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Analyzing the Relationship Between Last Planner System, BIM, and Risk Factors on Project Time Performance

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ABSTRACT: *Last Planner System (LPS) is widely used in construction projects, including road and bridge infrastructure projects. The implementation of LPS offers numerous benefits that can mitigate most causes of project delays. However, its implementation still faces obstacles caused by various risk factors, which reduce its effectiveness and affect project time performance.*

This study aims to analyze the relationship between the integration of LPS implementation, BIM and risk factors on project time performance, particularly in road and bridge infrastructure projects. This study employs a quantitative approach analyzed using Partial Least Squares Structural Equation Modeling (PLS-SEM). Data were collected through a structured questionnaire from 66 construction practitioners at a construction company in Indonesia. LPS was measured using a multidimensional system and process indicators; risk factors were represented by using dominant risk factor indicators; and BIM was measured based on its role in mitigating dominant risks. The results indicate that risk factors have a negative and significant influence on LPS implementation, while BIM indicates positive and significant effect on both LPS and project time performance. Furthermore, LPS implementation is found to have a positive and significant impact on time performance.

These findings highlight the importance of integrating lean construction practices, digital technologies, and risk management strategies to enhance planning reliability and improve project time performance. The study provides practical insights for construction stakeholders in optimizing project performance through the combined application of LPS, BIM, and risk management. This study contributes by providing an integrated empirical model combining LPS, BIM, and risk factors in infrastructure projects

KEYWORDS – *BIM, infrastructure projects, Last Planner System, dominan risk factors, time performance*

I. INTRODUCTION

The development of road and bridge infrastructure projects in Indonesia is important to support economic growth and improve the connectivity between regions. However, many projects still face challenges that affect project performance, including project delays and cost overruns. Construction project delays have become a global phenomenon, affecting developed and developing countries [1]. These delays are often caused by poor planning, slow decision-making, poor communication, resource constraints, and uncertainty during the construction process [2]. These conditions highlight the need for a more reliable planning and control systems in construction projects.

The Last Planner System (LPS), is part of lean construction, has been widely used as an effective approach to improve planning reliability and workflow. Previous studies have shown that LPS can enhance coordination, improve schedule adherence, and reduce variability in construction processes [3], [4]. Furthermore, LPS has been proven to reduce construction duration, improve stakeholders' communications, and help early identification of constraints [5] . These benefits indicate that LPS has strong potential to improve project time performance, particularly in complex infrastructure projects.

Despite of its advantages, the implementation of LPS in most of road and bridge project constructed by PT X, a construction company in Indonesia, still ineffective. Empirical evidence shows that LPS does not always significantly influence project performance due to inconsistent application and lack of proper implementation strategies [6] . Additionally, several challenges such as limited stakeholder participation, insufficient data availability, and weak coordination mechanisms continue to reduce its effectiveness [4]. These findings suggest that LPS implementation requires additional support mechanisms to achieve optimal results.

Recent studies show that integrating LPS with digital technologies such as Building Information Modeling (BIM) can help on improving project performance. BIM provides visualization, simulation, and data integration capabilities that support better planning and decision-making processes. Moreover, LPS has been shown to mitigate several causes of delays, especially those related to planning inefficiencies and resource constraints [5]. Current studies have not fully explored the integration of LPS, BIM, and risk factors within a unified analytical framework.

Based on the previous studies, a significant research gap can be identified. Most studies examine LPS, BIM, or risk factors separately, and the studies about their integrated effect on project time performance is still limited, especially using a quantitative structural modeling approach. There is also a lack of empirical studies in the context of infrastructure projects in developing countries, including Indonesia.

This research fills the gap by developing an integrated structural model that simultaneously examines the relationships between LPS implementation, risk factors, and BIM in enhancing project time performance. This research adopts a holistic approach by combining lean construction practices (LPS), digital technology (BIM), and risk management into an integrated framework and contributes to provide empirical evidence based on real project data and Partial Least Squares Structural Equation Modeling (PLS-SEM) analysis to capture the complex interactions among variables. The findings are expected to provide theoretical insights as well as practical implications for construction stakeholders in improving planning reliability and achieving better project results.

II. THEORETICAL BACKGROUND

2.1 Last Planner System

Last Planner System (LPS) is a systematic approach for production planning and control system to increase reliability, improve production performance, and create a predictable/smooth workflow in the face of high uncertainty in design and construction operations [7]. Last Planner System comprising four levels of planning processes with different chronological spans: master scheduling, phase scheduling, lookahead planning, and commitment planning [8].

In infrastructure projects, LPS has been shown to improve time performance, reduce construction duration, and enhance communication and transparency among project participants [4], [5].The Percent Plant Completed (PPC) is the most used metrics to measure production planning and reliability in LPS [9]. A PPC higher than 75%, were likely to obtain a lower schedule deviation and had a higher probability of success in time performance [10].

However, despite its benefits, the implementation of LPS still faces several challenges. These include lack of understanding of LPS principles, resistance to organizational change, limited stakeholder involvement, and ineffective communication among project teams [4], [11], [12], [13]. In addition, previous studies indicate that the effectiveness of LPS depends heavily on the consistency of its implementation and the commitment of project participants [6]

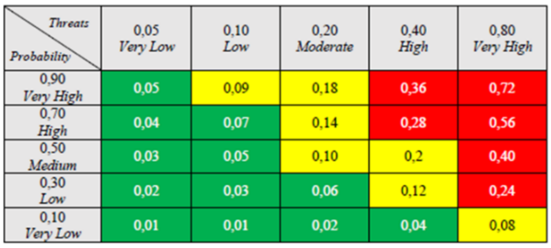
2.2 Project Time Performance

Project time performance is a critical measure of project success, reflecting the ability of a project to meet its planned schedule. It is commonly evaluated by comparing planned progress with actual progress during project execution. One widely used method for measuring time performance is Earned Value Method (EVM), a management methodology for integrating the project's scope, schedule, and resources, and for objectively measuring project performance and progress from project. [14]

Key indicators such as Schedule Variance (SV) and Schedule Performance Index (SPI) are commonly used to assess deviations from planned schedules and the efficiency of time utilization [15].

2.3 Risk Management

Project Risk Management includes the processes of conducting risk management planning, identification, analysis, response planning, response implementation, and monitoring risk on a project. The objectives of project risk management are to increase the probability and/or impact of positive risks and to decrease the probability and/or impact of negative risks, in order to optimize the chances of project success [14]. Perform Qualitative Risk Analysis assesses the priority of identified individual project risks using their probability of occurrence, the corresponding impact on project objectives if the risks occur, and other factors [14].



Threats *Probability*	0,05 *Very Low*	0,10 *Low*	0,20 *Moderate*	0,40 *High*	0,80 *Very High*
0,90 *Very High*	0,05	0,09	0,18	0,36	0,72
0,70 *High*	0,04	0,07	0,14	0,28	0,56
0,50 *Medium*	0,03	0,05	0,10	0,2	0,40
0,30 *Low*	0,02	0,03	0,06	0,12	0,24
0,10 *Very Low*	0,01	0,01	0,02	0,04	0,08

Figure 1. probability and impact matrix

2.4. Building Information Modeling (BIM)

Building Information Modeling (BIM) is a digital technology that supports the visualization, simulation, and integration of project information throughout the project lifecycle. The integration of BIM and LPS has significantly improve planning accuracy, resource allocation, and increased collaboration [16]

2.5 Conceptual Model

This study proposes a conceptual model that examines the relationships between LPS implementation, risk factors, and BIM in influencing project time performance. This integrated approach is expected to provide a more comprehensive understanding of how production planning and control systems, digital technologies, and risk management interact in construction projects.

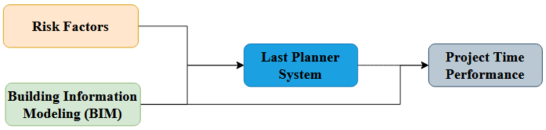


Figure 2. *model of relationships*

Based on the literature review, the hypothesis that is proposed in this study is integration between LPS, BIM, and risk factors can lead to improve project time performance.

III. METHOD

This study adopts a quantitative approach with an explanatory research design to analyze the relationships model between the implementation of the Last Planner System (LPS), Building Information Modeling (BIM), and dominant risk factors on project time performance.

Sample

The research sample consisted of construction practitioners at a construction company in Indonesia wit a total 66 respondents obtained through purposive sampling techniques to ensure that respondents have direct experience with the implementation of LPS, BIM, and project scheduling.

Data collection

Prior to questionnaire distribution, 41 indicators were validated by five construction (LPS and BIM) experts. The validation to experts process involved two main stages: *content validity* and *construct validity*. Next, a pilot survey to 10 respondents was conducted to ensure the questionnaire was easy to understand and aligned with the research objectives.

Data analysis

The next step, a statistical analysis was conducted using Partial Least Squares Structural Equation Modeling (PLS-SEM) through SmartPLS 4 software. PLS-SEM was chosen because it is suitable for analyzing complex models with multiple constructs and indicators, particularly in exploratory research with relatively small sample sizes and non-normal data distributions [17]. The analysis was conducted in two stages:

(1) testing the measurement model (outer model evaluation) includes tests of convergent validity, and construct reliability;
(2) testing discriminant validity using Heterotrait-Monotrait ratio (HTMT);
(3) testing the structural model (inner model evaluation) through analysis of path coefficients, coefficients of determination (R^2), and statistical significance based on bootstrapping.
The model results are used to answer research questions and test hypotheses on the relationship model between LPS, BIM, and risk factors variables on project time performance.

Instrument Development and Measurement
Based on literature review and expert validation that have been conducted, the dimensions and indicators that represent the variable with total 41 indicators, as follows:

Table 1. Research Variables, Dimensions and Indicators

Code	Variables, Dimensions and Indicators
X1	**Last Planner System (LPS) implementation**
X1.1	**Master Planning Phase**
X1.1.1	Developing a project charter and defining project objectives
X1.1.2	Identifying key milestones and sub-milestones
X1.1.3	Identifying initial project activities
X1.1.4	Creating a master schedule
X1.1.5	Identifying deliverables by phase
X1.2	**Phase Planning and Lookahead Planning Phase**
X1.2.1	Identify activities, durations, sequences, and resources
X1.2.2	Conduct collaborative pull planning
X1.2.3	Develop a phase schedule based on milestones
X1.2.4	Determine the work to be completed within 4–6 weeks
X1.2.5	Analyse the readiness of prerequisite work and resources using constraint analysis / identify constraints
X1.2.6	Create a list of constraints / constraint log
X1.2.7	Develop a schedule baseline and project production plan
X1.3	**Weekly Work Planning Phase**
X1.3.1	Develop weekly work plans
X1.3.2	Conduct daily coordination
X1.3.3	Track schedules using software (Primavera/MS Project)
X1.3.4	Integrate the LPS Board, Waste Register, and Constraint Log into project execution
X1.3	**Learning Phase**
X1.4.1	Calculate Percent Plan Completed (PPC)
X1.4.2	Identify Constraints
X1.4.3	Conduct a schedule variance analysis
X1.4.4	Report PPC results, the Constraint Log, and the variance analysis for the following week's planning
X1.4.5	Conduct a productivity analysis
X2	**Risk Factors**
X2.1.2	**Identifying key milestones and sub-milestones**
X2.1.2.2	Unidentified work in the initial planning
X2.2.1	**Identify activities, durations, sequences, and resources**
X2.2.1.1	Incomplete or unstructured detailed plans
X2.2.1.2	Limited resources and information
X2.2.4	**Determine the work to be completed within 4–6 weeks**
X2.2.4.1	Constraints not identified at the beginning phase
X2.3.1	**Develop weekly work plans**
X2.3.1.2	Ineffective coordination and lack of stakeholder participation
X2.4.3	**Conduct a schedule variance analysis**
X2.4.3.2	Ineffective coordination and lack of stakeholder participation

Code	Variables, Dimensions and Indicators
X3	**Building Information Modeling (BIM)**
X3.1	**3D BIM**
X3.1.1	BIM models are used to visualize the scope and key phases of a project
X3.1.2	3D BIM visualizations help ensure a shared understanding among project stakeholders
X3.1.3	Field teams access technical information through BIM models
X3.1.4	BIM models are used to identify project elements and activities
X3.1.5	BIM models are used to detect potential design conflicts
X3.1.6	BIM models help evaluate the technical readiness of the work
X3.1.7	BIM is used to document constraints during construction
X3.2	**4D BIM**
X3.2.1	BIM simulations are used to evaluate the sequence of project tasks
X3.2.2	BIM helps to understand the interrelationships and dependencies between activities
X3.2.3	BIM is used to identify constraints before work begins
X3.2.4	The BIM model is integrated with the project schedule to visualize the sequence and timing of work
X3.2.5	BIM is used to visualize deviations in project execution
Y	**Project Time Performance**
Y1.1	Schedule Variance (SV)
Y1.2	Schedule Performance Index (SPI)

Source : Processed Data, 2026

IV. RESULT

Survey consisting of 41 indicator statements was distributed to determine respondents' perceptions, resulting in a representative sample of 66 respondents. Respondents were classified into three profile categories: job position, working experience, and educational background.

Respondents' profiles

A total of 66 valid responses were collected from construction practitioners working in PT. X, a construction company in Indonesia. The respondents consist of site engineers, site engineer managers, and BIM engineers with different levels of experience and educational backgrounds.

Based on job position, most respondents are Site Managers (50%), followed by Site Engineers (36.36%) and BIM Engineers (13.64%). This indicates that most respondents are involved in project execution and decision-making process directly. Based on educational background, most of respondents had a bachelor's degree (89.39%) and the rest had a master's degree (10.61%).

Based on working experience in construction projects, most respondents have 5-10 years of working experience, indicating they have sufficient knowledge in project planning, LPS and BIM implementation. While the other respondents have over 10 years of working experience strengthening the reliability of the data.

Relationship model analysis

The relationship model between research variables was carried out using Partial least Squares – Structural Equation Modeling (PLS-SEM) to estimate causal-predictive relationships between LPS, BIM, and risk factors on project time performance. This model tests the influence of the integration variable of LPS (X1), risk factors (X2), and BIM (X3) on project time performance (Y), as in Fig. 3.

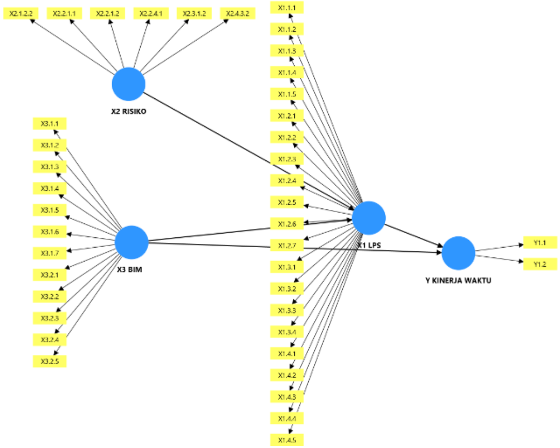


Figure 3. structural model diagram

Source: Processed SmartPLS 4 (2026)

The figure depicts a structural model consisting of 3 (three) independent variables, namely LPS, Risk, and BIM and 1 (one) dependent variable representing project time performance. This model is designed to test how the integration of variable X1 LPS, X2 risk, and X3 BIM affect project time performance.

Validity and reliability test

According to Ghozali (2015:69), convergent validity is acceptable when the loading factor value is greater than 0.7 for confirmatory research and the average variance extracted (AVE) value must be greater than 0.5. Based on Table 2. Below, the AVE value for all constructs are above 0.5, this indicates that the constructs are valid. Furthermore, the Cronbach's alpha value and the composite reliability value are greater than 0.7. Therefore, it can be concluded that all constructs are reliable.

Table 2. AVE, Cronbach's Alpha, and Composite Reliability Results

Variables	**Cronbach's alpha > 0,7**	**Composite reliability (rho_a) > 0,7**	**Composite reliability (rho_c) > 0,7**	**Average variance extracted (AVE) > 0,5**	**Results**
LPS	0.979	0.981	0.98	0.704	Valid
Risk	0.831	0.839	0.877	0.544	Valid
BIM	0.965	0.968	0.969	0.724	Valid
Project Time Performance	0.768	0.771	0.896	0.812	Valid

Source : PLS-SEM Processed Output, 2026

Discriminant Validity

Discriminant validity was examined using the Heterotrait-Monotrait ratio (HTMT). Table 3. below shows that HTMT value for all constructs range from 0.710 to 0.878 and below the recommended threshold of 0.90 indicating that discriminant validity is established for all constructs (Hair et al., 2017).

The results indicate that each construct is empirically distinct, although the relatively high HTMT value indicates a strong relationship between LPS, BIM, risk, and time performance, which is consistent with the conceptual model of this research. Although some HTMT values are relatively high, they remain within the acceptable threshold that indicating there are no critical issues regarding discriminant validity.

Table 3. HTMT Discriminant Validity Results

Variable	**LPS**	**Risk**	**BIM**	**Project Time Performance**
LPS				
Risk	0.748			
BIM	0.839	0.710		
Project Time Performance	0.854	0.778	0.878	

Source: PLS-SEM Processed Output, 2026

Structural model testing

The coefficient of determination or R-square (R^2) value of LPS construct is 73.2% and project time performance construct is 62.2%. The R-square value in the model indicates the level of ability of exogenous variables to explain variations in endogenous variables.

Table 4. R-Square Value

Variable	**R-square**	**R-square adjusted**
LPS	0.732	0.723
Project Time Performance	0.622	0.610

The analysis results show that LPS has an R-square value of 0.732 which means that the model can explain 73.2% of the variation in LPS implementation. Meanwhile, the project time performance obtained a R-square value of 0.622, which means the model can explain 62.2% of the variation in project time performance. Thus, all the variables have sufficient predictive power, because more than 60% of their variance can be explained by the independent variables in the model.

The factor with the largest path coefficient value is the most dominant factor.

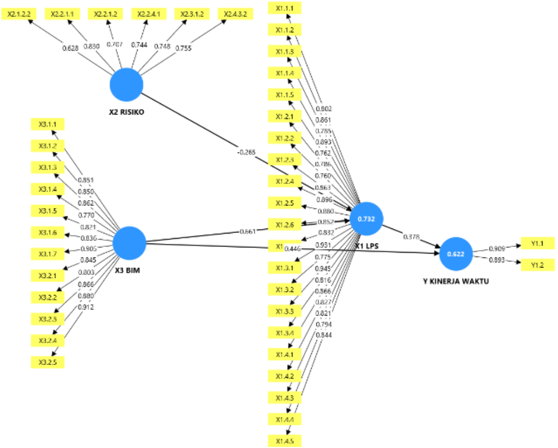


Figure 4. path coefficient results
Source: Processed SmartPLS 4 (2026)

PLS-SEM modeling results in Fig. 4 show the results of structural relationship that is evaluated using path coefficients. The path coefficient between Risk (X2) and LPS (X1) is β = -0.265, indicating a negative relationship. These results indicate that the higher level of risks will reduce the effectiveness of LPS implementation. The path coefficient between BIM (X3) and LPS (X1) is β = 0.661, indicating a strong positive relationship. This result indicates that BIM significantly improve the LPS implementation. The path coefficient between BIM (X3) and project time performance (Y) is β = 0.446, indicating a moderate positive relationship. This result indicates that BIM contributes to improve time performance project directly through visualization, scheduling, and coordination role. And the last, the path coefficient between LPS (X1) and project time performance (Y) is β = 0.378, indicating a positive relationship. This result indicates that effective LPS implementation will lead to improvement of project time performance by enhancing planning reliability and reducing variability in workflow.

Significance testing

The significance of the structural model was evaluated using bootstrapping procedure in PLS-SEM. The results were examined based on T-statistics and p-values to determine whether the data samples support the proposed hypothesis. A relationship is considered statistically significant when the value of t-statistic greater than 1.96 and the p-value is less than 0.05 at a 95% confidence level [17].

Table 5. Path Analysis Test Results

Relationship between variables	Original sample (O)	Sample mean (M)	Standard deviation (STDEV)	T-stat	P values	Results
X1 LPS -> Y Time Performance	0.378	0.392	0.147	2.561	0.010	Significant
X2 Risk -> X1 LPS	-0.265	-0.272	0.084	3.152	0.002	Significant
X3 BIM -> X1 LPS	0.661	0.655	0.080	8.248	0.000	Significant
X3 BIM -> Y Time Performance	0.446	0.429	0.157	2.844	0.004	Significant

Source : Processed Results of PLS-SEM (2026)

The relationship between research variables

a. Risk (X2) has an effect on LPS (X1) with path coefficient value of -0.265, which is acceptable with a significance level of 3.152 greater than 1.96.
b. BIM (X3) has an effect on LPS (X1) with path coefficient value of 0.661, which is acceptable with a significance level of 8.248 greater than 1.96.

c. BIM (X3) has an effect on project time performance (Y) with path coefficient value of 0.446, which is acceptable with a significance level of 2.844 greater than 1.96.
d. LPS (X1) has an effect on project time performance (Y) with path coefficient value of 0.378, which is acceptable with a significance level of 2.561 greater than 1.96.

V.DISCUSSION

This section discusses the research findings by connecting PLS-SEM results to theoretical background to answer the question of how the relationship model between LPS, BIM, and risk to project time performance.

Relationship between Risk on LPS

The findings show that risk has a negative effect on LPS, indicates that higher level of risks will reduce the effectiveness of LPS implementation. Unmitigated risks will disrupt planning processes, reduce workflow reliability, increase variability, and leading to poor planning.

Relationship between BIM on LPS

The findings show that BIM has a strong positive effect on LPS, indicates that BIM significantly improve the effectiveness of LPS implementation. BIM supports in mitigating risk and improve planning reliability through improved visualization, enhanced coordination, clash detection, and scheduling integration.

Relationship between BIM on Time Performance

The findings show that BIM also has a positive direct effect on time performance. This indicates that BIM has contribution on improving project time performance independently. These results can be explained by BIM ability to do 4D simulation, identify conflicts early, and support decision-making through visualization.

Relationship between LPS on Time Performance

The findings show that LPS has a positive effect on time performance. This result confirms that the implementation of LPS improves planning reliability and reduces variability in workflow, which improves project time performance. This finding supports previous studies that show the role of LPS implementation providing significant improvements in planning accuracy, resource allocation, collaboration, and continuous improvement [16].

Relationship between integrated LPS, BIM, and Risk on Time Performance

The findings of this research indicate that risk factors reduce the effectiveness of LPS implementation and mitigating risk through the support of BIM can improve the effectiveness of LPS implementation. BIM also directly improve time performance. These findings confirm that integrating LPS with BIM will effectively mitigating risk and can significantly enhance project time performance.

VI. CONCLUSION

This study provides a comprehensive analysis of the relationship model between Last Planner System (LPS), risk factors, and Building Information Modeling (BIM) in influencing the project time performance in road and bridge infrastructure projects.

The results show that LPS has positive and significant effect on time performance, confirming the previous studies about its role in improving coordination, planning accuracy and reduce variability ini workflow [3], [4], [5]. On the other hand, risk has negative and significant effect on LPS that indicates unmitigated risks can disrupts planning processes and reduce workflow reliability, which is consistent to the finding of previous studies that poor planning, lack of coordination, and uncertainty are the major causes of construction project delays [18].

While BIM plays an important role by strengthening LPS implementation through its support in mitigating dominant risk factors associated with its implementation. BIM provides enhanced visualization, coordination, and scheduling integration, which is consistent with previous studies that shows benefits of integrating BIM with LPS to improve project performance [5].

Contribution

1. One of the main advantages of this study is the development of integrated model combining LPS, BIM, and risk provides a more

comprehensive understanding of project performance compared to previous studies that evaluated these variables separately.

2. Provide empirical evidence that LPS improves project time performance, supporting the previous studies that LPS reduce delays and enhances planning reliability and workflow in construction projects [4],[5] and also shows that BIM strengthens LPS implementation, which aligns with previous studies about integration of BIM and LPS improve coordination and reduce variability [3].
3. Confirm that risk is a critical factor and has significant and negative effect on LPS implementation, that can affect the planning accuracy. These results is consistent with previous studies that identifying uncertainty, poor communication, and inadequate planning is the major causes of construction project delays [2].
4. The study also contributes methodologically by applying a structural modeling approach to capture the complex relationships among variables in construction projects.

Research Limitations

Despite its contribution, this study has several limitations. Datas were collected from a single company and limited to road and bridge infrastructure project which may limit the generalizability of the finding to other contexts. Furthermore, this study only focuses on time performance, whereas project success is also influenced by cost and quality performance [14].

Contribution to Future Research

Future research can extend this study by developing the integration of LPS, BIM, and risk management by adding new variables such as human resource competency and organizational culture to improve the explanatory power of the model. Second, the dimension of BIM can be expanded higher than 4D to advanced dimensions such as 5D BIM and 6D BIM, to enable a more comprehensive evaluation of its effect on project performance. Third, future studies may explore the effect of integration of the LPS-BIM-risk framework to other dimensions of project performance such as cost and quality. And last, to improve generalizability, future studies should examine proposed model across different types of construction projects, such as high-rise building, port infrastructure, dams, and EPC projects with different levels of complexity.

VII.Acknowledgements

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