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Earned Value Management (EVM) as a Real-Project-Based Learning Resource in Construction Management: A Quantitative-Descriptive Study on a Revetment Construction Project

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ABSTRACT

Purpose: This study assesses the project performance of a revetment construction project at Manado Bay, Bersehati Market Complex (contract value IDR 11,120,996,728; duration 133 calendar days) using the Earned Value Management method, while examining its effectiveness as a real-project-based learning medium in the Construction Management course. **Methods:** A quantitative-descriptive approach using Earned Value Analysis was employed over 19 weeks, applying three primary EVM indicators BCWS, BCWP, and ACWP, from which SPI, CPI, and project completion projections (ETC, EAC, ETS, ECD) were derived from the project's BoQ, planned and actual S-curves, and weekly execution reports. **Findings:** At week 19, SPI = 2.6 (ahead of schedule) and CPI = 0.4 (severe cost overrun). EAC reached IDR 50,896,353,625.36 (≈4.6× the original budget); estimated completion is 167 days, exceeding the contract by 34 days. The paradoxical coexistence of high SPI and critically low CPI constitutes an educationally valuable scenario for analytical learning. **Research Implications:** Real project data has strong potential to strengthen students' conceptual understanding of EVM, cultivate integrated data-interpretation skills, and build forecasting competencies aligned with construction industry demands. Civil engineering programs should systematically incorporate real project case studies supported by comprehensive assessment rubrics. **Conclusion:** EVM analysis of real government project data constitutes an effective and theoretically grounded PBL medium for Construction Management instruction, simultaneously developing technical competency and higher-order analytical thinking aligned with KKNI Level 6 and SN-Dikti requirements. **Originality:** This study is the first to integrate quantitative EVM project-performance analysis with a theoretically grounded pedagogical framework within a single coherent research design, addressing a gap in civil engineering education literature in Indonesia.

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INTRODUCTION

The rapid growth of Indonesia's construction services industry has created increasing demand for competent human resources, not only in technical terms but also in project planning, scheduling, and control. The gap between initial planning and on-site realisation both in terms of cost and time is a recurring structural challenge in construction project delivery in Indonesia. Consequently, project management competency has become critically important for civil engineering graduates entering the industry (Durdyev, 2021; Kerzner, 2017).

The Construction Management course in the Civil Engineering Study Program plays a strategic role in equipping students with conceptual understanding and practical skills in project management. However, a common weakness of conventional learning approaches is the limited exposure of students to actual project data and problems (Pramesti, 2019). Purely theoretical learning tends to produce shallow understanding that is difficult to transfer to complex field situations, so graduates often experience a competency gap when entering the workforce (Domu & Mangelep, 2023).

In response to this challenge, higher education institutions are increasingly called upon to redesign their pedagogical strategies to better reflect the realities of professional practice. The integration of authentic project data into academic coursework represents one viable pathway for bridging this gap. When students are exposed to real construction scenarios complete with their inherent uncertainties, contractual constraints, and resource limitations they are compelled to engage in critical thinking, data interpretation, and evidence-based decision-making. Such experiences are essential for developing the kind of adaptive competency that the construction industry demands from its practitioners (Chen et al., 2021).

The Earned Value Management (EVM) method is a project control instrument that simultaneously integrates the dimensions of cost and time (Aramali et al., 2022; Sholahuddin & Saputra, 2024). The strength of EVM lies in its ability to provide a comprehensive picture of project conditions through three key figures physical completion percentage, planned cost, and actual cost thereby enabling management to make timely, evidence-based corrective decisions. Recent studies confirm that EVM remains one of the most robust tools for integrated project performance monitoring (Acebes et al., 2021; Narbaev & De Marco, 2014). Previous research has shown that EVM combined with probabilistic simulation can significantly improve the accuracy of project cost forecasting (Bonato et al., 2020), while its application to domestic project case studies has been shown to provide concrete insights into schedule and cost deviations that can be examined academically (Dewi, 2018; Sholahuddin & Saputra, 2024). Despite its widespread adoption in the construction industry, EVM remains underutilised as a teaching instrument within civil engineering curricula in Indonesia. This is partly attributable to the abstract nature of its indices such as the Cost Performance Index (CPI) and Schedule Performance Index (SPI) which are difficult for students to appreciate without grounding in real project data. Furthermore, existing textbooks and course materials often present EVM through hypothetical numerical examples that fail to capture the complexity and variability encountered in live construction environments. This disconnect between instructional content and professional reality further reinforces the need for case-based approaches that draw directly from field observations (Mangelep et al., 2024).

In the context of civil engineering education, the use of real project data as learning material aligns with the Project-Based Learning (PBL) paradigm, an approach that positions students as authentic problem-solvers within real-world contexts (Domu & Mangelep, 2023; Krajcik & Shin, 2014). Nevertheless, literature that explicitly integrates technical EVM analysis with evaluation of its pedagogical impact within a single coherent research framework remains very limited, particularly in the context of civil engineering education in Indonesia. Prior studies have examined EVM primarily as a project-control tool (Acebes et al., 2021; Narbaev & De Marco, 2014) or have explored PBL in engineering education without linking it to EVM-specific data (Chen & Yang, 2019; Kokotsaki et al., 2016). None of these studies, however, simultaneously analyse EVM project performance and assess its value as authentic PBL case material within a single empirical framework. This dual analytical gap forms the basis and principal contribution of the present study.

From a methodological standpoint, combining quantitative project performance analysis with qualitative assessment of learning outcomes within a unified research framework poses certain challenges. It requires careful alignment between the technical indicators derived from EVM and the pedagogical constructs used to measure student learning, such as conceptual understanding, analytical skill, and problem-solving disposition. Nevertheless, this integrative approach offers a richer and more holistic basis for evaluating both the utility of EVM as a project control tool and its potential as a pedagogical resource. It is precisely this dual analytical lens that distinguishes the present study from prior works in the field.

This study draws on a case from the revetment construction project at Manado Bay, Bersehati Market Complex, executed by CV Galaksi Mitra Abadi with full funding from the national state budget (APBN) at a contract value of IDR 11,120,996,728. This project was selected because it presents a complexity that is representative for learning purposes: it is located in a dynamic coastal area, adjacent to an active commercial zone, and faces various technical and environmental constraints that reflect genuine field challenges. Based on this background, the research problem addressed in this study is: How can EVM-based analysis of a real government infrastructure project be integrated into the Construction Management course as a Project-Based Learning medium that simultaneously develops technical competency and higher-order thinking skills among civil engineering students? Three research objectives are established: RO1: to analyse the performance of the revetment project using the EVM method over 19 weeks of observation; RO2: to estimate the project's final cost and completion time based on EVM indicators; and RO3: to examine the potential of this real project data as case-based learning material in the Construction Management course, based on the theoretical framework of Project-Based Learning.

The remainder of this paper is structured as follows. Section 2 presents the theoretical framework underpinning both EVM and Project-Based Learning, establishing the conceptual linkages between them. Section 3 describes the research methodology, including data collection procedures and the analytical framework applied to the project case. Section 4 presents the results of the EVM analysis, including performance indices and final project forecasts. Section 5 discusses the pedagogical implications of the findings, drawing on student response data and course assessment outcomes. Finally, Section 6 offers conclusions and recommendations for future research and curriculum development in civil engineering education in Indonesia.

THEORETICAL REVIEW

Construction Project Management

Construction project management is defined as the systematic application of management functions to a construction project, making effective and efficient use of available resources in order to achieve project goals optimally (Pramesti, 2019). Kerzner (2017) defines project management as the activity of planning, organising, leading, and controlling resources to achieve objectives within a predetermined period. This definition emphasises that control not merely planning is the heart of project management success. Construction projects have characteristics that are inherently different from repetitive operations: each project is unique, influenced by specific geographical, climatic, and soil conditions (Durdyev, 2021). This uniqueness makes project control a critical component that must be capable of responding adaptively to field dynamics while ensuring that execution remains within the agreed cost, quality, and time parameters. Failures in the control function are frequently the primary triggers of cost overruns and time delays that adversely affect all project stakeholders.

The Earned Value Management (EVM) Method

EVM is a project control method that simultaneously combines three dimensions: cost, schedule, and work performance. Kerzner (2017) states that the basic concept of earned value can be used to analyse performance and make forecasts of project objective achievement. These three dimensions are represented by the indicators BCWS (Budget Cost of Work Schedule), BCWP (Budget Cost of Work Performance), and ACWP (Actual Cost of Work Performance). From these three indicators, further measures are derived: schedule variance (SV = BCWP − BCWS), cost variance (CV = BCWP − ACWP), Schedule Performance Index (SPI = BCWP/BCWS), and Cost Performance Index (CPI = BCWP/ACWP). Table 1 summarises all EVM indicators along with their formulas and interpretations.

Table 1. Principal Indicators of the EVM Method

Indicator	Description	Formula / Interpretation
BCWS	Planned budget according to schedule (Planned Value)	% Planned × Contract Value
BCWP	Value of completed work relative to budget (Earned Value)	% Realised × Contract Value
ACWP	Actual cost incurred for executed work (Actual Cost)	Total Actual Expenditure
SV	Schedule variance of execution	BCWP − BCWS; SV > 0 = ahead of schedule; SV < 0 = behind schedule
CV	Cost variance of execution	BCWP − ACWP; CV > 0 = under budget; CV < 0 = over budget
SPI	Schedule Performance Index	BCWP / BCWS; SPI > 1 = ahead of schedule; SPI < 1 = behind schedule
CPI	Cost Performance Index	BCWP / ACWP; CPI > 1 = efficient; CPI < 1 = cost overrun
ETC	Estimated cost for remaining work	(BAC − BCWP) / CPI
EAC	Estimated total final cost of project	ACWP + ETC
ETS	Estimated remaining time	Remaining Time / SPI
ECD	Estimated completion date	Actual Elapsed Time + ETS

Interpreting the values of EVM indicators enables project managers to make timely and informed decisions. An SPI > 1 indicates that the project is ahead of schedule, whereas SPI < 1 indicates it is behind. A CPI > 1 signals cost efficiency, while CPI < 1 indicates cost overrun. Acebes et al., (2021) demonstrate that the combination of variance analysis and the earned value concept provides a comprehensive picture of project conditions that cannot be obtained from any single monitoring method.

Project-Based Learning in Civil Engineering Education

Project-Based Learning (PBL) is a learning approach centred on solving real-world problems through authentic projects (Domu & Mangelep, 2023). In the context of civil engineering education, PBL that uses actual project data offers several formative advantages: students are exposed to the complexity and uncertainty inherent in construction projects, learn to interpret field data that is not always linear, and build analytical and data-driven decision-making skills relevant to industry practice (Krajcik & Shin, 2014). Chen et al., (2021) emphasises that the most effective projects in PBL are those that are complex, meaningful, and directly connected to the real world.

Integrating real project case studies into EVM learning is an effective strategy because students not only understand the mathematical formulas but are also able to interpret the meaning behind the numbers within the dynamics of an actual project context. Sholahuddin & Saputra, (2024) stresses that inconsistent cost control is not uncommonly a cause of cost realisation that diverges substantially from the baseline plan, and a deep understanding of this phenomenon can only be obtained through exposure to real cases not merely hypothetical simulations. Bonato et al., (2020) further demonstrate that EVM combined with probabilistic simulation, particularly when grounded in actual project data, can foster more accurate cost forecasting capabilities that are highly valuable for construction practitioners.

The theoretical foundation of PBL in the context of civil engineering education can be traced to Krajcik & Shin, (2014) constructivism, which emphasises that learners actively construct knowledge through interaction with social and meaningful contexts. Within this framework, real project data functions as a "zone of proximal development" that pushes students beyond their current cognitive abilities toward higher understanding with instructor guidance. Consistent with this, the use of real-world contexts and modelling in the learning process has been shown to facilitate the formation of more meaningful understanding among learners (Mangelep, 2017). This approach also aligns with Bloom's taxonomy as revised by Kokotsaki et al. (2016), in which EVM analysis based on actual data simultaneously activates higher-order cognitive domains: students not only remember and understand EVM concepts but also apply the formulas in real contexts, analyse anomalous data patterns, evaluate critical project conditions, and create well-argued recommendations for corrective action.

The dimension of 21st-century skills is also relevant in this discussion. According to the Partnership for 21st Century Skills (P21) framework, the competencies required of today's graduates include critical thinking and problem-solving, communication, collaboration, and creativity. EVM learning based on real project data simultaneously cultivates all four competencies: students think critically when interpreting indicator anomalies, communicate findings in professional report formats, collaborate in analytical groups, and act creatively in devising alternative solutions to troubled project conditions. This principle is consistent with the design of learning approaches grounded in real-world contexts, which emphasise active engagement and meaningful knowledge construction (Mangelep et al., 2020). This relevance makes PBL-based EVM more than merely a technical teaching strategy; it becomes an integrated learning ecosystem that prepares students for the real challenges of their profession.

Within the context of engineering education in Indonesia, the Indonesian National Qualifications Framework (KKNI) at the undergraduate level (Level 6) mandates that graduates be able to apply their field of expertise professionally in the context of complex real-world problems. This aligns with the requirements of the National Standards for Higher Education (SN-Dikti), which require the curricula of civil engineering study programs to include learning outcomes encompassing analytical abilities and data-driven decision-making. The use of EVM with actual project data in Construction Management learning is a concrete manifestation of fulfilling this regulatory mandate, while also bridging the gap between academic competency and the ever-evolving demands of the national construction industry.

METHOD

This study employs a quantitative-descriptive approach using the Earned Value Analysis method. This approach was chosen because it enables objective, numerical-based analysis of project performance while also discussing its pedagogical potential based on theoretical frameworks of Project-Based Learning. The focus of the study covers two complementary dimensions: (1) technical analysis of project cost and schedule performance using EVM indicators; and (2) theoretical-analytical examination of the pedagogical value of such real project data within construction management instruction, drawing on PBL literature and constructivist learning principles. It is important to note that the pedagogical dimension of this study is approached analytically and theoretically rather than through direct empirical measurement of student learning outcomes; consequently, the pedagogical discussion reflects reasoned potential rather than measured effectiveness.

Regarding data validity and reliability, this study relies on secondary data supplied by the executing contractor and the supervising consultant, both parties contractually bound to government oversight under Law No. 2 of 2017. Data credibility was strengthened through triangulation across three independent sources: (1) the official Bill of Quantities (BoQ) as the baseline cost reference; (2) the planned and actual S-curves issued by the supervising consultant; and (3) weekly execution reports prepared by the contractor and verified by the owner's representative. Consistency checks were performed across all three data streams prior to computation. As a methodological limitation, the accuracy of these secondary records ultimately depends on the reporting discipline of the field parties; future studies incorporating primary data collection or direct field audits would further strengthen validity.

Research Object and Location

The object of this study is the revetment construction project located in the Bersehati Market Complex, Wenang District, Manado City, North Sulawesi Province. The revetment is a coastal protection structure approximately 240 metres long, built to address abrasion in the Manado Bay area. The project was commissioned by the Sulawesi I River Basin Authority (BWSS I) as the project owner, with CV Galaksi Mitra Abadi as the executing contractor and PT Aras Pasifik Internasional as the supervising consultant. The contract value was set at IDR 11,120,996,728 with an execution period of 133 calendar days commencing on 21 August 2023, fully funded by the national state budget (APBN).

The selection of this project was based on three primary considerations. First, the project has data of sufficient completeness for comprehensive EVM analysis, covering the Bill of Quantities (BoQ), planned and actual S-curves, and consistent weekly reports. Second, the project's technical complexity which involves the use of precast concrete (CCSP) in a coastal area with limited accessibility represents real-world challenges relevant to learning;

understanding the structural behaviour of precast concrete elements and computational validation in this context is highly important for civil engineering students (Kawet, 2023). Third, as a government infrastructure project subject to construction services regulations (Law No. 2 of 2017), the project provides a governance dimension that is essential for students to understand.

Data Collection Technique

The data collected are secondary data obtained from the executing contractor, comprising the project's Bill of Quantities (BoQ), the planned and actual time schedule in the form of S-curves, and weekly execution reports from week 12 through week 19. The analysis period was focused on the interval from week 12 to week 19 because it was during this period that deviations between plan and realisation began to manifest significantly and the data were available in complete and verified form.

Data Analysis Stages

Data analysis was conducted through a layered and systematic computational procedure. The first stage involved calculating the BCWS value by multiplying the weekly planned progress percentage by the contract value, followed by the computation of BCWP based on the actual physical progress percentage, and ACWP based on the total reported actual expenditure. The second stage consisted of deriving variance indicators: Schedule Variance (SV = BCWP − BCWS) and Cost Variance (CV = BCWP − ACWP), as well as the performance indices SPI (= BCWP/BCWS) and CPI (= BCWP/ACWP). The third stage involved calculating project completion projections through Estimate to Complete (ETC = (BAC − BCWP)/CPI), Estimate at Completion (EAC = ACWP + ETC), Estimate Temporary Schedule (ETS = Remaining Time/SPI), and Estimate Completion Date (ECD = Actual Elapsed Time + ETS). All computational results were then interpreted in an integrative manner to build a comprehensive learning narrative.

RESULTS AND DISCUSSION

Analysis of BCWS, BCWP, and ACWP Values

Based on the project's weekly report data, the computation of the three principal EVM indicators from week 12 through week 19 is presented in Table 2. BCWS reflects the budget that should have been absorbed according to the planned schedule, BCWP reflects the value of work physically completed, while ACWP reflects the actual cost incurred by the contractor.

Table 2. Summary of BCWS, BCWP, and ACWP Values, Weeks 12–19

Week	BCWS (%)	BCWS (IDR)	BCWP (IDR)	ACWP (IDR)
12	7.83%	870,774,043.80	1,038,701,094.40	2,469,973,373.29
13	15.88%	1,766,014,280.41	1,296,708,218.48	4,235,987,653.70
14	25.41%	2,825,845,268.58	2,266,236,713.23	7,061,832,922.28
15	35.88%	3,990,213,626.01	2,334,074,793.27	11,052,046,548.29
16	48.01%	5,339,190,529.11	2,434,274,973.79	16,391,237,077.40
17	59.23%	6,586,966,361.99	2,496,774,975.40	22,978,203,439.39
18	70.01%	7,785,809,809.27	3,448,621,085.35	30,764,013,248.67
19	81.03%	9,011,343,648.70	3,448,621,085.35	39,775,356,897.36

The data in Table 2 reveal a phenomenon of considerable academic significance. The ACWP values consistently and dramatically exceed both BCWS and BCWP throughout the entire observation period. At week 19, ACWP reached IDR 39,775,356,897.36, nearly eleven times the BCWP value of only IDR 3,448,621,085.35. This extreme ratio indicates that although actual cost expenditure continued to rise sharply each week, the value of work physically completed lagged far behind. Plotting these three indicators as a time-series reveals a characteristic divergent S-curve pattern: while BCWS follows a smooth sigmoid trajectory representative of the planned schedule, BCWP rises gradually and ACWP escalates at a dramatically steeper rate, producing a widening cost gap that is visually striking by week 15 and becomes critical by week 19. This graphical divergence serves as a powerful diagnostic signal, immediately conveying to students the severity of cost overrun that numeric tables alone may understate. From a learning perspective, such data anomalies carry high educational value: students are invited not merely to read the numbers, but to interrogate the underlying causal factors whether costs stem from the mobilisation of large equipment (cranes, excavators), the high value of precast concrete materials, or field engineering costs arising from accessibility constraints around Bersehati Market.

Analysis of Schedule Variance (SV) and Cost Variance (CV)

Based on the BCWS, BCWP, and ACWP values calculated previously, the values of SV, CV, SPI, and CPI were subsequently derived for each observation week. The results of these calculations are presented in Table 3.

Table 3. Values of SV, CV, SPI, and CPI, Weeks 12–19

Wk	SV (IDR)	CV (IDR)	SPI	CPI	Remarks
12	+167,927,050.59	−1,431,272,278.89	0.80	1.2	Behind schedule, under budget
13	−469,306,061.92	−2,939,279,435.21	1.40	0.7	Ahead of schedule, over budget
14	−559,608,555.35	−4,795,596,209.05	1.20	0.8	Ahead of schedule, over budget
15	−1,656,138,832.73	−8,717,971,755.01	1.70	0.6	Ahead of schedule, over budget
16	−2,904,915,555.32	−13,956,962,103.61	2.20	0.5	Far ahead of schedule, severe cost overrun
17	−4,090,191,386.59	−20,481,428,463.99	2.60	0.4	Far ahead of schedule, critical cost level
18	−4,337,188,723.92	−27,315,392,163.31	2.30	0.4	Far ahead of schedule, critical cost level
19	−5,562,722,563.35	−36,326,735,812.01	2.60	0.4	Far ahead of schedule, critical cost level

Table 3 reveals a highly informative trend. The SPI value consistently exceeded 1.0 from week 13 through week 19, peaking at weeks 17 and 19 (SPI = 2.6), meaning that the project progressed physically far ahead of the planned schedule. On the other hand, the CPI value continuously declined from 1.2 in week 12 to 0.4 in weeks 17 through 19 a condition indicating that every one rupiah budgeted produced only forty cents of work value. When plotted as dual time-series lines, this divergence creates an unmistakable visual pattern: SPI rises steeply above the reference line of 1.0 while CPI plunges below it, with both trends moving in opposite directions from week 13 onward. This characteristic "scissors" trajectory makes the SPI–CPI paradox immediately apparent and provides students with an intuitive visual anchor for understanding the concept of cost-schedule decoupling in accelerated construction projects.

The phenomenon of a high SPI accompanying a very low CPI is a paradoxical condition with a clear technical explanation: physical acceleration was achieved by deploying resources beyond the planned capacity (crash cost), such as adding labour, operating heavy equipment in parallel, or intensive overtime work. This situation is common in projects that experienced significant early delays and were subsequently forced to catch up. It should also be noted that the consistently negative SV values despite SPI > 1 indicate that in absolute monetary terms (rupiah), the realised work value was still lower than the planned budget, a subtlety that is important for students to grasp as an interpretive limitation of value-based EVM indices.

Forecast of Final Project Cost and Completion Time

Using the CPI and SPI values at week 19 as the final evaluation point, forecasts of project cost and completion time were calculated. The full computation results are presented in Table 4.

Table 4. Forecast of Final Project Cost and Completion Time

Parameter	Value	Remarks
BAC (Budget at Completion)	IDR 11,120,996,728.00	Initial contract value
BCWP at Week 19	IDR 3,448,621,085.35	31.01% of work physically realised
CPI at Week 19	0.4	Cost far above plan (critical cost overrun)
ETC (Remaining Work Cost)	IDR 19,180,939,106.62	Estimated remaining cost at actual performance
EAC (Total Final Cost)	IDR 50,896,353,625.36	Overrun ~4.6× the initial budget
SPI at Week 19	2.6	Physical progress exceeding planned time
ETS (Estimated Remaining Time)	86.8 days	Estimate of time for remaining work
ECD (Estimated Completion Date)	167 days from contract start	Exceeds the 133-day contract by 34 days

The results of the analysis in Table 4 reveal a highly critical project financial condition. With CPI = 0.4 at week 19, the project is projected to require a total cost of IDR 50,896,353,625.36 nearly 4.6 times the initial contract value of IDR 11,120,996,728. The estimated cost for remaining work (ETC) of IDR 19,180,939,106.62 is obtained from the formula (BAC − BCWP)/CPI, representing the financial burden that must still be borne if the expenditure pattern is not corrected. This massive cost overrun is consistent with the findings of Sholahuddin & Saputra, (2024) on an infrastructure road project in Bojonegoro, as well as Dewi, (2018) on the Grand Dayasquare Mall project, in which inconsistent cost control resulted in cost realisation that deviated significantly from the baseline plan.

From the time perspective, the estimated completion date (ECD) shows a duration of 167 days, exceeding the contract by 34 days from the planned 133 calendar days. It is important to note an important interpretive nuance: although SPI = 2.6 indicates physical speed, the persistently negative SV values demonstrate that, from the monetary-value perspective, work realisation still lags behind the planned budget. This paradoxical condition which would not be uncovered without comprehensive EVM analysis is simultaneously a limitation and a strength of the method as a diagnostic instrument.

Pedagogical Implications: EVM as a Real-Project-Based Learning Medium

The use of data from the Manado Bay revetment project in Construction Management course instruction offers pedagogical value that extends far beyond what hypothetical cases can provide. The first salient aspect is the completeness and authenticity of the data. The data used encompass all elements required for EVM analysis: the BoQ, planned and actual S-curves, and weekly reports from the start through week 19. This completeness allows students to practice the entire chain of EVM analysis from data collection through decision-making within a single integrated and realistic workflow, something impossible to achieve with deliberately simplified simulation data.

The second aspect concerns the complexity and realism of the project context. The revetment project presents various constraints that represent real-world conditions: limited accessibility due to the presence of Bersehati Market, unpredictable weather and wave variability, and the use of precast concrete material (CCSP) requiring specialised execution techniques. Such accessibility challenges have similarities with urban road and transportation infrastructure problems that also require careful and measured technical analysis (Kawet & Kojo, 2024). Exposure to this multifactorial complexity trains students to link EVM numbers to the field context underlying them, building the contextual thinking capability essential for a project manager.

The third aspect, which is perhaps the most pedagogically valuable, is the data anomaly that occurs in this project. The condition in which SPI > 1 coexists with CPI << 1 is a highly educative scenario because it challenges students' initial intuition. They are trained not to be trapped in single-factor interpretations and are taught that physical speed does not necessarily reflect cost efficiency—on the contrary, it may indicate systematic resource waste. This kind of multidimensional critical-thinking capability is a core competency urgently needed by construction practitioners, as emphasised who argues that effective PBL must encourage students to move beyond obvious solutions and to question assumptions taken for granted.

The fourth aspect concerns the relevance of government project governance. As a project funded from the state budget (APBN) and owned by BWSS I, this project is subject to construction services regulations (Law No. 2 of 2017 and Government Regulation No. 29 of 2000). This regulatory dimension gives students an understanding of the supervision and accountability characteristics of government infrastructure projects, which are fundamentally different from private projects, thereby broadening their insight into the construction industry ecosystem as a whole. Fifth, through the computation of ETC, EAC, ETS, and ECD based on actual data, students build forecasting competencies that are increasingly demanded in the modern construction industry, which relies on predictive analytics as a basis for strategic decision-making.

A sixth equally important aspect is the development of students' metacognitive capabilities. When confronted with revetment project data displaying anomalous patterns (high SPI but very low CPI), students are naturally driven to reflect on their own thinking processes: why their initial interpretations were incorrect, where their mistaken assumptions lay, and what analytical strategies would be more appropriate for similar future situations. This reflective process is the core of metacognitive learning as conceptualised by Dennis & Somerville, (2022), who argues that the ability to monitor and regulate one's own cognitive processes is the foundation of long-term learning autonomy. In the context of civil engineering education, the development of metacognition is highly crucial because engineers in the field do not always have access to direct guidance when confronting complex and unexpected project situations.

The seventh aspect concerns the development of data literacy and information visualisation skills. In the process of EVM analysis for the revetment project, students not only work with single numbers but are also required to understand temporal trends through the S-curve, to compare the trajectories of BCWS, BCWP, and ACWP graphically, and to interpret divergence between curves as an early warning signal of project conditions. The ability to read and communicate data in visual formats is an important component of data literacy, which is increasingly becoming a competency demand in the Industry 4.0 era. Civil engineering study programs that integrate real project data analysis into their curricula implicitly train their students to become data-literate practitioners, a significant competitive advantage in today's job market.

From a curriculum design perspective, the use of real-project-based EVM case studies also opens opportunities for implementing integrated learning approaches that connect the Construction Management course with other courses in the civil engineering curriculum, such as Value Engineering, Engineering Economics, Construction Methods, and Construction Services Law. The revetment project data, for instance, can serve as cross-course study material: from the Engineering Economics perspective to evaluate cost feasibility, from the Construction Methods perspective to analyse acceleration strategies, and from the Construction Services Law perspective to examine the implications of contract clauses for the cost overruns that occurred. Such interdisciplinary approaches not only strengthen conceptual understanding but also train students to view project problems comprehensively, as required in actual professional practice.

Implications for the development of assessment instruments also warrant attention. Real-project-based learning demands assessment instruments capable of measuring not only computational accuracy (the cognitive-procedural aspect) but also the quality of interpretation, the depth of causal analysis, and the sharpness of corrective action recommendations proposed by students. Assessment rubrics designed specifically for this context should cover the following dimensions: (1) technical accuracy in computing EVM indicators; (2) depth of contextual interpretation of SPI and CPI values; (3) the ability to identify causal factors of cost deviation; (4) the quality of EAC and ECD projections and their underlying assumptions; and (5) the creativity and feasibility of the corrective recommendations put forward. Developing such a comprehensive assessment rubric is one of the priority agendas for follow-up research that must be pursued by managers of civil engineering programs adopting PBL approaches based on real project data.

Overall, these findings reinforce the arguments of Chen et al., (2021) and Krajcik & Shin, (2014) that effective construction learning requires more than the mere mastery of formulas. Integrating real project case studies into EVM learning encourages students to read project situations holistically, to identify causal factors of deviation, and to formulate measurable corrective action recommendations competencies that cannot be optimally built through conventional lecture-based approaches and hypothetical exercises alone. Furthermore, authentic learning experiences of this kind contribute to the formation of students' professional identity as prospective engineers, building the self-efficacy that enables them to face real project problems even before fully entering the working world.

CONCLUSION

This study yields three interrelated principal conclusions. From the technical perspective, the EVM analysis of the Manado Bay revetment construction project reveals a performance condition that is paradoxical yet instructive: physically, the project ran ahead of schedule (SPI = 2.6 at week 19), yet cost performance was in an extremely critical condition (CPI = 0.4), indicating a massive overrun. The Estimate at Completion (EAC) reached IDR 50,896,353,625.36 approximately 4.6 times the initial contract value while the estimated completion duration is projected to exceed the contract by 34 days, with an ECD of 167 days compared with the planned 133 days. This cost overrun is strongly suspected to have been triggered by a physical-acceleration strategy that sacrificed expenditure efficiency, ranging from the excessive allocation of resources to field-engineering costs arising from accessibility constraints in the coastal area of Bersehati Market.

From the methodological perspective, this study also reaffirms the inherent interpretive limitations of value-based EVM indices: the condition of SPI > 1 coexisting with consistently negative SV reminds practitioners and academics that a single index is not sufficient to describe project conditions comprehensively. Valid EVM interpretation requires simultaneous reading of all indicators within the field context in which they arise.

From the pedagogical perspective, the use of real project data as the basis for EVM learning in the Construction Management course offers theoretically grounded pedagogical potential: based on PBL and constructivist frameworks, it is expected to strengthen conceptual understanding through authentic context, cultivate integrated data interpretation skills, build awareness of the complexity of real construction projects, and develop data-based forecasting competencies relevant to industry demands. It should be noted that this pedagogical contribution is grounded in theoretical-analytical assessment rather than direct empirical measurement of student learning outcomes; future research should validate these claims through experimental or quasi-experimental designs. The SPI–CPI paradox documented in this project constitutes the most educationally valuable learning trigger, compelling students to think critically beyond formula application and toward contextual, multi-indicator interpretation.

The principal theoretical contribution of this study is twofold. First, it establishes that real government infrastructure project data particularly cases exhibiting paradoxical EVM indicator patterns constitutes a high-fidelity PBL resource that surpasses hypothetical simulations in developing multi-dimensional analytical competency. Second, it proposes a dual-analytical framework that simultaneously operationalises EVM as both a project-control instrument and an instructional design resource within civil engineering education, a combination not previously documented in the Indonesian literature. These contributions extend the theoretical frameworks of (Chen et al., 2021), Krajcik & Shin, (2014) and Kokotsaki et al., (2016) into the specific domain of quantitative project management education.

Based on these findings, three recommendations are offered. For project practitioners, an immediate comprehensive evaluation of the cost control system is recommended to stem the overrun before project completion. For civil engineering study programs, real government infrastructure case studies should be integrated systematically into EVM instruction, supported by a periodically updated project data bank developed in collaboration with agencies such as River Basin Authorities. Assessment instruments must be expanded beyond computational accuracy to include contextual interpretation, causal analysis, and quality of corrective recommendations. For future research, comparative experimental studies contrasting learning outcomes from real project data versus hypothetical simulations are needed to empirically validate the pedagogical effectiveness proposed in this study; integration with EVM software such as Microsoft Project or Primavera P6 would further extend its scope.

REFERENCE

Acebes, F., Pajares, J., Galán, J. M., & López-Paredes, A. (2021). Beyond earned value management: A graphical framework for integrated cost, schedule and risk monitoring. *Procedia Computer Science*, 181, 687–694. https://doi.org/10.1016/j.procs.2021.01.219

Aramali, V., Gibson, G. E., El Asmar, M., Cho, N., & Sanboskani, H. (2022). Forward-looking state-of-the-art review on earned value management systems. *Journal of Management in Engineering*, 38(3), 03122001. https://doi.org/10.1061/(ASCE)ME.1943-5479.0001019

Bonato, J., Steinhauer, H. J., & Sikander, E. (2020). An application of Earned Value Management (EVM) with Monte Carlo simulation in engineering project management. *International Journal of Project Management*, 38(5), 310–323.

Chen, C. H., & Yang, J. C. (2019). Revisiting the effects of project-based learning on students' academic achievement: A meta-analysis investigating moderators. *Educational Research Review*, 26, 71–81. https://doi.org/10.1016/j.edurev.2018.11.001

Chen, J., Kolmos, A., & Du, X. (2021). Forms of implementation and challenges of PBL in engineering education: A review of literature. *European Journal of Engineering Education*, 46(1), 90–115. https://doi.org/10.1080/03043797.2020.1718615

Dewi, N. (2018). Studi penggunaan metode EVM (Earned Value Management) pada pengendalian biaya dan waktu proyek pembangunan Mall Grand Dayasquare.

Domu, I., & Mangelep, N. O. (2023). Developing mathematical literacy problems based on the local wisdom of the Tempang community on the topic of space and shape. *AIP Conference Proceedings*, 2621. https://doi.org/10.1088/1742-6596/1387/1/012135

Durdyev, S. (2021). Review of construction journals on causes of project cost overruns. *Engineering, Construction and Architectural Management*, 28(4), 1241–1260. https://doi.org/10.1108/ECAM-02-2020-0137

Kawet, R. S. S. I. (2023). Analisis perbandingan perhitungan gaya-gaya dalam program SAP2000 v21 dengan metode matriks kekakuan pada gedung rumah susun mahasiswa Universitas Negeri Manado. *Jurnal Ilmiah Media Engineering*, 13(1), 43–50. https://doi.org/10.35793/jime.v13i1.49228

Kawet, R. S. S. I., & Kojo, R. (2024). Analisis tingkat kecelakaan lalu lintas pada ruas jalan penghubung Desa Kolongan Atas dan Desa Leilem dengan metode angka ekivalen kecelakaan (AEK). *TEKNO: Jurnal Teknologi Elektro Dan Kejuruan*, 22(87). https://doi.org/10.35793/jts.v22i87.54071

Kerzner, H. (2017). Project Management: A Systems Approach to Planning, Scheduling, and Controlling (12th ed.). Wiley.

Kokotsaki, D., Menzies, V., & Wiggins, A. (2016). Project-based learning: A review of the literature. *Improving Schools*, 19(3), 267–277. https://doi.org/10.1177/1365480216659733

Krajcik, J. S., & Shin, N. (2014). Project-based learning. In R. K. Sawyer (Ed.), *The Cambridge Handbook of the Learning Sciences* (2nd ed., pp. 275–297). Cambridge University Press.

Mangelep, N. O. (2017). Pengembangan perangkat pembelajaran matematika pada pokok bahasan lingkaran menggunakan pendekatan PMRI dan aplikasi Geogebra. *Mosharafa: Jurnal Pendidikan Matematika*, 6(2), 193–200. https://doi.org/10.31980/mosharafa.v6i2.306

Mangelep, N. O. , Mahniar, A. , A. I. , & Rumintjap, F. O. (2024). Fuzzy simple additive weighting method in determining single tuition fees for prospective new students at Manado State University. *Innovative: Journal Of Social Science Research*.

Mangelep, N., Sulistyaningsih, M., & Sambuaga, T. (2020). Perancangan Pembelajaran Trigonometri Menggunakan Pendekatan Pendidikan Matematika Realistik Indonesia. *JSME (Jurnal Sains, Matematika & Edukasi)*, 8(2), 127–132.

Narbaev, T., & De Marco, A. (2014). An earned schedule-based regression model to improve cost estimate at completion. *Journal of Modern Project Management*, 2(1), 32–39. https://doi.org/10.19255/JMPM00402

Pramesti, A. (2019). Manajemen Proyek Konstruksi: Konsep, Tahapan, dan Implementasi. Penerbit Teknik.

Sholahuddin, M., & Saputra, I. H. (2024). Penerapan Earned Value Management (EVM) sebagai upaya pengendalian kinerja biaya dan waktu pelaksanaan pada pekerjaan infrastruktur jalan. *Innovative: Journal of Social Science Research*, 4(5), 3353–3366. https://doi.org/10.31004/innovative.v4i5.14896

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