# A BIM-Based Automated System for Estimating Structural Temporary Support Cost and Schedule

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**Abstract – Building Information Modeling (BIM) is an innovative digital approach in the construction industry that enhances conventional practices such as cost estimation and scheduling. It employs a concise 3D model containing geometry to depict actual conditions and produce precise quantity take-offs and time-phased visualizations. However, there are still limited practices for costing and scheduling temporary supports such as shoring, since these elements are rarely modeled. This often hinders the full automation of cost estimation and scheduling, requiring contractors to manually estimate temporary supports, which is both time-consuming and error-prone. This research proposes a BIM-based automated system to estimate the cost and schedule of temporary supports. The system utilizes a 3D model to automatically assign temporary supports. It also focuses on estimating the quantity and cost of these elements. In addition, it integrates visualization of the time-based schedule for the construction phase and shoring movements. The prototype system is developed using Autodesk Revit and Dynamo Visual Programming. Later, a simple real construction project is used to validate the proposed system. The proposed system can support contractors in accurately estimating temporary works to streamline project execution.**

**Keywords – Building Information Modeling (BIM), temporary supports, quantity take-off (QTO), cost estimation, scheduling, shoring system**

## 1 Introduction

Building construction projects are predominantly composed of concrete works, which involve not just the concrete structure itself but also temporary works such as formwork and scaffolding. Studies have shown that temporary works account for roughly 35–60% of the cost of cast-in-place concrete structures with the exact figure depending on labor rates, repetition, system formwork, and project type [1]. In addition to cost, temporary works also influence the duration of construction, thereby affecting not only expenses but also potential delays and quality.

Temporary works in building construction projects are commonly prepared by contractors based on concrete specifications. Contractors must develop strategies regarding the selection of temporary structure materials and systems, as well as determine the required resources to optimize cost, time, and quality. However, in many cases, temporary support is overlooked, with the focus placed on the permanent structure. As a result, temporary structures such as scaffolding or shoring are often planned using conventional methods, such as 2D drawings along with manual cost and time calculations. This approach leads to several drawbacks including time-consuming planning processes and inaccurate estimations. Another approach that is typically used involves calculating temporary support in bulk without considering detailed elements. There is also no specific systematic approach that easily considers the sequence of temporary work movements. Given these limitations, innovation is needed to help contractors plan temporary works systematically and accurately.

Building Information Modeling (BIM) is an evolving tool in the construction industry that integrates information and provides more accurate and real-time data for various applications in construction projects. Virtual construction models generated from BIM are powerful in depicting actual construction conditions. The concept of clash detection allows us to review the design and helps prevent any potential rework [2]. Another critical project element that is widely supported by BIM is quantity take-off and cost estimation [3]. When combined with project management practices, it becomes a powerful tool for simulating construction processes through schedule integration [4]. During the construction stage, BIM is useful for progress monitoring [5] and change order management [6]. BIM has also extended its implementation to operation and maintenance management [7], energy analysis [8], and safety management [9]. Therefore, the current BIM implementation has the potential to be used for managing temporary works by utilizing the 3D model integrated with cost and schedule aspects.

This research leverages BIM to virtually model construction practices by integrating temporary works, cost, and schedule elements. It proposes a BIM-based system that extracts geometric information from 3D models to automatically generate temporary works for concrete casting, particularly the shoring system. The system allows us to simulate shoring movements from one story to another by integrating scheduling processes as well as quantifying the cost. The proposed framework is presented through a case study of a small-scale construction project. The results serve as an initial investigation toward optimizing shoring movements. This approach is expected to help contractors systematically plan detailed concrete works to achieve efficient construction processes.

## 2 Literature Review

The implementation of the BIM concept for temporary works has been investigated by several researchers. Hyun [10] and Singh [11] proposed a BIM-based system for designing formwork by considering structural aspects such as bending and deflection. Their approach is conceptually similar to the work of Jiang and Leicht [12], who developed a BIM-based automated rule-based checking system to assess the constructability of different formwork types. Similarly, Lee [13] proposed a BIM-based formwork layout generation method focused on panelized formwork, enabling the placement of formwork according to predefined layouts and a formwork library. Another contribution by Kim and Teizer [14] demonstrated the automation of temporary works generation by analyzing complex geometric conditions, creating scaffolding objects, and incorporating 4D visualization.

In addition to formwork design, several studies have explored BIM implementation for scaffolding with a focus on safety. Collins [15] proposed a framework to analyze safety and mitigation measures by generating a 4D BIM model that visualizes risks alongside scaffolding installation progress. Kim [16] extended safety planning through BIM by integrating crew movement simulations with Job Safety Analysis (JSA) and schedule inspections. Subsequently, Kim [17] developed a BIM-driven automated decision support system for safety planning of temporary structures, incorporating a decision-making engine to evaluate alternative scaffolding utilization scenarios based on hazard scores, duration, and cost. Kim [18] further extended this work by proposing a BIM-based decision-making framework for scaffolding planning, which supports the evaluation and selection of scaffolding alternatives based on multiple criteria including safety, time, and cost efficiency.

Previous research shows that generating temporary works based on permanent structural components is a common approach and this concept is also adopted in this study. However, most existing studies have focused primarily on structural analysis and safety considerations, often addressing the aspects in isolation. Investigations addressing the cost and scheduling implications of temporary work utilization remain limited. For example, Mansuri et al. [19] proposed a scheduled formwork reuse plan to minimize the required quantity of formwork, but the scope was limited to wall elements. While Mansuri's concept incorporates the concept of formwork reuse, it does not fully capture the complexity of floor-based construction in multi-story building, where varying floor layouts and both vertical and horizontal movements influence temporary work planning. In additions, the current framework represent a relatively static manner and does not explicitly simulate the detailed phases of temporary work operations, such as installation, reshoring, and dismantling.

In contrast, this study extends the scope by considering the dynamic behaviour of shoring system throughout different construction stages. By incorporating this, the framework not only support cost and schedule optimization but also enables visual simulation, providing a more comprehensive understanding how temporary works evolve over time.

## 3 The Proposed Framework

A BIM-based system proposed in this research aims to (1) provide automated generation of shoring visualization embedded in the existing structural model, (2) enable the integration of construction work schedules that involve both permanent and temporary structures, and (3) generate detailed quantity take-off and cost estimates for temporary works. This study focuses only on reinforced cast-in-place concrete elements, which require temporary structures, specifically shoring. The proposed framework consists of four main components, which are elaborated in this section and illustrated in Figure 1.

### 3.1 The BIM Model Development

The utilization of a 3D BIM model consisting of permanent structural elements such as columns, beams, and slabs is required. All cast-in-place concrete elements are modeled as an integrated building structure. The model should be clash-free to ensure that element properties such as length, cut length, and height can be accurately read. The components are also arranged according to the element hierarchy that is commonly applied in Indonesia for quantity take-off. In this hierarchy, columns are modeled first with their full length from floor to floor, followed by beams and then slabs.

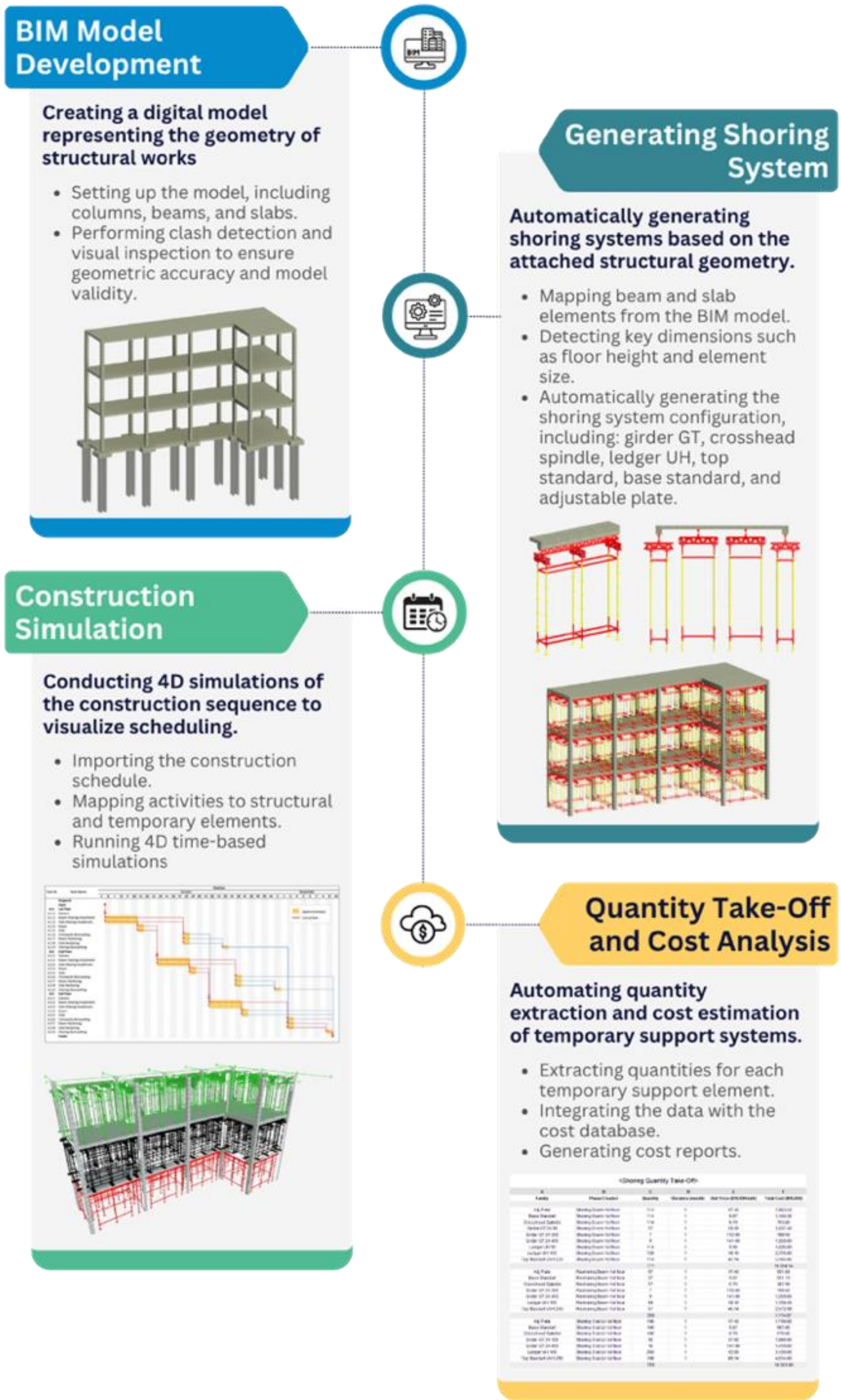



Figure 1. The proposed framework

### 3.2 The Automated Generation of Shoring System

The second stage of the proposed framework focuses on automatically generating the shoring system based on the geometry of structural elements. The system first identifies and maps beams and slabs directly from the BIM model, then extracts key element properties. For beams, the properties include height and width, span length (cut length and total length), and floor-to-floor height. For slabs, the properties include thickness, area, and cut length. Using these properties, the system computes the centroid of each beam and slab, which serves as the reference point for positioning shoring nodes. From these centroid references, the program automatically creates a 3D shoring configuration without manual modeling.

The shoring spacing and component configurations are rule based and derived from industry practice, manufacturer recommendations, and common temporary works guidelines. The predefined parameters set for this study use a typical shoring spacing of 1.5 meters with a practical maximum span of 6 meters to generate layouts that are constructible and consistent with standard field practice. Future development of the system will focus on incorporating structural verification checks to strengthen and complement these practice-based rules.

### 3.3 The Construction Simulation

The third stage of the framework involves simulating the construction sequence in 4D by integrating the project schedule with the complete 3D model, which includes both permanent and temporary works. Before running the simulation, several prerequisites and setup steps must be completed. First, the construction schedule should be broken down into a higher level of detail to accurately reflect the installation, dismantling, and reshoring of temporary structures. These additional activity definitions enable the simulation to represent not only permanent works, such as concrete casting, but also the preparation and execution of temporary structural elements, including shoring installation and dismantling over time. Once the schedule is finalized, each activity is mapped to its corresponding permanent and temporary elements in the BIM model. This mapping allows the program to run time-based simulations and clearly visualize the construction sequence in detail.

### 3.4 The Quantity Take-off and Cost Analysis

The final stage of the framework focuses on automating the quantity take-off process for temporary work elements and integrating it with cost estimation. As each shoring component is extracted from the BIM model, cost data is used to generate detailed cost estimates. It is noted that during the creation of shoring components, each element is given a specific type of name. This name matches the entries in the cost database, which is structured in spreadsheet form. As a result, the generated shoring components contain not only geometric information but also non-geometric information, including the unit price. During the automated quantity take-off process, the extracted quantities are directly combined with the unit prices to produce cost estimation.

The current system perform calculations at the component level allowing for more transparent and accurate reporting. However, the proposed system has the potential to be extended to accommodate different measurement types, such as area-based ($m^2$), volume-based ($m^3$), and unit-based activities.

For area-based measurements ($m^2$), the system can aggregate the relevant components of each shoring configuration and then organize the results per floor. For volume-based measurements ($m^3$), the shoring configuration can be aligned with the related concrete volume. On the other hand, the unit-based activities can be performed by grouping the shoring components based on the construction stages or locations. Therefore, the system can support multiple measurement approaches, enhancing its flexibility and applicability for different construction scenarios.

Another area for further development, at this stage, the system does not yet include an optimization feature that considers the reuse of shoring elements across different construction sequences. Incorporating this factor in future work would make the cost estimation more realistic and better aligned with actual site practices. Further study can be extended by integrating it with permanent structural works such as concrete and reinforcement, enabling a more comprehensive construction simulation system.

## 4 The Framework Prototype

A prototype system was developed to test the proposed method. The proposed framework is validated using a case study of a simple construction projects, 3-story building for educational purposes as shown in Figure 2. Focusing on the structural works which consist of column, beam, and slab. For the infrastructure support to run the proposed framework, the utilization of Autodesk Revit and Dynamo, a visual programming. The beam and slab span for this case study is limited no more than 6 meters, creating a seragam components.

As the building model is validated through visual inspection and clash detection, the generation of the shoring system can be implemented. The typical shoring system for beams is shown in Figure 3. (a), consisting of Girder GT, Crosshead Spindle, Ledger UH, Top Standard, Base Standard, and Adjustable Plate. The generation process also considers reshoring conditions, as shown in Figure 3. (b), where the number of girders and top standards is reduced. This generation is applied to the entire floor system and serves as the basis for the subsequent simulation process

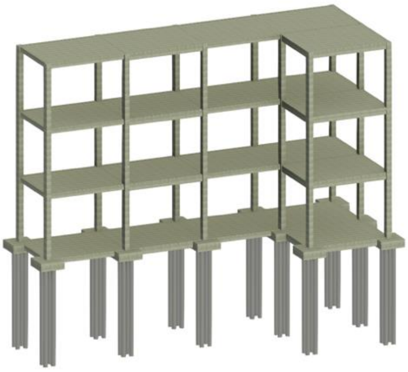
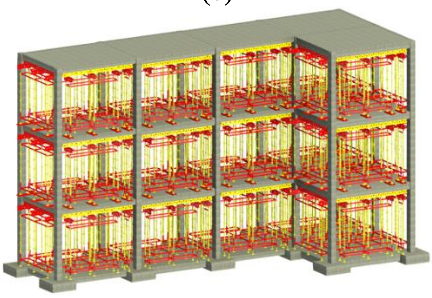


Figure 2. Building model

(a)

(b)



(c)

Figure 3. Shoring system configuration for (a) beam shoring, (b) slab reshoring, and (c) overall shoring system

Figure 4 illustrates the construction schedule that serves as the foundation for simulating the sequence of activities. The schedule is detailed to include key stages of temporary and permanent works, such as shoring installation, concrete casting, reshoring, and dismantling. It is assumed that the beam and slab shoring installation is carried out simultaneously and takes approximately four days. Once the concrete is cast, the reshoring phase requires about six days, followed by another six days for dismantling. These activities are then mapped to their respective elements in the BIM model to enable 4D simulation. Figure 5 visualizes the step-by-step construction process, including (a) shoring installation, (b) concrete casting, (c) reshoring, and (d) dismantling. The color coding helps distinguish the status of each activity. Figure 6 presents the construction progress simulation, where the green elements indicate ongoing works, red represents dismantling, and grey represents completed works.

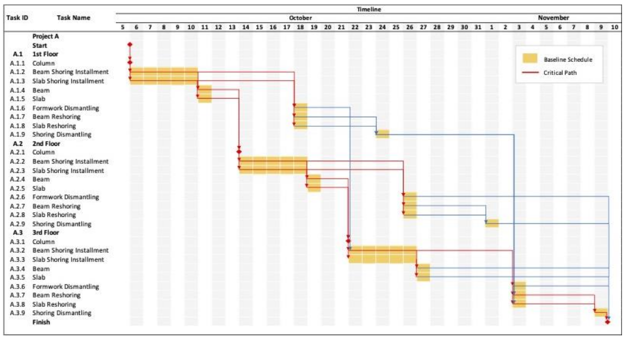
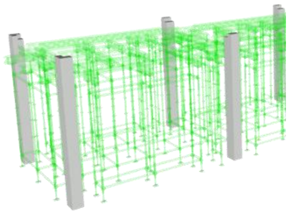
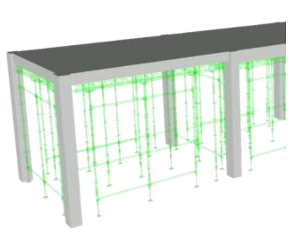



Figure 4. Construction schedule

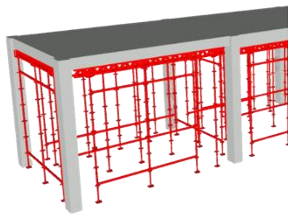


(a)

(b)



(c)



(d)

Figure 5. Beam and slab (a) shoring installment, (b) concrete casting, (c) reshoring, and (d) dismantling

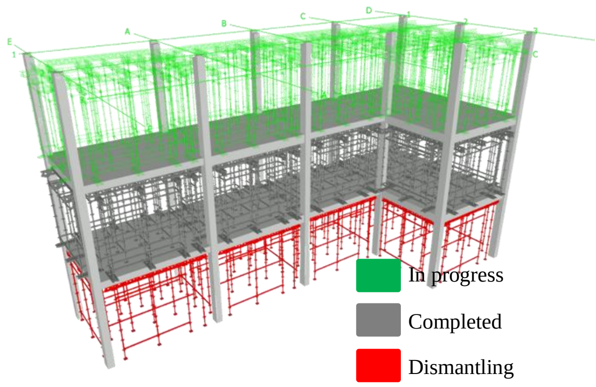



Figure 6. Construction progress simulation

<Shoring Quantity Take-Off>

| A | B | C | D | E | F |
|---|---|---|---|---|---|
| Family | Phase Created | Quantity | Duration (month) | Unit Price (IDR.000/mth) | Total Cost (IDR.000) |
| | | | | | |
| Adj Plate | Shoring Beam-1st floor | 114 | 1 | 17.40 | 1,983.60 |
| Base Standart | Shoring Beam-1st floor | 114 | 1 | 9.67 | 1,102.38 |
| Crosshead Spindle | Shoring Beam-1st floor | 114 | 1 | 6.70 | 763.80 |
| Girder GT 24 90 | Shoring Beam-1st floor | 57 | 1 | 28.20 | 1,607.40 |
| Girder GT 24 360 | Shoring Beam-1st floor | 7 | 1 | 112.80 | 789.60 |
| Girder GT 24 450 | Shoring Beam-1st floor | 9 | 1 | 141.00 | 1,269.00 |
| Ledger UH 50 | Shoring Beam-1st floor | 114 | 1 | 9.00 | 1,026.00 |
| Ledger UH 150 | Shoring Beam-1st floor | 128 | 1 | 18.10 | 2,316.80 |
| Top Standart UVH 250 | Shoring Beam-1st floor | 114 | 1 | 45.14 | 5,145.96 |
| | | 771 | | | 16,004.54 |
| Adj Plate | Reshoring Beam-1st floor | 57 | 1 | 17.40 | 991.80 |
| Base Standart | Reshoring Beam-1st floor | 57 | 1 | 9.67 | 551.19 |
| Crosshead Spindle | Reshoring Beam-1st floor | 57 | 1 | 6.70 | 381.90 |
| Girder GT 24 360 | Reshoring Beam-1st floor | 7 | 1 | 112.80 | 789.60 |
| Girder GT 24 450 | Reshoring Beam-1st floor | 9 | 1 | 141.00 | 1,269.00 |
| Ledger UH 150 | Reshoring Beam-1st floor | 64 | 1 | 18.10 | 1,158.40 |
| Top Standart UVH 250 | Reshoring Beam-1st floor | 57 | 1 | 45.14 | 2,572.98 |
| | | 308 | | | 7,714.87 |
| Adj Plate | Shoring Slab LI-1st floor | 100 | 1 | 17.40 | 1,740.00 |
| Base Standart | Shoring Slab LI-1st floor | 100 | 1 | 9.67 | 967.00 |
| Crosshead Spindle | Shoring Slab LI-1st floor | 100 | 1 | 6.70 | 670.00 |
| Girder GT 24 120 | Shoring Slab LI-1st floor | 50 | 1 | 37.60 | 1,880.00 |
| Girder GT 24 450 | Shoring Slab LI-1st floor | 10 | 1 | 141.00 | 1,410.00 |
| Ledger UH 100 | Shoring Slab LI-1st floor | 260 | 1 | 12.00 | 3,120.00 |
| Top Standart UVH 250 | Shoring Slab LI-1st floor | 100 | 1 | 45.14 | 4,514.00 |
| | | 720 | | | 14,301.00 |
| Adj Plate | Reshoring Slab-1st floor | 50 | 1 | 17.40 | 870.00 |
| Base Standart | Reshoring Slab-1st floor | 50 | 1 | 9.67 | 483.50 |
| Crosshead Spindle | Reshoring Slab-1st floor | 50 | 1 | 6.70 | 335.00 |
| Girder GT 24 450 | Reshoring Slab-1st floor | 10 | 1 | 141.00 | 1,410.00 |
| Ledger UH 100 | Reshoring Slab-1st floor | 80 | 1 | 12.00 | 960.00 |
| Top Standart UVH 250 | Reshoring Slab-1st floor | 50 | 1 | 45.14 | 2,257.00 |
| | | 290 | | | 6,315.50 |

<Shoring Quantity Take-Off>

| A | B | C | D | E | F |
|---|---|---|---|---|---|
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| Ledger UH 50 | Shoring Beam-1st floor | 114 | 1 | 9.00 | 1,026.00 |
| Ledger UH 150 | Shoring Beam-1st floor | 128 | 1 | 18.10 | 2,316.80 |
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| Crosshead Spindle | Shoring Slab LI-1st floor | 100 | 1 | 6.70 | 670.00 |
| Girder GT 24 120 | Shoring Slab LI-1st floor | 50 | 1 | 37.60 | 1,880.00 |
| Girder GT 24 450 | Shoring Slab LI-1st floor | 10 | 1 | 141.00 | 1,410.00 |
| Ledger UH 100 | Shoring Slab LI-1st floor | 260 | 1 | 12.00 | 3,120.00 |
| Top Standart UVH 250 | Shoring Slab LI-1st floor | 100 | 1 | 45.14 | 4,514.00 |
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| Girder GT 24 450 | Reshoring Slab-1st floor | 10 | 1 | 141.00 | 1,410.00 |
| Ledger UH 100 | Reshoring Slab-1st floor | 80 | 1 | 12.00 | 960.00 |
| Top Standart UVH 250 | Reshoring Slab-1st floor | 50 | 1 | 45.14 | 2,257.00 |
| | | 290 | | | 6,315.50 |

Figure 7. Shoring quantity take-off and cost summary for each floor

Figure 6 also illustrates the detailed sequence and status of each shoring system on every floor. As the shoring system is installed for a particular duration, there are overlapping activities with the succeeding storey. This overlap highlights the potential for optimizing the reuse of shoring components, since reshoring typically requires only half of the shoring quantity during the first twelve days of concrete work on a given floor. Although the optimization process is not yet implemented in this research, this simulation provides an important initial step toward achieving it.

The last step is the quantification of shoring elements on each floor, as shown in

<Shoring Quantity Take-Off>

| A | B | C | D | E | F |
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<Shoring Quantity Take-Off>

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|---|---|---|---|---|---|
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| Crosshead Spindle | Shoring Slab LI-1st floor | 100 | 1 | 6.70 | 670.00 |
| Girder GT 24 120 | Shoring Slab LI-1st floor | 50 | 1 | 37.60 | 1,880.00 |
| Girder GT 24 450 | Shoring Slab LI-1st floor | 10 | 1 | 141.00 | 1,410.00 |
| Ledger UH 100 | Shoring Slab LI-1st floor | 260 | 1 | 12.00 | 3,120.00 |
| Top Standart UVH 250 | Shoring Slab LI-1st floor | 100 | 1 | 45.14 | 4,514.00 |
| | | 720 | | | 14,301.00 |
| Adj Plate | Reshoring Slab-1st floor | 50 | 1 | 17.40 | 870.00 |
| Base Standart | Reshoring Slab-1st floor | 50 | 1 | 9.67 | 483.50 |
| Crosshead Spindle | Reshoring Slab-1st floor | 50 | 1 | 6.70 | 335.00 |
| Girder GT 24 450 | Reshoring Slab-1st floor | 10 | 1 | 141.00 | 1,410.00 |
| Ledger UH 100 | Reshoring Slab-1st floor | 80 | 1 | 12.00 | 960.00 |
| Top Standart UVH 250 | Reshoring Slab-1st floor | 50 | 1 | 45.14 | 2,257.00 |
| | | 290 | | | 6,315.50 |

Figure 7. The BIM model enables detailed quantity extraction for every floor, providing contractors with precise information on the required materials. This level of detail supports accurate procurement planning and resource allocation. Future research will focus on optimizing these quantities by considering construction sequences and the potential for shoring reuse.

## 5 Conclusion and Future Works

This study presented a BIM-based automated system to estimate the cost and schedule of temporary works, particularly shoring systems for reinforced concrete structures. The framework integrates 3D geometry, construction schedule, and cost data to enable the automated generation, construction visualization, and quantification of shoring elements. By simulating shoring installation, reshoring, and dismantling processes, the system provides a clear representation of shoring utilization over time. The prototype was applied to a three-story educational building as a case study. The results demonstrated that the proposed system is capable of producing a detailed shoring layout, enabling 4D construction simulations and accurate quantity take-offs. This approach offers improved efficiency and accuracy compared to conventional methods which typically rely on manual calculation and generalized estimation.

Although the framework represents a significant step toward automation, several limitations remain. The current system generates shoring configurations based on predefined rules and is limited to specific configurations. In practice, shoring arrangements can vary significantly depending on site conditions and structural design, indicating the need for further development to accommodate a wider range of configurations. In addition, the current implementation focuses on the component-level calculations, while it has the potential to support multiple quantity measurement types such as area-based ($m^2$), volume-based ($m^3$), and unit-based activities, to enhance practicality. Furthermore, the current scope is limited to temporary works while future works could integrate both temporary and permanent structural element such as concrete and reinforcement to provide a more comprehensive estimation.

Another future work will focus on optimizing shoring quantity and reuse through scenario-based simulations with validation with more complex structures, including irregular floor plans and varying span lengths, will be conducted to improve the system's applicability. Integration with structural verification will also be explored to enhance practical implementation in construction workflows.

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