

EVALUATION OF DELAYS USING BIM 4D IN PROJECTS IMPLEMENTING *LAST PLANNER SYSTEM* (CASE STUDY: PROJECT X)

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ABSTRACT

The Indonesian construction sector is a vital economic driver but suffers from frequent setbacks, with approximately 38% of projects experiencing delays. Traditional scheduling methods, such as CPM and PERT, often lack the flexibility and collaborative potential required for dynamic modern projects. Consequently, this study evaluates the Last Planner System (LPS) integrated with 4D Building Information Modeling (BIM) to anticipate delays and implement the Lean Construction mechanism. Focusing on "Project X" in Semarang, the research utilized quantitative data, including S-Curves and weekly work plans alongside 4D simulations created with Microsoft Project and Autodesk Navisworks. Performance was measured using Percent Plan Complete (PPC) to track the consistency between planned and realized work. The results were significant: integrating LPS with 4D BIM achieved a 100% PPC and saved 15 working days compared to using LPS alone. This demonstrates that combining collaborative planning with advanced visualization effectively enhances productivity. Future research is suggested to expand this interoperability to include cost-benefit analysis (BIM 5D).

KEYWORDS

Last Planner® System, BIM, lean construction, delay, percent plan complete.

INTRODUCTION

The growth of Indonesia's construction sector from 2022 to 2024 will increase its contribution to the Gross Domestic Product (GDP) ([Indonesian Central Statistics Agency](#), 2024), but it has an impact on increasing project complexity that poses challenges such as the need for skilled labor, technological developments, and limited facilities (Muamalah, et al., 2023; Zoubair, et al., 2024). Unpreparedness in managing this complexity will result in inefficiencies and delays in projects (Willar and Trigunarsyah, 2021; Auliasari et al., 2023), while the scheduling methods, such as CPM, Bar Chart, and PERT, have not been fully able to respond effectively to field dynamics (Kerzner, 2017; Santika et al., 2022).

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Alternatively, the Last Planner System (LPS) offers a collaboration-based scheduling approach and a lean construction mechanism to improve the reliability of work plans (Choo et al., 1998; Olivieri et al., 2019). Interoperability between LPS and 4D BIM through software such as Autodesk Navisworks allows visualization of the relationship between 3D models and schedules, thus supporting better time control. Research by Cam et al. (2025) reveals that Lean construction mechanisms enhance BIM by improving interoperability and supporting real-time decision-making. This study examines the effectiveness of such integration in increasing productivity and minimizing construction project delays (Huang and Bhat, 2017).

BACKGROUND

PERFORMANCE AND CHALLENGES IN INDONESIA'S CONSTRUCTION INDUSTRY

The construction industry has great potential to drive national economic growth and improve infrastructure development. However, despite its contribution to Indonesia's GDP showing a stable recovery trend in the 2022–2024 period, the sector still faces various challenges that hinder optimal performance. Various studies show that the increase in the volume of work and the complexity of projects bring their own difficulties in the design, management, and implementation of construction projects (Zoubeir et al., 2024). On the other hand, the dynamics of technological change, the shortage of skilled labor, the shortage of facilities, and the weak integration between theory and practice also worsen these conditions (Muamalah et al., 2023).

According to Kerzner (2017), these challenges indicate that although the construction sector is growing continuously, project management capacity has not kept pace with the increasing complexity of work. When such obstacles are not addressed through proper management, construction projects run the risk of inefficiencies and failure to meet targets. This condition underscores the need to implement a more systematic management framework and methods to improve the performance and competitiveness of the construction sector.

LEAN CONSTRUCTION-BASED SCHEDULING

Many construction projects still rely on scheduling methods such as the Critical Path Method (CPM), the Bar Chart, and the Program Evaluation and Review Technique (PERT) to map the relationships among project activities and predict the duration of work (Kerzner, 2017; Santika et al., 2022). Although these methods have long been used in project management, various studies show that their effectiveness is increasingly limited in the face of the complexity of modern projects. CPMs, for example, tend to focus on critical paths without accounting for the variability of dynamic field conditions (Olivieri et al., 2019). Bar Charts provide only a simple visual representation, whereas PERT requires probabilistic estimates that are difficult to apply to projects with high uncertainty (Adwitya et al., 2020).

The limitations of these methods suggest that traditional scheduling approaches have not supported the integration, collaboration, and adaptive responses required in current construction projects. In response to these weaknesses, the Last Planner System (LPS) was introduced as a more collaborative, plan-reliability-oriented production planning method (Ballard, 2000; Olivieri et al., 2019). LPS emphasizes the commitment of the implementers who directly understand the workflow in the field, as well as shifting the focus of planning from planned to realized work. By measuring the Percent Plan Complete (PPC) indicator, LPS helps identify the main causes of weekly plan non-fulfillment and systematically improves scheduling accuracy (Lagos et al., 2021). In addition, implementing LPS can eliminate activities that do not add value, aligning with the principles of lean construction, which focus on reducing waste and increasing value for customers (Heigermoser et al., 2019; Danureswara and Suripto, 2025).

THE ROLE OF BIM IN SUPPORTING THE LAST PLANNER SYSTEM

To facilitate the implementation of the Last Planner System (LPS), a digital approach using Building Information Modeling (BIM) is adopted. BIM is an integrated system across architecture, engineering, and construction that enables comprehensive collaboration among project parties through 3D-based building models (Borrmann et al., 2018). By visualizing building components and their relationships, BIM helps identify potential conflicts, understand the sequence of work, and estimate resource needs before construction begins. According to Koo and Fischer (2000) and Mieslenna and Wibowo (2019), BIM has several dimensions ranging from 3D to 7D. In the context of LPS scheduling, 4D BIM is used because it integrates time information into 3D models, thereby facilitating more effective visualization of construction sequences and project planning.

Project scheduling generally uses software such as Primavera P6, Synchro 4D, and Bentley Systems (Newitt, 2009; Kenley and Seppanen, 2010; Mubarak, 2015). However, Navisworks was chosen in this study because it excels in 4D simulation, inter-disciplinary coordination, and BIM model integration. Navisworks can combine various design models into a single work environment for design review, coordination analysis, construction simulation, and presentation (Huang and Bhat, 2017; Maulana et al., 2023).

RESEARCH METHOD

This research process consists of four main stages that are carried out sequentially. The first stage focuses on collecting information through literature reviews on construction management, planning, scheduling, the Last Planner System (LPS), Building Information Modeling (BIM), and Lean Construction. At this stage, a review of theories and previous literature was also conducted as a basis for preparing the framework of thought and research objectives. The result of this initial stage is the preparation of a final project proposal. The second stage is the process of collecting project data, including implementation schedule data (S Curve) and 3D BIM models, which are the main basis for the next data processing process, and field verification is carried out to ensure the suitability of project data with actual conditions to increase the reliability of analysis results.

The third stage is the data processing stage, which includes modeling the existing schedule using the LPS method in the Microsoft Project, determining the duration of each work item based on the modeling results, and integrating the 3D BIM model with the LPS project schedule using Navisworks software to produce a 4D BIM simulation that displays the construction sequence according to the planned implementation time. This stage produces an optimal scheduling model based on lean construction using BIM 4D and LPS methods, and provides a detailed visualization of potential clashes that enables early mitigation before construction. Furthermore, in the fourth stage, an analysis of delays in construction implementation and an evaluation of the LPS method were conducted to assess construction performance using the Percent Plan Complete (PPC) indicator. This stage compares 4D BIM and 4D BIM-based scheduling, and evaluates construction implementation performance through PPC analysis to assess the level of plan reliability and the effectiveness of eliminating obstacles in the project implementation process. This analysis also allows the identification of patterns that cause delays, enabling more comprehensive improvement recommendations to be compiled and applied to similar projects in the future. The research method is illustrated in Figure 1.

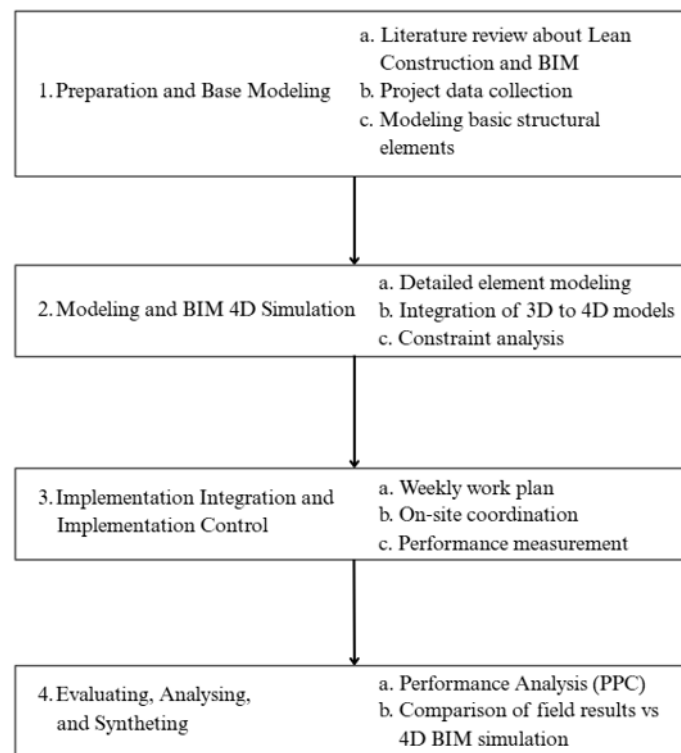


Figure 1: Research method workflow

RESULTS AND FINDINGS

This study aims to evaluate the impact of integrating 4D Building Information Modeling (BIM) with the Last Planner System (LPS) on project scheduling performance. The findings are grouped into two main aspects: the efficiency of schedule duration and planning reliability, as measured by PPC metrics. This study compared the actual schedule (LPS method without BIM 4D) with the simulation schedule (LPS method with BIM 4D) for the upper structure work (Floors 7-9) on Project X during the 6-week observation period (weeks 47 – 52 from the first week).

The integration of BIM 4D enables visualization of construction sequences, facilitating the identification of opportunities for overlapping work and resource optimization. The comparison between the actual duration (executed using LPS only) and the plan duration (simulated with LPS + BIM 4D) for the 8th Floor structure work is summarized in Table 1.

Table 1: Results of estimated difference in actual day duration with day duration of 4D BIM modeling plan

Category	Duration (Days)
Actual Duration (Field)	38 Days
Plan Duration (4D BIM Modeling)	23 Days
Duration Difference (Actual Duration – Plan Duration)	15 Days

The results in Table 1 show a significant reduction in project duration. The actual project progress takes 38 days to finish the complete structural works of the 9th floor, while the 4D BIM simulation (p.s. the schedule model is only a hypothesis and hasn't been put into practice on site) shows that the same scope of work and goals can be completed in 23 days. This results in a 15-day difference, representing a potential time reduction of around 39.5%. The visualizations provided by Navisworks facilitate the identification of idle time and enable Just-in-Time coordination, so that work that was previously scheduled sequentially (such as ironing, formwork, and casting) can be carried out in parallel or overlap.

PERCENT PLAN COMPLETE

The reliability of the planning system is evaluated using the Percent Plan Complete (PPC) metric. Data were collected over six weeks by comparing the number of planned tasks with the number of completed tasks. The work items for compiling the PPC value are presented in Table 2.

Table 2: Work Items

Floor	Beam	Column	Floor Deck
Floor 7	Formwork, Reinforcement, and Concrete Casting	Formwork, Reinforcement, and Concrete Casting	Formwork, Reinforcement, and Concrete Casting
Floor 8	Formwork, Reinforcement, and Concrete Casting	Formwork, Reinforcement, and Concrete Casting	Formwork, Reinforcement, and Concrete Casting
Floor 9	Formwork, Reinforcement, and Concrete Casting	Formwork, Reinforcement, and Concrete Casting	Formwork, Reinforcement, and Concrete Casting

The distribution of weekly tasks is reported every weekend on the working week, and the person who usually checks the working result will calculate the PPC. The results of PPC values for week 47 until week 52 are presented in Table 3.

Table 3: PPC Calculation Results

Week	Planned Work	Planned Work	PPC (%)
Week 47	12	12	100%
Week 48	17	17	100%
Week 49	16	16	100%
Week 50	17	17	100%
Week 51	15	15	100%
Week 52	18	18	100%
Average			100%

As shown in Table 3, the project achieved a consistent Percent Plan Complete (PPC) value of 100% throughout the observation period. This achievement reflects a very high level of commitment and reliability, which can be achieved only if the planning process is carried out in a disciplined manner and the constraint-removal mechanism is effectively implemented. The stable performance of PPC also shows that each planned task can be executed on schedule without significant delays, thus indicating the good quality of coordination between the implementation teams. The implementation of the Last Planner System (LPS) combined with 4D BIM visualization plays an important role in ensuring the creation of a realistic and reliable "Weekly Work Plan". Through this integration, any constraints, whether internal, such as the availability of labor, materials, and tools, or external, such as access to work areas and dependencies on other subcontractors' work, can be identified and resolved before tasks are allocated. Thus, subcontractors can receive a completely make-ready task, which ultimately improves the consistency of field execution and strengthens the culture of reliability in the construction process.

IMPACT ON LEAN CONSTRUCTION MECHANISM

This study identifies that the integration of the Last Planner System (LPS) and 4D Building Information Modeling (BIM) directly supports the application of the main mechanism of Lean Construction in the project planning and control process. Through an in-depth analysis of the schedule differences produced by the two approaches, this study found significant improvements in the aspect of smooth workflow (flow) and reduction of various forms of waste that previously occurred at the implementation stage. LPS integration provides improved reliability of weekly plans, while BIM 4D strengthens the visualization of work sequences so that coordination between activities becomes more effective. The combination of the two results in a process that is more adaptive and responsive to changing field conditions. Table 4 summarizes the various forms of improvement identified and maps the results against the relevant Lean mechanism based on a thorough comparison between conventional methods and such integrated approaches.

Table 4: Improvements identified through LPS and 4D BIM integration

Lean Mechanism	Identified Improvements	Observations from Case Studies
Create Flow	Reduction of idle time	The 4D BIM visualization uncovered gaps in the schedule, allowing the installation of formwork (Zone 1) to begin earlier than originally planned.
Value Stream	Increased productivity	The number of tasks completed increased from ± 28 (Actual) to ± 43 (Simulation) in the same time span.
Reducing Waste	Increased task overlap	Zoning optimization (Zones 1-3) and task overlapping reduce waiting time for subcontractors (e.g. ironing and formwork teams)

As shown in Table 4, the data reveal that while the approach without BIM 4D experiences sequential delays and uneven resource allocation, the BIM 4D approach enables a denser, more

sustainable workflow. The ability to visualize constraints enables teams to reorganize workable backlogs, eliminating non-value-added time (waiting) and maximizing subcontractor productivity. The results of the comparison of these two approaches (scheduling without BIM 4D and scheduling using BIM 4D) can be seen in Figure 2 and Figure 3.

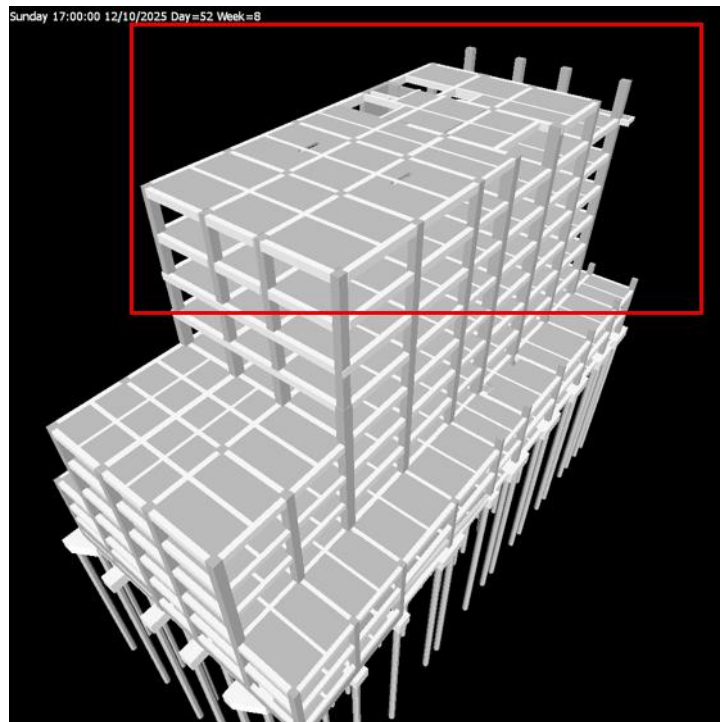


Figure 2: Scheduling results without BIM 4D

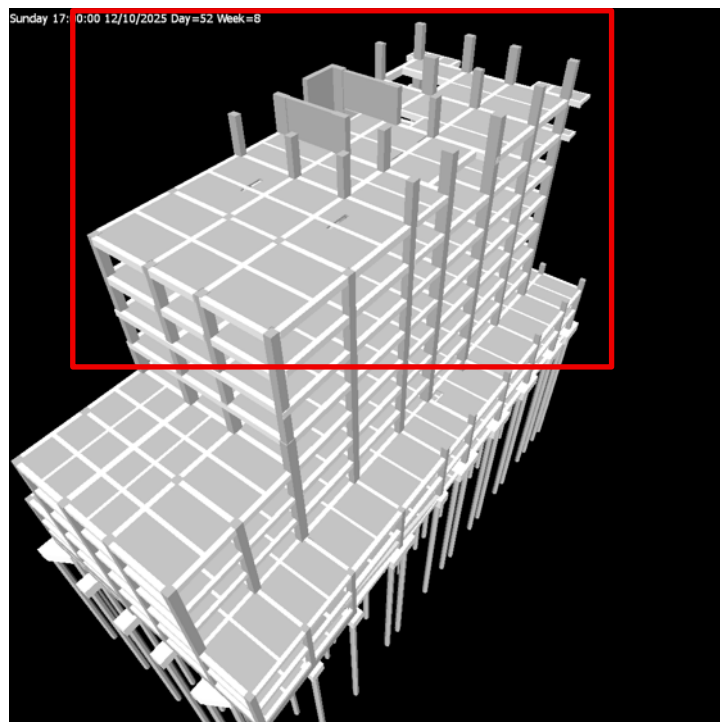


Figure 3: Scheduling Results Using BIM 4D

Based on Figure 2 and Figure 3, it can be seen that there is a significant difference between the final observation results of these two approaches (scheduling without BIM 4D and scheduling

using BIM 4D) there is a significant difference, namely in the scheduling of LPS with BIM 4D the work of the upper structure of the 9th floor has been completely completed up to the column casting work. Meanwhile, LPS scheduling without BIM 4D cannot complete all the work of the upper structure. Lean construction, such as daily huddle meetings, can provide a new platform to help increase the value of the BIM 4D and on-site construction team collaboration (Von Heyl and Demir, 2019).

DISCUSSION

RELIABILITY OF PLANNING AND CONSTRAINT MANAGEMENT

Analysis of Project X showed an average Percent Plan Complete (PPC) of 100% over the 6-week observation period, from week 47 to week 52, from the project's start date. Although Ballard (2000) states that PPC is a key indicator of workflow reliability and commitment, this study highlights an important nuance: a perfect PPC value does not necessarily indicate that a project is free of cumulative delays. As noted in the results, there is a deviation between the Plan and Actual S Curves before September 22, 2025, especially for the 9th-floor structure work. This aligns with the opinion of Asadian et al. (2023), who argue that PPC should be used not only as a final score but also as a diagnostic tool to identify fundamental barriers to continuous improvement.

The achievement of 100% PPC stability during the implementation phase is greatly influenced by effective management to prevent external and internal constraints, particularly on-site material availability and allocation. Brioso, et al. (2024) used BIM modeling at several stages, it helps subcontractors to better predict and allocate materials. The application of the Just-in-Time (JIT) method, facilitated by rigorous Lookahead Planning, successfully mitigated the risk of material shortages and storage limitations. This supports the Lean Construction mechanism for waste reduction through inventory and waiting time, as explained by Ballard (2000). By ensuring materials arrive exactly at the site when they are needed, the project team successfully separates workflows from upstream supply chain variability.

However, external constraints pose significant challenges, particularly regarding design approvals and owner-managed demolition works. These external factors emphasize the LPS's reliance on factors beyond the direct control of the "Last Planners", which demands a more integrated stakeholder management approach (Gehbauer, et al., 2007).

THE ROLE OF BIM 4D IN THE LAST PLANNER SYSTEM STAGE

This study strengthens and extends the findings of Bhatla and Leite (2012) regarding the interoperability of BIM 4D within the LPS framework. The integration of BIM 4D has been proven to improve decision-making and visualization in all five stages of the LPS hierarchy. At the macro level, BIM 4D facilitates the determination of milestones and the collaborative development of Phase Schedules. Consistent with the findings of Bayhan et al. (2021), the visualization of the master schedule enables stakeholders to set realistic commitments and optimize workflow strategies from the outset of the project cycle. This allows the team to visualize handoffs between subcontractors, thereby minimizing the friction that often occurs in traditional scheduling (Bhatla and Leite, 2012). Lookahead Planning, as studied by Bhatla and Leite (2012), confirms that the most critical value of BIM 4D lies in the Lookahead stage, especially for eliminating constraints and "make-ready" processes. In line with Schimanski et al. (2020), BIM 4D enables teams to virtually validate that the work for the next six weeks is free of spatial conflicts. By identifying clashes between utility systems and structural elements before execution, the team ensured that only "can-do" tasks were included in the weekly plan, contributing directly to the observed high PPC.

At the micro-level Weekly Work Planning stage, BIM 4D serves as a visual communication tool for weekly commitment sessions. Supporting the findings of Schimanski et al. (2021) and Etges et al. (2020), the 4D model helps communicate logistics, such as the movement of tower cranes and preparation areas, ensuring safety and logistics factors are integrated into daily workflows. At the Learning stage, BIM 4D facilitates Root Cause Analysis (RCA) by enabling teams to visualize the gap between planned and actual performance. As suggested by Schimanski et al. (2020), this visual feedback validates planning performance and accelerates the learning curve for future planning cycles.

CONCLUSIONS

This study systematically evaluated the effectiveness of the integration of the Last Planner System (LPS) with 4D Building Information Modeling (BIM) in mitigating delays and improving time performance in high-rise building construction projects. Through a case study approach to the work of the upper structure of Project X, this study compares the scheduling performance between the conventional LPS method and the LPS method supported by digital visualization. The findings highlight that incorporating 4D dynamic visualizations into the LPS framework has a significant impact on scheduling efficiency, planning reliability, and resource optimization in the field.

The application of the LPS method integrated with BIM 4D has been proven to improve workflow efficiency by allowing for the identification of idle time and the implementation of more aggressive but realistic parallel work strategies. The results of the analysis showed a substantial reduction in the duration of implementation, such as the work of the 8th floor structure could be completed in 23 days through a simulated plan, compared to 38 days in the actual implementation, resulting in a potential time reduction of 15 days. In addition, the reliability of the planning system was validated with an average Percent Plan Complete (PPC) achievement of 100% during the six weeks of observation, indicating that Navisworks' visualization was effective in helping project teams build valid and constraint-free work commitments.

The synergy between LPS and BIM 4D in this study also emphasizes support for Lean Construction mechanism, especially in the aspects of flow improvement and waste reduction. 4D visualization facilitates more transparent coordination between subcontractors, minimizes waiting time, and ensures Just-in-Time availability of materials. This transforms work patterns that were previously sequential and prone to delays into more dense, sustainable, and productive workflows.

While it provides significant benefits, this study has limitations on the use of Weekly Work Planning data that is still manual-based (analog), which may limit the integration of real-time data on a larger project scale. The focus of the research is also limited to the time dimension (4D) without taking into account the cost impact in depth. These limitations indicate the need for further development in the full digitization of LPS systems to support more comprehensive data management.

Future research is suggested to prioritize the development of frameworks that integrate more complete scheduling data, including Master Schedule, Phase Schedule, and Lookahead Planning into digital platforms. In addition, extending interoperability analysis to the cost dimension (BIM 5D) to conduct a cost-benefit analysis will provide a more holistic understanding of the economic impact of the application of this method. By adopting a more comprehensive digital approach, the integration of LPS and BIM can shift from just a visualization tool to the main instrument of sustainable production control.

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