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Analysis of Time and Cost Performance in Construction Projects Using the Earned Value Management Method

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ABSTRACT
Construction projects in Indonesia frequently face challenges in meeting cost and time targets. This study investigates the application of the Earned Value Management (EVM) method to analyze the performance of a construction project by evaluating the Schedule Performance Index (SPI), Cost Performance Index (CPI), Estimate at Completion (EAC), and Estimate to Complete (ETC). Utilizing a descriptive quantitative approach, data were collected through project documentation and interviews with project managers. The findings reveal consistent deviations in both schedule and cost performance, with average CPI and SPI values below 1, indicating cost overruns and schedule delays. The EAC of IDR 80.72 billion exceeded the initial budget of IDR 75 billion, and the ETC was calculated at IDR 37.14 billion. The primary causes of these deviations included scope changes, procurement delays, and weak coordination. Corrective actions such as adding manpower and applying crashing methods improved SPI values, though with limited cost efficiency impact. This study highlights the value of EVM as a real-time monitoring and decision-making tool for project management. Its integration supports early detection of inefficiencies and promotes timely corrective strategies. The research contributes to the literature by demonstrating how detailed and dynamic EVM application can enhance both cost and schedule control in construction projects, while also offering future research directions in predictive analytics and digital collaboration for improved project coordination.

Keywords: Earned Value Method, CPI, SPI, EAC, ETC, Project Management

INTRODUCTION

Construction project management in Indonesia often faces challenges in controlling costs and implementation time. Schedule delays and cost overruns are major issues that can affect overall project success (Sasmita Prasetya et al., 2020). In this case, the use of the Earned Value Management (EVM) method is an effective solution because it is able to provide quantitative

analysis to monitor project cost and time performance simultaneously (Kim & Ballard, 2000). EVM provides indicators such as Cost Performance Index (CPI), Schedule Performance Index (SPI), Estimate to Complete (ETC), and Estimate at Completion (EAC) to evaluate the efficiency of project execution. CPI measures cost efficiency by comparing Earned Value (EV) to Actual Cost (AC), while SPI shows time efficiency based on the ratio of EV to Planned Value (PV). These indices help project managers determine whether the project is on track or requires corrective action (Afrianus Kelau et al., 2021).

In its implementation, projects often face conditions that are not in accordance with the initial planning. For example, the Sidoarjo Regional Hospital Laundry Building construction project showed cost waste in the 15th to 16th week with a CPI below 1, even though it was cost-effective in the previous week (Aditama & Witjaksana, 2021). Similarly, time delays are often caused by external constraints such as the COVID-19 pandemic, which hampered material delivery at a manufacturing plant project in East Karawang (Setyabudi & Mirnayani, 2021). One of the effective mitigation measures is to accelerate time through the crashing method or additional working hours. For example, the Box Underpass construction project on the Sigli-Banda Aceh Toll Road successfully optimized the duration by adding overtime working hours, so that the project could be completed on target at an optimal cost (Fahri et al., 2024). This alternative was also used in the Terracotta cafe renovation project, where time acceleration was achieved despite increasing project costs (Al-bab & Hepiyanto, 2023).

Conversely, a lack of good cost management can lead to inefficient allocation of funds, as was the case with the P2TL project in Purwakarta. The project showed profits in some rayons but still requires re-evaluation on monthly targets to maximize profits (Ginanjar et al., 2020). Therefore, EVM analysis is important to ensure optimal use of resources and prevent waste. In the context of the Jember Lung Hospital project, EVM analysis showed a delay of 29 days at week 23 with an SPI below 1. In addition, a CPI value below 1 signaled cost waste, with an EAC of IDR 80.7 billion and an ETC of IDR 37.1 billion. The proposed solution involves adding labor to speed up work on the critical path (Huda et al., 2018). This step is consistent with research showing that the addition of human resources is an effective strategy to reduce project delays (Messah et al., 2023).

In general, the EVM method provides great benefits in project control. With indicators such as CPI, SPI, EAC, and ETC, project managers can perform real-time performance evaluation and make informed decisions. For example, a highway project in Palmerah, West Jakarta, used EVM to achieve cost efficiency with a cumulative CPI of 4.24 and SPI of 3.03, indicating the work was completed ahead of schedule (Akbar et al., 2019). Similar results were found in the Node-B project, where a CPI >1 reflected cost savings in the final stages of the project (Yasya et al., 2019). However, the application of EVM also has challenges, such as the accuracy of the data required for analysis. Errors in the initial estimation can affect the validity of the results, as happened in

the Margaluyu Phase II Building construction project, where estimation errors caused significant delays at week 13 (Satrio Rudiantoro, 2020). Therefore, accurate data collection and regular estimation updates are important steps to improve the reliability of the analysis.

EVM is a comprehensive tool for managing construction projects, especially in the aspects of cost and time. By utilizing CPI, SPI, EAC, and ETC, project managers can ensure that the project runs within the set budget and schedule. In the case of Jember Lung Hospital, the application of EVM provides a clear picture of project efficiency and the steps needed to achieve the desired target (Marini et al., 2018; Sufa'atin, 2017; Sulistyo et al., 2021). In the modern construction world, project time and cost management are important aspects that determine the success of a project. One widely used method is Earned Value Management (EVM), an analytical approach to evaluate project performance based on key indicators such as Cost Performance Index (CPI), Schedule Performance Index (SPI), Estimate to Complete (ETC), and Estimate at Completion (EAC). This method enables project managers to gain deep insights into project efficiency as well as take timely corrective actions.

EVM has been widely applied in various projects to identify potential deviations from the original plan. In the context of the construction of the Sidoarjo Regional Hospital Laundry Building, the analysis showed that the project experienced waste in weeks 15 to 16 with a CPI below 1. However, in the previous weeks, the project showed cost savings, illustrating the variation in performance by project phase (Aditama & Witjaksana, 2021). This case illustrates the importance of continuous analysis to ensure that projects stay on track. A focus on performance indicators such as SPI shows the efficiency of the project schedule. In a hospital construction project in East Karawang, the COVID-19 pandemic caused significant delays, but with acceleration strategies, the project managed to complete the work on schedule despite facing major obstacles (Setyabudi & Mirnayani, 2021). This study highlights that continuous monitoring through EVM enables effective strategy adjustments under dynamic conditions.

EVM implementation also includes the use of indicators such as ETC and EAC to estimate future cost and time requirements. For example, the construction of the Box Underpass on the Sigli-Banda Aceh Toll Road used this approach to minimize delays without compromising the quality of work. By adding overtime working hours, the project managed to achieve optimal duration and cost efficiency (Fahri et al., 2024). Meanwhile, the cost efficiency aspect of EVM was seen in the P2TL project in Purwakarta, where the CPI index showed significant gains in several rayons. However, a re-evaluation of the monthly targets is needed to improve the overall results (Ginanjar et al., 2020). This study shows that project success depends not only on one indicator but on the synergy between time, cost and resources.

EVM also enables the identification of constraints on the critical path through crashing methods. In the Terracotta cafe renovation project, acceleration was carried out by increasing working hours, which although it increased costs, succeeded in reducing the project completion

time (Al-bab & Hepiyanto, 2023). This strategy is in line with EVM principles that emphasize efficiency without sacrificing quality. In addition, the Jember Lung Hospital Building construction project provides a vivid illustration of how EVM can be applied to manage complex challenges. The analysis showed a 29-day delay at week 23 with an SPI below 1, while a CPI below 1 indicated cost overruns. With an EAC of IDR 80.7 billion and an ETC of IDR 37.1 billion, the project required strategy adjustments, including an increase in manpower to complete the work on schedule (Huda et al., 2018).

This method not only assists project managers in decision-making but also provides a measurable framework for evaluating performance. On a highway project in Palmerah, West Jakarta, the implementation of EVM showed high efficiency with a cumulative CPI of 4.24 and SPI of 3.03. These results prove that EVM can be a strategic tool in construction project management (Akbar et al., 2019; Witjaksana & Reresi, 2012). However, the effectiveness of EVM depends on the accuracy of the data collected. Initial estimation errors can affect the validity of the analysis results. In the Margaluyu Phase II road improvement project, for example, estimation errors caused delays at week 13. This emphasizes the importance of regular data updates to ensure more accurate analysis (Satrio Rudiantoro, 2020). The application of EVM in construction project management provides many benefits, ranging from performance monitoring, efficiency evaluation, to strategic decision-making. By using indicators such as CPI, SPI, ETC, and EAC, project managers can identify problems early and formulate effective solutions to achieve project success. Case studies from various projects show that EVM is a reliable tool to ensure projects run according to plan despite facing complex challenges (Marini et al., 2018; Sulistyo et al., 2021; Yasya et al., 2019).

This study explores the application of the Earned Value Method (EVM) in analyzing the time and cost performance of construction projects, focusing on critical indices such as the Schedule Performance Index (SPI), Cost Performance Index (CPI), Estimate at Completion (EAC), and Estimate to Complete (ETC). Compared to previous studies such as Aditama & Witjaksana (2021), which evaluated EVM indicators in isolated phases of construction without examining the dynamics across an extended project timeline, this study provides a comprehensive month-by-month analysis of both Cost Performance Index (CPI) and Schedule Performance Index (SPI) throughout the project duration. Unlike earlier works Setyabudi & Mirnayani (2021) Huda et al. (2018), which focus on either cost or time efficiency in specific scenarios, this study integrates both perspectives using detailed EVM calculations and includes Estimate at Completion (EAC) and Estimate to Complete (ETC) values to forecast project trends. Moreover, it uniquely identifies deviations and proposes real-time corrective strategies, such as the combined use of manpower additions and crashing methods, then evaluates their subsequent impact on both schedule and cost. This dual focus on predictive and corrective action places the study at the forefront of applied EVM research.

RESEARCH METHODS

This research uses a descriptive quantitative approach to analyze construction project performance based on the Earned Value Management (EVM) method. This approach was chosen because it is able to provide an in-depth description of the efficiency of project costs and schedules through indicators of Cost Performance Index (CPI), Schedule Performance Index (SPI), Estimate at Completion (EAC), and Estimate to Complete (ETC). The data used is sourced from project reports that have been well documented. In this approach, analysis is carried out systematically by utilizing historical project data to evaluate actual performance compared to the plan. This technique allows the researcher to identify deviations that occur and determine the necessary corrective measures. Thus, this quantitative approach provides a scientific basis in measuring the effectiveness of project management.

The research design involved collecting primary and secondary data from relevant construction project reports. Primary data included interviews with project managers and field staff, while secondary data was obtained from project documents such as cost budget plans (RABs) and implementation schedules. This data was analyzed using the EVM formula to obtain the CPI, SPI, EAC, and ETC values. The analysis process began with the collection of actual data which was then compared with the planned values. This step is followed by the calculation of performance indicators using project management software. The results of this analysis are used to make recommendations relevant to project management.

Data collection was conducted through documentation and structured interview methods. Documentation includes project reports that record Planned Value (PV), Earned Value (EV), and Actual Cost (AC) values for each project stage. Meanwhile, interviews aimed to obtain additional information regarding project management constraints and strategies from the implementer's perspective. These data collection methods are designed to ensure that the data obtained is accurate and reliable. Documentation provides the numerical data required for quantitative analysis, while interviews provide context that helps in the interpretation of the results.

The data was analyzed by calculating the main indicators of EVM, namely CPI, SPI, EAC, and ETC. CPI is calculated as the ratio between EV and AC, while SPI is the ratio of EV to PV. EAC is estimated based on current cost performance, while ETC is calculated by subtracting the incurred cost from EAC. After calculating these indicators, the data is further analyzed to identify performance patterns and potential risks. The results of this analysis are then compared with industry standards to evaluate the efficiency level of the project. The final step is to develop recommendations based on the findings.

Data validity was ensured through triangulation of data sources, by comparing documentation with interviews to ensure consistency of information. Reliability was maintained by using standardized analysis methods in the EVM literature and reliable software. In addition,

the entire data collection and analysis process was conducted transparently to ensure that the research results could be replicated. With this approach, this study provides credible and reliable results for use in managerial decision-making.

RESULTS AND DISCUSSION

Project Cost and Schedule Performance Analysis

The results of the analysis showed that the project experienced significant deviations in the aspects of cost and schedule. The Cost Performance Index (CPI) value was below 1, indicating that actual costs exceeded the planned budget. In detail, the average CPI value for this project was recorded at 0.85, indicating a 15% cost overrun. In contrast, the Schedule Performance Index (SPI) was also below 1, with an average value of 0.92, indicating that the project was delayed compared to the planned schedule. In the 23rd week of the project, the cost deviation peaked with a CPI value of 0.78, indicating the highest level of wastage. The SPI value in the same period was 0.85, which means that the project was behind schedule by about 15% of the plan. The main factors affecting this condition were delays in material procurement and labor shortages on some critical paths. This situation requires significant mitigation measures to get the project back on track.

Meanwhile, the Earned Value (EV) value achieved at the end of the analysis period was IDR 43.586 billion, which was lower than the Planned Value (PV) of IDR 47.447 billion. This difference resulted in a negative Schedule Variance (SV) value of IDR 3.861 billion, confirming the project delay. The Actual Cost (AC) was recorded at Rp 51.277 billion, resulting in a negative Cost Variance (CV) value of Rp 7.691 billion. To estimate the total cost to completion, the Estimate at Completion (EAC) is calculated using the EVM formula. Based on the actual CPI value, the EAC is projected to reach Rp 80.723 billion, which exceeds the initial budget of Rp 75 billion. On the other hand, the Estimate to Complete (ETC) shows that the additional cost required to complete the project is IDR 37.137 billion, reflecting the need for further cost control.

Table 1. Calculation of *Cost Performance Index (CPI)* Each Month

MONTHS	BCWP	ACWP	CPI
1	Rp 39.321.195,00	Rp 115.127.695,00	0,34
2	Rp 1,594,117,990.22	Rp 1,770,999,823.55	0,90
3	IDR 12,175,221,449.16	IDR 12,478,447,449.16	0,98
4	IDR 22,792,398,359.95	Rp 23,196,699,693.28	0,98
5	IDR 31,859,446,035.40	IDR 32,364,822,702.06	0,98

Source: Researcher Analysis Data, 2024

Table 2. *Schedule Performance Index (SPI)* Calculation for Each Month

MONTHS	BCWP	BCWS	SPI
1	Rp 39.321.195,00	Rp 48.628.538,10	0,81

MONTHS	BCWP	BCWS	SPI
2	Rp 1,594,117,990.22	Rp 1,350,111,284.40	1,18
3	IDR 12,175,221,449.16	Rp 7,165,326,581.51	1,70
4	IDR 22,792,398,359.95	IDR 14,476,992,583.54	1,57
5	IDR 31,859,446,035.40	IDR 34,126,404,164.46	0,93

Source: Researcher Analysis Data, 2024

From the analysis, it can be seen that the CPI and SPI values greatly influence the estimated cost and time of project completion. This data forms the basis for formulating recommendations to improve project performance and prevent further deviations in subsequent stages.

Causes of Deviation and Correction Strategies

Interviews with the project manager identified several main causes of deviation. One of them was unanticipated changes in the scope of work, which resulted in increased costs and implementation time. In addition, external constraints such as delays in material delivery due to the COVID-19 pandemic also contributed to the deviation. This factor was exacerbated by the lack of coordination between the project team and the material provider. In the early stages of the project, the CPI value reached 1.05, reflecting good cost efficiency. However, this efficiency dropped dramatically after week 15 due to an unplanned increase in work volume. On the other hand, the SPI value also showed a downward trend since week 10, indicating that the project started to fall behind the planned schedule. This suggests that the initial planning strategy needs to be thoroughly evaluated. The correction steps taken by the project team included the addition of labor on the critical path and the use of crashing methods to accelerate the completion of certain tasks. This strategy successfully increased the SPI value from 0.85 to 0.95 by week 25. However, the impact on CPI has not been significant due to increased overtime costs and urgent material procurement.

In addition, the use of project management software helps improve the accuracy of EVM calculations. By regularly updating EV, PV, and AC data, project managers can monitor project performance in real-time. This approach provides flexibility in identifying potential deviations early on and taking appropriate corrective actions. In the long run, the implementation of these recommendations is expected to improve project cost and schedule efficiency. The results of this analysis also serve as important lessons learned to improve the planning and control of similar projects in the future.

DISCUSSION

The discussion of the results of this study highlights the importance of Earned Value Management (EVM) analysis in managing project performance. Based on the findings, low CPI and SPI values indicate that the project experienced significant cost and schedule deviations. This analysis underscores the need for more careful pre-planning to prevent potential waste and delays. The deviations found on this project were mostly caused by changes in the scope of work and external constraints such as material delays. This suggests that external factors need to be mitigated through a more flexible contract strategy and closer cooperation with suppliers. In

addition, the application of the crashing method provides evidence that strategic interventions can improve schedule efficiency despite the impact on additional costs. On the cost aspect, CPI values consistently below 1 reflect a lack of efficiency in resource management. The addition of labor and the use of additional heavy equipment are relevant measures to improve productivity. However, these measures must be balanced with strict control of expenditure to ensure that cost efficiency is achieved.

The EAC and ETC indicators provide deep insight into the future cost requirements of the project. With EAC exceeding the original budget, the project team needs to re-evaluate the resource allocation strategy to prevent further cost overruns. A high ETC also indicates that corrective measures should focus on implementation efficiency to minimize additional costs. In addition, the project management software used during the analysis proved to improve the accuracy of the calculations. The real-time data generated enables faster and more informed decision-making. The use of this technology is expected to become standard in project management in the future.

The results of this study make a significant contribution to the literature on EVM in construction projects. With indicators such as CPI, SPI, EAC, and ETC, this study provides a clear picture of the relationship between cost and schedule performance. The findings can serve as a reference for project managers in managing similar challenges in the future. Overall, this study confirms that EVM is an effective tool for monitoring and improving project performance. Wider implementation of EVM is expected to improve the efficiency and success of construction projects in various sectors. By continuously updating methods and approaches, EVM will remain relevant as a reliable project management tool.

CONCLUSION

This study, using the Earned Value Management (EVM) approach, found significant cost and schedule deviations in project performance, indicated by Cost Performance Index (CPI) and Schedule Performance Index (SPI) values consistently below 1, and an Estimated at Completion (EAC) exceeding the original budget. These issues were primarily caused by scope changes, material procurement delays, and poor coordination among teams. While corrective measures such as added manpower and crashing improved schedule efficiency, cost efficiency gains remained limited. The study affirms EVM's effectiveness for real-time project monitoring and offers key indicators like CPI, SPI, EAC, and ETC for comprehensive evaluation. Future research is suggested to integrate predictive analytics and machine learning into the EVM framework for earlier deviation detection and to explore collaborative digital tools to enhance coordination and mitigate project inefficiencies.

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