



A Study on 5D BIM Implementation for Construction Cost and Quantity Management in the AEC Industry

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Abstract

The current methods of cost estimating and monitoring of Projects are becoming inoperative as forthcoming construction endeavors are increasing in scale and complexity. The 5D BIM (Building Information Modeling) can integrate cost data with 3D models and time scheduling, it is enabled engineers to predict project expenses more accurately through real-time quantity take-offs and dynamic cost estimation. The AEC (Architecture, Engineering, Construction) professionals and researchers successfully execute their plans in the construction industry. The 5D BIM tools were developed through the medium of information technology. It can be implemented from the very beginning of construction; it can be implemented from land acquisition to operational to the final stage of demolition. This paper presents a practical methodology for quantification of construction materials and cost estimation through the implementation of 5D BIM, into the four levels, foundations and framing, focuses on wall systems, addresses architectural finishing elements, and the MEP system. All levels are demonstrating its effectiveness in quantification and cost estimation through a detailed case study of a multi-storey office building modeled in Autodesk Revit 2019.

Subject Areas

Civil and Architecture Engineering

Keywords

5D BIM, Project Management, Quantification, Cost Estimation and Scheduling, Multi-Storey Building

1. Introduction

Currently, the construction industry contributes a significant portion of the GDP of many countries. Like other sectors, a construction project's success is often measured by maximizing return on investment. The success of a project is primarily influenced by two key factors: the time taken and the cost involved. Consequently, it is essential to ensure that cost estimation is both accurate and optimal to achieve successful project execution and maximize profit from the investment, all while maintaining construction quality. Therefore, the core elements of a successful project are time, cost and quality.

Traditional methods currently used in construction are often manual and time-consuming. Moreover, miscommunication among stakeholders frequently leads to secondary or even tertiary issues during the course of a project [1]. Approximately 33% of the building materials delivered on-site are wasted during a project [2]. Therefore, traditional 2-Dimensional modeling used in modern projects is not an accurate approach and often results in wasted time, errors, and financial losses. To address this issue, Building Information Modelling (BIM) is introduced. BIM offers tools that enhance the accuracy and efficiency of estimating both the cost and duration of a project.

Firstly, BIM employs a three-dimensional representation of the construction project, providing a realistic and comprehensive understanding of the project to all parties involved in its completion [3]. BIM is a process that generates a model comprising both graphical and non-graphical information. This approach enables multiple stakeholders and AEC (Architecture, Engineering, and Construction) professionals to work collaboratively on the planning, design, and construction phases of a building within a single 3D model [4]. M. Suraj *et al.* (2020) demonstrates the 5D BIM integrates time and cost data with 3D models to enhance project planning, estimation, and management in construction. It highlights the benefits, challenges, and potential of BIM to improve efficiency and accuracy throughout the project lifecycle [5]. P. Pishdad *et al.* (2024) explored the potential of 5D BIM to enhance cost estimation, control, and payments throughout construction projects, emphasizing the need for standardization and integration of modern technologies at analysis of 5D BIM for cost estimation, cost control and payments. It identifies challenges such as lack of automation, inconsistent data standards, and limited real-time monitoring capabilities. Incorporating AI, smart contracts, and advanced visualization tools can streamline processes, automate workflows, and improve overall project efficiency and transparency [6]. Peter Smith *et al.* (2026) examine the challenges and con-

straints faced by project cost management professionals in utilizing the rapidly developing Building Information Modeling (BIM) software, technologies, and tools, particularly in project cost management with 5D BIM [7]. T. Moses *et al.* (2020) report on primary research finding that sought to investigate and analyses salient issues on the implementation of 5D building information modelling (BIM) from the UK contractors' perspective to development of a 5D BIM cost protocol with a possible impact to the UK construction industry practice and further industry evaluation of the costing framework (5D-CF) [8]. A. N. Hasan *et al.* (2018) investigate the benefits of and challenges to implement 5D BIM in construction industry in Iraq [2]. The case of Armenia by Ghazaryan *et al.* (2019) highlights the need for standardized BIM technology implementation from the design phase. This standardization involves developing reference books and databases for joint use by designers, architects, engineers, and cost estimators [9]. Consequently, based on a review of recent research and analysis of a completed case study, it is evident that 5D Building Information Modeling (BIM) offers substantial benefits for cost estimation in construction projects. By integrating cost data directly with the 3D model, 5D BIM enables more accurate and dynamic cost forecasting throughout the project lifecycle. This integration enhances transparency, reduces manual errors, and allows real-time updates as design or scope changes occur. The reviewed case study further demonstrated how 5D BIM facilitates the early identification of budget risks and supports more informed decision-making. These findings underscore the potential of 5D BIM to transform traditional cost estimation practices, especially when combined with standardized data protocols and collaborative workflows.

This study focuses on exploring the potential benefits and challenges of implementing 5D BIM in the Bangladeshi construction industry, particularly in the areas of material quantification and cost management, by adopting a dual methodology to achieve these objectives: 1) A technical case study that demonstrates the application of 5D BIM across four construction levels, structural components, wall systems, architectural finishes, and MEP phase. 2) a stakeholder-focused investigation that examines the barriers and perceived advantages of BIM adoption. By integrate practical modeling with a stakeholder-informed evaluation, this research aims to illustrate the functional capabilities of 5D BIM while contextualizing its applicability within the construction markets of developing countries. It also provides valuable insights to guide policymakers and industry practitioners in advancing BIM implementation in Bangladesh.

2. Research Methodology and Model Development

The research methodology designed to integrate Autodesk Revit for the implementation of 5D BIM in construction management, with a specific emphasis on project scheduling and cost estimation. The initial phase involved collecting 2D documentation, including structural and architectural drawings of the multi-storey building. Access to accurate and detailed plans at various stages of the con-

struction process was essential to ensure the reliability of the BIM outputs [10]. To evaluate the current level of BIM adoption in Bangladesh, a structured questionnaire was developed. This study aimed to assess the degree of 5D BIM implementation, identify the perceived benefits among construction professionals, and investigate the challenges hindering its wider adoption in the Bangladeshi construction sector [11].

Cost estimation was carried out using Autodesk Revit, which proved to be highly effective in producing accurate project results [12]. The overall BIM model was developed to offer multiple functionalities, supporting detailed project planning and efficient resource management. The success of this approach heavily depended on accurate scheduling and the integration capabilities of Revit, enabling a comprehensive understanding of project cost analysis [13].

Figure 1 highlights the key components used for comparative cost analysis between BIM-based and manual estimation methods. This comparison focused on evaluating each approach in terms of cost accuracy, management efficiency, and its impact on overall project performance [14] [15].

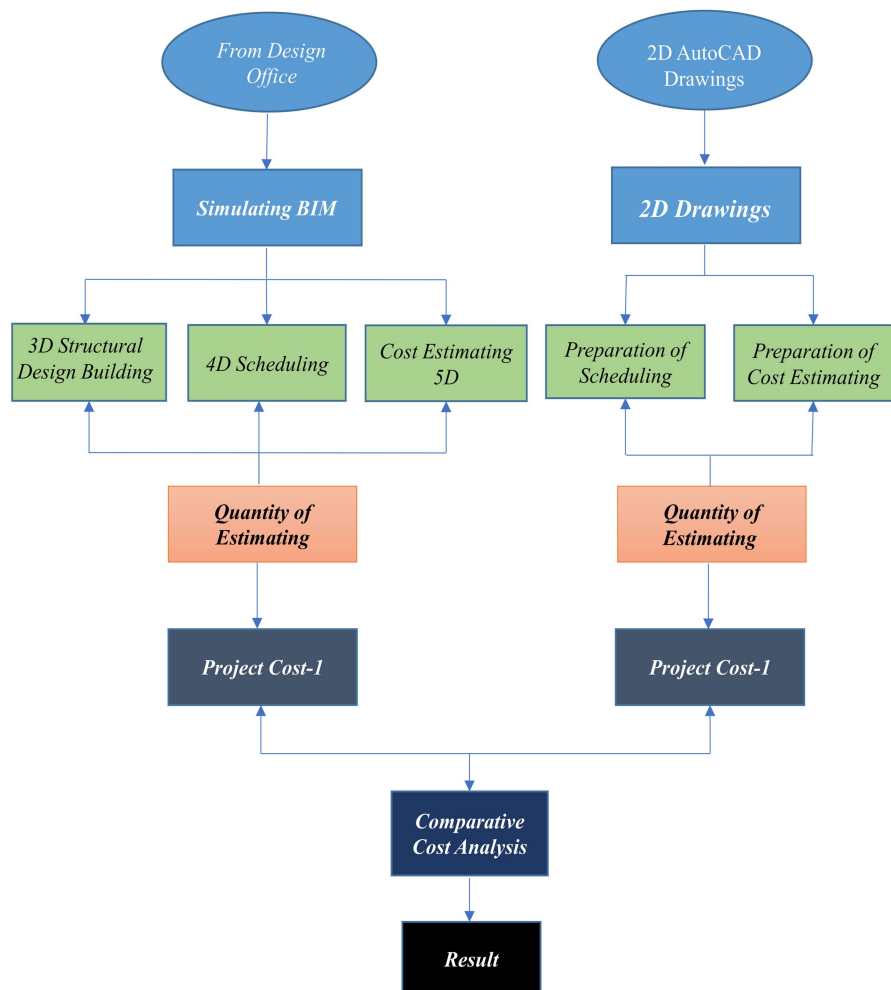


Figure 1. Comparative cost analysis with BIM and manual estimation.

2.1. Model Development for 5D BIM-Element Implementation

This is an experimental investigation employing an action research methodology, lacking rigorous data collecting, yet yielding outputs such as model drawings, schedules, and timelines for analysis [16]. The outcomes of this paper will subsequently be evaluated by industry professionals and it can serve as a valuable reference for future studies and early-stage research in the field. The research methodology explores the simulating and analyze the entire 5D BIM model, concentrating on modeling effort, interoperability between human and automation, information output, and limitations using a practical approach divided into four steps, as seen in (Figure 2). Observations are recorded to assess the feasibility of 5D BIM.

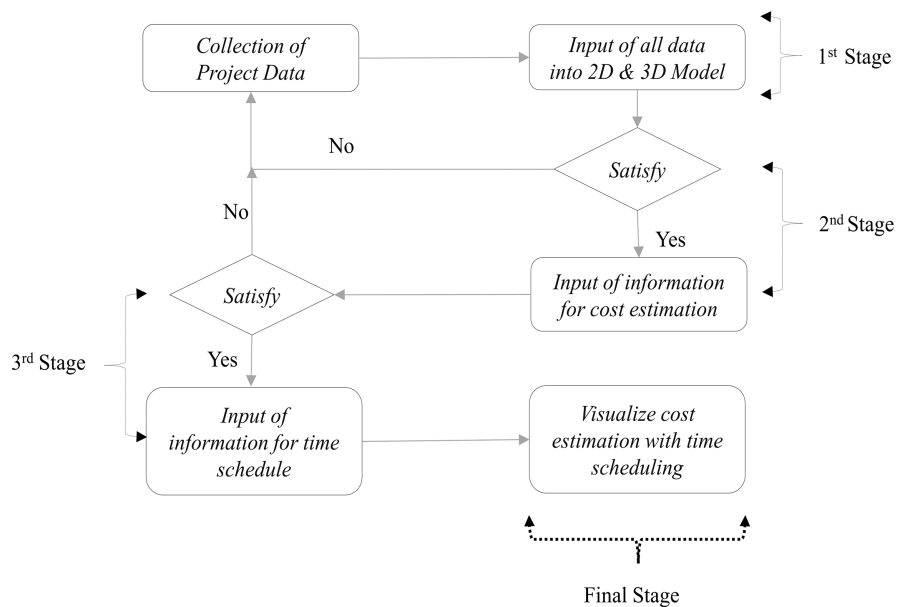


Figure 2. The 5D BIM working flowchart.

The initial phase entails the categorization and integration of building information into 2D and 3D models [16]. This method commences with clients outlining their requirements, resulting in an initial proposal. The architectural application is developed, followed by the creation of a 3D model that integrates various disciplines, including civil and structural engineering, mechanical and electrical engineering, and interior design. The 3D model has information that delineates each component precisely [17].

Once clients are happy with the initial design that complies with the specifications, quantity surveyors or rate engineers will start the second process, which involves entering the cost estimating data into the 3D model [18]. At this stage, 4D BIM is very useful to assist clients in refining their priorities from the perspective of cost estimation, as the price estimation is done by automating quantification of building features with unit price [17].

The third stage will continue if the clients are satisfied with the concluding 4D

BIM. At this point, project managers will make a Work Breakdown Structure (WBS) for all types of construction activities [19]. Once the integration with BIM is complete, it can cater to a huge quantity of information, with the Work Breakdown Structure (WBS) containing more levels compared to a conventional system. Some factors, such as construction method, human resources, material procurement, and supply, will affect the project time scheduling. In the final stage, all the compulsory information is integrated as 5D BIM [20] [21]. In the ultimate stage, Virtual Design and Construction (VDC) will be implemented to current 5D BIM project components to visualize project cost and time scheduling [12] [22].

Recruitment and Input of Building Information of Model

1) Input 2D CAD information for the BIM design

The practicability of BIM will be precious by competency in integrating pre-BIM information such as 2D CAD information. Even if BIM has gained fame over the years, there are stakeholders who are still comparatively new to this new approach [23]. The initial 2D drawings must be examined to identify the primary grid lines and boundary lines. As illustrated in (Figure 3), the grid lines of a bungalow unit are essential for accurately positioning structural elements such as columns, slabs, beams, and walls.

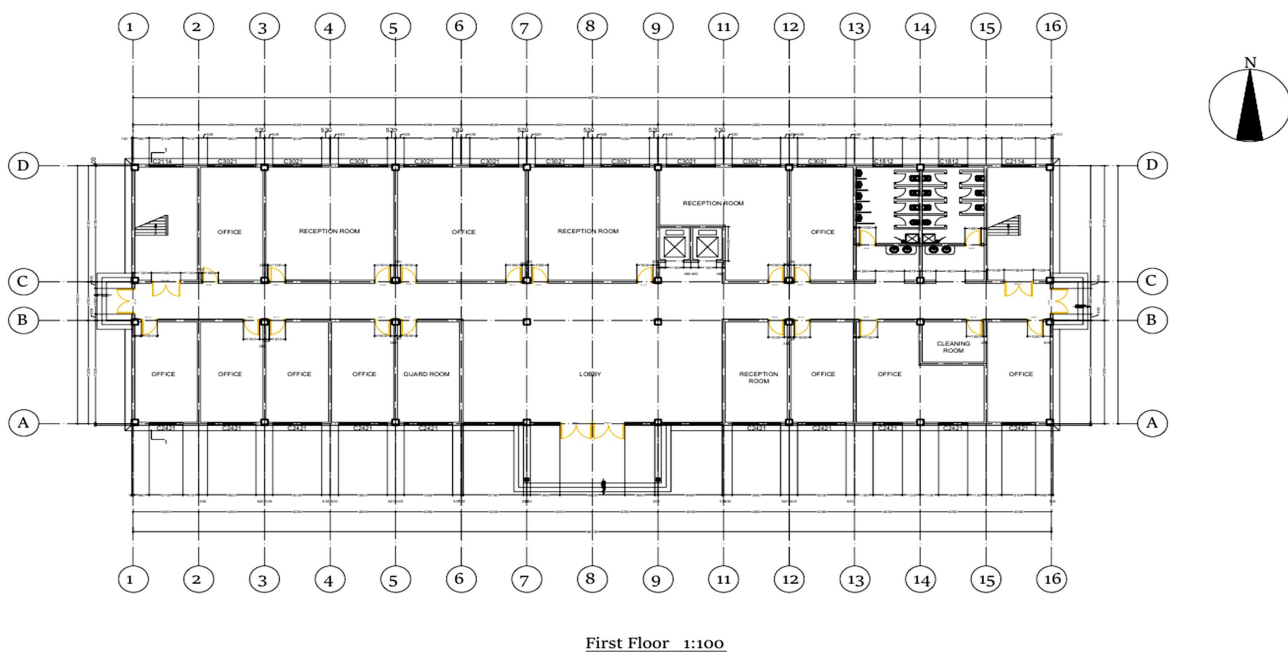


Figure 3. Floor plan for revit 2019 conceptual drawing.

2) Conversion of 2D drawings into 3D structural BIM model

The present study deals with converting of 2D drawings into 3D modeling replication using REVIT Architecture 2019 for construction of structural building information model. This helps us to imagine the inside structure and make changes before starting construction. Figure 4 indicates Modeling of Building in Revit Architecture Software.

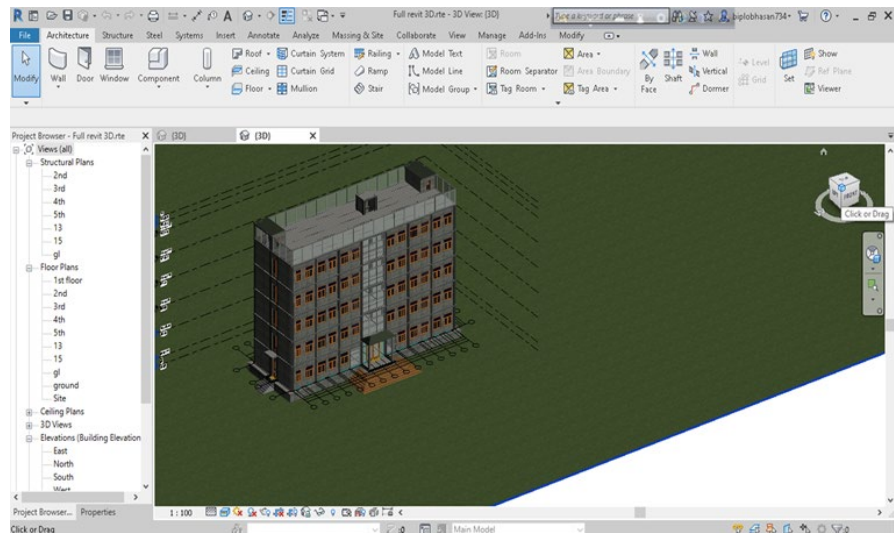


Figure 4. Input 2D information implementing to 3D Model by REVIT.

3) Integration of the 3D model into the 5D BIM framework for cost estimation

The 3D model serves as the foundational input for developing a 5D BIM framework, enabling accurate and dynamic cost estimation. By linking geometric and spatial data from the 3D model with cost-related information, the 5D model provides a comprehensive platform for visualizing, analyzing, and managing construction costs throughout the project lifecycle [24].

The cost estimation is completed by approaching stakeholders involved in estimation areas by using REVIT Software [25]. The process of estimation is effortless and can be controlled easily if the estimation is done by absolutely suited to some costing workflows. In the procedure of cost estimation, estimating the quantities take off stakes a lot of time just about 50% - 80% of the time required for cost estimation [21] [26].

Sattineni and Bradford (2011) agree that Building Information Modeling (BIM) is one of the best automatic approaches to directly generate an accurate quantity take off from 3D product models. Cost estimation will need automated information extraction of different properties such as “Family and Type” and “Volume” of the components [13] [14] [22]. After the extraction of component properties, amount surveyors or cost engineers will input the components’ information of per unit “Cost”. This information is then connected through formula or percentage computation (as shown in **Figure 5**) with “Family and Type” and “Volume” of the components. **Figure 6** shows an example of the complete plan of properties with cost estimation.

3. Implementation of BIM Model for Cost Analysis and Monitoring

3.1. The Role of BIM in Modern Construction Projects

The Building Information Modeling (BIM) process to manage the cost aspects of

a construction projects and it can evaluate its advantages over conventional methods. The process begins with the procurement of 2D AutoCAD drawings, including floor plans and elevation sections of the building. Structural reinforcement details are provided through structural consultant, while the necessary architectural and structural data for 3D modeling are sourced from the respective design teams.

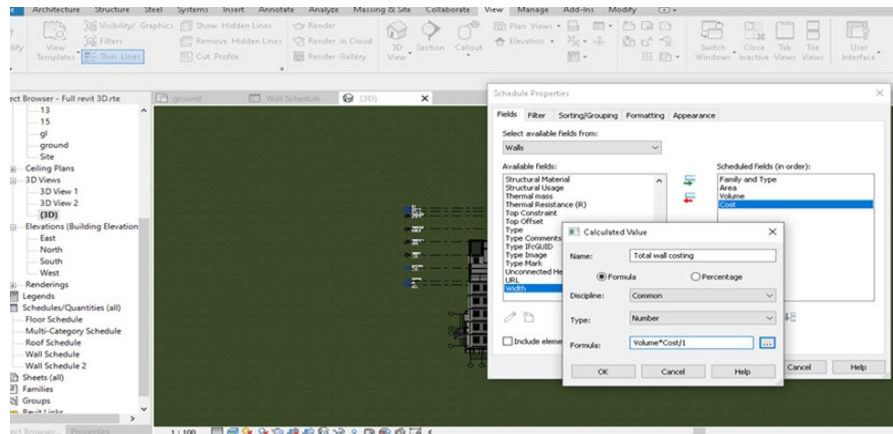


Figure 5. Application of a calculated value formula in Revit to estimate cost, based on the product of volume and unit.

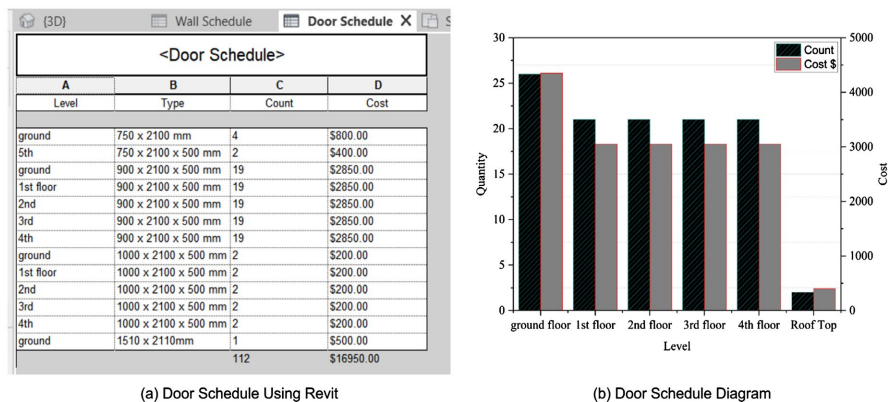


Figure 6. Door schedule cost tracking.

Using BIM software, a three-dimensional (3D) model of the office building is developed. This model is integrated with quantification and scheduling data to create a comprehensive five-dimensional (5D) BIM model for investigate the cost of each floor materials. The 5D BIM driven is analyzed to demonstrate how this model work for advanced project delivery method can enhance efficiency in both time and cost management. **Figure 7(a)** shows the first step in the design process: creating the structural components, i.e., beams, columns, slabs, and stairs. **Figure 7(b)** shows the second step: making walls according to the thickness mentioned in the AutoCAD drawings. Now, add doors and windows to the walls. These three steps helped create a 3D model. The 3D model generated conceptual design, working drawings, and material requirements.

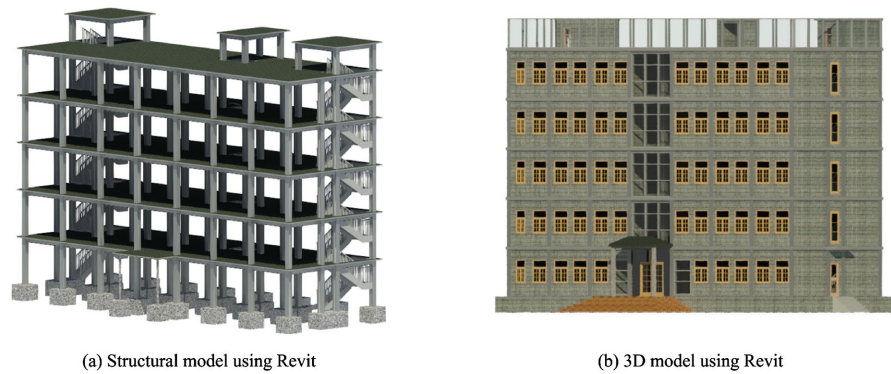


Figure 7. Flowing 3D BIM process—structure and architectural model.

3.2. Project Phase-Wise Assessment of 5D BIM Cost Management

The assessment of 5D BIM study process into four hierarchical levels, each corresponding to a major building system. At (Level 1), forming the cost baseline of the project structural components as foundations, columns, beams, and slabs are modeled and quantified. (Level 2) focuses on wall systems, where quantifications based on area and thickness. The architectural finishing elements, including floor and windows, doors address by (Level 3). Finally, (Level 4) focuses on mechanical, electrical, and plumbing (MEP) elements, including ductwork, piping, lighting fixtures, and HVAC systems. This structured breakdown enables detailed and level of specific quantity and cost tracking for stakeholders, it is offering significant advantages over conventional lump-sum estimation methods.

3.2.1. Structural Component Analysis: Foundations Using BIM

Table 1 presented the Revit superstructure element measurements for L1 estimates are calculated within the tool and explore the calculation equation methods. It is investigating the integration of Building Information Modeling (BIM) for structural component analysis, focusing on foundation, Beam, column and slabs estimation through different way. This approach demonstrates the early-stage quantification system and enhances precision in 5D BIM workflows for structural engineering, where it can track the material take-off with indicate measured geometry is shown in different colors.

3.2.2. Quantitative Wall Schedule Generation and Analysis Through BIM Scheduling

Level 2 focuses on detailed quantification of wall construction costs through Building Information Modeling (BIM), this method enables dynamic cost estimation as design details presented. **Figure 8** shows that it can be specifying every wall types as like 140 mm masonry, 200 mm masonry wall, and premium curtain wall systems separately.

3.2.3. Analysis of Architectural and Finishing Elements Using BIM

Figure 9 illustrates the architectural elevations of the case study building, it highlighting the placement and distribution of windows and doors. The left side of the figure indicate the configuration of windows across all floors, and the right side of

the figure focuses on the positioning of doors in the whole model, including main entry doors, floor access doors, and stairwell entrances. These two pictures enable the extraction of data specific to components and the generation of schedules within Revit. It emphasizes how crucial exactness and consistency are for correct quantitative materials and costing.

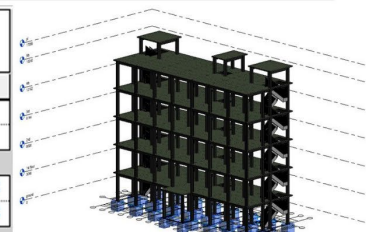
Table 1. Illustrating how the Revit superstructure element measurements for Level 1.

1 Foundation

$L \times W \times D$ (m³)

Foundation geometric measurements for footing schedules are extracted directly from the 3D model.

<Schedule of Foundation>								
A	B	C	D	E	F	G	H	I
Footing Mark	Size of Footing			Volume	Bottom Reinforcement		Top Reinforcement	
	L	W	D		A	B	A	B
F1	1200	1200	1000	46.08 m ³	T16-100 C/C	T16-100 C/	T16-100 C/C	T16-100 C/C
F2	1000	1000	1000	2.00 m ³	T16-150 C/C	T16-150 C/	T16-150 C/C	T16-150 C/C

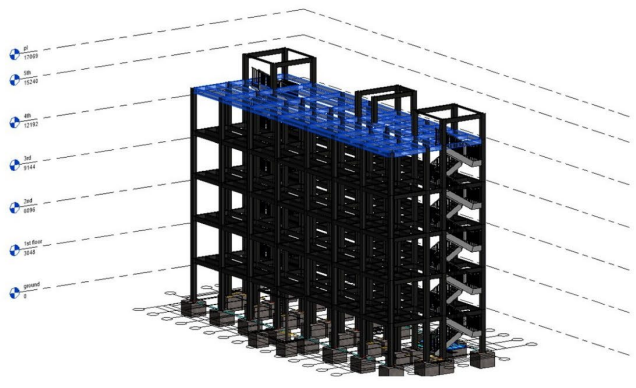


2 Beam

$W \times \text{Length} / 1000$ mm
(Tonnage)

The beam quantities are calculated by multiplying the cross-sectional width (W) by the length, then converting the result to tonnage for material estimation. This method, standardized in millimeters ($W \times \text{Length} / 1000$), ensures seamless integration with BIM-derived data, enabling automated weight and cost analysis.

<Beam Schedule>				
A	B	C	D	E
Family	Type	Length	W	Tonnage
UB-Universal Beam	305x165x40UB	6523	0.1488	0.161759
UB-Universal Beam	305x165x40UB	1546	0.0248	0.038342
UB-Universal Beam	305x165x40UB	1592	0.0248	0.039484
UB-Universal Beam	100x100	3281	0.0496	0.081359
UB-Universal Beam	305x165x40UB	1960	0.0248	0.048608
UB-Universal Beam	305x165x40UB	34817	0.2976	0.863454
UB-Universal Beam	305x165x40UB	114794	0.868	2.846896
UB-Universal Beam	100x100	37466	0.2728	0.929152
UB-Universal Beam	305x165x40UB	43560	0.1488	1.080288
UB-Universal Beam	305x165x40UB	45120	0.1488	1.118976
UB-Universal Beam	305x165x40UB	272479	0.8928	6.757468
UB-Universal Beam	305x165x40UB	7600	0.0248	0.18848
UB-Universal Beam	305x165x40UB	51090	0.1488	1.267025
UB-Universal Beam	305x165x40UB	61308	0.1488	1.52043
UB-Universal Beam	305x165x40UB	112397	0.1488	2.787456
UB-Universal Beam	305x165x40UB	142200	0.1488	3.52656
UB-Universal Beam	305x165x40UB	285709	0.2976	7.085595
UB-Universal Beam	305x165x40UB	143051	0.1488	3.547671
UB-Universal Beam	305x165x40UB	286112	0.2976	7.09557
Grand total:	172	1652604	4.2656	40.984574

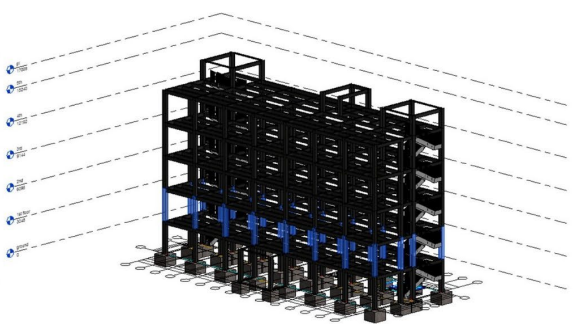


3 Column

$W \times \text{Length} / 1000$ mm
(Tonnage)

The column quantities are derived by calculating the cross-sectional area ($W \times \text{Length}$) and converting the volume to tonnage for material estimation.

<Structural Column Schedule>						
A	B	C	D	E	F	G
Family	Length	W	Tonnage	Type	Base Level	Count
UC-Universal Column-Column	3048	1.6864	5.140147	305x305x97UC	ground	68
UC-Universal Column-Column	3048	0.7936	2.418893	305x305x97UC	1st floor	32
UC-Universal Column-Column	3048	0.7936	2.418893	305x305x97UC	2nd	32
UC-Universal Column-Column	3048	0.7936	2.418893	305x305x97UC	3rd	32
UC-Universal Column-Column	3048	0.7936	2.418893	305x305x97UC	4th	32
UC-Universal Column-Column	1829	0.2976	0.544251	305x305x97UC	5th	12
Grand total:	208	5.1584	15.359969			

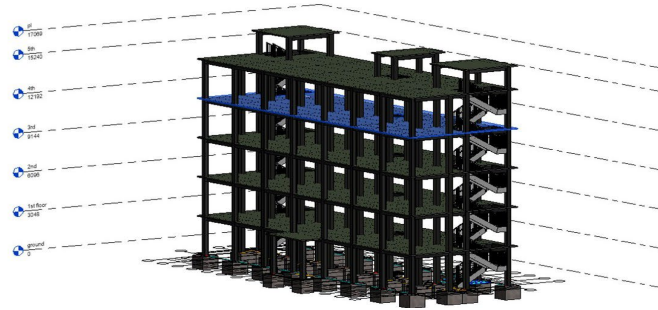


Continued

4 Slabs Area*Thickness (m³)

Slabs perimeter is found a horizontal intersection at each floor height. Area calculation excludes external wall depth (shown in blue).

Slabs Schedule				
A	B	C	D	E
Type	Level	Perimeter	Area	Volume
Generic 150mm	1st floor	94986	202 m ²	15.38 m ³
Generic 150mm	2nd	91766	195 m ²	14.88 m ³
Generic 150mm	3rd	91766	195 m ²	14.88 m ³
Generic 150mm	4th	91766	195 m ²	14.88 m ³
Generic 150mm	5th	91766	195 m ²	14.88 m ³
Generic 150mm	pl	16463	17 m ²	1.29 m ³
Generic 150mm	pl	16463	17 m ²	1.29 m ³
Generic 150mm	pl	13285	10 m ²	0.79 m ³
Grand total: 8			1027 m ²	78.28 m ³



<Wall Schedule>			
A	B	C	D
Family and Type	Top Constraint	Area	Total wall cost
Basic Wall - Generic - 140mm Masonry	Up to level: ground	70 m ²	\$8408.55
Basic Wall - Generic - 140mm Masonry	Up to level: 1st floor	202 m ²	\$24222.17
Basic Wall - Generic - 140mm Masonry	Up to level: 2nd	195 m ²	\$22199.94
Basic Wall - Generic - 140mm Masonry	Up to level: 3rd	195 m ²	\$22199.94
Basic Wall - Generic - 140mm Masonry	Up to level: 4th	195 m ²	\$22199.94
Basic Wall - Generic - 140mm Masonry	Up to level: 5th	197 m ²	\$22403.29
Basic Wall - Generic - 140mm Masonry	Up to level: 6th	16 m ²	\$1943.16
Basic Wall - Generic - 140mm Masonry: 115		1030 m ²	\$123676.98
Basic Wall - Generic - 200mm	Up to level: 1st floor	203 m ²	\$30366.04
Basic Wall - Generic - 200mm	Up to level: 2nd	240 m ²	\$36016.36
Basic Wall - Generic - 200mm	Up to level: 3rd	198 m ²	\$29634.14
Basic Wall - Generic - 200mm	Up to level: 4th	198 m ²	\$29710.64
Basic Wall - Generic - 200mm	Up to level: 5th	196 m ²	\$29423.17
Basic Wall - Generic - 200mm	Up to level: 6th	82 m ²	\$12281.72
Basic Wall - Generic - 200mm: 41		1116 m ²	\$181452.06
Curtain Wall - Storefront	Up to level: 1st floor	9 m ²	\$1835.53
Curtain Wall - Storefront	Up to level: 2nd	15 m ²	\$3062.81
Curtain Wall - Storefront	Up to level: 3rd	9 m ²	\$1854.41
Curtain Wall - Storefront	Up to level: 4th	9 m ²	\$1854.41
Curtain Wall - Storefront	Up to level: 5th	9 m ²	\$1854.41
Curtain Wall - Storefront: 7		51 m ²	\$10291.62
Grand total		2198 m ²	\$381320.67

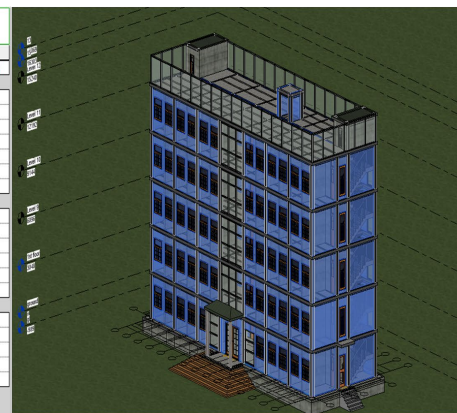


Figure 8. Wall Schedule and estimation process.



Figure 9. Illustrating the view of window and door for the scheduling.

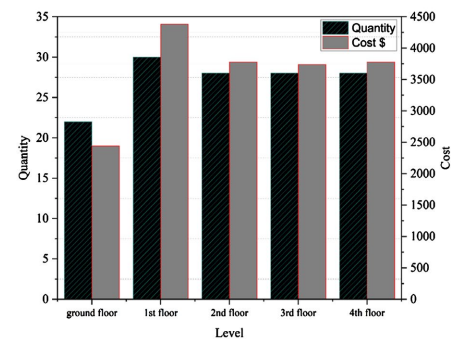
The model represents that each window and door type is properly accounted for based on floor level. It embedding these elements into the 3D model and associating them with corresponding cost parameters, Revit enables the automatic generation of door and window schedules. These schedules are then linked to material specifications and unit costs, supporting real-time budget calculations. This

BIM based model enhances precision in materials quantity, cost forecasting and allows stakeholders to verify the completeness of the design model before starting the on-field construction.

The windows schedule represents by (Figure 10), it provides detailed information for all window types across different floors of the building, including total quantity, dimensions, and related costs, and also shows each floor windows category each floor level and type as like 915 × 1830 mm, 1200 × 1500 mm, 1500 × 1500 mm, and 600 × 1500 mm with the total cost calculation multiplying by the unit cost which is depends on the windows materials. This analysis data supports the architectural and finishing elements of the building, forming an essential part of Level 3 estimation in the overall cost management framework. The schedule calculates the result 136 windows totaling \$18120.00, it illustrates how 5D BIM enables real-time quantify and more information budgeting decisions during the design phase.

<Window Schedule>			
A	B	C	D
Level	Type	Count	Cost
ground	1200x1500 mm	10	\$1000 00
ground	1500x1500 mm	12	\$1440 00
1st floor	600 x 1500 mm	4	\$1200 00
1st floor	0915 x 1830mm	2	\$500 00
1st floor	1200x1500 mm	10	\$1000 00
1st floor	1500x1500 mm	14	\$1680 00
2nd	600 x 1500 mm	2	\$600 00
2nd	0915 x 1830mm	2	\$500 00
2nd	1200x1500 mm	10	\$1000 00
2nd	1500x1500 mm	14	\$1680 00
3rd	600 x 1500 mm	2	\$600 00
3rd	0915 x 1830mm	2	\$500 00
3rd	1200x1500 mm	12	\$1200 00
3rd	1500x1500 mm	12	\$1440 00
4th	600 x 1500 mm	2	\$600 00
4th	0915 x 1830mm	2	\$500 00
4th	1200x1500 mm	10	\$1000 00
4th	1500x1500 mm	14	\$1680 00
		136	\$18120 00

(a) Window Schedule using Revit



(b) Schedule Diagram

Figure 10. Window schedule for cost information tracking.

Figure 6(a) presents the door schedule generated from the BIM model using Autodesk Revit, its representation of door quantity and associated cost distribution across floors levels. The schedule includes detailed information such as door dimensions, placement level, count, and total cost per type. A total of 112 door units, resulting in an estimated cost of \$16,950.00. Figure 6(b) diagram illustrates that the differentiation cost with each floor, it evaluates that ground floor contains the highest quantity of doors 27 units as well as high cost, it followed by the door materials and unit each floor. The consistent of distribution across the ground to 4th floors, each with approximately 19 units. The cost distribution closely follows the quantity trend, confirming proportional pricing per unit according to usable material. The minimal installations are observed on the rooftop and 5th floor.

This schedule data underscores the efficiency of 5D BIM in enabling precise and level wise cost estimation. The visual integration of schedule data with quantity-cost diagrams enhances decision making by allowing stakeholders to identify cost-intensive floors and optimize material allocation accordingly.

3.2.4. Analysis of MEP Elements Using 5D BIM Methods

To provide a complete view of Level 4 using 5D BIM, this study extends beyond traditional building components to include MEP scheduling. (Figure 11) extracting mechanical, electrical, and plumbing quantities directly from the BIM model, this study ensures accurate assessment of building services, and it can take step to underrepresented in early-stage cost planning of the project. This studies objective to demonstrate how BIM can play its role for the decision-making tools across all phases for construction project quantification.

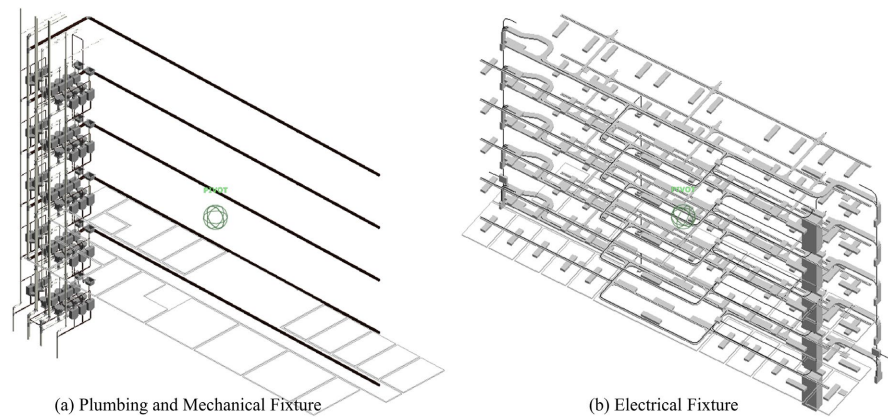


Figure 11. MEP estimation framework extracted from the 5D BIM model.

Figure 12 illustrates a three-dimensional visual arrangement that integrates data from several key schedules including all sanitary fixtures, plumbing pipe, pipe fittings, and sprinkler systems for fire safety. These components that are bring out from the MEP schedule all are essential for ensuring the buildings operational functionality and compliance with fire protection and sanitary requirements. This comprehensive breakdown of mechanical and plumbing systems extracted directly from the BIM model, these forming represent the basis of quantity and cost estimation within the 5D BIM framework.

The Plumbing Fixture Schedule shows the sanitary installations requirements such as urinals, sinks, and water closets categorized by type, type mark and level, with associated costs. This facilitates precise cost aggregation across all floors. The Sprinkler Schedule are categorized under mechanical properties, quantifies the fire protection elements such as pendent heads distributed across different levels with specified drop size classifications.

At the same time, the pipe and pipe fitting schedule provide comprehensive information about the materials specifications, and aiding in the calculation of costs associated with infrastructure. This MEP model ensures that these schedules are dynamically linked to the 5D MIB model geometry, it can allow any design changes directly reflects in real time project quantification. This integrated schedule approach not only reduces manual estimation errors but also improves cost transparency and efficiency in MEP system planning.

Figure 13 brings out the Electrical Fittings Schedule derived from the 5D BIM model; it is extending Level 4 of the 5D BIM framework to quantification of elec-

trical elements. This diagram integrates multiple detailed schedules, which is expressed as cable trays, cable tray fittings, conduit fittings, conduit runs, electrical equipment, and lighting fixtures, all essential for cost estimation, equipment quantification and coordination in building systems.

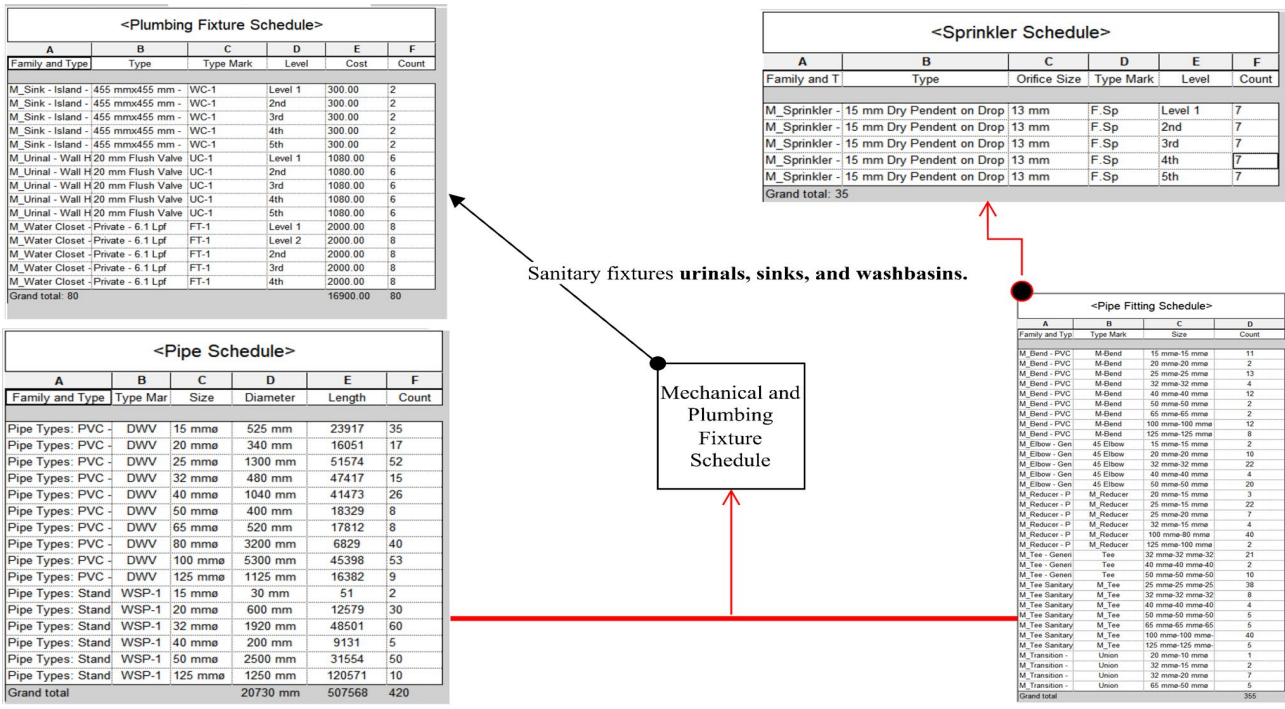


Figure 12. Integrated mechanical and plumbing fixture schedule extracted for Level 4 using 5D BIM.

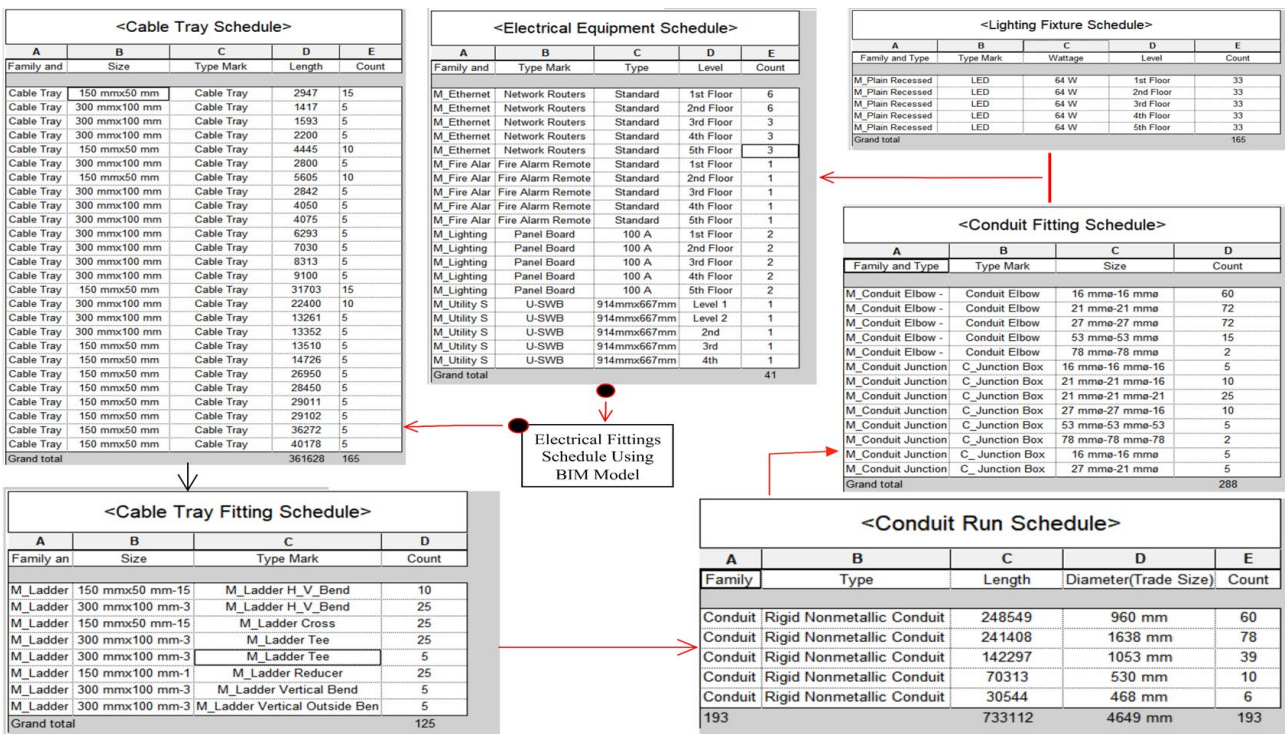


Figure 13. Electrical fittings and equipment schedule from 5D BIM model.

The Cable Tray Schedule, along with the corresponding Cable Tray Fitting Schedule, provides a detailed account of the total lengths and sizes of cable trays, as well as important accessories like horizontal bends, tees, and reducers, which are vital for the logistics of installation. The Conduit Fitting Schedule shows the types and sizes of elbows and junction boxes, and the Conduit Run Schedule represent with a volumetric overview of rigid nonmetallic conduits categorized by length, diameter, and floor count. The comprehensive details provided in these schedules facilitate a high degree of precision in both quantification and cost estimation. The Electrical Equipment Schedule details network routers, fire alarms, lighting control panels, and utility switchboards, each associated with level-specific count data. This data enhanced further Lighting Fixture Schedule, which shows the LED wattage and the quantity allocated across floors, thereby ensuring precise energy and procurement planning.

Furthermore, when these schedules are dynamically linked to the BIM model in software such as Autodesk Revit, they guarantee real-time updates in response to design changes. This methodology enhances the capabilities of 5D BIM by increasing cost accuracy, supporting early-stage budgeting, and improving collaboration between stakeholder disciplines and other trades related to the ACE industry.

4. Limitations

1) Single Case Study Basis: These study relies on one office building project, which is not fully represent the diversity of project scales, construction methods, or management practices across Bangladesh's construction industry.

2) Absence of Real-Time Cost Feedback: The cost estimations were generated from static design data without real-time updates during construction, which is limiting the validation of BIM's dynamic cost-tracking potential.

3) Limited Stakeholder Diversity: The perception analysis focused on a relatively small group of professionals, which may not capture the full range of stakeholder views.

4) Exclusion of Lifecycle Cost Analysis: The study focuses mainly on construction-phase cost estimation and does not extend to operation, maintenance, or demolition costs, which are key aspects of 5D BIM's full potential.

5. Conclusions

This study demonstrates the effective application of a three-level 5D BIM framework for detailed construction cost estimation.

- At Level 1, study the structural components such as foundations, columns, beams, and slabs. These were precisely modeled and quantified, providing a reliable material estimation baseline for the entire project, where the material is quantified by tonnage system using a specific equation.
- The detailed quantification of wall construction evaluation of wall systems executed by Level 2, the integration of this wall quantification procedure within

a 5D BIM framework enhances adaptive budget forecasting and promotes decision-making in the early stages. Overall, the model driven workflow presented more transparent, data-rich, and adaptable method for managing wall-related construction costs throughout the project lifecycle.

- Level 3 focused on architectural and finishing elements, windows, including doors, and flooring, offering a comprehensive analysis of the more variable and design dependent aspects of construction material quantify.
- Level 4 expressed the encompasses MEP systems, which are included in one part with plumbing fixtures, sprinklers, electrical conduits, lighting, and cable management. These all layers integrate into a single BIM environment allows for minimizes manual estimation errors, and facilitates with real time data extraction, improves quantification accuracy, which is informed decision making throughout the project entire lifecycle.

The results highlight how 5D BIM driven scheduling the building materials each level and cost estimation support with quantity takeoff, reduce manual errors, and improve budgeting transparency. These methods approach the ACE industry and stakeholders to take their decision with a structured understanding of cost distribution across different building systems, from structural cores to aesthetic components. Overall, this level wise 5D BIM application strategy not only enhances accuracy but also contributes to ACE industry and stakeholders for more informed decision making during both design and execution stages.

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Conflicts of Interest

The authors declare that they have no conflict of interest.

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