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Earned Value Method in Evaluating Time and Cost Deviations of Projects in Road Improvement Work in Jember Regency

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***Abstract*— Project control is an essential aspect of project management. The earned value method is one of the control methods available for use. This research aims to assess the extent of time and cost deviations in the Mayang-Kalisat-Ajung road improvement project in Jember Regency, utilizing the earned value method as an analytical tool. This research employs secondary data, such as the Cost Budget Plan (RAB), project schedule, and weekly or monthly project reports, to measure key indicators such as Actual Cost Work Performed (ACWP), Budgeted Cost of Work Scheduled (BCWS), and Budgeted Cost of Work Performed (BCWP), to identify deviations in project cost and schedule performance. This research employs a quantitative analysis method, utilizing Microsoft Project and Microsoft Excel software to generate metrics like the cost performance index (CPI) and schedule performance index (SPI). The research results show that the project experienced a time delay of -10.63% with a time realization of 89.37%, as well as cost overruns with an Estimate at Completion (EAC) value reaching Rp20,298,475,550.24. The CPI value during the research period was 0.90, indicating low-cost efficiency. The results show that the project experienced significant deviations in cost and time. The implications of this research provide important insights for improvements in the management of similar construction projects, emphasizing the evaluation of cost efficiency and timeliness using the earned value method to reduce the risk of delays and cost overruns in the future.**

***Keywords*—Deviation; time; cost; earned value.**

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I. INTRODUCTION

As the economic growth in Indonesia increases, it impacts the rising demand for construction projects. We must take construction development seriously to achieve optimal results. Construction management is crucial in ensuring that projects do not encounter any undesirable issues. According to [1], weather conditions, work rescheduling, and heavy traffic are among the factors that cause project time and cost deviations. Nejatyan et al [2] identified factors affecting the performance of construction project management and evaluated them through quantitative analysis. Therefore, good cost and time management are necessary for the project to proceed as planned[3]. One of the methods for controlling project time and cost that can be used to evaluate deviations in the project is the earned value method. As explained by previous studies [4], [5], [6], [7], [8] have investigated the concept, definition, and factors influencing Earned Value Management. Implementing the K3 Management System would affect project performance achievement [9]. A comparative analysis has been conducted on the stability and accuracy of 30 existing methods for project final cost prediction using the earned value method [10]. The research findings indicate that methods with the simplest mathematics achieve better stability and accuracy, finding out which methods are more stable and accurate will help project practitioners manage projects more efficiently.

Mayo-Alvarez et al [11] conducted a study that compared the most suitable and efficient EVM methods for monitoring and controlling projects. Another previous study [12] conducted research to measure the performance of a project by focusing on developing a fuzzy-based value analysis model. The randomized earned value method was used by [13] to control the time and cost of work on construction projects. This method ensures that random factors have a realistic effect on the progress and outcomes of both individual tasks and the project. Research by [14] confirms that the results of the randomized Earned Value Method reflect the actual work execution situation well.

Several methods for project management aim at ensuring the project is completed as planned [15]. Ugural and Burgan [16] conducted an evaluation of an operational bridge project in terms of its performance using the Earned Value Analysis

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(EVA) technique. The study by [17] uses the EVM method to look at four building construction projects. It looks at the projects' performance, costs, completion times, and how well the plans were carried out compared to the actual completion of the projects. Researchers [18] hypothesize that the simultaneous improvement of earned value management systems and social environmental elements will significantly impact project performance outcomes. Nejatyan et al [19] conducted research to rank and prioritize aspects that have been proven to impact the improvement of construction project management performance.

Project time and cost have been predicted using an efficient machine learning algorithm based on several directly measurable variables [20]. A study by [21] combined EVM and a new risk-based duration management model (RBEDM) to track and estimate how well a project's schedule was doing. A new study suggests a way to estimate that combines improved EVM, the Critical Path Method (CPM), the Program Evaluation and Review Technique (PERT), and Monte Carlo Simulation (MCS) [22]. Konior [23] developed a method that enables the analysis and evaluation of deviations during the implementation phase of construction investments in various construction sectors. The studies conducted by [24], [25], [26], [27] also conducted time and cost control evaluations on their projects, serving as valuable references for the authors.

The improvement project for the Mayang-Kalisat-Ajung Road is located in Jember Regency. This project involves repairing damaged roads to a stable condition according to the planned lifespan. The project currently faces a time delay of -10.63%, with an actual realization time of 89.37%, and a project value of IDR 18,286,914,000.00. We still conduct the project review using traditional processes, necessitating the evaluation of time and cost deviations using the earned value method. This research aims to evaluate the project deviations and determine the extent of cost and time deviations in the Mayang-Kalisat-Ajung Road Improvement Project in Jember Regency, using the earned value method.

II. Materials and Method

A. Type of Research

This research type employs descriptive analysis based on quantifiable data. This research uses the earned value method or the value outcome concept.

B. Research Object

This research is situated in Jember Regency and focuses on the Mayang-Kalisat-Ajung Road route, with a project value of Rp 18,286,914,000.00. This research uses the earned value concept method, which involves analyzing performance and estimating time and cost on the project to determine the extent of deviations in the Mayang-Kalisat-Ajung Road improvement project in Jember Regency. The secondary data required is:

- Draft Budget
- Time Schedule
- Weekly or Monthly Report

C. Stages of the Analysis Process Using the Earned Value Method

Based on the data obtained, a data analysis was conducted, with stages or steps carried out systematically according to the theoretical basis, as in previous research. The research stages begin with a literature study, followed by data collection, such as time schedules, budget plans (RAB), and weekly project reports. Then, data analysis was performed according to the guidelines of previous researchers. We utilize Microsoft Project 2016 and Microsoft Excel tools for data analysis to streamline the process. Using this document as a camera-ready template is an effortless way to comply with the conference paper formatting requirements.

A. Earned Value Indicators

Hussein and Moradinia [28] explains the indicators used in the concept of earned value:

1) ACWP (Actual Cost Work Performed): ACWP is the actual cost of the work performed.

2) BCWP (Budgeted Cost of Work Performed): BCWP is the budgeted amount for activities that have been completed, or it can be said to be the cost that should have been incurred according to the progress made. People often refer to BCWP as the actual S-curve. You can calculate BCWP (Budgeted Cost of Work Performed) using the following formula:

$$\text{BCWP} = \%\ \text{Progress Realization x Project Value} \quad (1)$$

3) BCWS (Budgeted Cost of Work Schedule): BCWS is the budget planned for the activities carried out or the budget planned according to the implementation schedule and is the S-curve of the plan. The calculation of BCWS uses the following formula:

$$\text{BCWS} = \%\ \text{Planned Progress x Project Value} \quad (2)$$

B. Variance Earned Value

1) Cost Variance (CV): It is the result of the subtraction between Budget Cost of Work Performed (BCWP) and Actual Cost of Work Performed (ACWP). The calculation of cost variance (CV) uses the following formula:

$$\text{CV} = \text{BCWP} - \text{ACWP} \quad (3)$$

2) Schedule Variance (SV): It is the result of subtracting the Budget Cost of Work Performed (BCWP) from the Budgeted Cost of Work Scheduled (BCWS). The calculation of SV (Schedule Variance) uses the following formula:

$$\text{SV} = \text{BCWP} - \text{BCWS} \quad (4)$$

Table 1 illustrates the provisions for the earned value variance as explained in the research by [3].

C. Earned Value Performance Index

1) SPI (Schedule Performance Index): As indicated by the equation, the SPI value indicates the extent of the planned work. The calculation of SPI (Schedule Performance Index) uses the following formula:

$$\text{SPI} = \text{BCWP} / \text{BCWS} \quad (5)$$

TABLE I
EARNED VALUE VARIANCE PROVISIONS

No	Schedule Variance (SV)	Cost Variance (CV)	Remarks
1	Positive	Positive	The work was completed faster than scheduled and at a lower cost than the budget
2	Zero	Positive	The work was completed precisely on schedule and at a lower cost than the budget.
3	Positive	Zero	The work was completed within budget and finished faster than scheduled.
4	Zero	Zero	The project was completed on schedule and within budget.
5	Negative	Negative	The work was completed late and exceeded the budget
6	Zero	Negative	The work was completed late but within the budget
7	Negative	Zero	The work was completed late but within the budget
8	Positive	Negative	The work was completed ahead of schedule and at a cost that exceeded the budget

2) CPI (Cost Performance Index): The CPI measures the efficiency of incurred costs using an equation. The calculation of the CPI (cost performance index) uses the following formula:

$$CPI = BCWP / ACWP \quad (6)$$

The research by [29] explains the provisions of the earned value indicator. Table 2 displays the provisions of the SPI and CPI.

TABLE II
SPI AND CPI PROVISIONS

No	Name	Value	Remarks
1	SPI (*Schedule Performance Index*)	>1	Work is ahead of schedule
2	SPI (*Schedule Performance Index*)	<1	Work is behind schedule
3	CPI (*Cost Performance Index*)	>1	Cost is below budget
4	CPI (*Cost Performance Index*)	<1	Cost exceeds budget

D. Project Cost Estimation and Completion

The research by [1] mentions the following formula for estimating project costs and completion:

1) Estimate to Complete (ETC): The ETC method estimates the cost of the remaining work using the following equation:

$$ETC = (Total\ Budget - BCWP) / CPI \quad (7)$$

2) Estimate at Complete (EAC): EAC is the total estimate at the end of the project obtained from the actual cost plus ETC, with the following equation:

$$EAC = ACWP + ETC \quad (8)$$

3) Estimate Temporary Schedule (ETS): The ETS estimates the remaining work time using the following equation:

$$ETS = Remaining\ Time/SPI \quad (9)$$

4) Estimate All Schedule (EAS): EAS is the estimated total completion time of the project, with the following equation:

$$EAS = ETS + Finish\ Time \quad (10)$$

Fig. 1 below displays a cost and time performance graph.

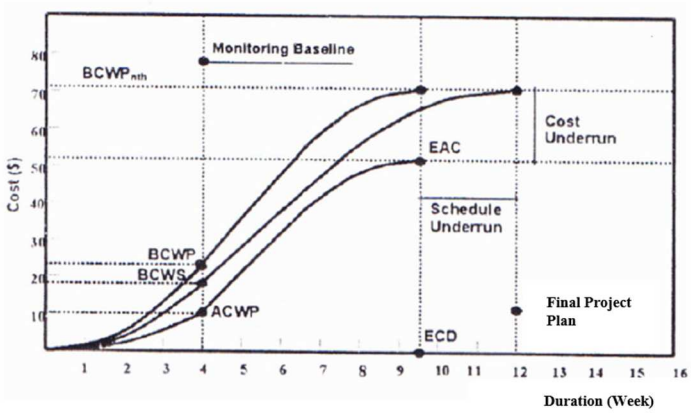

Fig. 1 Cost and time performance graph

III. RESULTS AND DISCUSSION

A. Project Data

The Mayang-Kalisat—Ajung road in Jember Regency has a road improvement package worth Rp. 18,286,914,000.00, including VAT. The supervising consultant is PT Dhiratama Cipta Persada, and the service provider is PT Diatasa Jaya Mandiri. The project duration is 180 days.

B. Calculation of Indicators, Variance, Performance Index, and Time and Cost Estimates

We conducted calculations based on previous research and analyzed them using Microsoft Excel tools to achieve optimal and specific results. The research by [30] provides a calculation example. Table 3 displays the results BCWP, ACWP, and BCWS.

TABLE III
THE RESULTS OF THE BCWS, BCWP, AND ACWP CALCULATIONS

Week	ACWP (IDR)	BCWS (IDR)	BCWP (IDR)
1	1,828,691.49	3,294,939.62	1,647,469.81
2	3,657,382.98	6,589,879.25	3,294,939.62
3	5,486,074.47	9,884,818.87	4,942,409.44
4	7,314,765.96	11,532,288.68	6,589,879.25
5	9,143,457.46	13,179,758.49	8,237,349.06
6	10,972,148.95	14,827,228.31	9,884,818.87
7	12,800,840.44	16,474,698.12	11,532,288.68
8	14,629,531.93	18,122,167.93	13,179,758.49
9	16,458,223.42	19,769,637.74	14,827,228.31
10	20,115,606.40	34,596,866.05	18,122,167.93
11	23,772,989.38	49,424,094.35	21,417,107.55
12	208,470,829.97	64,251,322.66	187,811,558.53
13	1,382,490,767.20	130,150,115.12	1,245,487,177.65
14	3,346,505,428.53	459,644,077.46	3,014,869,755.41
15	4,942,953,100.17	2,299,867,857.13	4,453,110,901.03
16	6,636,321,420.84	4,336,140,544.39	5,978,667,946.66
17	8,550,961,411.92	6,822,172,490.25	7,703,568,839.51

Week	ACWP (IDR)	BCWS (IDR)	BCWP (IDR)
18	10,732,590,360.68	9,308,204,436.11	9,669,000,324.87
19	11,539,043,308.21	9,308,204,436.11	10,395,534,511.83
20	11,539,043,308.21	9,308,204,436.11	10,395,534,511.83
21	12,617,971,287.90	10,952,379,308.18	11,367,541,700.73
22	13,023,940,798.90	12,598,201,650.07	11,733,279,998.93
23	13,204,981,256.51	13,996,903,520.20	11,896,379,510.29
24	13,663,982,820.75	15,253,922,986.53	12,309,894,433.02
25	14,997,098,917.69	16,459,870,888.69	13,510,899,925.75
26	16,343,015,855.07	16,474,698,117.00	14,723,437,707.16
27	18,286,914,910.00	16,474,698,117.00	16,474,698,117.00

Source: Calculation Result

Fig. 2 below presents a graph based on the results of Table 2 above.

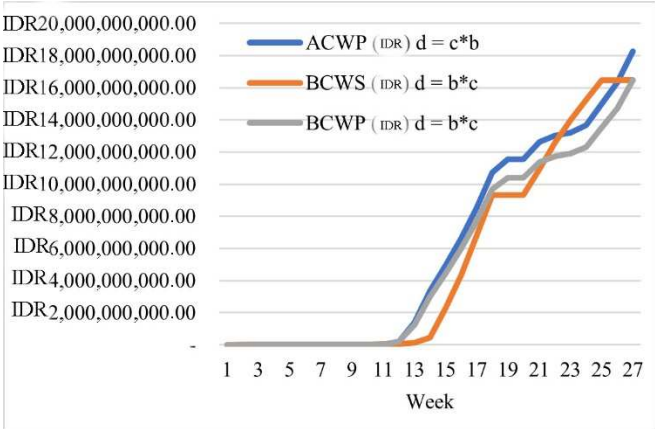

Fig. 2 Graphical Images of Earned Value Indicators

Table 4 below displays the results of the SV and CV calculations.

TABLE IV
THE RESULTS OF THE SV AND CV CALCULATIONS

Week	SV (IDR)	CV (IDR)
1	-1.647.469,81	-181.221,68
2	-3.294.939,62	-362.443,36
3	-4.942.409,44	-543.665,04
4	-4.942.409,44	-724.886,72
5	-4.942.409,44	-906.108,40
6	-4.942.409,44	-1.087.330,08
7	-4.942.409,44	-1.268.551,76
8	-4.942.409,44	-1.449.773,43
9	-4.942.409,44	-1.630.995,11
10	-16.474.698,12	-1.993.438,47
11	-28.006.986,80	-2.355.881,83
12	123.560.235,88	-20.659.271,44
13	1.115.337.062,52	-137.003.589,55
14	2.555.225.677,95	-331.635.673,12
15	2.153.243.043,89	-489.842.199,15
16	1.642.527.402,26	-657.653.474,18
17	881.396.349,26	-847.392.572,41
18	360.795.888,76	-1.063.590.035,81
19	1.087.330.075,72	-1.143.508.796,38
20	1.087.330.075,72	-1.143.508.796,38
21	415.162.392,55	-1.250.429.587,17
22	-864.921.651,14	-1.290.660.799,97
23	-2.100.524.009,92	-1.308.601.746,23
24	-2.944.028.553,51	-1.354.088.387,73
25	-2.948.970.962,94	-1.486.198.991,94
26	-1.751.260.409,84	-1.619.578.147,90
27	-	-1.812.216.793,00

Source: Calculation Result

Fig. 3 below displays the graph of the relationship between SV and CV.

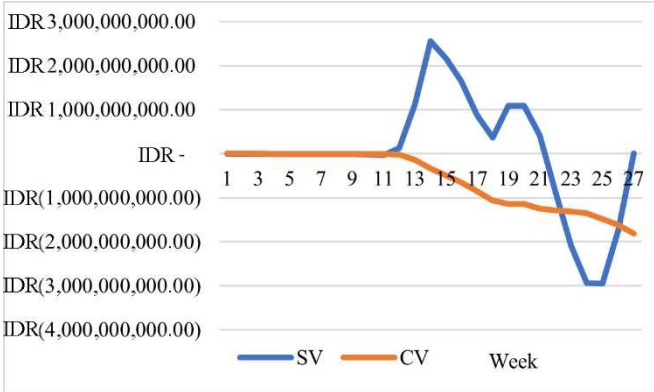

Fig. 3 Graph of the Relationship between SV and CV

Table 5 below displays the results of the SPI and CPI calculations.

TABLE V
THE RESULTS OF THE SPI AND CPI CALCULATIONS

Week	SPI	CPI
1	0.50	0.90
2	0.50	0.90
3	0.50	0.90
4	0.57	0.90
5	0.63	0.90
6	0.67	0.90
7	0.70	0.90
8	0.73	0.90
9	0.75	0.90
10	0.52	0.90
11	0.43	0.90
12	2.92	0.90
13	9.57	0.90
14	6.56	0.90
15	1.94	0.90
16	1.38	0.90
17	1.13	0.90
18	1.04	0.90
19	1.12	0.90
20	1.12	0.90
21	1.04	0.90
22	0.93	0.90
23	0.85	0.90
24	0.81	0.90
25	0.82	0.90
26	0.89	0.90
27	1.00	0.90

Source: Calculation Result

Fig. 4 displays the graph of the relationship between SPI and CPI.

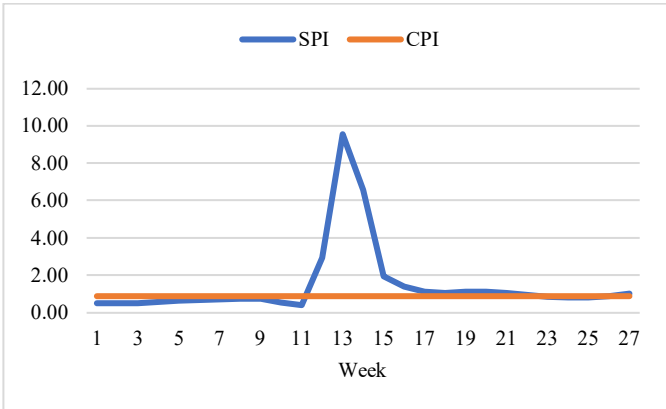

Fig. 4 Graph of the Relationship between SPI and CPI

Table 6 displays the results of the ETC, EAC and EAS calculations.

TABLE VI
THE RESULTS OF THE SPI AND CPI CALCULATIONS

Week To	ETC (IDR)	EAC (IDR)	EAS
1	20.296.646.858,75	20.298.475.550,24	355
2	20.294.818.167,26	20.298.475.550,24	348
3	20.292.989.475,77	20.298.475.550,24	341
4	20.291.160.784,28	20.298.475.550,24	296
5	20.289.332.092,79	20.298.475.550,24	268
6	20.287.503.401,30	20.298.475.550,24	250
7	20.285.674.709,81	20.298.475.550,24	237
8	20.283.846.018,32	20.298.475.550,24	227
9	20.282.017.326,83	20.298.475.550,24	220
10	20.278.359.943,84	20.298.475.550,24	282
11	20.274.702.560,86	20.298.475.550,24	317
12	20.090.004.720,27	20.298.475.550,24	116
13	18.915.984.783,05	20.298.475.550,24	99
14	16.951.970.121,71	20.298.475.550,24	109
15	15.355.522.450,07	20.298.475.550,24	143
16	13.662.154.129,41	20.298.475.550,24	161
17	11.747.514.138,33	20.298.475.550,24	173
18	9.565.885.189,57	20.298.475.550,24	178
19	8.759.432.242,03	20.298.475.550,24	175
20	8.759.432.242,03	20.298.475.550,24	176
21	7.680.504.262,34	20.298.475.550,24	179
22	7.274.534.751,34	20.298.475.550,24	182
23	7.093.494.293,73	20.298.475.550,24	184
24	6.634.492.729,49	20.298.475.550,24	183
25	5.301.376.632,55	20.298.475.550,24	182
26	3.955.459.695,18	20.298.475.550,24	180
27	2.011.560.640,24	20.298.475.550,24	180

Source: Calculation Result

Fig. 5 displays the graph of the relationship between ETC and EAC.

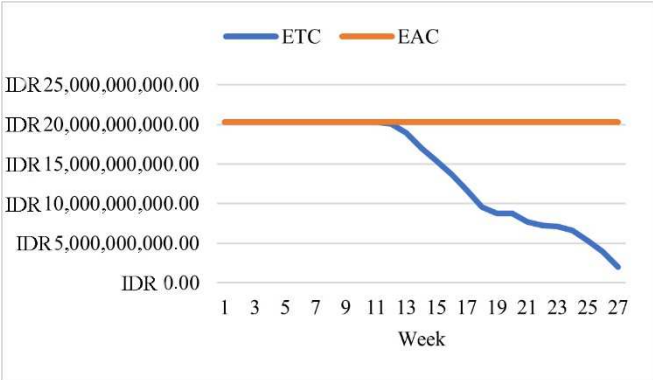

Fig. 5 Graph of the Relationship between ETC and EAC

Fig. 6 below displays the EAS value graph.

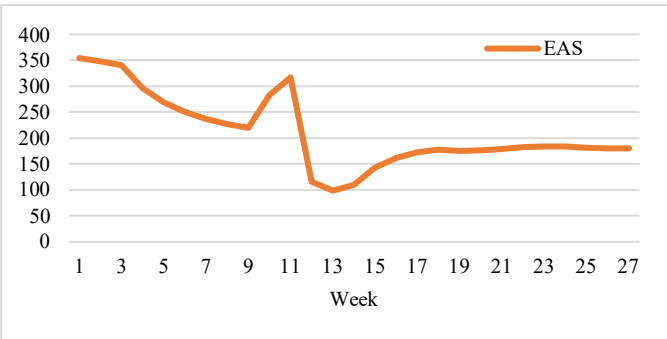

Fig. 6 EAS Value Graph

C. Calculation of Project Loss Value

We calculated the loss value using the following formula: ACWP – EAC = Rp 18,286,914,910.00 – Rp 20,298,475,550.24 = -Rp 2,011,560,640.24. The ΔH EAC is negative, indicating the project has a projected loss of Rp 2,011,560,640.24.

D. Discussion

This research uses the earned value method to evaluate time and cost deviations in the Mayang-Kalisat-Ajung Road improvement project in Jember Regency. The earned value method is one project control technique that can analyze cost and time performance in an integrated manner. The analysis results show that the project experienced a delay of -10.63% with a realization time of 89.37%. In weeks 1-11, the SPI value was less than 1, signifying a delay in the project. In weeks 12–21, the SPI value was more than 1, indicating that the project was progressing faster than planned. However, in weeks 22-26, the SPI value dropped below 1 again, indicating a delay. Week 27 saw the SPI value reach 1, signifying the project's timely completion, despite surpassing the contract time.

From a cost perspective, the CPI value for weeks 1-27 is 0.90, which means the project is experiencing cost overruns or wastage. The EAC value of Rp 20,298,475,550.24 further supports this, showing a 0.11% increase in the final cost estimate compared to the initial budget. We also calculate the project loss value at Rp 2,011,560,640.24. The practical implication of this research is the need for improved time and cost management in similar projects. The earned value method has proven effective in the early detection of potential deviations, making it a valuable tool for decision-making and appropriate corrective actions. In addition, this research also provides insights for practitioners and academics regarding the importance of comprehensive project performance evaluation to minimize the risk of delays and cost overruns in the future.

Theoretically, this study enriches the project management literature by applying the earned value method for time and cost variance analysis. These findings can serve as a reference for similar research in the future and encourage the development of more effective project control models and methods. Future research should investigate the factors causing deviations and explore mitigation strategies to enhance construction project performance. To gain a more comprehensive perspective, we can also compare the earned value method with other approaches, such as earned schedules.

IV. CONCLUSION

We can determine the extent of time and cost deviations based on the above research results. The SPI value from week 1 to week 11 is 0.59, indicating a delay in the project; from week 12 to week 21, the SPI value is 2.78, indicating a project ahead of schedule; from week 22 to week 26, the SPI value is 0.86, indicating a delay in the project; in week 27, the SPI value is 1, indicating a project that is on time but exceeds the contract time; and from week 1 to week 27, the CPI value is 0.90, indicating a cost overrun. The cost estimation results, calculated using the earned value method, amount to Rp20,298,475,550.24. This suggests that the final cost estimate has increased by 0.11% and has a negative EAC value, indicating a loss of Rp2,001,560,640. The earned value

method yielded a time estimation of 180 days, aligning with the plan. However, an additional 4 days resulted in a 2% increase in the project's time compared to the original plan.

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