Implementation of Earned Value Management (EVM) method in analyzing delays in construction projects using python programming

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Abstract

Construction projects are inherently complex and dynamic, involving the management of Construction projects frequently face delays that lead to budget overruns and reduced stakeholder satisfaction. Earned Value Management (EVM) offers a quantitative approach for assessing time and cost performance by integrating planned value, earned value, and actual cost, allowing project managers to calculate objective indicators such as the Cost Performance Index (CPI) and Schedule Performance Index (SPI). However, manual EVM calculations in large-scale projects are often inefficient and prone to error. This study aims to implement the EVM method using Python programming to analyze delays in the Santa Ursula Female Dormitory Building construction project. The system developed automates the calculation of EVM indicators while providing visualization and report generation for effective project monitoring. Results indicate that the project experiences a delay of 12.5 weeks from the planned 80 weeks, with an estimated completion duration of 92.5 weeks. Additionally, the estimated cost at completion is IDR 21,115,552,959, which exceeds the planned budget of IDR 18,712,612,545, reflecting significant cost overruns. The application of Python programming in EVM analysis enhances the speed, accuracy, and systematic assessment of project performance, enabling real-time monitoring and data-driven decision-making for project managers. This study demonstrates that integrating EVM with Python programming can effectively address delays and budget deviations, improving project management practices in the construction sector.

Keywords: Earned Value Management, Project delay, Python programming, Cost analysis, Construction management

1. Introduction

Construction projects constitute complex and dynamic undertakings that involve the large-scale interaction of multiple resources, including labor, materials, equipment, cost, and time. In practice, construction projects frequently encounter challenges in maintaining alignment between planned objectives and actual implementation, particularly with respect to time and cost control. Project delays remain a dominant issue, as they directly contribute to cost overruns, deterioration in work quality, and declining levels of stakeholder satisfaction. (Shen & Ying, 2022; Panchal, 2025) [13, 9].

Accordingly, an approach is required that not only monitors project progress but also quantitatively and measurably evaluates actual project performance. One method that has been proven effective and is widely recommended in international project management practice is Earned Value Management (EVM). Unlike conventional methods such as the S-curve or time-based scheduling techniques (CPM/PERT), EVM provides a comprehensive perspective by integrating three fundamental project dimensions: time, cost, and scope of work. Through key parameters-namely Planned Value (PV), Earned Value (EV), and Actual Cost (AC) project managers are able to calculate performance indicators such as the Cost Performance Index (CPI) and Schedule Performance Index (SPI), enabling objective assessment of cost efficiency and schedule deviations. (Umana, *et al*., 2022; Fullerton, 2025; Mayo-Alvarez, *et al*., 2022; Zahoor, *et al*., 2022) [15, 3, 7, 18].

However, the manual implementation of EVM in large-scale projects with numerous activities is highly susceptible to human error, slow data processing, and limited capacity for real-time evaluation. These limitations can reduce the effectiveness of project management, particularly in supporting timely and informed decision-making in the field. Therefore, a computerized and automated analytical system is required to enhance the speed and accuracy of project performance analysis (Sanusi, 2024) [12].

Within this context, the utilization of programming-based technology becomes highly relevant. Python is selected as the primary tool due to its open-source nature, flexibility, and robust libraries for numerical data processing and visualization, such as Pandas, NumPy, and Matplotlib. Moreover, Python offers strong support for web-based system development and integration with various reporting formats, including PDF and Excel, making it well suited for the development of interactive and responsive project monitoring systems. (Yáñez-Casas, *et al*., 2025; Batukan & Mercan, 2024) [17, 1].

By integrating the EVM method with Python-based technology, this study aims to develop a system capable of analyzing project delays in a faster, more accurate, systematic, and user-friendly manner. The proposed system is expected to deliver real-time analytical outputs and to support project managers in evaluating and controlling projects more efficiently. (Wiśniewski, Szymański, & Starostka-Patyk, 2025) [16].

2. Materials and methods

Construction projects are activities associated with the process of developing infrastructure structures, which generally encompass core works within the disciplines of civil engineering and architecture (Ikudayisi, *et al*., 2023) [5]. The construction services industry is one of the industrial sectors characterized by a relatively high risk of occupational accidents. The principal causes of such accidents in construction projects are closely related to the inherent characteristics of construction activities, which are unique in nature, (Chan, *et al*., 2022) [2] carried out at varying locations, conducted in open environments and influenced by weather conditions, constrained by limited execution time, dynamic in operation, physically demanding, and heavily reliant on unskilled labor. When these conditions are compounded by weak occupational safety management, workers are often required to perform construction methods that involve high levels of risk. To reduce the risk of workplace accidents, since the early 1980s the government has issued specific occupational safety regulations for the construction sector, namely the Regulation of the Minister of Manpower and Transmigration No. Per-01/Men/1980.

Project management is defined as the application of knowledge, skills, tools, and techniques to project activities in order to meet project objectives. Project management is carried out through the application and integration of project management process stages, namely initiation, planning, execution, monitoring and controlling, and project closure (Santosa, 2013). In its implementation, every project inevitably faces interrelated constraints known as the project constraint triangle, which consists of scope, time, and cost. The balance among these three constraints determines the overall quality of a project (Soeharto, 1999).

It is well understood that projects possess distinctive characteristics that differentiate them from other types of activities, particularly in terms of organizational structure, management approach, resource utilization, duration, level of complexity, and degree of uncertainty. Consequently, the need for project management becomes evident. The proper application of project management can provide benefits in terms of time efficiency and cost savings when compared to management approaches that treat projects as routine operations (Soeharto, 1999).

In project implementation, it is necessary to examine project performance in order to determine whether the project is progressing in accordance with the planned objectives. According to Mahsun (2009), performance represents the level of success in carrying out an activity, program, or policy to achieve the goals, objectives, mission, and vision of an organization as formulated in its strategic planning.

Project performance in terms of work progress must be measured and evaluated based on the level of time control considered appropriate and feasible for the specific work involved. Within certain limits, the higher the frequency of feedback and response, the greater the likelihood that project time objectives will be achieved. However, this principle must be balanced against other considerations, such as the trade-off between the costs and efforts required and the managerial benefits obtained (Gamil & Rahman, 2023) [4].

Project scheduling constitutes an essential component of planning outputs. A project schedule presents information on targeted progress and actual project development in terms of resource utilization, including cost, labor, equipment, materials, execution time, and estimated project completion (Husen, 2009). During the planning stage, each activity and the relationships among activities are systematically detailed with the objective of supporting effective project evaluation. Scheduling also involves the efficient allocation of time for each task so that the project can be completed with optimal results, while taking into account various existing constraints.

During the project control process, scheduling follows project progress along with the problems that arise. Continuous monitoring and updating processes are conducted to ensure that the schedule remains accurate and realistic, so that resource allocation and task duration determination are aligned with project targets and objectives.

In the preparation of schedules or project networks, it has traditionally been assumed that all required resources will always be available. This implies that calculations and analyses have not taken into account the possibility of resource limitations (Dipohusodo, 1996). As a consequence, schedules developed under such assumptions tend to be less realistic when resource availability is, in fact, constrained. Therefore, before a schedule is practically applied in project execution, it is essential to first consider resource availability factors.

The Earned Value Management System (EVMS), also referred to as the Cost/Schedule Control System Criteria, represents an extension of time–cost control principles (S. Keoki Sears *et al*., 2015). Initially developed by industrial engineers to measure manufacturing output performance, EVMS compares the physical work accomplished to date with actual cost expenditures and the work planned to be completed. This comparison across three dimensions determines the earned value of a project and forms the basis for more accurate projections of final project costs than those obtained by merely comparing actual costs with planned budgets.

3. Research procedures

The research procedures undertaken in this study consist of the following stages:

- Review of the theoretical framework
- Data collection from the project site
- Data processing and analysis using Python
- Presentation and discussion of research findings
- Conclusions and recommendations
- Completion of the study (Proaño-Narváez, *et al*., 2022) [10]

Research location

Project Name : Construction of the Santa Ursula Female Student Dormitory Building

Project Duration : 80 weeks

Total Budget : IDR 18,712,612,545

Data collection

The data required for this study are derived from project planning documents. The data include:

- Project schedule
- Weekly progress reports
- Cost Budget Plan (RAB)

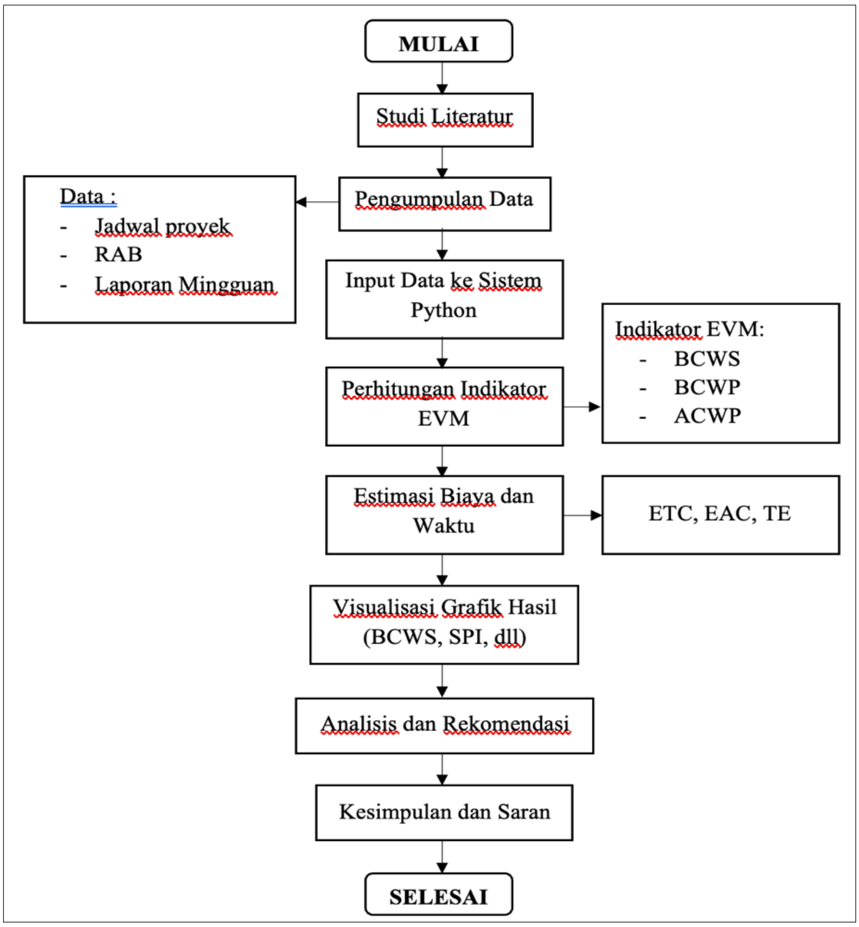

Fig 1: Research flowchart

4. Results and Discussion

Data analysis calculations

Data analysis using the Earned Value method consists of several stages, namely: the calculation of Earned Value indicators, the calculation of integrated cost and schedule variances, and the calculation of performance indices.

Calculation of earned value indicators

a) Budgeted Cost of Work Scheduled (BCWS)

To determine the planned weekly cost based on the planned work weighting, BCWS is calculated by multiplying the cumulative planned work weight per week by the Budget at Completion (BAC).

BCWS in Week 41

= 47.55% × IDR 18,712,612,545.00

= IDR 8,898,142,529.00

b) Budgeted Cost of Work Performed (BCWP)

To determine the cost corresponding to the actual work progress based on the work weighting, BCWP is calculated by multiplying the cumulative actual work weight per week by the Budget at Completion (BAC).

BCWP in Week 41

= 38.56% × IDR 18,712,612,545.00

= IDR 7,216,188,369.00

c) Actual Cost of Work Performed (ACWP)

To determine the actual weekly cost incurred based on work progress, ACWP is calculated by summing the direct costs and indirect costs. As actual project cost data are unavailable due to confidentiality, an assumption is applied whereby indirect costs account for 5% and direct costs account for 85%, based on experience from previous projects.

ACWP in Week 41

= IDR 7,563,421,149.65 + IDR 444,907,126.45

= IDR 8,008,328,276.00

The following figure presents a comparative graph of the BCWS, BCWP, and ACWP values.

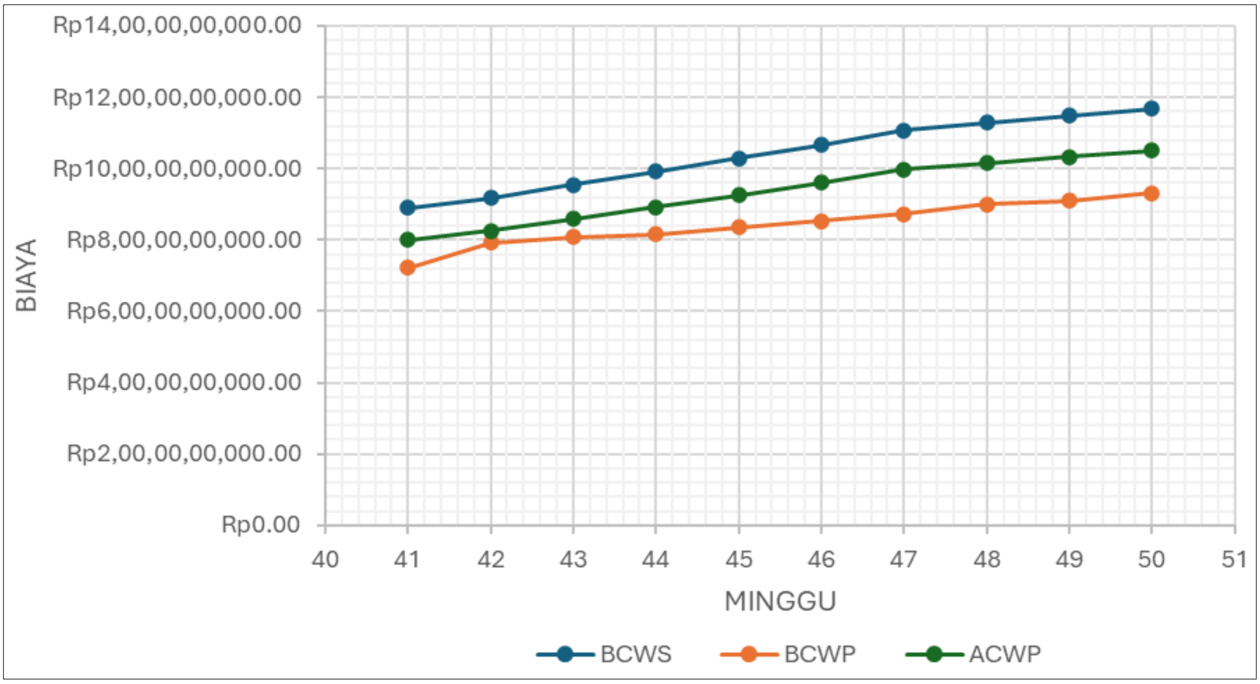

Fig 2: Comparison of BCWS, BCWP, and ACWP Values

From the graph above, the comparison among BCWS, BCWP, and ACWP from Week 41 to Week 50 can be observed. The graph indicates that the ACWP values are lower than both BCWS and BCWP, which implies that the actual costs incurred are lower than the planned costs.

Calculation of integrated cost and schedule variances

To determine the weekly cost and schedule variances, Equations (1) and (2) are applied as follows:

Schedule Variance (SV) in Week 41

SV = BCWP – BCWS

= IDR 7,216,188,369.00 − IDR 8,898,142,529.00

= −IDR 1,681,954,160.00

Cost Variance (CV) in Week 41

CV = BCWP – ACWP

= IDR 7,216,188,369.00 − IDR 8,008,328,276.00

= −IDR 792,139,907.00

The variance values for the subsequent weeks are presented in Table 4.4.

The following figure illustrates the comparison between Schedule Variance (SV) and Cost Variance (CV).

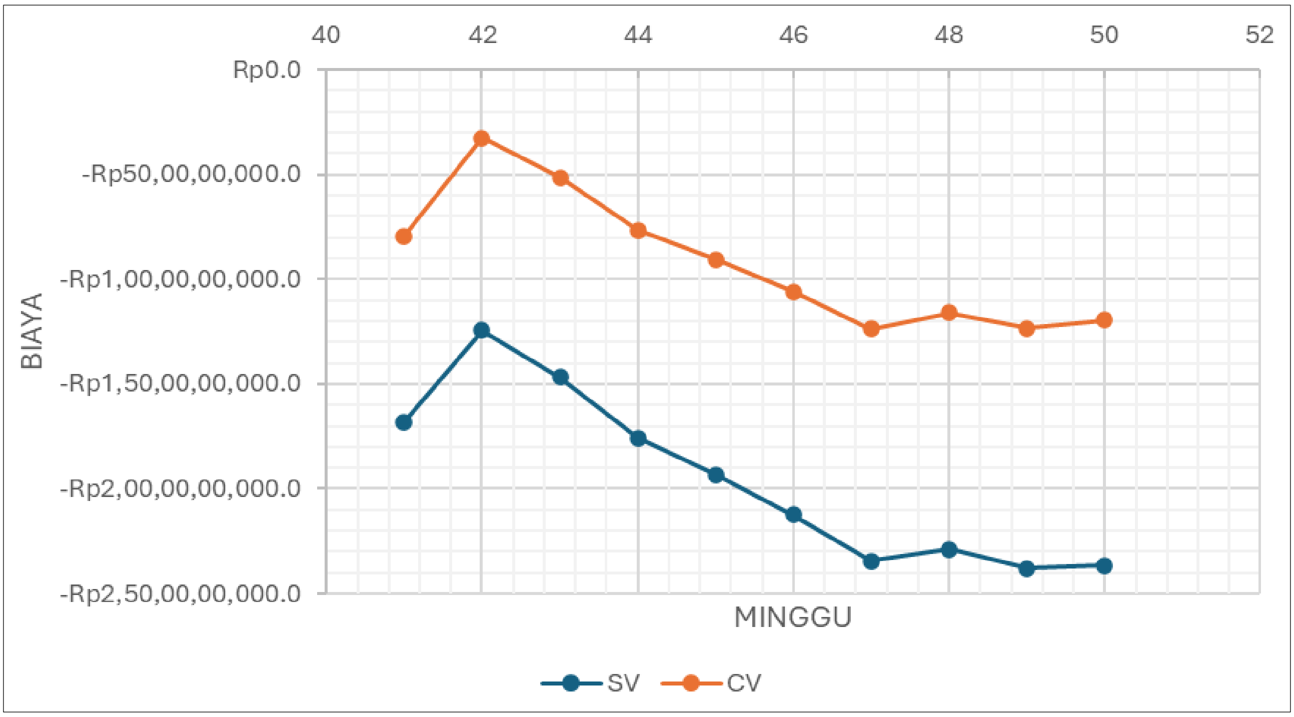

Fig 3: Comparison of SV and CV Values

From the graph above, the comparison between Schedule Variance (SV) and Cost Variance (CV) from week 41 to week 50 can be observed. The graph shows that the SV values are negative in several weeks. This condition indicates that during those weeks the project performance did not meet the planned schedule, or the realized work weight did not reach the planned value.

Table 1

Week	Cost and schedule analysis	Variance analysis	Remarks
	BCWP	BCWS	ACWP
41	7,216,188,369	8,898,142,529	8,008,328,276
42	7,924,020,786	9,167,854,317	8,251,068,885
43	8,075,476,250	9,541,995,684	8,587,796,116
44	8,157,410,858	9,916,137,051	8,924,523,346
45	8,357,531,000	10,290,278,418	9,261,250,576
46	8,540,000,798	10,664,419,785	9,597,977,807
47	8,733,469,133	11,079,143,502	9,971,229,152
48	8,990,978,767	11,278,548,980	10,150,694,082
49	9,098,091,512	11,477,954,458	10,330,159,012
50	9,313,633,473	11,677,359,935	10,509,623,942

Performance index calculation

To determine the performance indices for each week, calculations were conducted using Equation (3) and Equation (4).

SPI for Week 41

SPI = BCWP / BCWS
= Rp 7,216,188,369.00 / Rp 8,898,142,529.00
= 0.901085485

CPI for Week 41

CPI = BCWP / ACWP
= Rp 7,216,188,369.00 / Rp 8,008,328,276.00
= 0.810976937

From the previous graph, the comparison between SPI and CPI from week 16 to week 21 can be observed. The graph indicates that the SPI values fall below zero in several weeks. This condition signifies that during those weeks the project performance did not meet the planned schedule or the realized work weight failed to achieve the planned value.

Estimation of cost expenditure and project duration forecast

To estimate the projected cost expenditure and project duration at the final week of the project, indicator values from week 50 were used. The estimates were calculated using Equation (5), Equation (6), and Equation (7).

Estimate to Complete (ETC)

ETC = (BAC – BCWP) / CPI
= (Rp 18,712,612,545.00 – Rp 9,313,633,473.00) / 0.886200451
= Rp 10,605,929,017.00

Estimate at Completion (EAC)

EAC = ETC + ACWP
= Rp 10,605,929,017.00 + Rp 10,509,623,942.00
= Rp 21,115,552,959.00

Time Estimate (TE)

TE = (Remaining time / SPI) + Elapsed time
= (50 / 0.797628) + 30 weeks
= 92.5 weeks

Total Duration

Planned duration = 80 weeks
Estimated duration = 92.5 weeks
Delay = 12.5 weeks

Calculation using Python

Description of the EVM analysis application system

The developed application is a web-based system built using the Flask framework in the Python programming language. This system is designed to analyze construction project performance based on the Earned Value Management (EVM) approach. The main system inputs include:

1. **Budget at Completion (BAC):** The total project budget.
2. **Weekly data**, consisting of:
   - Cumulative planned progress (%),
   - Cumulative actual progress (%),
   - Weekly actual cost (ACWP).

Based on these inputs, the system calculates various key EVM indicators, including BCWS, BCWP, CV, SV, CPI, SPI, EAC, ETC, and TE, which are subsequently visualized in the form of graphs and tables.(Reda, *et al.*, 2025; Morichetta, Paoloni, & Re, 2025).

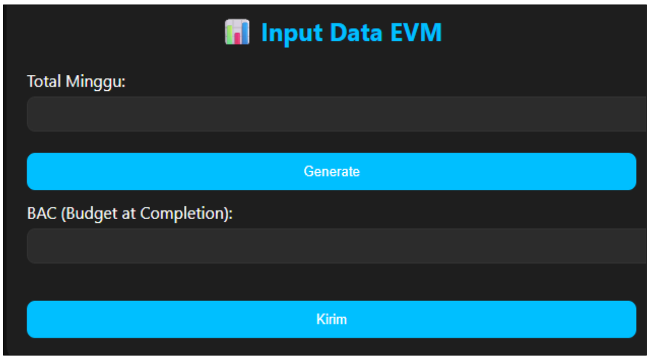

Fig 4

EVM indicator calculation

After the user inputs all weekly data into the form, the system generates the following calculations.

Hasil Analisis Earned Value Management

Minggu	Rencana Kumulatif (%)	Progres Kumulatif (%)	ACWP (Actual Cost)	BCWS	BCWP	SV	CV	SPI	CPI	ETC	EAC	TE
1	47.551578	38.563233	8.008328e+09	8.898143e+09	7.216188e+09	-1.681954e+09	-7.921399e+08	0.810977	0.901085	1.275842e+10	2.076675e+10	12.330807
2	48.992915	42.345882	8.251069e+09	9.167854e+09	7.924021e+09	-1.243834e+09	-3.270481e+08	0.864327	0.960363	1.123387e+10	1.948494e+10	11.569700
3	50.992322	43.155258	8.587796e+09	9.541996e+09	8.075476e+09	-1.466519e+09	-5.123199e+08	0.846309	0.940343	1.131197e+10	1.989977e+10	11.816016
4	52.990000	43.593116	8.924523e+09	9.915813e+09	8.157411e+09	-1.758403e+09	-7.671125e+08	0.822667	0.914044	1.154780e+10	2.047232e+10	12.155589
5	54.990000	44.662556	9.261251e+09	1.029007e+10	8.357531e+09	-1.932535e+09	-9.037196e+08	0.812194	0.902419	1.147480e+10	2.073605e+10	12.312327
6	56.990000	45.637672	9.597978e+09	1.066432e+10	8.540001e+09	-2.124317e+09	-1.057977e+09	0.800801	0.889771	1.143284e+10	2.103082e+10	12.487491
7	59.206824	46.671565	9.971229e+09	1.107914e+10	8.733469e+09	-2.345674e+09	-1.237760e+09	0.788280	0.875867	1.139345e+10	2.136468e+10	12.685845
8	60.272444	48.047694	1.015069e+10	1.127855e+10	8.990979e+09	-2.287570e+09	-1.159715e+09	0.797175	0.885750	1.097559e+10	2.112629e+10	12.544295
9	61.340000	48.620103	1.033016e+10	1.147832e+10	9.098092e+09	-2.380225e+09	-1.232067e+09	0.792633	0.880731	1.091652e+10	2.124668e+10	12.616181
10	62.400000	49.771957	1.050962e+10	1.167667e+10	9.313633e+09	-2.363037e+09	-1.195990e+09	0.797628	0.886200	1.060593e+10	2.111555e+10	12.537180

Fig 5

5. Conclusion

Based on the results of the data analysis conducted to evaluate the project performance of the Construction of the Santa Ursula Female Student Dormitory Building, the following conclusions can be drawn:

- The results obtained from the Earned Value Method calculations using Microsoft Excel and those performed using Python produce identical outcomes.
- The completion time for the Construction of the Integrated Santa Ursula Female Student Dormitory Building in Manado, as analyzed using the Earned Value Method, is estimated to be 92.5 weeks. The project experienced delays compared to the planned schedule, as the planned work weight at week 50 had not yet been fully completed, and an additional 12 weeks are required to achieve project completion.
- The total cost incurred for the Construction of the Santa Ursula Female Student Dormitory Building, as estimated using the Earned Value Method, is Rp 21,115,552,959.00. This expenditure exceeds the initial budget of Rp 18,712,612,545.00.

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References

1. Batukan MB, Mercan O. Modular Building Py: a Python-based numerical modeling and analysis tool for volumetric modular steel buildings. In: Canadian Society of Civil Engineering Annual Conference. Cham: Springer Nature Switzerland, 2024 Jun, p309-320.
2. Chan AP, Yang Y, Choi TN, Nwaogu JM. Characteristics and causes of construction accidents in a large-scale development project. Sustainability. 2022;14(8):4449.
3. Fullerton JR. Planning and forecasting level of effort contracts with Monte Carlo simulation [doctoral dissertation]. Washington (DC): The George Washington University, 2025.
4. Gamil Y, Abd Rahman I. Studying the relationship between causes and effects of poor communication in construction projects using PLS-SEM approach. J Facil Manag. 2023;21(1):102-148.
5. Ikudayisi AE, Chan AP, Darko A, Adedeji YM. Integrated practices in the architecture, engineering, and construction industry: current scope and pathway towards industry 5.0. J Build Eng. 2023;73:106788.
6. Liawan C. Analisis penggunaan dana Badan Layanan Umum Daerah (BLUD) pada Rumah Sakit Umum Daerah Sele Be Solu Kota Sorong. Jurnal Pitis AKP. 2018;3(1):27-38.
7. Mayo-Alvarez L, Alvarez-Risco A, Del-Aguila-Arcentales S, Sekar MC, Yáñez JA. A systematic review of earned value management methods for monitoring and control of project schedule performance: an AHP approach. Sustainability. 2022;14(22):15259.
8. Morichetta A, Paoloni Y, Re B. Event log extraction methodology for Ethereum applications. Future Gener Comput Syst. 2025;164:107566.

9. Panchal PB. Use of integrated intelligence scheduling system (IISS) for heavy civil construction projects. J Emerg Technol Innov Res. 2025;12(5):a800-a815.
10. Proaño-Narváez M, Flores-Vázquez C, Vásquez Quiroz P, Avila-Calle M. Earned value method (EVM) for construction projects: current application and future projections. Buildings. 2022;12(3):301.
11. Reda SG, Belachew KT, Demiss BA, Ali SK. Performance evaluation of construction project by earned value management system in Amhara Waterworks Construction Enterprise. Discover Civ Eng. 2025;2(1):1-25.
12. Sanusi BO. The role of data-driven decision-making in reducing project delays and cost overruns in civil engineering projects. SAMRIDDHI J Phys Sci Eng Technol. 2024;16(4):182-192.
13. Shen W, Ying W. Large-scale construction programme resilience against creeping disruptions: towards inter-project coordination. Int J Proj Manag. 2022;40(6):671-684.
14. Todaro M. Pembangunan ekonomi di dunia ketiga. Jakarta: Erlangga, 2000.
15. Umana AU, Afrihyia E, Appoh M, Frempong D, Akinboboye O, Okoli I, *et al*. Data-driven project monitoring: leveraging dashboards and KPIs to track performance in technology implementation projects. J Front Multidiscip Res. 2022;3(2):35-48.
16. Wiśniewski T, Szymański R, Starostka-Patyk M. Sprint into the future: intelligent management through LLM-powered computer simulations in agile projects. In: Intelligent Management and Artificial Intelligence: Trends, Challenges, and Opportunities. 2025;2:482-495.
17. Yáñez-Casas GA, Hernández-Gómez JJ, Cruz-Aparicio A, Ruán-Aldana A, Gutiérrez-Aguilar A, Trujillo-Alcántara A. Databases in seismic data analysis and processing: a dedicated web application. In: GIS LATAM Conference; Cham: Springer Nature Switzerland, 2025, p152-169.
18. Zahoor H, Khan RM, Nawaz A, Ayaz M, Maqsoom A. Project control and forecast assessment of building projects in Pakistan using earned value management. Eng Constr Archit Manag. 2022;29(2):842-869.