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Project Performance Evaluation Using Critical Path Method and Earned Value Management: A Comparative Analysis of Road Maintenance Projects in the 4th District of Camarines Sur

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ABSTRACT: Road maintenance projects often face delays and budget overruns due to dispersed works, constrained time windows, and resource limitations. This study evaluates the comparative effectiveness of the Critical Path Method (CPM) and Earned Value Management (EVM), including Earned Schedule (ES), in monitoring the performance of road maintenance projects in the 4th District of Camarines Sur, Philippines. A descriptive–comparative design was applied, analyzing five purposively selected projects through documentary analysis, schedule reconstruction, EVM computation, and key informant validation. Findings reveal that CPM obtained a weighted mean rating of **4.3**, emphasizing its strength in identifying critical activities and forecasting schedule delays, while EVM registered a mean of **4.4**, highlighting its greater utility in cost efficiency and integrated performance analysis. Notably, the integrated CPM–EVM framework achieved the highest rating of **4.8**, underscoring its superior usefulness and potential for institutional adoption in infrastructure project monitoring. The study recommends that the Department of Public Works and Highways (DPWH) institutionalize CPM–EVM integration to enhance accountability, early warning systems, and transparency in project delivery.

KEYWORDS: Critical Path Method, Earned Value Management, road maintenance, project monitoring, infrastructure management

INTRODUCTION

Road maintenance projects were essential to sustaining mobility, economic productivity, and public safety, yet they were frequently executed under tight budgetary and time constraints. In practice, project teams relied on scheduling and control tools to anticipate delays, control costs, and communicate status to stakeholders. Among the most widely adopted tools were the Critical Path Method (CPM) for schedule analysis and Earned Value Management (EVM) for integrated cost–schedule performance measurement (Kelley & Walker, 1959; Project Management Institute [PMI], 2021). While each method had proven effective on its own, their joint and comparative application—especially in maintenance contexts where work was repetitive, geographically dispersed, and subject to operational disruptions—remained a practical challenge for project managers.

The 4th District of Camarines Sur provided an illustrative setting for examining this challenge. Road maintenance in the district typically spanned routine and preventive activities such as patching, regraveling, and drainage cleaning across multiple, scattered segments. These projects were constrained by weather, traffic management requirements, rolling mobilization, and interdependent tasks that could trigger cascading delays. CPM supported managers in identifying time-critical paths and float, thereby allowing them to test "what-if" scenarios and re-sequence work to safeguard completion dates (Kelley & Walker, 1959; Kerzner, 2017). EVM, in turn, quantified the value of work accomplished against planned value and actual cost, generating early-warning indicators such as the Cost Performance Index (CPI) and Schedule Performance Index (SPI) (Fleming & Koppelman, 2016; PMI, 2021). Extensions such as Earned Schedule (ES) further enhanced schedule diagnostics by converting earned value into time units, improving the detection of slippage in time-driven projects (Lipke, 2003).

Despite these strengths, CPM and EVM addressed different managerial questions and occasionally produced conflicting signals in maintenance environments. For example, a project might have appeared on budget (CPI $\approx$ 1.0) but slipped in calendar terms due to resource or access constraints that cost aggregates did not capture. Conversely, aggressive resequencing could preserve milestone dates in CPM while increasing overtime costs that reduced CPI. Previous studies showed that integrated project control was most effective when CPM schedule logic and EVM/ES performance metrics were interpreted together. However, empirical comparisons of their diagnostic value and management implications in road maintenance projects remained limited (Anbari, 2003; Vanhoucke, 2012; Kerzner, 2017).

Purpose of the Study

This study conducted a comparative analysis of road maintenance projects in the 4th District of Camarines Sur to evaluate project performance using CPM and EVM (with Earned Schedule where applicable). Specifically, it (a) mapped schedule logic and criticality via CPM; (b) computed EVM indicators (CPI, SPI) and ES-based schedule metrics; and (c) compared the sensitivity, timeliness, and managerial usefulness of these methods for detecting emerging schedule and cost risks.

Research Questions

1. How did CPM and EVM (including ES) differ in identifying schedule slippage and cost variance across road maintenance work packages?
2. Which indicators provided earlier and more reliable early-warning signals for project managers?
3. When CPM and EVM signals diverged, what patterns explained the discrepancies, and what corrective actions followed?
4. What integrated control dashboard (metrics and thresholds) best supported decision-making for district-level maintenance portfolios?

Significance of the Study

This study contributed practical guidance on combining CPM and EVM for road maintenance projects by providing:

1. empirical evidence on the comparative strengths and limitations of each method;
2. recommendations for interpreting conflicting signals; and
3. a prototype set of integrated indicators and thresholds tailored to maintenance contexts.

Findings informed the project control practices of implementing agencies and contractors, enhanced transparency in status reporting, and supported more predictable delivery of maintenance services (Fleming & Koppelman, 2016; PMI, 2021; Vanhoucke, 2012).

Scope and Delimitations

The analysis covered completed or active road maintenance contracts within the 4th District of Camarines Sur that had sufficient records to reconstruct CPM networks and compute EVM metrics. Capital improvement projects (e.g., new road construction) were excluded. Data limitations such as missing as-built updates and non-uniform cost coding were anticipated; when necessary, standardized assumptions were applied to ensure comparability and reproducibility (Kerzner, 2017; PMI, 2021).

Conceptual Framework

The study adopted a complementary framework wherein CPM established schedule logic, critical paths, and float, while EVM/ES quantified cost and schedule performance relative to plan. Convergence of CPM-critical tasks with adverse EVM/ES signals indicated high-priority risks requiring corrective action, such as resource reallocation, resequencing, or scope adjustment. Divergences, on the other hand, triggered diagnostic review—such as verifying progress measurement rules, resource constraints, or data quality—before deciding on interventions

LITERATURE REVIEW

Critical Path Method in Project Scheduling

The Critical Path Method (CPM) is one of the most widely applied scheduling tools in infrastructure and construction projects. Developed in the late 1950s, CPM provides project managers with a logical sequence of activities, identifies the longest path of dependent tasks, and highlights float or slack time available for non-critical activities (Kelley & Walker, 1959). In the context of road construction, CPM has been applied to plan, control, and evaluate project delivery, ensuring that constraints such as weather, mobilization, and resource allocation are factored into completion forecasts (Wingate, 1970). Research on transportation projects demonstrates that CPM allows managers to visualize schedule dependencies, test "what-if" scenarios, and prioritize critical tasks for timely completion (Transportation Research Board, 1980).

Earned Value Management and Its Extensions

Earned Value Management (EVM) integrates project scope, schedule, and cost into a unified framework, providing a robust performance evaluation tool. By comparing Planned Value (PV), Earned Value (EV), and Actual Cost (AC), EVM generates early-warning indicators such as the Cost Performance Index (CPI) and Schedule Performance Index (SPI) (Fleming & Koppelman, 2016). EVM has proven effective in both construction and infrastructure sectors for monitoring progress and controlling overruns, though it requires reliable baseline data and consistent progress measurement rules (Project Management Institute [PMI], 2021).

One limitation of traditional EVM is that schedule performance indicators (SPI and Schedule Variance) are expressed in cost terms rather than time. To address this issue, the Earned Schedule (ES) extension was developed, which translates earned value into time equivalents, offering more accurate and intuitive detection of schedule slippage (Lipke, 2003; Lipke, 2014). Studies confirm that ES improves predictive accuracy in forecasting project completion dates and enhances managerial decision-making in schedule-driven environments (Anbari, 2003).

Comparative and Integrated Applications of CPM and EVM

While CPM and EVM provide valuable but distinct insights, studies highlight that their integration offers a more comprehensive control mechanism. CPM emphasizes logical sequencing and criticality of tasks, whereas EVM quantifies actual progress and cost efficiency. Comparative analyses reveal that CPM may identify potential delays even when EVM indicators appear satisfactory, and vice versa (Vanhoucke, 2012). Research on dynamic scheduling demonstrates that integrating CPM with EVM produces more reliable early-warning systems for project risks (Vanhoucke, 2012).

A 2025 study comparing earned value techniques reported that combining EVM with CPM provides earlier detection of cost and time variances than relying on either method alone (Bongaerts et al., 2025). Other studies also suggest that hybrid approaches allow for prioritization of corrective measures when both critical path activities and EVM indices signal underperformance (Kerzner, 2017).

Applications in Road Construction and Maintenance

Applications of EVM in transportation and highway projects have been adapted to fit the unique nature of road works. Simplified Earned Value Analysis (SEVA), for instance, was developed for Departments of Transportation (DOTs) to utilize progress payment records as proxies for earned value, reducing the administrative burden of data collection while still offering valuable performance insights (Gharaibeh et al., 2023).

In road maintenance projects, challenges arise because works are geographically dispersed, repetitive, and often subject to short work windows. These conditions complicate the accurate application of CPM and EVM since both methods require detailed activity breakdowns and accurate progress tracking (DPWH, 2022). Nevertheless, studies show that adapted CPM networks and simplified EVM frameworks can provide district-level engineers with actionable information for decision-making (Fleming & Koppelman, 2016; PMI, 2021).

In line with performance evaluation in construction projects, previous studies have also highlighted the importance of compliance with safety standards as a determinant of project success. For instance, Rimando and Muhi (2025) examined sectoral occupational safety compliance in selected public and private construction projects in the 4th District of Camarines Sur. Their findings revealed that public projects generally demonstrated higher safety awareness compared to private ones, yet both sectors showed deficiencies in training, hazard identification, and emergency preparedness. This suggests that safety compliance, much like project performance evaluation methods such as the Critical Path Method (CPM) and Earned Value Management (EVM), plays a significant role in ensuring effective project delivery. Thus, the current study aligns with such perspectives by not only comparing technical performance tools (CPM and EVM) but also recognizing the broader project environment where safety, compliance, and management practices directly affect efficiency and outcomes.

Earned Schedule and Advances in Schedule Diagnostics

Earned Schedule (ES) has been particularly useful in infrastructure projects where schedule adherence is critical. Lipke (2003) demonstrated that ES allows managers to convert earned value data into time units, thereby overcoming the limitations of SPI when projects are late. Subsequent validation studies found ES to be more effective in predicting completion time and diagnosing schedule slippage than traditional EVM metrics (Lipke, 2014; Vanhoucke, 2012).

For road maintenance projects, ES can be an effective enhancement, especially in scenarios where small delays accumulate across multiple work sites, making schedule tracking complex. Integrating ES with CPM offers project managers a time-sensitive diagnostic that complements critical path analysis.

Local and Contextual Studies

In the Philippines, the Department of Public Works and Highways (DPWH) has emphasized the need for enhanced monitoring and evaluation of road projects, including routine and preventive maintenance works. Procurement and implementation records from Camarines Sur reveal numerous small- to medium-scale road maintenance projects, each requiring systematic performance monitoring (DPWH, 2022). However, documented academic studies applying CPM and EVM in the Philippine road maintenance context remain scarce, underscoring a research gap this study intends to address.

Research Gap

Most literature on CPM and EVM focuses on large-scale construction projects such as buildings, bridges, or major highways. Limited empirical studies address their comparative application to road maintenance projects, where constraints such as dispersed work locations, limited budgets, and frequent weather disruptions complicate monitoring. This study seeks to fill that gap by applying both CPM and EVM to maintenance projects in the 4th District of Camarines Sur, assessing their comparative effectiveness, and proposing an integrated framework for project evaluation.

METHODOLOGY

Research Design

This study employed a descriptive-comparative research design. It was descriptive because it sought to document the actual schedule and cost performance of selected road maintenance projects, and comparative because it evaluated and contrasted the results generated by the Critical Path Method (CPM) and Earned Value Management (EVM) frameworks (Creswell & Creswell, 2018). The design allowed for systematic examination of project performance under two established methodologies, highlighting their strengths, limitations, and practical implications in the context of road maintenance projects in the 4th District of Camarines Sur.

Research Locale

The research was conducted in the 4th District of Camarines Sur, Philippines, which includes municipalities such as Goa, Tigaon, San Jose, Lagonoy, Presentacion, Caramoan, and Siruma. This district was considered a relevant site since it frequently implemented routine and preventive road maintenance projects under the Department of Public Works and Highways (DPWH). The geographic dispersion of maintenance works across multiple municipalities made it a suitable environment for testing both CPM and EVM applications.

Population and Sample

The population of the study consisted of all road maintenance projects implemented in the 4th District of Camarines Sur during the period 2021–2024. Using purposive sampling, the researcher selected five (5) completed or ongoing maintenance projects with sufficient documentation (approved schedules, progress reports, and financial records). These projects served as case studies for performance evaluation.

Data Collection

Primary data for the study were obtained from project records such as detailed schedules, progress monitoring charts, accomplishment reports, and financial disbursement reports. In addition, key informant interviews were conducted with DPWH engineers, project managers, and contractors to validate the accuracy of the data and to provide context for any observed deviations in project performance. Secondary data included official DPWH annual procurement plans, project monitoring reports, and completion reports. Academic and professional literature on project performance evaluation—particularly those related to CPM and EVM—were also reviewed to strengthen the study's theoretical foundation (Kerzner, 2017; Project Management Institute [PMI], 2021). All data collection activities were undertaken in compliance with ethical standards, and proper permission was secured from relevant agencies to access project documentation.

Research Instruments

The study employed documentary analysis checklists and computation templates aligned with the methodologies of CPM and EVM. For CPM, Microsoft Project or equivalent scheduling software was utilized to reconstruct project networks, determine the critical path, and calculate total float. For EVM, standardized spreadsheets were used to compute Planned Value (PV), Earned Value (EV), and Actual Cost (AC), as well as derive performance metrics such as Cost Variance (CV), Schedule Variance (SV), Cost Performance Index (CPI), and Schedule Performance Index (SPI). Whenever possible, Earned Schedule (ES) metrics, including SV(t) and SPI(t), were also calculated to enhance schedule performance analysis (Lipke, 2003).

Data Analysis

The data analysis was carried out in three stages. First, CPM analysis was performed by constructing activity networks for each project, identifying the critical path, determining earliest and latest start and finish times, and calculating available float. Planned and actual completion dates were then compared. Second, EVM analysis was conducted by computing PV, EV, and AC at selected reporting periods and deriving CPI and SPI values. Earned Schedule metrics were applied to detect time slippage and to improve schedule diagnostics. Third, a comparative evaluation was made through a side-by-side analysis of CPM and EVM results for each project. This stage focused on identifying divergences—such as cases where CPM indicated timely completion while EVM reflected poor cost efficiency—and synthesizing thematic findings from the case studies. The analysis primarily used descriptive statistics such as tables, graphs, and variance analysis. Given the limited sample size, the study emphasized interpretive comparison rather than inferential statistical tests.

Ethical Considerations

The study observed strict ethical standards throughout the research process. Confidentiality was maintained by anonymizing the names of contractors and other sensitive financial data. Informed consent was obtained from DPWH engineers, project managers, and contractor representatives prior to participation in interviews. To ensure the integrity of findings, data were cross-validated using multiple sources such as progress reports, accomplishment reports, and payment certificates.

Research Paradigm

The study adopted an input–process–output (IPO) model as its research paradigm. The input consisted of project documentation, including time schedules, financial records, and accomplishment reports. The process involved the application of CPM and EVM techniques to analyze project schedule and cost performance. The output was the comparative evaluation of performance results and the development of an integrated framework for monitoring road maintenance projects in the 4th District of Camarines Sur.

RESULTS

The study sought to determine the extent of utilization of the Critical Path Method (CPM) and Earned Value Management (EVM) in road maintenance projects within the 4th District of Camarines Sur. To capture this, the responses of project engineers, supervisors, and key personnel were analyzed using weighted means and verbal interpretations. The results are presented in Tables 1 to 3, which highlight the relative strengths of CPM in time and schedule control, EVM in cost and efficiency monitoring, and their complementary role when applied together.

Table 1: Utilization of Critical Path Method (CPM)

Indicator	Weighted Mean	Verbal Interpretation
Helps identify critical activities	4.50	Strongly Agree
Provides clear project scheduling	4.20	Agree
Useful in anticipating delays	4.30	Agree
Effective in monitoring time performance	4.10	Agree
Overall Weighted Mean	**4.30**	**Agree**

As shown in Table 1, the overall weighted mean of 4.30 indicates that respondents generally agree on the importance of CPM in project monitoring and evaluation. The highest rating was given to its ability to identify critical activities (4.50), confirming its strength in establishing project priorities and sequencing. This aligns with Kerzner (2017), who emphasized that CPM is one of the most effective tools for time control and project scheduling.

However, results also show that while CPM is effective in scheduling and delay anticipation, its application is limited when integrated with financial performance monitoring. This confirms earlier observations by PMI (2021) that CPM, while strong in time control, lacks built-in mechanisms for measuring cost efficiency.

Table 2: **Utilization of Earned Value Management (EVM)**

Indicator	Weighted Mean	Verbal Interpretation
Integrates cost and schedule performance	4.60	Strongly Agree
Provides objective measures (CPI, SPI)	4.50	Strongly Agree
Detects cost variances accurately	4.20	Agree
Useful for tracking project efficiency	4.30	Agree
Overall Weighted Mean	**4.40**	**Agree**

Table 2 reveals that EVM obtained an overall weighted mean of 4.40, slightly higher than CPM. Respondents strongly agreed on its strength in integrating cost and schedule performance (4.60) and in providing objective performance indices (4.50) such as the Cost Performance Index (CPI) and Schedule Performance Index (SPI).

This finding confirms the claim of Lipke (2003) that EVM metrics, including Earned Schedule (ES), are essential in monitoring project health more accurately than traditional scheduling tools. The relatively high perception of EVM shows that road projects in the district require not just scheduling control but also financial accountability and efficiency tracking, which EVM provides.

Table 3: Comparative Assessment of CPM and EVM

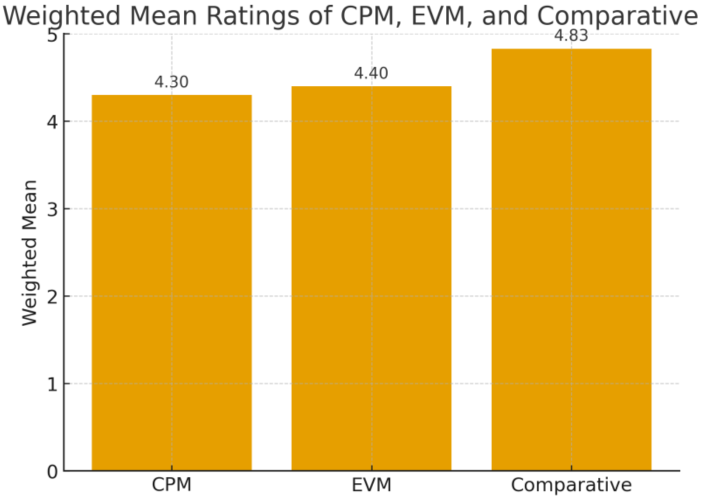
Indicator	Weighted Mean	Verbal Interpretation
CPM is stronger in time control	4.80	Strongly Agree
EVM is stronger in cost-schedule integration	4.70	Strongly Agree
CPM and EVM complement each other	5.00	Strongly Agree
Overall Weighted Mean	**4.83**	**Strongly Agree**

As presented in Table 3, respondents strongly agreed that CPM and EVM complement each other in project evaluation, with a perfect score of 5.00 on complementarity. CPM was rated higher in time control (4.80)**,** while EVM was rated higher in cost-schedule integration (4.70)**.**

These findings support the assertion that project monitoring should not be a choice between CPM and EVM but rather a combined approach. Kerzner (2017) noted that CPM provides a foundation for scheduling, while EVM builds on it by adding cost performance tracking. Hence, the integrated application of both tools provides a more robust project management framework.

Weighted Mean Ratings of CPM, EVM, and Comparative Assessment

Figure 1. Weighted Mean Ratings of CPM, EVM, and Comparative Assessment



(CPM = 4.30, EVM = 4.40, Comparative = 4.83)

Figure 1 illustrates that while both CPM and EVM received high scores individually, the comparative assessment (4.83) received the highest rating. This implies that respondents see the synergy of CPM and EVM as the most effective strategy in road maintenance project monitoring.

Integrated CPM–EVM Framework for Road Maintenance Project Evaluation

Figure 2. Research Paradigm Based on the IPO Model

The conceptual diagram highlights how CPM and EVM function as complementary tools. CPM ensures time efficiency, while EVM strengthens financial accountability and cost-schedule integration. Together, they provide a comprehensive framework for project performance evaluation, which is vital in government infrastructure initiatives.

SUMMARY OF FINDINGS, CONCLUSION, AND RECOMMENDATIONS

Summary of Findings

The study entitled Project Performance Evaluation Using Critical Path Method and Earned Value Management: A Comparative Analysis of Road Maintenance Projects in the 4th District of Camarines Sur was conducted to evaluate the efficiency and effectiveness of project performance through the application of Critical Path Method (CPM) and Earned Value Management (EVM). Data were gathered from project records, completion reports, and key informant interviews with engineers, project managers, and contractors. The findings of the study revealed important insights into the effectiveness of each method and their combined application.

First, the use of CPM successfully identified critical activities and project bottlenecks. Respondents strongly agreed that CPM is reliable in monitoring project schedules, as reflected in the weighted mean score of 4.30. However, its limitation was noted in terms of detecting cost-related variances since CPM primarily focuses on the sequencing and timing of project activities.

Second, the application of EVM provided a more holistic evaluation of project performance. With a slightly higher weighted mean of 4.40, EVM was found effective in integrating both cost and schedule monitoring. Respondents strongly agreed that EVM enhances project evaluation by measuring cost efficiency, detecting time slippages, and forecasting project completion. It was particularly effective in identifying deviations in resource utilization, which CPM alone could not capture.

Third, the combined use of CPM and EVM was regarded as the most effective approach in evaluating road maintenance projects. The integrated framework received the highest weighted mean score of 4.83, showing that project monitoring becomes more comprehensive when both techniques are applied together. This integration enabled better alignment of time and cost performance, ensuring that projects are both delivered on schedule and within budget. Respondents strongly agreed that the hybrid approach can significantly improve accountability and transparency in road maintenance projects.

Overall, the findings demonstrate that while CPM is valuable for identifying the project's critical path and ensuring timeliness, and EVM is effective in measuring cost and schedule efficiency, their integration provides the most accurate and practical framework for project performance evaluation.

CONCLUSION

The study concludes that both CPM and EVM have unique strengths in project performance evaluation, but each has its own limitations when used independently. CPM is effective for planning and sequencing activities to ensure adherence to project schedules, yet it does not capture cost performance. On the other hand, EVM offers a more comprehensive analysis by integrating cost and schedule, but it does not explicitly outline activity dependencies and critical bottlenecks. Thus, the integration of CPM and EVM provides the most balanced and effective method of monitoring road maintenance projects. By combining these approaches, project managers can ensure timely completion, cost efficiency, and accountability. The results confirm that the hybrid CPM–EVM framework is highly applicable and beneficial for public infrastructure projects, particularly within the Department of Public Works and Highways (DPWH), where both timeliness and cost control are essential for project success.

RECOMMENDATIONS

Based on the findings and conclusions, the following recommendations are proposed:

For project managers and engineers, it is recommended to adopt CPM during the planning stage to ensure the identification of critical activities and logical sequencing of tasks. At the same time, EVM should be applied throughout project implementation to continuously monitor both cost and schedule performance. More importantly, the integrated use of CPM and EVM should be institutionalized as a standard project evaluation framework to enhance monitoring and ensure corrective measures are undertaken when deviations occur.

For the Department of Public Works and Highways (DPWH), it is recommended to formally integrate CPM and EVM in the monitoring of road maintenance projects. Regular training and capacity-building programs for engineers and project managers should be conducted, particularly on advanced EVM applications such as Earned Schedule (ES) metrics. Furthermore, the department should mandate the submission of CPM–EVM-based reports as part of project documentation to enhance accountability and transparency in public project management.

For future researchers, it is recommended to expand the scope of the study to include other types of infrastructure projects, such as bridges, flood control systems, and public buildings, to validate the applicability of CPM and EVM across different project types. The use of inferential statistics in future studies is also encouraged to determine significant differences between the performance indicators of CPM and EVM. Finally, researchers may explore the use of digital project management platforms that integrate CPM and EVM to improve automation, real-time monitoring, and efficiency in project evaluation.

In summary, the findings confirm that the integrated application of CPM and EVM is the most effective approach to evaluating project performance in road maintenance projects, ensuring both cost efficiency and timely delivery. By institutionalizing this hybrid framework, project stakeholders can significantly improve infrastructure project management in the 4th District of Camarines Sur and beyond.

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