beginning stages is slow, which is the infancy stage. The wheels are just beginning to turn; team members are either researching the industry or just starting to engage in the first phase of execution, which can be slow before working out the kinks. As more progress is made, the growth accelerates rapidly (rapid growth stage)—creating that upward slope that forms the middle part of the "S". This point of maximum growth is called the point of inflection. During this period, project team members are working heavily on the project, and many of the major costs are incurred. After the point of inflection, the growth begins to plateau, forming the upper part of the "S" known as the upper asymptote—and the "mature" phase of the project. This is because the project is mostly finished at this point and is winding down — typically the finishing works reflect this point. This curve can be used to measure progress, evaluate performance and make cash-flow forecasts. The curve reflects that the project cost is found to be maximum towards the end, where the works have to be completed overwhelming the scheduled cost in order to complete the project as per the schedule.

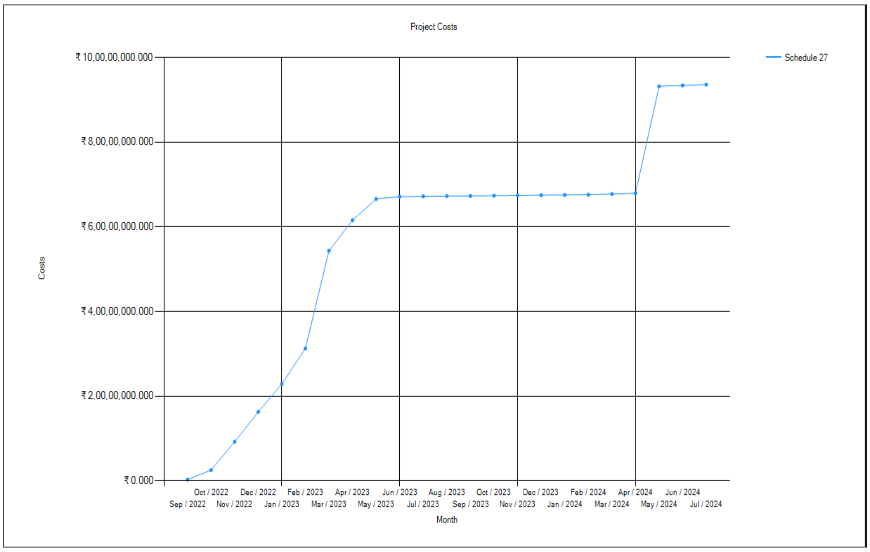


Figure 6.33 Cumulative Cost Curve (S-curve)

6.2.9 Expert Feedback Survey

The standardized templates were referred to ten experts in the industry with considerable experience in the field of civil engineering and their feedback was recorded. The team of experts included two project managers (PM), five project engineers (PE) and three supervisors (SUP) in percentages of 20, 50 and 30 respectively. The percentage of experts consulted and their average experience is plotted in Figure 6.34 and Figure 6.35. 60% of the respondents with 10 years experience, 30% with 5 years and the remaining 10% with 3 years experience took part in the survey. A questionnaire survey was conducted to study the significance of each performance indicators of using the integrated BIM approach over the traditional approach, was prepared and the responses of 10 experts were studied.

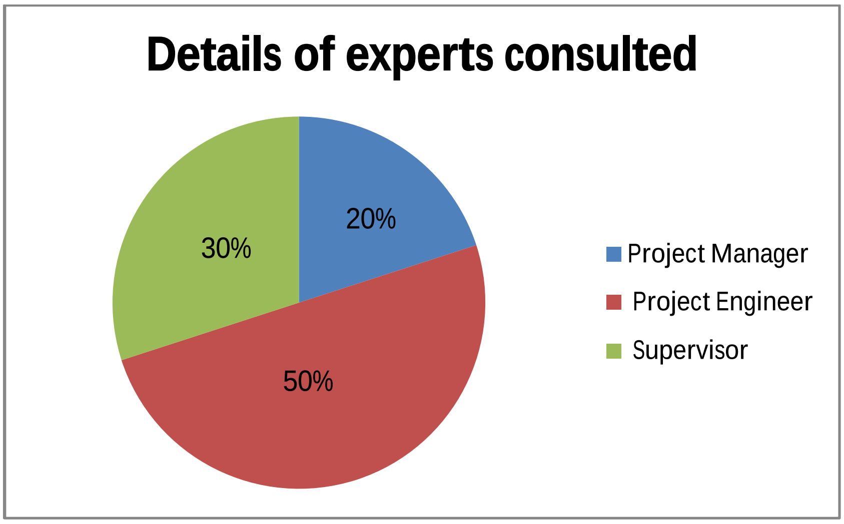


Figure 6.34 Percentage of Experts Participated in the Survey

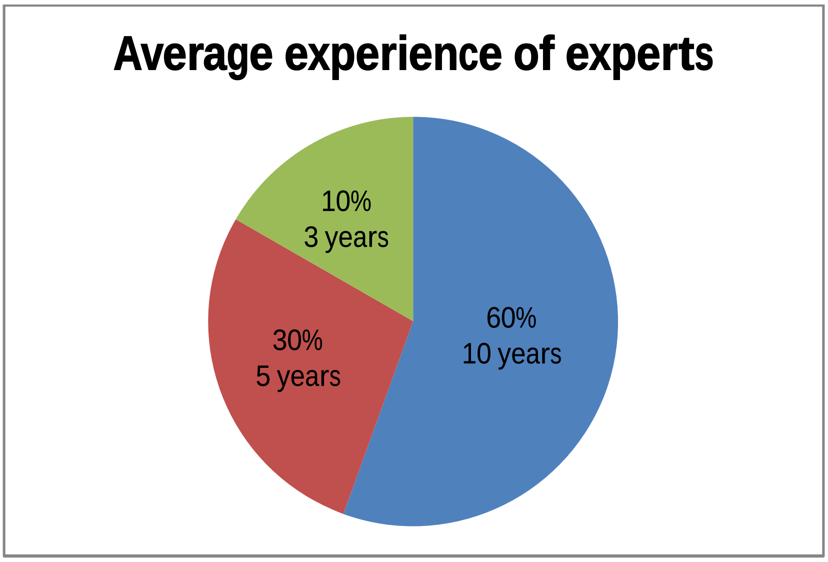


Figure 6.35 Average Experience of the Experts Participated in the Survey

The questionnaire is attached in Appendix B. Table 6.2 shows the key performance indicators specified in the questionnaire survey.

Table 6.2 Key Performance Indicators Portrayed in the Questionnaire Survey

Sl. No.	Performance indicators
a	Quantity take-off
b	Collaboration of multiple stakeholders throughout all steps of project lifecycle
c	Efficiency in detecting clashes from 3D model
d	Cost savings met with by eradicating clashes at the design stage
e	Resource savings
f	Transparency during design phase
g	Digital visualizing and planning site logistics ahead of time
h	Easiness in planning and scheduling project
i	Safety in construction
j	Seamless communication between various project teams

k	Control during the operation phase
l	Accuracy and precision in the project
m	Quality of the work
n	Potential time savings by extermination of rework
o	Client satisfaction
p	Ease in interpreting the standard templates

The significance/rating of the feedback from the experts in the industry was plotted (shown in Figure 6.36) and studied.

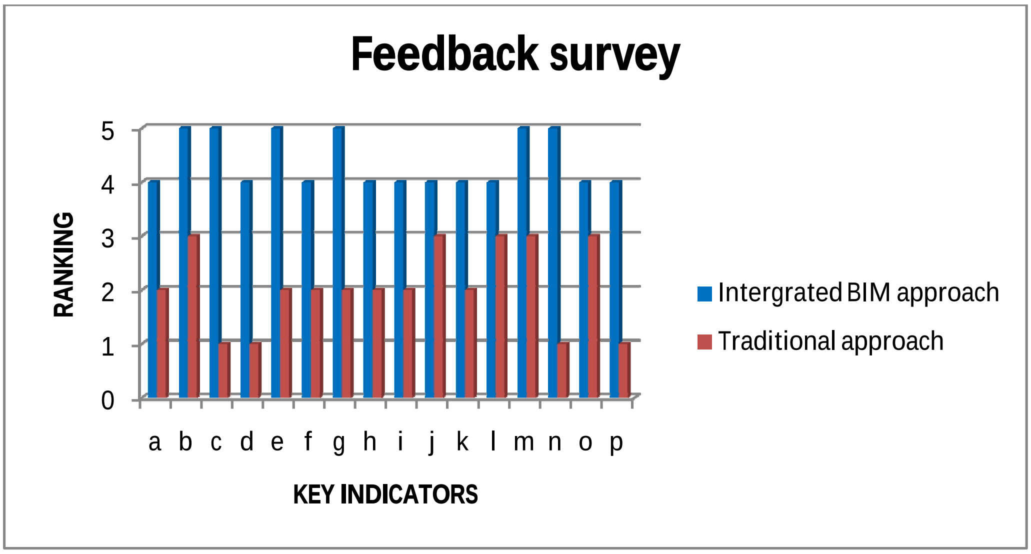


Figure 6.36 Feedback from Experts

The survey results showed that the rating was maximum for six indicators namely: Collaboration of multiple stakeholders throughout all steps of project lifecycle, Efficiency in detecting clashes from 3D model, Resource savings, Digital visualizing and planning site logistics ahead of time, Quality of the work and Potential time savings by extermination of rework. The survey result also uplifted that the officials in the industry with low level of experience, highly remarked the use of the standardized templates, claiming that their work on scheduling massive projects have become easier compared to the traditional scheduling methods. Similarly, respondents with high level of experience affirmed that the traditional method was found to be time-consuming compared to the recent technique.

The study showed that integrated BIM approach in project management, by making use of the standard templates for scheduling similar massive projects, showed potential difference in cost, quality and time, compared to the traditional approach of project management.

CHAPTER 7

CONCLUSIONS

7.1 GENERAL

Construction projects in India, especially Kerala, are notorious for the time and cost over runs. While modern tools are developed for overcoming these handicaps, they are rarely applied in construction industry. This study is an attempt to understand the potential of BIM and apply it to a construction project, bringing out the benefits of its application. Since the study was done on a villa project, in which only one villa was completed and 28 were yet to be taken up, there is ample scope for comparing and contrasting the traditional technique with the one in which BIM is incorporated and also for refining the latter.

The main aim of the project was generating a model-based schedule by standardization of workflows, with a villa project. The template can be of use in similar projects, and with appropriate modifications, in projects of other genres. Also, lean management has been incorporated by developing a complete clash free model. These modern tools define the industrial relevance of the project.

The project, initially meant to be executed with traditional tools, shows an obvious saving in time and cost in the planning stage itself when BIM is used. As per the 4D/5D model re-developed, the whole project cost reduced to Rs.12,35,98,364.05. Therefore, the savings in cost amounted to a total of Rs.42,76,396.75. Also, the number of days saved was about 639 days.

The authenticity of the study depended on getting as much field data for the study. Hence the initial input to the study was through collection of data regarding productivity through a questionnaire survey. The survey was done on thirty site engineers who are used to take up large projects as such and the responses have been recorded. The responses accounted to the output of their crew (no. of skilled workers and no. of helpers). The output was measured on the basis of their output per day (8 man hours). Using the output quantity, the productivity (productivity standards) of the crew size was determined. This data was used as an input to develop the 4D/5D model of the villa. The 3D model of the villa was developed using Autodesk Revit. The model was then detected for any clash. A total of 17 hard clashes were detected and removed by analyzing the model via BCF Manager and the 3D model was redesigned and the difference in cost was computed. The discipline of the clashes was studied precisely and based on assumptions the types of clashes were standardized into a template.

The properties required for a perfect BIM model as per LOD 300 has been standardized in the form of a template. This template was imported to the villa project and was made to run and the property check was carried out, which showed few failures in the prepared model. The model was then rectified and was made to link to all the required properties necessary to form a perfect BIM model as per LOD 300 in the BIM Forum. The quantity take-off template was then standardized so that the structure can be used in similar projects to carry out quantity take-off easily. The classification and the cost items required for the villa project was developed and it was then standardized so that it could be used in deriving the activities and the costs for similar projects. Also, the resources required for a villa project has been standardized. These can be studied closely and referred to any builder to carry out quantification with ease.

Then, the methodology required for the project has been developed in two levels in the form of a template, with cost item as the second level. This methodology template can be incorporated in developing methodologies for projects of similar genre. Using these workflow templates, the schedule of the entire villa project has been developed. With the use of these templates the schedule required for such a massive project was developed within a few seconds. Since the schedule was developed from the model (intelligent scheduling), the duration was even broken down and the original duration required for the construction was calculated.

A task report for the schedule was then generated and the project cost at each month has been accounted and studied and the cumulative cost curve was obtained as an S-curve, so that the progress of the project was obtained and compared. Construction costs were modified automatically in real-time with the alterations made in the model. And finally, a feedback survey on examination of the efficiency of the developed templates has been conducted from 10 industry experts comprising of two project managers, five project engineers, three supervisors and the result was plotted. The responses reflected that the integrated BIM approach was found to be significant and more useful in project management over traditional approach in terms of cost and time-savings. BIM is emerging as an innovative way to virtually design and manage projects. The report illustrates how BIM may improve decision-making and work processes by integrating construction information across trades and communicating it more effectively. In the initial times, BIM was considered as an important tool for updating the information flow throughout a project only, but in the recent times, BIM continues to improve the efficiency of its tools, present procedures enable a BIM-enabled user to carry out duties rather effectively. More precisely, the implementation of the model to help planning and scheduling of the operation in India was the focus of the study. BIM helps us save time and money across the whole lifecycle of a structure, not only during its design and construction but also in its facility management.

On the other side, BIM is a digital process that requires an investment in software and computer resources. Instead of expecting large cost savings and advantages on the initial project, it needs to be viewed as a long-term investment for the company, with returns increasing over time. To use BIM, devoting time and money to training is essential. As with learning anything new, the initial stages may take longer because employees first go through training before learning essentially on the job. As change gets embedded in the routines of the company, there needs to be an attitude and a resolve that this will get easier over time.

BIM as its core, is not just software but a human activity that ultimately involves broad process changes with demanding benefits, predominantly: model based cost estimation, visualization of project even in the preconstruction phase, better on-site collaboration and communication, better coordination and clash detection, risk mitigation and reduction of cost, improved scheduling/sequencing, increased productivity with prefabrication, better safety on construction sites and streamlined facility management and strengthen building handover.

7.2 SCOPE FOR FUTURE WORK

This project was initiated in order to plan, carry out, and manage significant massive projects that fall under the same category as this villa project. The structure analyzed and studied in this work was constrained to just two-storeys, without accommodating/considering any further storeys. Further projects can be done by considering more storeys to the structure. Also, the dimensions considered was limited to 5D. The future work can be indulged upon developing facility management (6D) and operation of the structure with the hope that it will lead to a better commercial result. According to the 6D method, a model made by a designer is updated or changed as the building is being built. Ultimately, apart from considering the construction work being carried out in parallel, the whole project comprising of the 29 villas could be divided into clusters of four/five/six, so that the best schedule possible in order to carry out the construction more efficiently, can be developed and compared. Thereby, the most eminent schedule can be accomplished.

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APPENDICES

APPENDIX A

QUESTIONNAIRE ON LABOUR PRODUCTIVITY FOR A VILLA PROJECT

INTRODUCTION

This questionnaire is aimed to obtain the labour productivity for a villa project.

As an expert professional with rich experience in construction industry, we would be grateful if you would help us by filling the questionnaire. Please respond to each question accurately.

We assure you that the responses will be kept confidential and the data will be used only for academic/research purposes.

For any queries/suggestions concerning the survey, please contact: **Jasmin Jabbar, PG Scholar, Dept. of Civil Engineering, TKM College of Engineering, Kollam.**

Builder Details
Name**:**
Designation & experience**:**
Company name (optional) **:**
Company's turnover**:**
Staff size**:**
Year of establishment**:**

Condition: This survey can either be conducted in person or via phone.

Sl no.	**Activity**	**Crew size (No.)**	**Crew composition**		**Output quantity per day**	**Unit**	**Include major equipments if any**	**Remarks**
			No. of skilled workers	**No. of helpers**				
1	Site clearence							
2	Setting out							
3	Excavation							
4	Footing for pillars							
5	Foundation work							
6	Setting up main door frame and other room door frames							
7	Brick masonry until window frame base							

8	Setting up window frames							
9	Shuttering and rebar placement for lintel beam							
10	Concreting lintel beam							
11	Brick masonry until beams if needed							
12	Setting up kitchen ventilators for exhaust fans or bathroom ventilators							
13	Formwork for roof slab							
14	Bar bending work for beams and roof							
15	Electric pipes setup inside roof							
16	Concreting of slab							
17	Curing on roof top							
18	Laying electric conduits in the walls and setting up electric boxes							
19	Plumbing work for kitchen and bathroom							
20	Setup kitchen platform and sink							
21	Tiles laying in bathroom and kitchen for walls							
22	Plastering							
23	Water-proofing for wall							
24	Fixing window and door shutters							
25	Flooring							
26	Sanitary fittings							
27	Painting							
28	Electric work							
29	External paint coating							
30	Laying electric service wire from pole to meter board							

31	Fixing meters in panel board							
32	Digging pit for power earth							
33	Motor & connection to tank							
34	Laying sewage lines to pit							
35	Compound wall construction							
36	Construction of parapet wall							
37	Fixing false ceiling works							

Thank You for your valuable time

APPENDIX B

QUESTIONNAIRE SURVEY FOR OBTAINING THE FEEDBACK OF INDUSTRY EXPERTS ON EFFICIENCY OF TOOL

INTRODUCTION

This questionnaire is aimed to obtain your valuable feedback of using integrated BIM technology using the standard workflow templates over traditional project management tools. As an expert professional with rich experience in construction industry, we would be grateful if you would help us filling the questionnaire by rating your experience using the Integrated BIM templates on the basis of the key performanc indicators specified. Please respond to each question accurately. (*1- no significance, 2- slightly significant, 3- moderately significant, 4- very significant, 5- extremely significant*). **We assure you that the responses will be kept confidential and the data will be used only for academic/research purposes.** For any queries/suggestions concerning the survey, please contact: **Jasmin Jabbar, PG Scholar, Dept. of Civil Engineering, TKM College of Engineering, Kollam.**

GENERAL INFORMATION

Respondent name :

Designation :

Experience :

Sl No.	Performance indicators	Significance of performance indicators				
1	Quantity take-off	1	2	3	4	5
2	Collaboration of multiple stakeholders throughout all steps of project lifecycle	1	2	3	4	5
3	Efficiency in detecting clashes from 3D model	1	2	3	4	5
4	Cost savings met with by eradicating clashes at the design stage	1	2	3	4	5
5	Resource savings	1	2	3	4	5
6	Transparency during design phase	1	2	3	4	5

7	Digital visualizing and planning site logistics ahead of time	1	2	3	4	5
8	Easiness in planning and scheduling project	1	2	3	4	5
9	Safety in construction	1	2	3	4	5
10	Seamless communication between various project teams	1	2	3	4	5
11	Control during the operation phase	1	2	3	4	5
12	Accuracy and precision in the project	1	2	3	4	5
13	Quality of the work	1	2	3	4	5
14	Potential time savings by extermination of rework	1	2	3	4	5
15	Client satisfaction	1	2	3	4	5
16	Ease in interpreting the standard templates	1	2	3	4	5

Thank you for your valuable time.

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