Cost and Time Control Analysis in the Neucentrix Building Renovation Project Using the Earned Value Method

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Abstract. In the Neucentrix renovation project, an addendum caused an extension. This study analyzes the weekly performance of the 2023 Neucentrix Pugeran Yogyakarta Project in terms of cost and time using the Earned Value method. The data analyzed using the Earned Value method using ACWP, BCWS, and BCWP indicators. From these indicators, CV, SV, CPI, SPI, EAS and EAC values are obtained. The analysis reveals cost savings from the first to the seventeenth week, with initial acceleration in the first four weeks followed by delays from weeks five to seventeen. The project is expected to take 19 weeks to complete, with a final estimated cost of IDR 2,294,673,540.

Keywords: cost, time, earned value

1. Introduction

Infrastructure is crucial for economic and social progress, making its development key to future growth. Building renovation, which includes repairs, maintenance, and effective management, is one important form of infrastructure development. The Supervisor of the 2023 Neucentrix Pugeran Yogyakarta Project stated that the project was planned for 19 weeks. In week 8, a -17.92% progress deviation occurred, leading to an addendum and an extension, which impacted project costs.

[1] Effective project management, with strong cost and time control, can minimize deviations, reduce potential losses, and optimize the use of time, money, and resources. A project is a complex effort, typically lasting under three years, involving interconnected tasks, schedules, and budgets. According to [2], Project management involves planning, executing, controlling, and coordinating a project from its inception to completion to ensure it is finished on time, within budget, and with the desired quality.[3] Earned Value Management is widely used for tracking, analyzing, and predicting project performance.

[4] It highlights how Earned Value differs from traditional cost management. Traditional methods only compare actual and planned costs, while Earned Value adds a third dimension: the amount of work completed. This helps project managers better understand the link between costs and performance.

[5] The earned value concept measures costs based on completed work (Budgeted Cost of Work Performed) by tracking work units completed over time and comparing them to the budget. This method clarifies the relationship between actual achievements and the budget spent. [6] It was noted that using the earned value control method on asphalt road projects can reveal potential profits and help estimate the final project duration. This method effectively controls costs and time. Consequently, the author plans to research the weekly performance of the 2023 Pugeran Yogyakarta Neucentrix Development Project to assess costs, time, and completion estimates.

2. Research Methods

2.1. Research Methodology
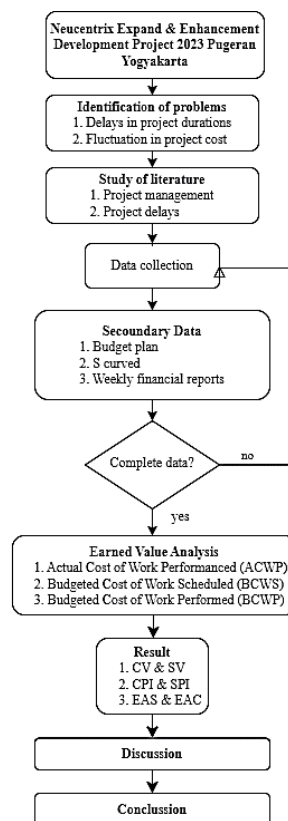The research design is as follows:

Figure 1. Research Methodology

2.2. Data Collection Technique
The following are the techniques used by the author to obtain the data needed in the research:

Studi of Literature: This method involves reviewing relevant literature, including articles, journals, prior research, and related books.

Field Observation: Observation involves directly monitoring the project site to assess progress, schedule adherence, and other factors. Researchers can gather secondary data, including the Cost Budget Plan (RAB), S curve, and financial reports, from these observations.

Documentation: Documentation complements observation data by visualizing the ongoing project.

2.3. Data Analysis Technique

Cost of Work on Budget: The Earned Value concept measures budget usage based on the amount of completed work [1]. The earned value based on the budget can be calculated using the following formula:

$$Result\ Value = (\%\ Realized\ Weight) \times (Budget) \tag{1}$$

Analysis of ACWP, BCWS, and BCWP Indicators: Actual Cost of Work Performed (ACWP) is the actual expenditure or funds used for work during a specific period.[7]. ACWP includes the total costs incurred up to that point or within a specific period.

$$ACWP = Actual\ Expenditure \tag{2}$$

[8] Budgeted Cost of Work Scheduled (BCWS) represents the planned budget for activities based on the work plan and schedule. It is calculated by summing the planned costs for work over a period. At project completion, BCWS becomes Budget At Completion (BAC). BCWS also serves as a standard for evaluating time performance.

$$BCWS = (Total\ Plan\ Budget) \times (\%\ Plan\ Weight) \tag{3}$$

Budgeted Cost of Work Performed (BCWP), also known as Earned Value, reflects the value of work completed over a specific period. [8]. BCWP is calculated by summing the value of completed work.

$$BCWP = (Total\ Planned\ Budget) \times (\%\ Realization\ Weight) \tag{4}$$

Cost and Schedule Variance Analysis: Cost Variance (CV) is the difference between the value of completed work and the actual costs incurred. [7].

$$CV = BCWP - ACWP \tag{5}$$

CV results show cost variances with the following conditions:
CV < 0, if costs are greater than planned.
CV = 0, if costs are according to plan.
CV > 0, if costs are smaller than planned.

Schedule Variance (SV) measures the extent of schedule deviations relative to cost differences, determined after completing work packages. [7].

$$SV = BCWP - BCWS \tag{6}$$

The SV result shows the schedule variance with the following conditions:
SV < 0, if the project is behind schedule.
SV = 0, if the project is according to plan / on time.
SV > 0, if the project is ahead of plan.

Cost and Time Performance Index Analysis: Cost Performance Index (CPI) is used to evaluate project conditions. According to [7], The Cost Performance Index (CPI) is calculated by comparing the value of results to the costs incurred.

$$CPI = BCWP/ACWP \tag{7}$$

The CPI value can be interpreted according to the following conditions:
CPI = 1 indicates the project is right on budget.
CPI > 1 indicates the project is more cost efficient, indicating savings.
CPI < 1 indicates the project is cost-inefficient.

The Schedule Performance Index (SPI) compares actual work progress to the plan, derived from the ratio of the value of results to the planned work.[7].

$$SPI = BCWP/ BCWS \tag{8}$$

The SPI value has the following parameters:
    a.   SPI value < 1 indicates that the project is delayed compared to the plan.
    b.   SPI value > 1 indicates that the project has an acceleration of time compared to the plan.
To determine when an activity needs special attention, the Critical Ratio (CR) is used.

$$CR = CPI \times SPI \tag{9}$$

Recommended limits for CR are as follows:
    a.   If the CR ranges from 0.9 to 1.2, the activity is doing well.
    b.   If the CR ranges from 0.8 to 0.9 or between 1.2 to 1.3, the activity requires special attention.
    c.   If the CR is below 0.8 or above 1.3, then the activity is in critical condition

Final Time and Cost Estimation: [9] Estimate At Schedule (EAS) assesses the total time needed to complete the project, calculated from the Estimate Time Schedule (ETS).

$$ETS = Time\ remaining/SPI \tag{10}$$

$$EAS = Time\ elapsed + ETS \tag{11}$$

[10] Estimate At Completion (EAC) estimates the total costs to complete a project by adding current expenditures to the estimated costs for remaining work. Estimate To Complete (ETC) calculates the remaining costs needed for project completion and can be formulated as follows:

$$ETC = (BAC - BCWP) / CPI \tag{12}$$

Assuming the remaining project performance has remained constant since the time of reporting, the estimated completion time for the remaining work to be completed is:

$$EAC = ACWP + ETC \tag{13}$$

2.4. Previous Research

Table 1. Previous Research

Reference	Result	Method
[11]	a) The working capital needed is IDR 25,000,000 from own funds. b)The company's cash faced a deficit in the 13th week. Cost analysis from the CV shows a negative value in the first two months, but positive values from the third to the eighth month, indicating project expenditures were	Earned Value Concept

Reference	Result	Method
	below budget as actual costs were less than planned. The project progressed smoothly from July 2021 to January 2022, faced delays in February, and was completed as scheduled in March 2022.	
[12]	a) In week 10, the earned value method shows that the project is ahead of schedule with positive SV, and budget performance indicates cost savings with a positive CV. b) Time performance improves with faster completion using the combined acceleration method (crash and overlapping). c) Accelerating work with this method also leads to cost savings.	Earned Value Concept, Crash, and Overlapping
[13]	In the 25th week, the project was delayed by -3.070% of the planned progress. Analysis shows a negative CV, indicating a cost overrun, and a negative SV, signaling delays. A CPI and SPI both below 1 mean the project is costing more and taking longer than planned. The remaining estimated cost (EAC) is IDR 72,488,057,584, with 19 weeks left to complete the project, making the total estimated duration 44 weeks.	Earned Value Concept
[14]	The time difference between normal work and the fast track method is significant: 155 days for normal work versus 91 days with fast tracking, at an additional cost of IDR 142,000,000.	Fast Track
[15]	Cost optimization results show that using Method 1 (Additional Working Hours) reduces the total project cost to IDR 16,053,818,153 (IDR 10,053,447 less than normal). Method 2 (Additional Labor) lowers the cost to IDR 16,046,101,360 (IDR 17,770,240 less than normal). The normal cost is IDR 16,063,871,600.	Time Cost Trade Off

3. Result and Discussion

3.1. Cost of Work on Budget
Total Budget Plan The cost of implementing work on this project is IDR. 2,650,000,000.00 (two billion six hundred and fifty million rupiah), including Value Added Tax (VAT) of 10%.

3.2. Weight of Plan and Work Realization
During the implementation stage, a time schedule was created to guide and monitor work progress. Based on the S curve data, the following summarizes the planned and actual weekly work for the 2023 Neucentrix Expand & Enhancement Development Project in Pugeran Yogyakarta:

Table 2. Weight of Work Plans and Realization

Period	Plan Weight (%)	Realization Weight (%)	Cumulative Plan Weight (%)	Cumulative Realization Weight (%)	Deviation (%)
W1	0,65	2,33	0,65	2,33	1,68
W2	1,86	3,12	2,51	5,45	2,94
W3	4,01	6,04	6,52	11,49	4,97
W4	7,36	9,76	13,88	21,25	7,37
W5	11,88	3,99	25,76	25,24	-0,52
W6	17,05	0,92	42,81	26,16	-16,65
W7	14,76	17,72	57,57	43,88	-13,69
W8	14,80	10,57	72,37	54,45	-17,92
W9	8,43	16,33	80,80	70,78	-10,02

Period	Plan Weight (%)	Realization Weight (%)	Cumulative Plan Weight (%)	Cumulative Realization Weight (%)	Deviation (%)
W10	8,13	10,54	88,93	81,32	-7,61
W11	4,06	6,30	92,99	87,62	-5,37
W12	2,57	4,47	95,56	92,09	-3,47
W13	1,04	1,65	96,60	93,74	-2,86
W14	1,04	2,19	97,64	95,93	-1,71
W15	1,04	0,15	98,68	96,08	-2,60
W16	0,33	0,72	99,01	96,80	-2,21
W17	0,33	1,48	99,34	98,28	-1,06

The table above explains the progress of the plan after amendments were made. In the first to fourth weeks, there is a positive deviation which indicates acceleration (W1-W4) and in the fifth to seventeenth week, the deviation has a negative value which indicates a delay (W5-W17).

3.3. Analysis of ACWP, BCWS, and BCWP Indicators

Project performance is assessed using three variables: Actual Cost of Work Performed (ACWP) from the weekly financial report, Budgeted Cost of Work Performed (BCWP) from the Cost Budget Plan (RAB), and Budgeted Cost of Work Scheduled (BCWS) from the S curve. The analysis covers weeks one to seventeen, with weekly values for ACWP, BCWS, and BCWP shown in the table.

Table 3. Recapitulations of ACWP, BCWS, and BCWP Values

Period	ACWP (IDR)	Cumulative ACWP (IDR)	Contract Value (IDR)	Plan Weight (%)	BCWS (IDR)	Cumulative BCWS (IDR)	Realization Weight (%)	BCWP (IDR)	Cumulative BCWP (IDR)
			1	2	3 = 1 x 2		4	5 = 1 x 4	
W1	23.079.000	23.079.000	2.650.000.000	0,65	17.225.000	17.225.000	2,33	61.745.000	61.745.000
W2	70.716.869	93.795.869	2.650.000.000	1,86	49.290.000	66.515.000	3,12	82.680.000	144.425.000
W3	16.464.420	110.260.289	2.650.000.000	4,01	106.265.000	172.780.000	6,04	160.060.000	304.485.000
W4	136.869.202	247.129.491	2.650.000.000	7,36	195.040.000	367.820.000	9,76	258.640.000	563.125.000
W5	162.834.579	409.964.070	2.650.000.000	11,88	314.820.000	682.640.000	3,99	105.735.000	668.860.000
W6	83.198.600	493.162.670	2.650.000.000	17,05	451.825.000	1.134.465.000	0,92	24.380.000	693.240.000
W7	93.922.873	587.085.543	2.650.000.000	14,76	391.140.000	1.525.605.000	17,72	469.580.000	1.162.280.000
W8	92.556.920	679.642.463	2.650.000.000	14,80	392.200.000	1.917.805.000	10,57	280.105.000	1.442.925.000
W9	218.897.469	898.539.932	2.650.000.000	8,43	223.395.000	2.141.200.000	16,33	432.745.000	1.875.670.000
W10	340.789.477	1.239.329.409	2.650.000.000	8,13	215.445.000	2.356.645.000	10,54	279.310.000	2.154.980.000
W11	247.011.538	1.486.340.947	2.650.000.000	4,06	107.590.000	2.464.235.000	6,30	166.950.000	2.321.930.000
W12	168.871.604	1.655.212.551	2.650.000.000	2,57	68.105.000	2.532.340.000	4,47	118.455.000	2.440.385.000
W13	162.998.000	1.818.210.551	2.650.000.000	1,04	27.560.000	2.559.900.000	1,65	43.725.000	2.484.110.000
W14	95.563.908	1.913.774.459	2.650.000.000	1,04	27.560.000	2.587.460.000	2,19	58.035.000	2.542.145.000
W15	89.230.165	2.003.004.624	2.650.000.000	1,04	27.560.000	2.615.020.000	0,15	3.975.000	2.546.120.000
W16	128.545.631	2.131.550.255	2.650.000.000	0,33	8.745.000	2.623.765.000	0,72	19.080.000	2.565.200.000
W17	123.654.900	2.255.205.155	2.650.000.000	0,33	8.745.000	2.632.510.000	1,48	39.220.000	2.604.420.000

Based on the table above, it can be seen that the cumulative actual expenditure in the seventeenth week reached IDR 2,255,205,155.00, the BCWS value in the seventeenth week reached IDR 2,632,510,000.00, and it can be seen that the BCWP value in the seventeenth week reached IDR 2,604,420,000.00. A comparison of the three indicators in the earned value method can be seen in the following graph:
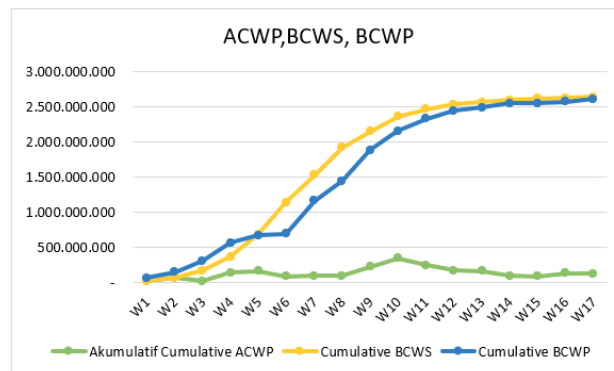

Figure 1. Three Indicator Charts (ACWP, BCWS, BCWP)

The graph shows that actual weekly costs (ACWP) are below both BCWS and BCWP lines, indicating cost savings compared to the plan. The BCWP line is below the BCWS line, meaning the actual costs are lower than planned costs. These variables illustrate the project's performance, revealing whether there are delays or accelerations.

3.4. Cost and Schedule Variance Analysis
The CV and SV value for each period can be seen in the table below:

Table 4. Recapitulations of CV and SV Values

Period	ACWP (IDR)	BCWS (IDR)	BCWP (IDR)	CV (IDR)	SV (IDR)
	1	2	3	4 = 3 - 1	5 = 3 - 2
W1	23.079.000	17.225.000	61.745.000	38.666.000	44.520.000
W2	93.795.869	66.515.000	144.425.000	50.629.131	77.910.000
W3	110.260.289	172.780.000	304.485.000	194.224.711	131.705.000
W4	247.129.491	367.820.000	563.125.000	315.995.509	195.305.000
W5	409.964.070	682.640.000	668.860.000	258.895.930	- 13.780.000
W6	493.162.670	1.134.465.000	693.240.000	200.077.330	- 441.225.000
W7	587.085.543	1.525.605.000	1.162.820.000	575.734.457	- 362.785.000
W8	679.642.463	1.917.805.000	1.442.925.000	763.282.537	- 474.880.000
W9	898.539.932	2.141.200.000	1.875.670.000	977.130.068	- 265.530.000
W10	1.239.329.409	2.356.645.000	2.154.980.000	915.650.591	- 201.665.000
W11	1.486.340.947	2.464.235.000	2.321.930.000	835.589.053	- 142.305.000
W12	1.655.212.551	2.532.340.000	2.440.385.000	785.172.449	- 91.955.000
W13	1.818.210.551	2.559.900.000	2.484.110.000	665.899.449	- 75.790.000
W14	1.913.774.459	2.587.460.000	2.542.145.000	628.370.541	- 45.315.000

Period	ACWP (IDR)	BCWS (IDR)	BCWP (IDR)	CV (IDR)	SV (IDR)
	1	2	3	4 = 3 - 1	5 = 3 - 2
W15	2.003.004.624	2.615.020.000	2.546.120.000	543.115.376	- 68.900.000
W16	2.131.550.255	2.623.765.000	2.565.200.000	433.649.745	- 58.565.000
W17	2.255.205.155	2.632.510.000	2.604.420.000	349.214.845	- 28.090.000

The table shows that from weeks one to seventeen, CV values are > 0, indicating actual costs are lower than budgeted. SV values are > 0 in weeks one to four, meaning the project is ahead of schedule, while values < 0 from weeks five to seventeen indicate the project is behind schedule.

3.5. Cost and Time Performance Index Analysis
The CPI and SPI value for each week can be found according to the following table:

Table 4. Recapitulations of CPI and SPI Values

Period	ACWP (IDR)	BCWS (IDR)	BCWP (IDR)	CPI (IDR)	SPI (IDR)	CR
	1	2	3	4 = 3/1	5 = 3/2	6 = 4 × 5
W1	23.079.000	17.225.000	61.745.000	2,68	3,58	9,59
W2	93.795.869	66.515.000	144.425.000	1,54	2,17	3,34
W3	110.260.289	172.780.000	304.485.000	2,76	1,76	4,87
W4	247.129.491	367.820.000	563.125.000	2,28	1,53	3,49
W5	409.964.070	682.640.000	668.860.000	1,63	0,98	1,60
W6	493.162.670	1.134.465.000	693.240.000	1,41	0,61	0,86
W7	587.085.543	1.525.605.000	1.162.820.000	1,98	0,76	1,51
W8	679.642.463	1.917.805.000	1.442.925.000	2,12	0,75	1,60
W9	898.539.932	2.141.200.000	1.875.670.000	2,09	0,88	1,83
W10	1.239.329.409	2.356.645.000	2.154.980.000	1,74	0,91	1,59
W11	1.486.340.947	2.464.235.000	2.321.930.000	1,56	0,94	1,47
W12	1.655.212.551	2.532.340.000	2.440.385.000	1,47	0,96	1,42
W13	1.818.210.551	2.559.900.000	2.484.110.000	1,37	0,97	1,33
W14	1.913.774.459	2.587.460.000	2.542.145.000	1,33	0,98	1,31
W15	2.003.004.624	2.615.020.000	2.546.120.000	1,27	0,97	1,24
W16	2.131.550.255	2.623.765.000	2.565.200.000	1,20	0,98	1,18
W17	2.255.205.155	2.632.510.000	2.604.420.000	1,15	0,99	1,14

The table shows that CPI values from weeks one to seventeen are all above 1, indicating cost savings. SPI was above 1 in weeks one to four, showing acceleration, but below 1 from weeks five to seventeen, indicating delays. CPI and SPI are linked: weeks one to four had both cost and time efficiency (CPI > 1, SPI > 1), while weeks five to seventeen had lower costs but delays (CPI < 1, SPI < 1). The project performed well in weeks sixteen and seventeen with a CR value between 0.9 and 1.2.

3.6. Final Time and Cost Analysis
The estimated time for project completion in each period and the results of estimating to complete can be seen in the following table:

Table 5. Recapitulations of EAS and EAC

Period	Remaining Time (weeks)	ETS (weeks)	Elapsed time (weeks)	EAS (weeks)	ETC (IDR)	EAC(IDR)
	1	2 = 1/ SPI	3	4 = 2+3	5 = (BAC-BCWP)/CPI	6 = ACWP+5
W1	18	5	1	6	967.436.021	990.515.021
W2	17	8	2	10	1.627.229.250	1.721.025.119
W3	16	9	3	12	849.359.285	959.619.574
W4	15	10	4	14	915.832.820	1.162.962.311
W5	14	14	5	19	1.214.299.282	1.624.263.352
W6	13	21	6	27	1.392.015.732	1.885.178.402
W7	12	16	7	23	750.848.694	1.337.934.237
W8	11	15	8	23	568.553.061	1.248.195.524
W9	10	11	9	20	370.942.877	1.269.482.809
W10	9	10	10	20	284.686.096	1.524.015.505
W11	8	8	11	19	210.008.000	1.696.348.947
W12	7	7	12	19	142.173.214	1.797.385.765
W13	6	6	13	19	121.420.931	1.939.631.482
W14	5	5	14	19	81.195.268	1.994.969.727
W15	4	4	15	19	81.721.254	2.084.725.878
W16	3	3	16	19	70.464.471	2.202.014.726
W17	2	2	17	19	39.468.385	2.294.673.540

The final estimated cost which is expected to be completed in the 19th week with a reference cost in the 17th week is IDR 2,294,673,540. It can be seen that these costs are smaller than the total planned costs and BCWP. When project costs and time are managed effectively, the project is completed faster or at a lower cost. As the project progresses weekly, estimated costs and completion times are adjusted. An increase in EAC indicates a need for a higher budget, while an increase in EAS requires schedule adjustments. Speeding up the schedule adds costs, raising the EAC.

4. Conclusion
The analysis leads to the following conclusions: (a) For the 2023 Neucentrix Expand & Enhancement Project in Pugeran Yogyakarta, cost performance index (CPI) indicates savings from weeks one to seventeen, while the schedule performance index (SPI) shows acceleration in the first four weeks and delays from weeks five to seventeen. (b) The project is expected to finish in 19 weeks, with an estimated total cost of IDR 2,294,673,540 by week 17.

5. Acknowledgements

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