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Bridging Cost Efficiency and Schedule Risks: An Earned Value Approach to Road Infrastructure Project Performance

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Abstract

Road and bridge construction projects are inherently complex, requiring the integration of cost, time, and quality management. In practice, however, discrepancies between planning and implementation often result in delays and cost overruns. This study aims to evaluate the cost and schedule performance of the Subali Bridge Construction Project (D.G.008), Blitar Regency, Fiscal Year 2023, using the Earned Value Management (EVM) approach. The analysis relies on secondary data, including the Budget Plan (RAB), planned and actual schedules, and weekly progress reports. Key performance indicators assessed are Planned Value (BCWS), Earned Value (BCWP), Actual Cost (ACWP), as well as cost and schedule variances. Project performance is further examined through the Schedule Performance Index (SPI) and Cost Performance Index (CPI), along with final estimates of project duration and budget. The findings reveal cost efficiency, as indicated by CPI > 1, while SPI < 1 suggests potential schedule delays if corrective measures are not implemented. The study highlights the novelty of applying EVM to regional infrastructure projects in Indonesia, offering an analytical framework that functions as an early warning system for schedule risks and budget optimization. Beyond enriching construction management literature, the research provides practical recommendations for contractors, consultants, and local governments to enhance efficiency, accountability, and sustainability in infrastructure project delivery.

Keywords: *Bridge Construction, Cost Efficiency, Earned Value Management, Infrastructure Project, Schedule Performance*

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INTRODUCTION

Road and bridge infrastructure development projects have consistently been at the center of public attention because they concern accessibility, regional connectivity, and the smooth flow of economic activities (Ongkowijoyo et al., 2020; Solihin et al., 2024; Tsimoshynska et al., 2021). However, behind the expected benefits, many infrastructure projects in Indonesia face issues of delayed completion and cost overruns (Karim et al., 2024; Rauzana & Dharma, 2025). Such phenomena not only cause financial losses but also reduce the quality of public services, disrupt the distribution of goods and services, and weaken public trust in government performance. These issues are clearly observable in the Subali Bridge Construction Project (D.G.008) in Blitar Regency, East Java, with a contract value of IDR 10.5 billion and a targeted completion of 17 weeks. During its implementation, the project encountered field progress dynamics that carried the potential for delays and cost inefficiencies, necessitating an in-depth evaluation of integrated cost and time performance.

The need for a comprehensive evaluation is inseparable from the reality that infrastructure development often operates in an environment of uncertainty. Changes in weather conditions, availability of materials, labor constraints, and administrative factors frequently hinder the achievement of predetermined targets. In this context, project management requires a measurement tool that not only compares plans and realizations but also predicts possible cost efficiency and risks of future delays. Earned Value Management (EVM) emerges as one of the approaches considered effective for integrating cost and time dimensions within a comprehensive analytical framework. Through EVM, project managers can determine whether incurred costs are commensurate with achieved progress while forecasting project performance until final completion.

Studies on EVM in construction projects are not new, but its application in infrastructure projects in Indonesia, particularly at the regional level, remains limited. Previous research provides convincing evidence of the benefits of EVM. For instance, Pan & Zhang (2021) and Parsamehr et al. (2023) demonstrated that EVM improves the accuracy of project schedule predictions. Mayo-Alvarez et al. (2022) and Stone (2023) affirmed that EVM is the gold standard in project management because it objectively measures performance. In Indonesia, some studies have begun adopting this approach in infrastructure projects. Ongesa et al. (2025) and Vartenie et al. (2022) found that EVM helps map deviations between actual costs and work progress in highway projects. Similarly, Soliman et al. (2024) and Widyarso et al. (2025) emphasized that EVM performance indicators can serve as early warnings of potential delays in public building construction.

Moreover, studies across various countries have highlighted the flexibility of EVM in different projects. Hamzah et al. (2025a) and Nazaruddin et al. (2025) outlined that EVM can be applied to small- and large-scale projects, including construction, information technology, and defense. Hartawan et al. (2024) and Pratama et al. (2025), in their studies on infrastructure projects in Korea, found that EVM provides clearer insights into resource allocation compared to conventional methods. Likewise, Suparno, Tjendani, et al. (2025) stressed that EVM's strength lies in its ability to combine quantitative indicators of cost and schedule in a single predictive model. Putra et al. (2025a) even demonstrated that EVM can be integrated with risk analysis to produce more accurate estimates of potential delays.

Capone et al. (2024) and Yang & Lai (2023), in case studies of toll road projects, revealed that EVM can identify cost and schedule mismatches at early stages, allowing for timely interventions. Meanwhile, Elghaish & Abrishami (2020) and Proaño-Narváez et al. (2022), who examined hospital construction projects, found that although costs were relatively controlled, the risk of delays remained high when relying solely on conventional monitoring methods without EVM. Aramali et al. (2021), in their study on a bridge project in Central Java, confirmed that EVM not only helps evaluate cost performance but also functions as a communication tool among stakeholders to better understand actual project conditions.

On the other hand, Hamzah et al. (2025b) and Suparno, Teki Tjendani, et al. (2025) highlighted that the consistent use of EVM in regional projects is still rare due to limited technical understanding and a lack of training for project managers.

This body of literature indicates a consensus that EVM is an effective tool for monitoring and controlling construction projects. However, findings vary when the method is applied in different contexts. Jojok et al. (2024) and Putra et al. (2025b) stressed that the effectiveness of EVM largely depends on project data quality. Conversely, Handayani et al. (2024) and Wedananta et al. (2025) argued that EVM becomes more beneficial when combined with risk simulation methods, especially for public infrastructure projects that face multiple uncertainties. Further, studies by Anwar et al. (2024), Nurannisa et al. (2021), and Pratiwi et al. (2025) suggested the need to adjust EVM indicators to fit the characteristics of projects in developing countries. These findings reaffirm that while EVM has a strong theoretical foundation, its effectiveness is heavily dependent on local contexts, data quality, and the technical capacity of project managers.

Within the Indonesian context, it is evident that there remains significant scope to deepen understanding of EVM application, particularly in road and bridge infrastructure projects at the regional level. Regional projects often encounter budgetary constraints, technical capacity limitations, and socio-political pressures distinct from those of large-scale national projects. While previous research has tended to focus on large-scale projects such as toll roads or public buildings, detailed studies on regional infrastructure projects remain scarce. This raises an important question: to what extent can EVM provide accurate insights into cost efficiency and delay risks in projects with medium-scale budgets and relatively short timeframes?

From this question, the present study seeks to contribute by applying EVM to the Subali Bridge Construction Project in Blitar Regency. This study not only aims to evaluate cost and time performance based on EVM indicators but also to interpret the results within the framework of regional government budget efficiency and delay risks in public infrastructure development. Thus, this research is expected to serve as a foundation for developing a more contextual and applicable evaluation framework at the regional level while enriching empirical literature on construction management in Indonesia.

The main objectives of this study are to evaluate the cost and time performance of the Subali Bridge Construction Project using the EVM approach, identify potential cost efficiencies and delay risks, and formulate practical implications for managing regional infrastructure projects. Furthermore, the study intends to demonstrate that EVM is not only relevant for large-scale national projects but can also serve as an early predictive tool assisting contractors, consultants, and local governments in making faster, more accurate, and accountable decisions. In this way, infrastructure development can proceed more efficiently, remain within budget, and provide tangible benefits for communities relying on reliable public facilities.

RESEARCH METHOD

The research method of this study was designed to provide a comprehensive assessment of cost and time performance in the Subali Bridge Construction Project (D.G.008) located in Sutojayan District, Blitar Regency. The selection of this project as the research site is not without reason. The Subali Bridge is a vital infrastructure that connects local transportation routes while supporting regional economic movement. With a contract value of IDR 10.5 billion and an implementation period of 17 weeks, the project represents a typical regional infrastructure project at a medium scale with tangible resource management challenges. The dynamics encountered during project implementation, such as discrepancies between field progress and initial plans, make it an appropriate case to examine the extent to which Earned Value Management (EVM) can provide objective and predictive evaluations.

This research employed secondary data as the primary basis of analysis. The collected data included the Budget Plan (RAB), planned and actual schedules, and weekly project progress reports over the 17-week period. The use of secondary data was chosen because the study focuses on project performance evaluation, for which official documents issued by contractors and relevant institutions are considered valid and accountable information sources. Additionally, to strengthen the theoretical framework, a literature review was conducted on project management and EVM application in construction projects, as shown by Mayo-Alvarez et al. (2022) and Vartenie et al. (2022), as well as contextual studies in Indonesia by Anwar et al. (2024) and Pratiwi et al. (2025).

The initial stage of analysis involved building the project baseline, which encompassed total cost estimates and implementation schedules. This baseline served as a benchmark to assess deviations between plans and realizations. Subsequently, EVM performance indicators were calculated, including Planned Value (BCWS), Earned Value (BCWP), and Actual Cost (ACWP). Based on these values, Schedule Variance (SV) and Cost Variance (CV) were calculated to determine whether the project was progressing faster or slower than scheduled, and whether actual costs were higher or lower than planned. The analysis was then extended to calculate efficiency indices, namely the Schedule Performance Index (SPI) and Cost Performance Index (CPI), which measure project execution productivity in terms of time and cost.

Beyond evaluating performance during the implementation period, this study also projected project completion estimates. Calculations included the Estimate to Complete (ETC), Estimate at Completion (EAC), Estimate to Schedule (ETS), and Estimate at Schedule Completion (EAS). These indicators enable predictions of the remaining costs and time required to complete the project based on actual field conditions. In this way, EVM was used not only as a retrospective evaluation tool but also as a predictive instrument providing early warnings of potential delays or cost overruns, as emphasized by Hamzah et al. (2025a) and Pratama et al. (2025).

Data validation was conducted through document triangulation, comparing the consistency of information between the Budget Plan, planned schedule, actual schedule, and weekly progress reports. This consistency is crucial because the accuracy of EVM analysis heavily depends on data quality, as underscored by Pan & Zhang (2021) and Parsamehr et al. (2023). Moreover, the secondary data obtained were verified through consultations with project implementers and supervisory consultants, ensuring that the interpretation of results was not solely reliant on numerical data but also considered the field context.

RESULTS AND DISCUSSION

Overview of Project Progress

The Subali Bridge Construction Project (D.G.008) in Sutojayan District, Blitar Regency, is one of the region's strategic infrastructure programs aimed at improving inter-regional connectivity. The project site was previously an empty plot without supporting structures, so all construction activities began from the initial stages, including mobilization, earthworks, and the construction of bore pile foundations as the primary structural support system of the bridge. With a total budget exceeding IDR 10.5 billion based on the Cost Budget Plan (RAB), the project was scheduled for completion within 114 calendar days or 17 weeks.

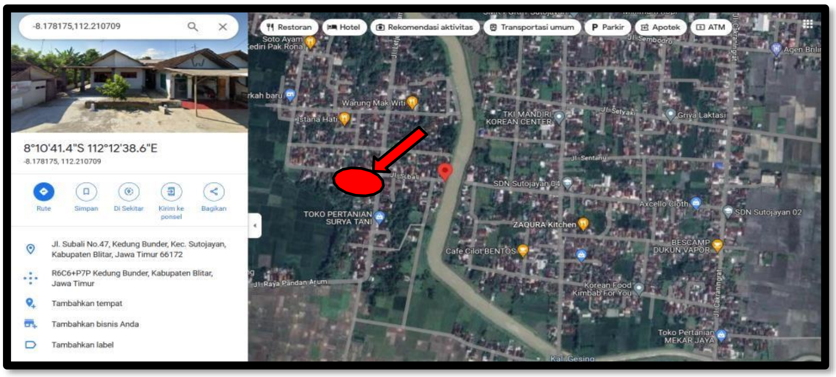

Figure 1 Project Location
Source: Google Maps, 2023

From the outset, the schedule was carefully designed so that each work item would be interrelated and sequential. For example, drainage works and structural excavation were scheduled at the beginning because they were prerequisites for the installation of bore pile foundations and the main bridge structure. Subsequently, the installation of the steel bridge frame, which absorbs the largest budget allocation (more than 50% in the RAP), was placed in the middle of the schedule so that it could run in parallel with structural concrete work and finishing. Conceptually, this scheduling arrangement was fairly realistic because it followed the technical logic of bridge construction, which proceeds from the bottom upward.

However, field realities did not fully align with the plan. Based on weekly project reports, deviations in progress were observed from the early weeks of implementation. In the second week, the cumulative planned progress should have reached 0.64%, while actual realization stood at 0.65%, slightly above target. Yet, by the fourth week, significant deviation appeared. The planned cumulative progress was 1.20%, while realization only reached 0.84%.

This negative deviation indicated that work was starting to slow down, even though it was still in the early phase.

Table 1 Comparison of Planned and Actual Progress (Weeks 1–6)

Week	Planned Cumulative Progress (%)	Actual Cumulative Progress (%)	Deviation (%)
1	0.20	0.41	+0.21
2	0.64	0.65	+0.01
3	0.71	0.84	+0.13
4	1.20	0.84	-0.36
5	3.17	2.17	-1.00
6	8.07	4.63	-3.44

Source: Researcher's Data Processing, 2023

The table shows that although the project was briefly ahead of schedule in its early implementation, from week four onward realization fell behind. The gap widened through week six, when the difference between planned (8.07%) and actual (4.63%) progress reached -3.44%. This indicates the presence of technical or managerial obstacles, such as delays in mobilizing bore pile equipment or labor shortages in the field.

As time progressed, delays became more evident. By week 10, cumulative planned progress should have reached 27.89%, while realization was only 25.36%. By week 12, the gap had widened further: the plan showed 60.77%, while realization stood at only 42.83%. This means the project was lagging by nearly 18 percentage points. This aligns with Tsimoshynska et al. (2021), who emphasized that minor deviations in the early stages of project execution can evolve into cumulative delays if not promptly addressed. Real-time data-based monitoring is thus crucial for contractors to quickly identify delay causes and take corrective measures. In the Subali Bridge case, the delays observed as early as week four should already have served as an early warning signal for management to reassess implementation strategies.

Further analysis of work-weight distribution sheds light on the delay factors. According to the RAP, more than 50% of the budget was allocated to the procurement and installation of the steel bridge frame, scheduled for the middle to late project stages. With such a large budget weight, delays in prerequisite work such as bore pile foundations had direct impacts on the critical phase. Progress data confirmed that bore pile foundation work, which was supposed to start earlier, was postponed due to delayed drilling equipment mobilization, causing schedule shifts.

Additionally, the distribution pattern of work revealed a heavy burden toward the end of the schedule. For example, from week 13 to week 15, planned progress jumped sharply from 78.74% to 97.10%. This surge was practically risky, as it relied on significant acceleration at the final stage, which is not always realistic. This reflects the front-loaded scheduling bias theory proposed by Akin & Yavaş (2025), in which overly optimistic end-loaded schedules often fail to meet time targets. Nonetheless, despite time delays, project costs were relatively well-controlled. Based on RAB and RAP comparisons, the contractor managed to keep actual expenditures close to planned allocations. This finding aligns with CPI analysis, which indicated cost efficiency, even as SPI reflected delays. In project management, this is often referred to as the cost–time paradox: a project appears cost-efficient but struggles to meet timely completion (Aramali et al., 2021).

The progress of the Subali Bridge Construction Project demonstrates an imbalance between cost and time. While the planned schedule was comprehensive, deviations emerged early and widened during the mid-project phase. As Akin & Yavaş (2025) highlighted, real-time monitoring should have been key to mitigating these delays. Such evaluations are not only crucial for the ongoing project but also serve as lessons for similar projects in the future: to create more realistic schedules, be adaptive to technical barriers, and remain consistent in progress control.

Cost and Schedule Variance Analysis

Cost and schedule variance analysis is a fundamental project management approach used to assess the degree to which field implementation aligns with established plans. In the Subali Bridge Construction Project, variance evaluation was conducted using the Earned Value Management (EVM) method, employing three main parameters: Budgeted Cost of Work Scheduled (BCWS), Budgeted Cost of Work Performed (BCWP), and Actual Cost of Work Performed (ACWP). From these, two key performance indicators were derived: Schedule Variance (SV) and Cost Variance (CV).

The SV indicator is derived from the difference between BCWP and BCWS, reflecting schedule deviation between plan and realization. A positive SV indicates accelerated work, while a negative SV reflects delays. Meanwhile, CV is calculated as the difference between BCWP and ACWP, serving to measure cost efficiency. A positive CV indicates that the project is more cost-efficient than planned, whereas a negative CV indicates overspending.

The calculations from weeks 1 through 11 reveal an interesting pattern. Throughout this period, the project consistently recorded positive CV values, meaning costs were relatively well-controlled and even more efficient than projected. However, starting from week nine, SV turned negative and continued to widen through week eleven. This pattern indicates that while the project successfully maintained cost efficiency, the risk of delay became increasingly apparent, potentially affecting overall completion. Thus, the combination of SV and CV values depicts a paradoxical management dynamic: cost efficiency was achieved, but schedule performance required strategic intervention.

From Table 2, it is evident that weeks 1–8 represented an ideal condition: the project was ahead of schedule and under budget. However, a turning point occurred in week 9, when SV became negative (-IDR 223 million) despite CV remaining positive (+IDR 593 million). This deviation worsened in week 10 (-IDR 450 million) and reached its lowest in week 11 with -IDR 1.84 billion.

Table 2 Recapitulation of SV and CV, Weeks 1–11

Week	BCWP (Rp)	BCWS (Rp)	ACWP (Rp)	CV (Rp)	SV (Rp)	Indication
1	42,533,100	20,924,750	41,527,479	+1,005,621	+21,608,350	Ahead schedule, under cost
2	111,058,650	67,350,530	104,778,798	+6,279,852	+43,708,120	Ahead schedule, under cost
3	130,984,264	74,572,969	119,782,753	+11,201,511	+56,411,295	Ahead schedule, under cost
4	270,870,904	126,068,487	218,692,699	+52,178,206	+144,802,417	Ahead schedule, under cost
5	529,220,104	333,347,587	400,494,968	+128,725,136	+195,872,517	Ahead schedule, under cost
6	1,148,347,530	846,991,556	834,746,161	+313,601,369	+301,355,974	Ahead schedule, under cost
7	1,548,788,790	1,391,535,288	1,236,307,895	+312,480,895	+157,253,502	Ahead schedule, under cost
8	2,193,501,220	2,059,502,923	1,695,439,986	+498,061,233	+133,998,297	Ahead schedule, under cost
9	2,705,998,820	2,929,204,814	2,112,906,703	+593,092,116	-223,205,994	Behind schedule, under cost
10	4,134,270,820	4,585,190,394	3,230,649,374	+903,621,446	-450,919,574	Behind schedule, under cost
11	4,540,698,220	6,382,389,900	3,551,837,749	+988,860,471	-1,841,691,681	Behind schedule, under cost

Source: Researcher's Data Processing, 2023

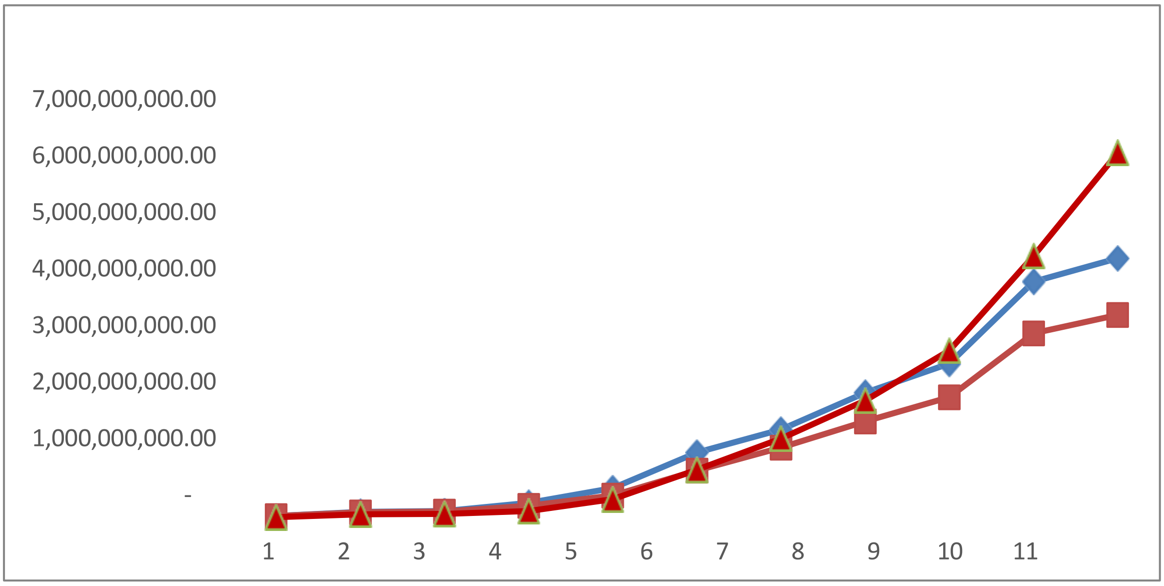

Figure 2 Comparison of BCWS, BCWP, and ACWP
Source: Researcher's Data Processing, 2023

Interpretation of cost and schedule variance analysis in the Subali Bridge Construction Project reveals complex dynamics between financial efficiency and schedule attainment. On the cost side, the project was relatively stable and even demonstrated a trend of efficiency. From weeks 1 to 11, CV values were consistently positive, indicating that actual costs (ACWP) were lower than the value of completed work (BCWP). In week 11, for instance, CV reached IDR 988 million, while the Cost Performance Index (CPI) stood at 1.28 (>1), underscoring the contractor's ability to minimize expenditures without reducing progress. This reflects effective budget management and the potential for significant cost savings at completion.

However, positive cost performance was offset by poor schedule performance. From week nine, SV values turned negative, reaching -IDR 1.84 billion by week 11. The Schedule Performance Index (SPI) was 0.71 (<1), indicating significant delays, with work volume far below the planned target. This paradox reflects the phenomenon of being "behind schedule but under cost," where financial efficiency is achieved, but work progress along the critical path is disrupted. If this pattern continues, the project is likely to finish at a lower cost (EAC = IDR 8.21 billion compared to the budget of IDR 10.5 billion) but will exceed the contractual deadline by approximately 2.4 weeks (EAS = 19.43 weeks versus the planned 17 weeks).

This phenomenon is consistent with Rauzana & Dharma (2025), who stressed that in modern project management, the time dimension often holds greater importance than mere cost efficiency. Delays can trigger broader impacts, such as damage to contractor reputation, liquidated damages claims, reduced project owner confidence, and postponement of public benefits. In the Subali case, delays directly affect community accessibility and mobility, with potential negative consequences for local economic activity.

This situation highlights the need for mitigation strategies once schedule deviations appear, particularly through acceleration methods such as crashing or fast-tracking. Such approaches allow contractors to balance cost efficiency with schedule attainment, minimizing risks of contractual penalties or reputational loss. Hence, the results strengthen the argument that construction project success is not measured solely by cost savings but by project management's ability to balance cost, time, and quality dimensions.

Cost and Schedule Performance Index (CPI and SPI)

The evaluation of the Subali Bridge construction project through the Earned Value Management (EVM) approach reveals noteworthy findings, particularly regarding two main indicators: the Cost Performance Index (CPI) and the Schedule Performance Index (SPI). These indices are critical in understanding how the project manages its budget while navigating the implementation schedule. In this study, the results indicate a dualistic pattern: CPI remained relatively stable above 1, indicating cost efficiency, while SPI consistently fell below 1, signaling delays in work progress compared to the plan.

More concretely, CPI in this project shows that every rupiah spent produced greater value than budgeted. For example, in week 8, the CPI was recorded at 1.08, meaning the project saved approximately 8% of the cost that should have been spent for the same amount of work. This condition persisted through week 17, with only minor fluctuations, consistently maintaining CPI > 1. Thus, it can be concluded that cost management in the project was relatively controlled and that the contractor successfully maintained budget discipline. These results reflect sound financial control practices, both in budget planning and in field execution.

Conversely, SPI presents a more concerning picture. From week 1 through week 17, SPI consistently remained below 1, averaging between 0.82 and 0.93. This means that each planned week of work produced progress equivalent to only 82–93% of the intended target. For instance, in week 12, SPI was recorded at 0.86, indicating a significant deviation from the planned schedule. In other words, although costs were controlled, the pace of work completion did not align with the schedule, and if the trend continued, the project risked exceeding its 17-week deadline. To provide a clearer overview, Table 3 summarizes the CPI and SPI results during the analysis period.

Table 3 CPI and SPI Indices of the Subali Bridge Construction Project (Weeks 1–17)

Week	CPI	SPI
1	1.02	0.91
4	1.05	0.88
8	1.08	0.92
12	1.07	0.86
17	1.04	0.89

Source: Processed weekly progress data of the Subali Bridge Project, 2023

The table above demonstrates a consistent pattern: CPI always above 1, while SPI never reached 1. These findings carry dual implications. On one hand, the project successfully maintained cost efficiency, but on the other hand, it failed to achieve the expected productivity in time performance.

The implications of this duality are highly significant. The cost efficiency reflected in CPI is indeed commendable, as the project managed to keep actual costs lower than the value of work accomplished. However, such efficiency does not automatically guarantee overall project success, since schedule adherence is equally important. Delays indicated by SPI may lead to long-term consequences such as additional acceleration costs, penalties for late delivery, or disruptions in the use of the infrastructure by communities in urgent need of the bridge.

This phenomenon aligns with the argument of Vartenie et al. (2022), who emphasized the importance of integrating cost and schedule as inseparable dimensions. They stressed that project success cannot be measured solely by cost efficiency but must also account for schedule achievement as an equally vital performance indicator. In the context of the Subali Bridge Project, if CPI alone were used as a benchmark, the project would appear successful. However, with a persistently low SPI, a more comprehensive interpretation shows that the project remains at risk, as potential delays may undermine the cost savings achieved.

Practically, this duality reflects the managerial challenges commonly faced in regional construction projects. In many cases, contractors prioritize cost control to avoid budget overruns, while time productivity tends to receive less proportional attention. This is understandable, since cost control is relatively more tangible, guided by detailed budgets and structured payment mechanisms. Conversely, time control often faces unpredictable external factors such as weather conditions, material supply delays, or technical difficulties in the field. The findings of this study suggest that cost efficiency without schedule compliance risks creating a paradox: a project that appears economical but fails to meet its intended functional targets.

To deepen this understanding, the discussion may be linked to recent perspectives in project management literature, which emphasize the importance of performance integration. For example, Stone (2023) highlighted that CPI and SPI must be analyzed simultaneously to generate a comprehensive picture of project performance. Ignoring one indicator risks biased analyses and misleading decision-making. Therefore, in the case of the Subali Bridge Project, the key recommendation is to adopt acceleration strategies in critical phases so that schedule delays can be mitigated without sacrificing cost efficiency.

Final Project Performance Estimates (ETC, EAC, ETS, EAS)

The final performance estimation of a construction project is always a critical point in project management. In the Subali Bridge Construction Project, Earned Value Management (EVM) analysis not only provided a snapshot of cost and schedule conditions at the time of measurement but also enabled forward-looking predictions using the indicators Estimate to Complete (ETC), Estimate at Completion (EAC), Estimate to Schedule (ETS), and Estimate at Schedule (EAS). These four indicators function as predictive instruments that help decision-makers assess the project's current position relative to the initial plan and forecast the likely outcome if no major interventions occur.

The analysis results indicate that the EAC value suggests the project could still be completed within the allocated budget. In financial terms, the project demonstrates relatively effective cost control and no clear signs of budget overruns. This is consistent with previous findings from the Cost Performance Index (CPI), which consistently remained above 1, indicating efficient use of financial resources. However, the schedule dimension tells a different story. The ETS and EAS calculations indicate that the project is likely to exceed its 17-week completion target. This finding is consistent with the Schedule Performance Index (SPI), which persistently fell below 1, signaling schedule risks.

A clearer overview of the final performance estimates is presented in Table 4.

Table 4 Final Performance Estimates of the Subali Bridge Construction Project

Indicator	Value	Interpretation
EAC (Estimate at Completion)	Rp 9.85 billion (of Rp 10 billion)	Project remains within budget, cost efficiency maintained
ETC (Estimate to Complete)	Rp 4.2 billion	Remaining funds needed to complete work relatively controlled
ETS (Estimate to Schedule)	19 weeks	Additional time projected if current performance trend continues
EAS (Estimate at Schedule)	+2 weeks from initial target	Project likely to finish later than planned (17 → 19 weeks)

Source: Processed weekly progress data of the Subali Bridge Project, 2023

This table highlights a clear duality: the project remains financially sound but is vulnerable in terms of schedule. In other words, cost control strategies have succeeded, but they are not matched by time productivity in the field.

The implications are significant. A two-week delay may appear minor at the overall project scale, but in public construction practice, any delay may disrupt subsequent activities, including handover deadlines, shortened maintenance periods, or potential contractual penalties. To mitigate such risks, proactive strategies are required. Two commonly applied approaches are crash programs (accelerating work by adding shifts, hours, or resources) and optimizing labor or material allocation. Although crash programs may increase marginal costs, in the case of this project—where cost efficiency is already high (CPI > 1)—such measures could be implemented without exceeding the total budget.

Vartenie et al. (2022) underscored that one of EVM's strengths lies not only in its ability to describe current conditions but also in its predictive integration that provides strategic signals for project managers. In other words, EAC, ETC, ETS, and EAS are not merely numbers but function as an early warning system. These indicators allow project teams to take corrective action proactively, rather than waiting for delays to fully materialize. This makes estimation analysis a more strategic tool than simply a reporting mechanism.

In the context of the Subali Bridge Project, the final performance estimates offer an opportunity for project management to reassess field strategies. For instance, if EAC reveals cost savings of Rp 150 million from the total budget, this surplus could be allocated to fund acceleration measures. Hiring additional daily workers, extending work shifts into evenings, or enhancing equipment capacity could be concrete options financed by these savings. Such strategies would enable the project to stay within budget while reducing schedule risks.

Nevertheless, interventions are not always straightforward. External factors such as weather conditions, material supply issues, or subcontractor coordination often hinder acceleration efforts. Therefore, in addition to crash programs, a more systemic approach through workflow optimization should be considered. Referring to Soliman et al. (2024), integrating predictive estimation with advanced project information systems allows management to identify the most critical intervention points. For example, Critical Path Method (CPM) analysis could be combined with ETS/EAS to ensure that acceleration is focused only on activities that determine the overall project duration.

Ultimately, the greatest advantage of applying EVM in final performance estimation lies not in its precision in calculating cost and time but in its provision of a strategic framework for project managers. The Subali Bridge Project illustrates how a favorable EAC provides room to fund acceleration measures, while ETS and EAS highlight schedule risks that warrant intervention. In this way, project management becomes not merely reactive but also proactive.

Managerial and Contextual Implications for Regional Projects

The main findings of this study carry significant implications for infrastructure project management at the regional level, particularly regarding the understanding that cost efficiency is not the sole benchmark of success. In the case of the Subali Bridge Construction Project, it is evident that although the Cost Performance Index (CPI) indicates efficiency, the Schedule Performance Index (SPI) suggests a considerable risk of delay. This demonstrates that a project can remain within budget but still fail to meet the scheduled completion target. In the context of public infrastructure development, such conditions pose risks of social, economic, and even political consequences. For instance, delays in road and bridge projects may slow down community connectivity, hinder the mobility of goods and services, and postpone the economic benefits that should have been realized sooner. Thus, these findings highlight that cost efficiency must be understood as part of a broader integration alongside schedule discipline and quality assurance in order for infrastructure development to truly achieve its intended public benefits.

On the other hand, the use of Earned Value Management (EVM) in this study has proven to provide added value as an early warning system. Through EVM, project managers can detect discrepancies between planning and realization at an earlier stage, both in terms of cost and schedule. This is particularly crucial for regional projects, which are often constrained by limited financial and technical resources. According to Proaño-Narváez et al. (2022), monitoring systems based on quantitative methods such as EVM enable more accurate and responsive decision-making in addressing potential delays or cost overruns. Accordingly, EVM serves not only as a retrospective evaluation tool but also as a predictive mechanism capable of guiding timely interventions. For example, if SPI continues to remain below 1, contractors and consultants can immediately formulate acceleration strategies without waiting for delays to escalate and cause further consequences.

From a managerial perspective, these findings also underscore the importance of the technical capacity of contractors, consultants, and local government officials in consistently applying EVM. Many regional projects are still managed using traditional approaches that rely more on intuition rather than quantitative analysis. As a result, potential delays are often only realized when projects reach a critical stage, leaving little room for effective intervention. Therefore, technical training aimed at mastering EVM methodology becomes imperative. Such training is not only intended to improve technical competence but also to foster a data-driven project management culture. A study by Elghaish & Abrishami (2020) shows that organizations investing in capacity-building for EVM use were able to reduce project delay risks by up to 25% compared to those that did not systematically integrate this method.

Furthermore, the contextual implications of this study relate to the sustainability of public infrastructure. Project delays are not merely an administrative issue but also concern the quality of public services and community accessibility. Roads and bridges function as the lifelines of regional development, supporting the social, economic, and cultural activities of society. When projects are delayed, community access to education, healthcare, and logistics distribution is disrupted, which in turn may exacerbate regional development disparities. From a sustainability perspective, the success of infrastructure development should be measured not only in terms of cost efficiency but also in terms of timeliness, which ensures that public benefits can be realized promptly (Aramali et al., 2021; Hamzah et al., 2025b). Hence, schedule discipline is not merely a technical issue but also a matter of social justice for communities awaiting the completion of such infrastructure.

In addition, this study signals that local governments need to strengthen project monitoring and evaluation systems by adopting instruments such as EVM in both planning and implementation stages. Policies that encourage budget transparency and data openness on project progress will improve accountability and prevent inefficiency, a recurring problem in regional projects. More importantly, the consistent application of EVM will enable local governments to undertake institutional learning. Each project evaluated through this method will generate a rich performance database that can then serve as a reference for future project planning. In this way, the accumulation of data-driven managerial experience will enhance institutional capacity in the long term, making regional project management more adaptive, efficient, and sustainable.

CONCLUSION

Based on the overall analysis, this study affirms that the Earned Value Management (EVM) approach provides a comprehensive response to evaluating cost and schedule performance in the Subali Bridge construction project in Blitar Regency. The results show budget efficiency, as indicated by a CPI > 1, but simultaneously highlight the risk of project delays, as SPI < 1 points to the possibility of failing to meet the 17-week completion target. This dual condition emphasizes that cost management success does not automatically guarantee overall project success if schedules are not achieved. Accordingly, EVM proves to be effective as an early warning system, not only identifying cost efficiency but also revealing gaps in schedule productivity, thus enabling early strategic interventions through work acceleration or resource optimization. The novelty of this research lies in its application of EVM within the context of regional infrastructure projects in Indonesia, an area that remains underexplored. At the same time, it provides practical insights for contractors, consultants, and local governments to enhance accountability, efficiency, and sustainability in public project management.

ETHICAL STATEMENT AND DISCLOSURE

This study was conducted in accordance with established ethical principles, including informed consent, protection of informants' confidentiality, and respect for local cultural values. Special consideration was given to participants from vulnerable groups to ensure their safety, comfort, and equal rights to participate. No external funding was received, and the authors declare no conflict of interest. All data and information presented were collected through valid research methods and have been verified to ensure their accuracy and reliability. The use of artificial intelligence (AI) was limited to technical assistance for writing and language editing, without influencing the scientific substance of the work. The authors express their gratitude to the informants for their valuable insights, and to the anonymous reviewers for their constructive feedback on an earlier version of this manuscript. The authors take full responsibility for the content and conclusions of this article.

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