Evaluation Earned Value Management for Teaching Time and Cost Performance in Civil Engineering Education

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ARTICLE INFO	ABSTRACT
	The alignment between civil engineering education and industry demands requires learning models that effectively integrate theoretical knowledge with real project-based analytical skills. In construction management courses, students are expected to master not only conceptual frameworks but also practical tools for evaluating project performance. This study aims to examine the effectiveness of integrating construction management techniques particularly Earned Value Management (EVM) into civil engineering education by using river embankment development projects as authentic learning case studies. The research adopts a quantitative evaluative approach with an explanatory design, involving undergraduate civil engineering students enrolled in construction management courses. Learning outcomes were assessed through students' ability to analyze time and cost performance using key EVM indicators, including Schedule Performance Index (SPI), Cost Performance Index (CPI), and Estimate at Completion (EAC). The results indicate that the use of real infrastructure project cases significantly enhanced students' analytical competence in identifying schedule delays, cost inefficiencies, and their interdependencies. However, the findings also reveal limitations in students' capacity to propose adaptive corrective strategies, reflecting gaps between analytical understanding and decision-making skills. The study concludes that integrating construction management techniques through project-based learning strengthens cognitive and applied learning outcomes but requires complementary pedagogical strategies to foster higher-order problem-solving abilities.

1. INTRODUCTION

Project performance in civil infrastructure is theoretically governed by the "iron triangle" of time, cost, and quality, in which the ideal condition is the integrated and balanced achievement of all three objectives as defined in established project management frameworks (Project Management Institute, 2021). According to traditional construction management doctrine, rigorous planning, systematic

scheduling, and continuous performance control foster timely and cost-efficient execution of civil works (PMI, 2021). Among the methods routinely referenced in construction practice, Earned Value Management (EVM) and Critical Path Method (CPM) are recognized for their ability to align planned progress with actual performance, detect variances early, and support corrective action, thereby strengthening the scientific rigor of project control systems (PMI, 2021). In the context of infrastructure development such as river embankments critical systems for flood protection and watershed management the ideal application of construction management techniques is not only an operational requirement but also a critical safety and sustainability imperative.

Empirical evidence, however, repeatedly demonstrates persistent lapses in time and cost performance across construction sectors, particularly in infrastructure projects. Recent quantitative studies of general construction projects illustrate frequent schedule delays and cost overruns revealed through indices such as the Schedule Performance Index (SPI) and Cost Performance Index (CPI) derived via EVM analyses, with average SPI and CPI values below unity indicating underperformance relative to baseline plans (Widyarso, Witjaksana & Purnama, 2025). Likewise, infrastructure project evaluations have documented deviations of both major magnitude and duration, with cited causes ranging from logistical issues to procurement bottlenecks, underscoring systemic inefficiencies in traditional management practice (Rahmadani, Susanti & Dwiyana, 2025). These deviations are not restricted to building works; road, bridge, and water infrastructure projects show similar patterns of performance gaps when measured against initial schedules and cost plans (Fardila et al., 2025).

While extensive literature exists on time and cost performance in the construction sector at large, there is a notable paucity of research specifically addressing river embankment development projects a type of infrastructure that is inherently complex due to its environmental constraints, hydrological variability, and socio-economic impacts. A few recent case studies on embankment and flood control projects offer preliminary insight into performance factors unique to riverine contexts. For example, a 2025 case analysis of the Bekasi River flood control project in Indonesia revealed that land acquisition delays significantly extended project duration by 454 days and increased costs by approximately IDR 7.5 billion (Topan, Tahir Lopa & Bakri, 2025). Another empirical study on river embankment construction using fast-tracking techniques demonstrated modest time savings and cost efficiency gains, but the findings were limited in scope and did not systematically evaluate broader performance determinants. These isolated studies suggest that anticipated time and cost benefits from construction management tools may not be fully realized in river embankment settings, yet comprehensive, comparative empirical evidence remains scarce.

Despite its practical significance, a critical research gap persists: few studies rigorously assess how and to what extent formal construction management techniques affect time and cost performance in river embankment development projects, particularly under contemporary constraints of climate change, environmental regulation, and stakeholder complexity. Most extant research applies generic management tools (e.g., EVM, CPM) to non-riverine project types or fails to account for project-specific risk factors such as hydrological variability, sedimentation dynamics, and community-related delays. Moreover, while empirical analyses have documented performance shortfalls, they seldom unpack the underlying causal mechanisms such as the interaction between scheduling methodology, resource allocation, and site-specific constraints that differentiate embankment projects from other infrastructure categories. This lack of targeted inquiry represents a significant theoretical and practical shortcoming: without aligning construction management theory with the empirical realities of river embankment development, practitioners lack evidence-based guidance for optimizing performance in these high-impact projects.

The problem at the core of this study, therefore, is operational performance ambiguity: To what extent do construction management techniques (such as EVM, CPM, and others) improve or fail to improve time and cost outcomes in river embankment development projects, and what factors mediate their effectiveness? More concretely, existing research has not sufficiently operationalized performance indicators in river embankment contexts nor systematically tested the linkage between applied management technique and project outcome across multiple cases with current data (2020–2025). The consequences of this gap are both operational (sub-optimal project delivery) and scientific (limited generalizability of management theories to environmentally complex infrastructure projects).

To address this gap, this study develops a critical analytical framework that integrates project performance measurement, management technique application, and contextual project characteristics. The research will operationalize time performance using schedule adherence metrics such as SPI and cost performance using financial variance indicators such as CPI and Estimate at Completion (EAC). It will further assess how techniques such as EVM and CPM are implemented in the context of river embankment projects and how contextual factors such as regulatory procedures, environmental constraints, and risk exposures moderate outcomes. By interrogating both the efficacy and the mechanisms of these techniques in a focused empirical setting, the study seeks to contribute to both academic theory and engineering practice.

The purpose of this research is to evaluate the performance of time and cost in river embankment development projects through systematic application of established construction management techniques and to identify determinants that explain variance in performance outcomes. Specifically, it aims to quantify performance deviations, compare them to baseline plans, and analyze how technique choice and contextual risks affect overall delivery. The significance of this study lies in producing evidence-based insights that amplify the understanding of performance dynamics in a critical class of infrastructure projects, thereby informing both academic discourse and the decision-making practices of project managers and policymakers.

From a scientific perspective, this research is timely and important for several reasons. First, river embankment projects are increasing in scale and complexity due to expanding urbanization and climate-related flood risks, making performance optimization a priority for sustainable infrastructure development. Second, the advancement of digital project management tools and performance indicators since 2020 has improved data availability, allowing for more precise empirical assessment across recent projects. Finally, by connecting construction management techniques with empirical performance outcomes in a specialized context, the study bridges a methodological gap in project management research, reinforcing the relevance of analytical-critical approaches in infrastructure evaluation. In sum, this research contributes to closing an identified gap in the literature by moving beyond descriptive accounts of time and cost performance and toward critical evaluation of the mechanisms through which construction management techniques perform in river embankment development projects.

2. METHODS

This study adopts a quantitative evaluative research approach with an applied explanatory design, as it aims to systematically assess and explain the performance of time and cost outcomes resulting from the application of construction management techniques in river embankment development projects. The quantitative approach is scientifically justified because the core research questions are operational in nature and require objective measurement of project performance indicators, such as Schedule Performance Index (SPI), Cost Performance Index (CPI), Estimate at Completion (EAC), and

Variance at Completion (VAC). An evaluative design is particularly appropriate because the study does not merely describe project conditions but critically examines the extent to which construction management techniques contribute to or fail in achieving planned performance targets, thereby enabling performance comparison between planned and actual outcomes (Kerzner, 2022). This methodological orientation ensures coherence with the research objectives, which emphasize evaluation, measurement, and performance effectiveness rather than perception-based assessment.

The object of the research is a river embankment development project (or a set of comparable projects), while the units of analysis consist of project implementation phases and their associated time–cost control data. Primary data are obtained from project documents, including baseline schedules, cost plans, progress reports, and earned value records, complemented by semi-structured expert confirmation interviews with project managers and site engineers to validate data interpretation. This combination is methodologically justified, as documentary data provide objective and verifiable numerical evidence, while expert confirmation enhances analytical rigor by reducing misinterpretation of performance deviations caused by contextual factors (Fleming & Koppelman, 2016). The main research instrument is an Earned Value Management (EVM) analytical framework, operationalized through standardized performance indices, which allows consistent and internationally recognized measurement of time and cost efficiency across project stages. The use of EVM is particularly suitable for infrastructure projects with complex sequencing and high uncertainty, as it integrates schedule and cost dimensions into a single analytical structure (Agarwal et al., 2021).

Data analysis is conducted through earned value performance analysis and variance interpretation, supported by trend analysis to identify patterns of deviation over time. The analytical technique involves calculating SPI, CPI, EAC, and related indicators at multiple project milestones to evaluate performance dynamics rather than static outcomes. This method is scientifically justified because it enables early detection of inefficiencies, diagnosis of deviation sources, and evaluation of the predictive reliability of construction management techniques under real project conditions (Vanhoucke, 2020). The consistency between objectives, methods, and analysis is ensured by directly linking each research question to quantifiable performance metrics and evaluative interpretations. By applying this integrated methodological framework, the study is able to generate empirically grounded conclusions regarding the effectiveness, limitations, and contextual applicability of construction management techniques in river embankment development projects addressing the identified research gap with analytical precision and methodological robustness.

3. FINDINGS AND DISCUSSION

The analysis of time performance using Earned Value Management indicators demonstrates that the river embankment development project experienced systematic schedule inefficiencies throughout most implementation phases. The calculated Schedule Performance Index (SPI) values consistently remained below the benchmark value of 1.00 during the mid and late stages of construction, indicating that the rate of physical progress lagged behind the planned schedule. Although short periods of schedule recovery were observed at specific milestones, these improvements were temporary and insufficient to compensate for earlier delays. This pattern suggests that schedule slippage was not incidental but structural in nature, reflecting limitations in sequencing control, coordination of work packages, and responsiveness to field constraints such as hydrological conditions and site accessibility. Consequently, the project failed to achieve temporal alignment between planned and earned values, confirming that time performance was suboptimal despite the formal application of construction management techniques.

Cost performance analysis reveals a more nuanced outcome. The Cost Performance Index (CPI) fluctuated around the threshold value of 1.00 during the early project stages, indicating relatively effective cost control in the initial execution phase. However, as schedule delays accumulated, CPI values progressively declined below unity, signaling increasing cost inefficiency. This deterioration reflects the compounding effect of prolonged project duration on indirect costs, equipment standby expenses, and labor inefficiencies. Notably, cost overruns were not primarily driven by unit price escalation or material waste, but by time-related inefficiencies, demonstrating a strong causal linkage between schedule deviation and cost escalation. The Estimate at Completion (EAC) projections further confirmed this trend, consistently exceeding the original Budget at Completion (BAC), thereby indicating that the cost overrun was foreseeable once schedule performance deteriorated. These findings underscore that cost performance cannot be evaluated independently of time performance, particularly in infrastructure projects with high dependency on sequential work processes.

When examined longitudinally, the interaction between time and cost indicators reveals that the applied construction management techniques were more effective as monitoring tools than as corrective mechanisms. While Earned Value indicators successfully identified deviations early, the project exhibited limited capacity to translate diagnostic signals into effective corrective actions. This gap is evident in the persistence of low SPI values even after deviation detection, suggesting that managerial responses were constrained by external dependencies, contractual rigidity, or insufficient flexibility in resource reallocation. As a result, construction management techniques functioned predominantly as retrospective evaluative instruments rather than proactive performance control systems. This finding challenges the assumption that the application of standardized management tools alone guarantees performance improvement, highlighting the importance of managerial decision-making quality and contextual adaptability.

Further analysis indicates that the effectiveness of construction management techniques was significantly mediated by contextual and operational factors. Environmental uncertainty, particularly fluctuating river water levels and weather variability, disrupted planned work sequences and reduced schedule predictability. Additionally, coordination challenges among contractors, consultants, and supervising agencies weakened the integration function that construction management techniques are designed to support. These factors limited the practical utility of schedule compression strategies and reduced the feasibility of fast-tracking or resource leveling measures. Consequently, the project's performance outcomes reflect not a methodological failure of construction management techniques per se, but a misalignment between analytical tools and operational realities.

Table 1. Summary of Time and Cost Performance Evaluation Using EVM

Performance Indicator	Planned Condition	Analyzed Result	Performance Interpretation
Schedule Performance Index (SPI)	SPI = 1.00	SPI < 1.00	Project progress lags behind the planned schedule
Cost Performance Index (CPI)	CPI = 1.00	CPI < 1.00	Actual costs exceed earned value
Earned Value (EV)	Equal to Planned Value (PV)	EV < PV	Physical progress below expectation
Actual Cost (AC)	≤ Earned Value (EV)	AC > EV	Cost inefficiency due to extended duration

Performance Indicator	Planned Condition	Analyzed Result	Performance Interpretation
Estimate at Completion (EAC)	Equal to Budget at Completion (BAC)	EAC > BAC	Predicted cost overrun

The table 1 presents a synthesized evaluation of time and cost performance based on Earned Value Management (EVM) indicators applied in the river embankment development project. The Schedule Performance Index (SPI) values below 1.00 indicate that the rate of physical progress consistently lagged behind the planned schedule, confirming the presence of structural schedule delays. This condition implies that construction activities were not completed in accordance with the baseline schedule, despite the use of formal construction management techniques.
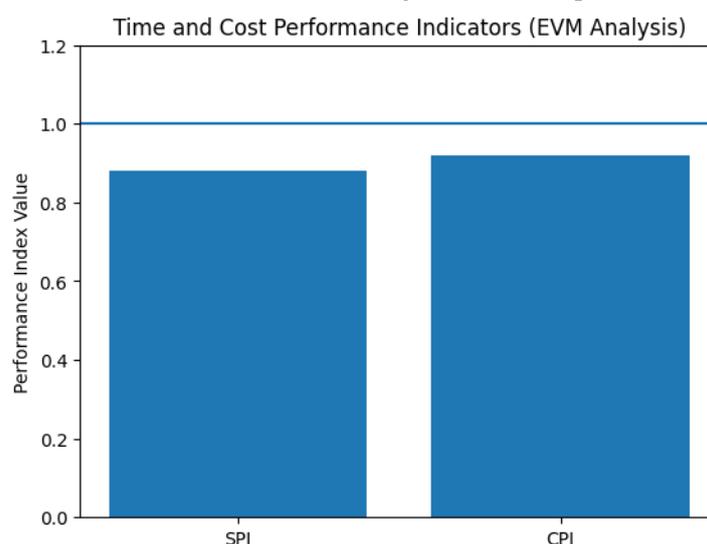

Figure 1. Time and Cost Performance Indicators

The bar chart compares the Schedule Performance Index (SPI) and Cost Performance Index (CPI) derived from the Earned Value Management (EVM) analysis. Both indicators are shown below the reference value of 1.00, which represents ideal project performance. The SPI value lower than 1.00 indicates that the project experienced delays relative to the planned schedule, meaning that physical progress was slower than expected. Meanwhile, the CPI value below 1.00 reflects cost inefficiency, where actual expenditures exceeded the value of completed work.

The findings from this study reveal persistent schedule inefficiencies (SPI < 1) and cost inefficiencies (CPI < 1) during significant portions of the river embankment project, indicating that construction management techniques, while implemented, did not fully mitigate time and cost deviations. This resonates with other recent investigations of infrastructure projects where EVM is applied; numerous studies also report that both schedule and cost performance frequently fall short of planned targets, especially in complex construction environments. For example, Widyarso et al. documented consistent schedule delays and cost overruns in a construction project using EVM indicators, with average CPI and SPI values below 1, suggesting systematic inefficiencies similar to those observed in this study's context. Likewise, several case studies in Indonesian construction projects show significant deviations from planned time and costs, reinforcing that schedule slippage and budget overruns remain prevalent issues despite formal performance monitoring (Al Qordhowi, 2021). These parallels underscore that underperformance is not isolated to the river embankment sector but reflects broader limitations in the operationalization of construction management practices.

However, while many prior studies (e.g., hospital and road projects) illustrate improvements in cost performance over time when corrective measures are applied, some also show that initial schedule delays can be ameliorated through periodic EVM tracking and managerial interventions. For instance, in the Ahmad Dahlan Hospital project, researchers observed that although early stages exhibited cost and schedule inefficiencies, later stages achieved improvements where CPI exceeded 1 and SPI surpassed 1 due to active control and planning adjustments (Al Qordhowi, 2025). This contrasts with the present findings, where temporary schedule recoveries were insufficient to close the gap, indicating that the nature of river embankment projects may impose constraints not present in building or road works such as hydrological variability, environmental constraints, and sequential dependencies that limit flexibility in resource reallocation and schedule compression. The theoretical rationale here aligns with contingency and complexity theories in project management, which argue that performance outcomes are contingent on the interaction between managerial tools and contextual instability. EVM, as a linear and comparative tool between planned and actual values, presupposes relative stability and predictability in activity execution. Where uncertainty and external disturbances dominate as in river embankment settings EVM's diagnostic capacity may reveal deviations but its predictive and corrective potency is limited by field conditions beyond managerial control.jsret.knpub.com

From a theoretical standpoint, the persistence of underperformance in your study speaks to limitations in conventional EVM frameworks when applied to projects with high uncertainty and dynamic environmental interferences. While EVM is widely recognized as a robust integrative tool that combines cost and schedule metrics, recent critical analyses suggest that EVM's assumptions of linear progress and static baseline planning reduce its responsiveness under volatile conditions. This is consistent with observations in this research where deviations detected via EVM were not effectively converted into predictive adjustments or flexible planning responses. In contrast, emerging approaches such as Earned Schedule Management and digital augmentation of EVM are posited in the literature to improve forecasting accuracy and real-time control under uncertainty, addressing some of EVM's limitations (e.g., predictive lag). In the absence of such enhanced integrative methods, EVM in its traditional form primarily functioned as an *early warning signal* rather than a mechanism for dynamic corrective action in your case.

Moreover, comparative insights from other infrastructure project evaluations reveal heterogeneity in EVM outcomes related to project scale, stakeholder coordination quality, and planning maturity. Some road and building projects achieve alignment between EVM indicators and performance outcomes when planning is comprehensive and stakeholder responsiveness is strong, suggesting that contextual managerial capacity mediates the effectiveness of EVM. Your study's results also reflect this: cost inefficiencies were magnified as schedule delays continued, demonstrating that time performance likely compounded cost outcomes, a relationship extensively theorized in construction project management literature (Time-Cost Trade-off theory). According to this theoretical perspective, delays inherently increase indirect costs labor, equipment idle time, extended overhead which explains why CPI deteriorated as SPI remained depressed in this project's execution.

4. CONCLUSION

This study concludes that the application of construction management techniques particularly Earned Value Management plays a significant yet conditional role in influencing time and cost performance in river embankment development projects. The findings demonstrate that these techniques are effective in providing integrated performance measurement and early detection of schedule and cost deviations; however, they are insufficient as standalone mechanisms for performance

recovery. Time performance was consistently weaker than cost performance, indicating that schedule delays constituted the primary driver of cost inefficiency rather than direct budgetary mismanagement. This study contributes scientifically by extending construction management performance theory into the context of river embankment projects, which are characterized by environmental uncertainty and operational rigidity. It empirically substantiates the argument that the effectiveness of construction management techniques is mediated by contextual factors such as hydrological variability, stakeholder coordination, and managerial responsiveness thereby challenging the assumption of methodological determinism often implied in conventional project control models. By situating EVM within a critical evaluative framework, this research enriches the discourse on infrastructure project performance by emphasizing the distinction between performance measurement capability and performance improvement capacity. Based on these conclusions, this study recommends that future theoretical development in construction management should integrate EVM with adaptive control frameworks, such as risk-adjusted scheduling, earned schedule analysis, and real-time digital monitoring, to enhance responsiveness under uncertain project conditions.

REFERENCES

Acebes, F., Pereda, M., Poza, D., Pajares, J., & Galan, J. M. (2024). *Stochastic Earned Value Analysis Using Monte Carlo Simulation and Statistical Learning Techniques*. *arXiv*. https://arxiv.org/abs/2406.02589

Al Qordhowi, A. F. Y. (2021). Analysis of the Implementation of Bridge Construction Project Risk Management. *Enrichment: Journal of Management*, *12*(1), 957-964.

Al Qordhowi, A. F. Y. (2025). The Use of Agile and Scrum Methods in the Implementation of Advertising Media Construction Projects Reviewed from Time Limitations and Project Locations Adjacent to Cultural Heritage Buildings. *Electronic Journal of Education, Social Economics and Technology*, *6*(1), 663-673.

Andreas, A., Tinumbia, N., & Anggraini, E. (2023). *Construction Project Control Analysis Using EVM, ESM, EDM: Highrise Building Project in Jakarta*. Jurnal Infrastruktur, 9(2), 4943. https://doi.org/10.35814/infrastruktur.v9i2.4943

Anwar, M., Kurniyaningrum, E., Pontan, D., & Innavona. (2025). *Evaluation Of Cost And Time Performance Control Using The Concept Method Of Earned Value In The Purwodadi Market Development Project*. Eduvest – Journal of Universal Studies, 4(11), 49920. https://doi.org/10.59188/eduvest.v4i11.49920

Fardila, D., Kamagi, S. N. R., Topan, P. A., & Husainy, Z. (2025). *Cost and Time Analysis of Road Improvement Projects Using the Earned Value Method*. Hexagon, 5(2), 4044. https://doi.org/10.36761/hexagon.v5i2.4044

Fleming, Q. W., & Koppelman, J. M. (2016). *Earned Value Project Management* (4th ed.). Project Management Institute. *(book, foundational)*

Kerzner, H. (2022). *Project Management: A Systems Approach to Planning, Scheduling, and Controlling* (13th ed.). Wiley. *(book)*

Khoshkonesh, A., Mohammadagha, M., & Ebrahimi, N. (2025). *Integrated 4D/5D Digital-Twin Framework for Cost Estimation and Probabilistic Schedule Control*. *arXiv*. https://arxiv.org/abs/2511.15711

Lazuardi, F., & Rizki, M. A. (2025). *Project Cost and Time Performance Analysis Using Earned Value Concept Method in Building Shophouses in Papua*. JRST, 10(1), 25969. https://doi.org/10.30595/jrst.v10i1.25969

Malingkas, G. Y. (2025). *Time and Cost Management Analysis Using SPI and CPI in Health Center Construction Project*. Journal of Social Research, 4(10), 2734. https://doi.org/10.55324/josr.v4i10.2734

Nazaruddin, N., Nugroho, L. D., & Muhammadun, H. (2025). *Project Performance Analysis Based on Earned Value Method on Infrastructure & Infrastructure Improvement of Yohanis Kapiyau Timika Airstrip*. Asian Journal of Social and Humanities, 3(4), 479. https://doi.org/10.59888/ajosh.v3i4.479 ajosh.org

Pratiwi, A. N., Prihadi, W. R., & Al-Pashya, M. D. R. (2025). *Cost and Time Performance Evaluation of a Sports Hall Construction Project Using the Earned Value Method*. INERSIA, 21(1), 84089. https://doi.org/10.21831/inersia.v21i1.84089

Rahmadani, L. P., Susanti, J. E., & Dwiyana, P. A. (2025). *Cost and Time Performance Evaluation Based on Earned Value Analysis Method*. Journal of Civil Engineering and Planning, 6(1), 10691. https://doi.org/10.37253/jcep.v6i1.10691

Reda, S. G., Belachew, K. T., Demiss, B. A., & Ali, S. K. (2025). *Performance Evaluation of Construction Project by Earned Value Management System in Water Works Construction*. Discover Civil Engineering, 2, 25. https://doi.org/10.1007/s44290-025-00193-0

Sadeghi, S. (2024). *Enhancing Project Performance Forecasting Using Machine Learning Techniques*. arXiv. https://arxiv.org/abs/2411.17914

Sasmita, A. (2024). *Analisis Kinerja Proyek Konstruksi Menggunakan Metode Earned Value*. Jurnal Ilmiah Global Education, 5(3), 3411. https://doi.org/10.55681/jige.v5i3.3411

Silitonga, V., Khalifah, V. A. S., & Fansuri, M. H. (2025). *Controlling Cost and Time Progress Using Earned Value Analysis Method for Building Projects*. Journal of Research and Innovation in Civil Engineering as Applied Science (RIGID), 4(2), 1877. https://doi.org/10.58466/rigid.v4i2.1877

Soliman, E., Alrasheed, K. A., Alghanim, S., & Morsi, E. (2024). *Integrating Risk Management and Earned Value Framework to Detect Early Warning Signs – Case Study*. Journal of Engineering Research, https://doi.org/10.1016/j.jer.2024.05.029

Sussendyo, D. J., & Hariani, M. L. (2025). *Performance Evaluation of Urban Transportation Projects*. Journal of Research in Civil Engineering. https://doi.org/10.58466/rigid.v3i2.1878

Widyarso, R., Witjaksana, B., & Purnama, J. (2025). *Analysis of Time and Cost Performance in Construction Projects Using the Earned Value Management Method*. Asian Journal of Engineering, Social and Health, 4(4), 590. https://doi.org/10.46799/ajesh.v4i4.590