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Optimizing Road Pavement Projects Through Earned Value Concepts

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Abstract

Every construction project faces cost, schedule, and quality constraints that must be managed to achieve the desired objectives. This research aims to control time and cost in construction projects by applying the Earned Value Concept and Crash Program methods. The subject of the study is the Preservation of Roads and Bridges project in Bireuen City - BTS, Lhokseumawe/North Aceh, Krueng Mane Buket Rata, SP. Krueng Geukeueh - PEL. Krueng Geukeueh (PEL. Lhokseumawe). The data analyzed includes the Budget Plan (RAB), project schedule, and reports on planned and actual work. This data is processed into three leading indicators: BCWS, BCWP, and ACWP, which are then analyzed through Schedule Variance (SV), Cost Variance (CV), Schedule Performance Index (SPI), and Cost Performance Index (CPI). The analysis results show that during weeks 22 to 23, the project had a positive Schedule Variance (SV) (>0), which then turned negative during weeks 24 to 28, with an average Schedule Performance Index (SPI) of 1.0096, indicating that project execution was ahead of schedule. Meanwhile, the Cost Variance (CV) was upbeat throughout the project, and the average Cost Performance Index (CPI) was 1.2118, indicating that actual costs did not exceed the budget. The application of the Crash Program method resulted in changes in heavy equipment rental costs and worker wages, from IDR 1,440,469,946.99 over 50 days to IDR 1,853,072,988.06 over 25 days, with a cost increase of IDR 412,603,041.07 and an acceleration ratio of 1.29. This research demonstrates that the Earned Value Concept and Crash Program methods effectively control time and cost in construction projects, helping achieve better project management efficiency.

Keywords: *Earned Value Management, Cost Variance, Cost Performance Index,*

1. Introduction

Pavement construction is a critical component of transportation infrastructure that determines the strength and durability of the road. Road construction projects often face challenges related to completion time and cost management [1]. In this context, effective project management becomes crucial to ensure that projects are completed on schedule and within the established budget [2]. One method that can enhance project completion efficiency is integrating the Earned Value Concept (EVC) [3]. EVC is a method to objectively evaluate project performance by comparing the value of completed work with the costs incurred and the scheduled timeline [4]. In other words, the EVC method provides a clear picture of project performance by comparing the earned value with the actual cost and the planned value. The Crash Program, on the other hand, is a technique used to accelerate project completion by reducing the completion time by adding resources or changes in work methods [5]. Combining these two methods can offer a comprehensive solution to address common issues in construction projects, particularly road pavement completion. The integration of EVC and CP provides a systematic and measurable approach to managing road pavement projects [6]. By applying EVC, project managers can monitor and control project performance more accurately, while CP can expedite delayed task completion [7]. Therefore, this research aims to explore how these two methods can be integrated to achieve optimal results in the completion of pavement work in the Preservation of Roads and Bridges project in Bireuen City - BTS, Lhokseumawe/North Aceh, Krueng Mane Buket Rata, SP. Krueng Geukeueh - PEL. Krueng Geukeueh (PEL. Lhokseumawe). Delays in completing pavement work can lead to increasingly higher costs, while uncontrolled expenditures can result in significant losses. This study's findings are expected to contribute substantially to the development of more effective and efficient project management strategies and improve the quality and success of future construction projects.

2. Literature Review

A project is a temporary endeavor undertaken within a specified timeframe, with allocated resources, to produce a product that meets quality requirements [8]. These objectives can be achieved by adhering to constraints, which include the budget allocated, the schedule, and the quality standards that must be met. These three constraints are essential parameters for project organizers and are often associated with project goals. They are also referred to as the triple constraints. Budget, schedule, and quality are crucial elements that determine project success [9], [10]. The budget refers to the allocation of financial resources designated for the project. Effective budget management involves strict monitoring and control of expenditures and rapid adjustments to any changes that may occur.

Additionally, the budget must consider factors such as inflation, currency exchange rate changes, and unforeseen risks that might affect project costs [11], [12]. The schedule is the timeline set for completing the project. Creating a realistic and flexible schedule is crucial to ensure the project can be completed on time [13]. This involves determining task durations, scheduling resources, and addressing potential obstacles or delays. For example, in construction projects, adverse weather or delays in material delivery can disrupt the schedule and require adjustments. Quality refers to the standards established for the project's outcomes. Project quality relates to the final product and the processes used to achieve that outcome [14]. Quality standards must be set and adhered to throughout the project, with procedures in place to ensure that every aspect of the project meets those standards. For instance, in software projects, testing processes, and code reviews are vital parts of ensuring quality. In project execution, it is evident that these three constraints—budget, schedule, and quality—are interrelated, and changes in one can affect the others. For instance, an increase in quality may require a more significant investment, impacting the project's budget and schedule. Therefore, effective project management must balance these three constraints to achieve optimal results.

2.1. Concept Earned Value

The concept of Earned Value Analysis (EVA) is a highly effective method for controlling construction projects [15]. Using indicators such as Planned Value, Earned Value, and Actual Cost, we can analyze project performance in detail and make predictive assessments. This helps identify potential issues before they escalate into more serious problems, allowing for timely corrective actions to ensure the project runs smoothly and efficiently [16], [17]. Thus, the earned value method becomes an essential tool in project management for achieving optimal success. Project execution is often accompanied by various issues that may lead to delays, resulting in cost losses. Therefore, control measures are necessary during the project lifecycle, and one control method that can be employed is Earned Value Analysis [18]. By applying this method, it is hoped that problems during project execution can be managed effectively, ensuring that the project does not experience delays or cost overruns by the completion stage. The concept of the earned value method involves calculating the extent of work progress made at a certain point in time based on the amount of budget spent and the agreed-upon budget according to the initial project plan. The earned value method allows for assessing the performance of an ongoing project.

2.2. Indicator-indicator Earned Value

According to Landau (2024) [19], there are three indicators in Earned Value Analysis, namely Actual Cost of Work Performed (ACWP), Budgeted Cost of Work Performed (BCWP), and Budgeted Cost of Work Scheduled (BCWS). These three indicators can be used to calculate various performance factors in project execution, including a. Schedule Variance (SV) and Cost Variance (CV); b. Productivity and Performance Index; c. Estimates of project costs and completion time.

2.2.1. Budgeted Cost of Work Scheduled

BCWS (Budgeted Cost of Work Scheduled) is the total budget based on the activity plan executed over a specific timeframe or the budget planned according to the execution schedule. BCWS can be calculated from the accumulated planned budget for work during a particular period, as shown in Equation 1.

BCWS = % (planned weight) × Contract Value (BoQ) ………………………………………………………………(1)

2.2.2. Budgeted Cost of Work Performed

BCWP (Budgeted Cost of Work Performed) is the amount allocated for work completed during a specific period or the actual costs incurred according to the progress of the work performed. BCWP can be calculated based on accumulated completed work, as shown in Equation 2.

BCWP = % (planned weight) × Contract Value (BoQ) ………………………………………………………………(2)

2.2.2. Actual Cost of Work Performed

ACWP (Actual Cost Work Performed) is the total actual cost incurred for the work that has been completed. ACWP can analyze project performance to determine whether the costs and timeline are still within the planned limits. ACWP is derived from the project's financial data during the reporting period (weekly or monthly financial reports). It can be cumulative up to the performance calculation period or represent the actual costs incurred within a specific timeframe. ACWP can be expressed as cumulative up to the performance calculation period or as the total expenditures over a certain period.

ACWP= % (planned execution weight) × Implementation Budget Plan Value ………………………………………………… (3)

2.3. Variance Analysis

Variance analysis is used to determine whether a project is proceeding according to the initial plan in terms of cost and time. Variance analysis includes Schedule Variance (SV) and Cost Variance (CV). SV assesses whether an ongoing project is on track with the planned timeline. In contrast, a CV determines whether an ongoing project is still within the planned budget.

2.3.1. Schedule Variance

SV is the result of the difference between BCWP and BCWS. If the calculation result yields a positive number (+), the work progresses faster than planned. Conversely, if the calculation yields a negative number (-), it indicates that the work schedule is behind the planned schedule.

2.3.2. Cost Variance

CV is the result of the difference between BCWP and ACWP. If the calculation result yields a positive number (+), the actual costs are less than the planned budget. Conversely, if the calculation yields a negative number (-), it indicates that the actual costs are more significant than the planned budget. If the calculation results in zero (0), it suggests that the actual expenses align with the planned costs.

2.4. Schedule Performance Index

Performance indices are used to assess the efficiency of resource utilization. Performance index analysis consists of:

2.4.1. Schedule Performance Index

The Schedule Performance Index (SPI) is used to compare the value of work completed (BCWP) with the planned expenditure based on the weight of planned work (BCWS). The formula for calculating the Schedule Performance Index is as follows:

$$SPI = \frac{BCWP}{BCWS} \qquad (4)$$

2.4.2. Cost Performance Index

The Cost Performance Index (CPI) measures cost efficiency for expenditures. CPI compares the value of work completed (BCWP) with the actual costs incurred during the same period (ACWP). The formula for calculating the Cost Performance Index is as follows:

$$CPI = \frac{BCWP}{ACWS} \qquad (5)$$

2.5. Network Planning

Network planning can use two main methods in its implementation: Activity on Arrow (AOA) and Activity on Node (AON). The AOA method represents activities with arrows, while events are depicted as nodes [20]. On the other hand, the AON method represents activities with nodes and events with arrows. Each of these methods has its advantages and can be chosen based on the project's specific needs. Appropriately using a technique will facilitate understanding the sequence and dependencies between various activities in the project.

Additionally, network planning allows managers to perform critical path analysis effectively. The critical path is the network's longest path, indicating which activities have no float or slack time. By identifying the critical path, managers can prioritize attention on these activities to prevent overall project delays. This is crucial because any delay in activities on the critical path will directly impact the overall project completion time.

3. Methode

3.1. Stages of Research Implementation

The stages in the research on Time and Cost Performance Analysis Using the Earned Value Concept and Crash Program are schematically illustrated in **Figure 1**.

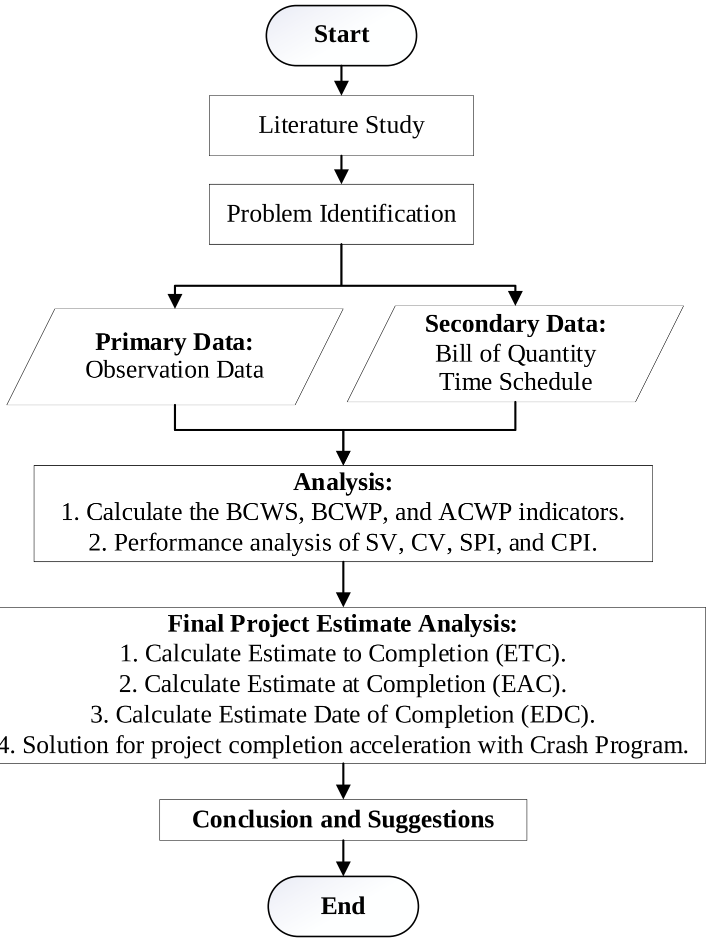

Fig. 1. Schematically Illustrated

3.2. Data Collection for Research

3.2.1. Research Objects

The object used in this research is the reconstruction project of the North Aceh Boundary Road segment from Lhokseumawe City to Bukit Rata.

3.2.2. Research Data Sources

Research data is essential to support the implementation of activities. In this stage, both primary and secondary data are used. Primary data is collected directly according to the existing conditions and is gathered by the researcher who has conducted surveys at the study location. Primary data includes Identification and Field Documentation. Secondary data is collected indirectly from relevant agencies and parties. The necessary data includes Time Schedule, Progress Realization Reports, Budget Plans (BoQ), Actual Budget Plans (ABP), and Working Drawings.

3.2.3. Data Analysis and Processing for Research

This research employs a quantitative descriptive approach to analyze the obtained values.

4. Result and Discussions

4.1. General Description

This research discusses the process of collecting, analyzing, and processing data, including indicator and tabulation calculations for variance identification analysis and the concept of earned value. Microsoft Excel software aided The entire data calculation and processing process. The study covers weeks 22^{nd} to 28^{th} of the Preservasi Jalan dan Jembatan Kota Bireuen – BTS. Kota Lhokseumawe/ North Aceh, Krueng Mane Buket Rata, SP. Krueng Geukeueh - PEL. Krueng Geukeueh (PEL. Lhokseumawe).
The data are from the Preservasi Roads and Bridges Kota Bireuen – BTS. Kota Lhokseumawe/ North Aceh, Krueng Mane Buket Rata, SP. Krueng Geukeueh - PEL. Krueng Geukeueh (PEL. Lhokseumawe), including:

1. Budget Plan (BoQ)
   Data from the BoQ can be seen in Table 1:

Table 1. Bill of Quantity

Payment Point	Description	Unit	Unit Price (Rupiah)	RDC OM Infrastructure for Land Connectivity (Road) (004) Priority Area Roads (ProPN) (323) Major Road Rehabilitation		(324) Road Reconstruction		TOTAL RDC (003)		Total Amount of All Outputs	
				Estimated Quantity	Total Price (Rupiah)	Estimated Quantity	Total Price (Rupiah)	Estimated Quantity	Total Price (Rupiah)	Estimated Quantity	Total Price (Rupiah)
a	b	c	d	g	h	i	j	k	l	ac	ad
	DIVISION 3. EARTHWORKS AND GEOSYNTHETICS										
3.1.(1)	Common Excavation	M^3	50.789,48	185,37	9.414.846,55	1.040,00	52.821.062,78	1.225,37	62.235.909,33	1.225,37	62.235.909,33
3.1.(9)	Granular Pavement Excavation	M^3	60.640,80	-	-	5.400,00	327.460.296,72	5.400,00	327.460.296,72	5.400,00	327.460.296,72
3.2.(1b)	Common Fill from Excavation Results	M^3	97.218,51	46,04	4.475.940,24	276,32	26.863.828,57	322,36	31.339.768,82	322,36	31.339.768,82
	Total Price of Work for DIVISION 3 (included in the Price Estimate Summary)				13.890.786,79		407.145.188,08		421.035.974,87		421.035.974,87
	DIVISION 5. GRANULAR PAVEMENT										
5.1.(1)	Class A Aggregate Base Layer	M^3	608.148,53	404,10	245.752.819,51	8.235,00	5.008.103.114,69	8.639,10	5.253.855.934,20	8.639,10	5.253.855.934,20
5.1.(3)	Class S Aggregate Base Layer	M^3	521.086,59	276,49	144.073.126,47	-	-	276,49	144.073.126,47	276,49	144.073.126,47
	Total Price of Work for DIVISION 5 (included in the Price Estimate Summary)				389.825.945,98		5.008.103.114,69		5.397.929.060,67		5.397.929.060,67
	DIVISION 6. ASPHALT PAVEMENT										
6.1 (1)	Binder Layer - Liquid Asphalt/Emulsion	Liter	20.353,06	3.251,25	66.172.893,11	14.025,00	285.451.695,78	17.276,25	351.624.588,89	17.276,25	351.624.588,89
6.1 (2a)	Adhesive Layer - Liquid Asphalt/Emulsion	Liter	19.039,57	2.395,05	45.600.717,65	3.675,00	69.970.412,88	6.070,05	115.571.130,53	6.070,05	115.571.130,53
6.3(5a)	Wearing Course Asphalt (AC-WC)	Ton	1.758.721,45	413,93	727.983.989,56	1.517,74	2.669.274.628,40	1.931,66	3.397.258.617,97	1.931,66	3.397.258.617,97
6.3(6a)	Intermediate Course Asphalt (AC-BC)	Ton	1.703.045,86	620,89	1.057.407.455,40	1.448,75	2.467.284.062,61	2.069,64	3.524.691.518,02	2.069,64	3.524.691.518,02
6.3.(8)	Anti-Stripping Material	Kg	92.565,00	180,09	16.670.030,85	516,26	47.787.421,77	696,35	64.457.452,62	696,35	64.457.452,62
	Total Price of Work for DIVISION 6 (included in the Price Estimate Summary)				1.913.835.086,58		5.539.768.221,44		7.453.603.308,02		7.453.603.308,02

2. Project Progress Report

Data from the Project Progress Report can be seen in Table 2:

Table 2. Work Progress Graph

Activity Description	Unit Price	Unit	RDC OM Infrastructure for Land Connectivity (Road) Volume	RDC OM Infrastructure for Land Connectivity (Road) Total Price	Integrity Plan (%)	Implementation Schedule (210 Calendar Days) March 1 19-Mar 25-Mar	March 2 26-Mar 31-Mar	April 1 01-Apr 07-Apr	April 2 08-Apr 15-Apr	April 3 16-Apr 22-Apr	April 4 23-Apr 30-Apr	May 1 01-May 07-May
DIVISION 3. EARTHWORKS AND GEOSYNTHETICS												
Common Excavation	50.789,48	M3	1.225,37	62.235.909	0,47	-	0,021	0,021		0,427	-	-
Granular Pavement Excavation	60.640,80	M3	5.400,00	327.460.297	2,47	-	-	-		-	0,493	0,493
Common Fill from Excavation Results	97.218,51	M3	322,36	31.339.769	0,24	-	-	-		-	-	-
DIVISION 5. GRANULAR PAVEMENT												
Class A Aggregate Base Layer	608.148,53	M3	8.639,10	5.253.855.934	39,58	-	-	-		-	-	-
Class S Aggregate Base Layer	521.086,59	M3	276,49	144.073.126	1,09	-	-	-		0,090	0,090	0,090
DIVISION 6. ASPHALT PAVEMENT												
Binder Layer - Liquid Asphalt/Emulsion	20.353,06	Liter	17.276,25	351.624.589	2,65	-	-	-		-	-	-
Adhesive Layer - Liquid Asphalt/Emulsion	19.039,57	Liter	6.070,05	115.571.131	0,87	-	-	-		-	-	-
Wearing Course Asphalt (AC-WC)	1.758.721,45	Ton	1.931,66	3.397.258.618	25,60	-	-	-		-	-	-
Intermediate Course Asphalt (AC-BC)	1.703.045,86	Ton	2.069,64	3.524.691.518	26,56	-	-	-		-	-	-
Anti-Stripping Material	92.565,00	Kg	696,35	64.457.453	0,49	-	-	-		-	-	-
TOTAL PRICE (RP)				13.272.568.343,55								
Total Intergrity					100,00							
Weekly Plan Progress (%)						-	0,021	0,021	-	0,518	0,584	0,584
Cumulative Weekly Plan Progress (%)						-	0,02	0,04	0,04	0,56	1,14	1,73
Weekly Actual Progress (%)						-	0,145	0,137	-	0,163	0,607	9,761
Cumulative Weekly Actual Progress (%)						-	0,14	0,28	0,28	0,44	1,05	10,81
Deviation (%)						-	0,12	0,24	0,24	(0,12)	(0,09)	9,08

Activity Description	May 2 08-May 15-May	May 3 16-May 22-May	May 4 23-May 31-May	June 1 01-Jun 07-Jun	June 2 08-Jun 15-Jun	June 3 16-Jun 22-Jun	June 4 23-Jun 30-Jun
DIVISION 3. EARTHWORKS AND GEOSYNTHETICS							
Common Excavation	-	-	-	-	-		-
Granular Pavement Excavation	0,493	0,493	0,493	-	-		-
Common Fill from Excavation Results	-	-	-	0,118	0,118		-
DIVISION 5. GRANULAR PAVEMENT							
Class A Aggregate Base Layer	-	-	-	-	-		6,597
Class S Aggregate Base Layer	0,090	0,090	0,090	0,090	0,090		0,090
DIVISION 6. ASPHALT PAVEMENT							
Binder Layer - Liquid Asphalt/Emulsion	-	-	-	-	-		0,189
Adhesive Layer - Liquid Asphalt/Emulsion	-	-	-	-	-		0,062
Wearing Course Asphalt (AC-WC)	-	-	-	-	-		1,828
Intermediate Course Asphalt (AC-BC)	-	-	-	-	-		1,897
Anti-Stripping Material	-	-	-	-	-		0,035
TOTAL PRICE (RP)							
Total Intergrity							
Weekly Plan Progress (%)	0,584	0,584	0,584	0,209	0,209	-	10,699
Cumulative Weekly Plan Progress (%)	2,31	2,90	3,48	3,69	3,90	3,90	14,60
Weekly Actual Progress (%)	3,945	3,497	9,051	2,474	0,402	-	0,124
Cumulative Weekly Actual Progress (%)	14,76	18,25	27,31	29,78	30,18	30,18	30,31
Deviation (%)	12,45	15,36	23,83	26,09	26,29	26,29	15,71

Activity Description	July 1 01-Jul 07-Jul	July 2 08-Jul 15-Jul	July 3 16-Jul 22-Jul	July 4 23-Jul 31-Jul	August 1 01-Aug 07-Aug	August 2 08-Aug 15-Aug	August 3 16-Aug 22-Aug
DIVISION 3. EARTHWORKS AND GEOSYNTHETICS							
Common Excavation	-	-	-	-	-	-	-
Granular Pavement Excavation	-	-	-	-	-	-	-
Common Fill from Excavation Results	-	-	-	-	-	-	-
DIVISION 5. GRANULAR PAVEMENT							
Class A Aggregate Base Layer	6,597	6,597	6,597	6,597	6,597	-	-
Class S Aggregate Base Layer	0,090	0,090	0,090	-	-	-	-
DIVISION 6. ASPHALT PAVEMENT							
Binder Layer - Liquid Asphalt/Emulsion	0,189	0,189	0,189	0,189	0,189	0,189	0,189
Adhesive Layer - Liquid Asphalt/Emulsion	0,062	0,062	0,062	0,062	0,062	0,062	0,062
Wearing Course Asphalt (AC-WC)	1,828	1,828	1,828	1,828	1,828	1,828	1,828
Intermediate Course Asphalt (AC-BC)	1,897	1,897	1,897	1,897	1,897	1,897	1,897
Anti-Stripping Material	0,035	0,035	0,035	0,035	0,035	0,035	0,035
TOTAL PRICE (RP)							
Total Intergrity							
Weekly Plan Progress (%)	10,699	10,699	10,699	10,609	10,609	4,011	4,011
Cumulative Weekly Plan Progress (%)	25,29	35,99	46,69	57,30	67,91	71,92	75,93
Weekly Actual Progress (%)	20,846	10,667	5,350	16,255	3,594	0,105	0,026
Cumulative Weekly Actual Progress (%)	51,15	61,82	67,17	83,42	87,02	87,12	87,15
Deviation (%)	25,86	25,82	20,48	26,12	19,11	15,20	11,22

Activity Description	August 4 23-Aug 31-Aug	September 1 01-Sep 07-Sep	September 2 08-Sep 15-Sep	September 3 16-Sep 22-Sep	September 4 23-Sep 30-Sep	October 1 01-Oct 07-Oct	October 2 08-Oct 14-Oct	Information
DIVISION 3. EARTHWORKS AND GEOSYNTHETICS								
Common Excavation	-	-	-	-	-	-	-	
Granular Pavement Excavation	-	-	-	-	-	-	-	
Common Fill from Excavation Results	-	-	-	-	-	-	-	
DIVISION 5. GRANULAR PAVEMENT								
Class A Aggregate Base Layer	-	-	-	-	-	-	-	
Class S Aggregate Base Layer	-	-	-	-	-	-	-	
DIVISION 6. ASPHALT PAVEMENT								
Binder Layer - Liquid Asphalt/Emulsion	0,189	0,189	0,189	0,189	0,189	0,189	-	
Adhesive Layer - Liquid Asphalt/Emulsion	0,062	0,062	0,062	0,062	0,062	0,062	-	
Wearing Course Asphalt (AC-WC)	1,828	1,828	1,828	1,828	1,828	1,828	-	
Intermediate Course Asphalt (AC-BC)	1,897	1,897	1,897	1,897	1,897	1,897	-	
Anti-Stripping Material	0,035	0,035	0,035	0,035	0,035	0,035	-	
TOTAL PRICE (RP)								
Total Intergrity								
Weekly Plan Progress (%)	4,011	4,011	4,011	4,011	4,011	4,011	-	
Cumulative Weekly Plan Progress (%)	79,94	83,96	87,97	91,98	95,99	100,00	100,00	
Weekly Actual Progress (%)	-	0,075	0,075	2,656	4,105	4,715	1,226	
Cumulative Weekly Actual Progress (%)	87,15	87,22	87,30	89,95	94,06	98,77	100,00	
Deviation (%)	7,20	3,27	(0,67)	(2,02)	(1,93)	(1,23)	(0,00)	

Note : [purple] : Actual Performance

[orange] : Plan

4.2. Analysis of Earned Value Indicators

4.2.1. Budgeted Cost of Work Scheduled

BCWS analysis was carried out from the 22nd week to the 28th week. The progress of the work plan is obtained from the weekly project report in the progress recapitulation section.

The BCWS calculation value using the normal implementation method is:

$BCWS_{22}$ = % Weekly plan progress$_{22}$ x Total BoQ value

= 4.011% x Rp. 13,272,568,343.55

= Rp. 532,400,236.29

Meanwhile, the cumulative BCWS calculation up to the 22nd week is:

BCWS cumulative$_{22}$ = % cumulative plan progress$_{22}$ x Total BoQ value

= 79.94% x Rp. 13,272,568,343.55

= Rp. 10,610,567,162.12

The results of the weekly and cumulative BCWS calculations from the 22nd to the 28th week can be seen in Table 3. below.

Table 3. Recap of weekly and cumulative BCWS from week 22nd to week 28th.

Week To-	Weekly plan progress (%)	Cumulative plan progress (%)	Weekly BCWS (Rp)	Cumulative BCWS (Rp)
22	4.011	79.94	Rp 532,400,236.29	Rp 10,610,567,162.12
23	4.011	83.95	Rp 532,400,236.29	Rp 11,142,967,398.41
24	4.011	87.97	Rp 532,400,236.29	Rp 11,675,367,634.69
25	4.011	91.98	Rp 532,400,236.29	Rp 12,207,767,870.98
26	4.011	95.99	Rp 532,400,236.29	Rp 12,740,168,107.27
27	4.011	100.00	Rp 532,400,236.29	Rp 13,272,568,343.55
28	0.000	100.00	Rp -	Rp 13,272,568,343.55

4.2.2. Budgeted Cost of Work Performed

Performance analysis using the BCWP indicator in the 22nd week can be calculated by weekly or cumulative of realization progress in the 22nd week by the total budget cost. The BCWP calculation for the 22nd week is:

$BCWP_{22}$ = % Weekly realization progress $_{22}$ × Total BoQ value

= 0.00% × Rp. 13,272,568,343.55

= Rp. 0,00

Meanwhile, the cumulative BCWP calculation up to the 22nd week is:

BCWP $cumulative_{22}$ = % cumulative realization $progress_{22}$× Total BoQ value

= 87.15% × Rp. 13,272,568,343.55

= Rp. 11,566,761,588.48

The results of the weekly and cumulative BCWP calculations from the 22nd to the 28th week can be seen in Table 4. below.

Table 4. Recap of weekly and cumulative BCWP from week 22nd to week 28th.

Week To-	Weekly realization progress (%)	Cumulative realization progress (%)	Weekly BCWP (Rp)	Cumulative BCWP (Rp)
22	0.000	85.81	Rp -	Rp 9,522,779,400.01
23	0.075	85.89	Rp 8,322,764.45	Rp 9,531,102,164.46
24	0.075	85.96	Rp 8,322,764.45	Rp 9,539,424,928.92
25	2.589	88.55	Rp 287,342,968.40	Rp 9,826,767,897.32
26	4.105	92.66	Rp 455,532,641.14	Rp10,282,300,538.45
27	4.715	97.37	Rp 523,224,458.70	Rp10,805,524,997.15
28	2.627	100.00	Rp 291,494,275.37	Rp11,097,019,272.52

4.2.3. Actual Cost of Work Performed

The ACWP calculation for the 22nd week is:

$ACWP_{22}$ = % Weekly realization implementation $progress_{22}$ × Total ABP value

= 0.00% × Rp. 11,097,019,272.52

= Rp. 0,00

Meanwhile, the cumulative ACWP calculation up to the 22nd week is:

ACWP $cumulative_{22}$ = % cumulative realization implementation $progress_{22}$× Total ABP value

= 85.81% × Rp. 11,097,019,272.52

= Rp. 9,522,779,400.01

The results of the weekly and cumulative ACWP calculations from the 22nd to the 28th week can be seen in Table 5. below:

Table 5. Recap of weekly and cumulative ACWP from week 22nd to week 28th.

Week To-	Weekly realization implementation progress (%)	Cumulative realization implementation progress (%)	Weekly BCWP (Rp)	Cumulative BCWP (Rp)
22	0.000	85.81	Rp -	Rp 9,522,779,400.01
23	0.075	85.89	Rp 8,322,764.45	Rp 9,531,102,164.46
24	0.075	85.96	Rp 8,322,764.45	Rp 9,539,424,928.92
25	2.589	88.55	Rp 287,342,968.40	Rp 9,826,767,897.32
26	4.105	92.66	Rp 455,532,641.14	Rp10,282,300,538.45
27	4.715	97.37	Rp 523,224,458.70	Rp10,805,524,997.15
28	2.627	100.00	Rp 291,494,275.37	Rp11,097,019,272.52

From the BCWS, BCWP, and ACWP indicators above, we can see the comparison between the three in the weekly cumulative shown in Figure 2.

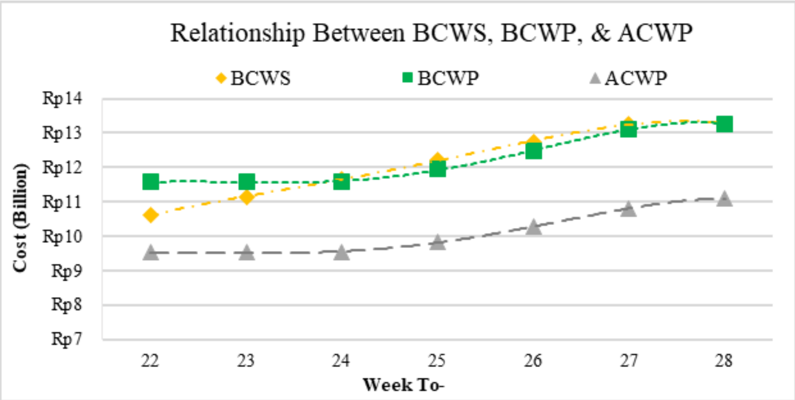

Fig 2. Graph of the Relationship Between BCWS, BCWP, and ACWP.

4.3. Cost Parameter Analysis

It can be analyzed using Cost Variance (CV) and Cost Performance Index (CPI) to assess cost performance during this project.

4.3.1. Cost Variance

The Cost Variance (CV) value can be calculated by subtracting the cumulative BCWP value from the cumulative ACWP for a certain week. The calculation of Cost Variance (CV) up to week 22nd is:

CV_{22} = BCWP cumulative$_{22}$ - ACWP cumulative$_{22}$

= Rp. 11,566,761,588.48 - Rp. 9,522,779,400.01

= Rp. 2,043,982,188.47

The Cost Variance (CV) results from the 22nd week to the 28th week can be seen in Table 6. below.

Table 6. Cost Variance (CV) values from week 22nd to week 28th.

Week To-	Cost Variance (CV)	Description
22	Rp 2,043,982,188.47	Actual costs are less than planned
23	Rp 2,045,613,850.27	Actual costs are less than planned
24	Rp 2,047,245,512.08	Actual costs are less than planned
25	Rp 2,112,432,161.33	Actual costs are less than planned
26	Rp 2,201,738,450.69	Actual costs are less than planned
27	Rp 2,304,315,589.39	Actual costs are less than planned
28	Rp 2,175,549,071.03	Actual costs are less than planned

The favorable cost variance (CV) result means the actual costs incurred to complete the work are less than the planned budget. Meanwhile, a negative Cost Variance (CV) indicates that the expenses incurred exceed the planned budget for carrying out the work.

4.3.2. Cost Performance Index

The Cost Performance Index (CPI) can be calculated by dividing the cumulative BCWP by the cumulative ACWP at a specific week. The calculation of the Cost Performance Index (CPI) up to the 22nd week is:

CPI_{22} = BCWP $cumulative_{22}$ / ACWP $cumulative_{22}$

= Rp. 11,566,761,588.48 / Rp. 9,522,779,400.01

= Rp. 1,215

The results of the Cost Performance Index (CPI) from the 22nd week to the 28th week can be seen in Table 7. below.

Table 7. Cost Performance Index (CPI) values from week 22nd to week 28th.

Week To-	Cost Performance Index (CPI)	Description
22	1.2146	Cost less than budget
23	1.2146	Cost less than budget
24	1.2146	Cost less than budget
25	1.2150	Cost less than budget
26	1.2141	Cost less than budget
27	1.2133	Cost less than budget
28	1.1960	Cost less than budget
CPI average	**1.2118**	**Cost less than budget**

The result of the Cost Performance Index (CPI) that is more than 1 (>1) means that the expenditure to complete the work is less than the planned budget. Meanwhile, a Cost Performance Index (CPI) that is less than 1 (<1) indicates that the expenditure exceeds the planned budget for carrying out the work. In this project, the average Cost Performance Index (CPI average) from the 22nd week to the 28th week is 1.2118. This value indicates that the costs incurred during these weeks did not exceed the planned budget.

4.4. Time Parameter Analysis

Time performance can be analyzed using Schedule Variance (SV) and Schedule Performance Index (SPI) to assess time performance during this project.

4.4.1. Schedule Variance

The Schedule Variance (SV) value can be calculated by subtracting the cumulative BCWP value from the cumulative BCWS for a certain week. The calculation of Schedule Variance (SV) up to week 22nd is:

SV_{22} = BCWP $cumulative_{22}$ - BCWS $cumulative_{22}$

= Rp. 11,566,761,588.48 - Rp. 10,610,567,162.12

= Rp. 956,194,426.36

The Schedule Variance (SV) results from the 22nd week to the 28th week can be seen in Table 8. below.

Table 8. Schedule Variance (SV) values from week 22nd to week 28th.

Week To-	Schedule Variance (CV)	Description
22	Rp 956,194,426.36	Progress is faster than planned
23	Rp 433,748,616.33	Progress is faster than planned
24	-Rp 88,697,193.70	Progress is slower than planned
25	-Rp 268,567,812.33	Progress is slower than planned
26	-Rp 256,129,118.12	Progress is slower than planned
27	-Rp 162,727,757.01	Progress is slower than planned
28	- Rp -	Progress is slower than planned

The result of the Schedule Variance (SV) that is positive means the time taken to complete the work is faster than the planned schedule. Meanwhile, a negative Schedule Variance (SV) indicates that the time required to complete the work is longer than the planned schedule.

4.4.2. Schedule Performance Index

The Schedule Performance Index (SPI) can be calculated by dividing the cumulative BCWP by the cumulative BCWS at a specific week. The calculation of the Schedule Performance Index (SPI) up to the 22^{nd} week is:

$$SPI_{22} = \text{BCWP cumulative}_{22} / \text{BCWS cumulative}_{22}$$
$$= \text{Rp. } 11{,}566{,}761{,}588.48 / \text{Rp. } 10{,}610{,}567{,}162.12$$
$$= \text{Rp. } 1{,}0901$$

The results of the Schedule Performance Index (SPI) from the 22^{nd} week to the 28^{th} week can be seen in Table 9. below:

Table 9. Schedule Performance Index (SPI) values from week 22^{nd} to week 28^{th}.

Week To-	Schedule Performance Index (SPI)	Description
22	1.0901	Time is faster than planned
23	1.0389	Time is faster than planned
24	0.9924	Time is slower than planned
25	0.9780	Time is slower than planned
26	0.9799	Time is slower than planned
27	0.9877	Time is slower than planned
28	1.0000	Time is faster than planned
$SPI_{average}$	**1.0096**	Time is faster than planned

The result of the Schedule Performance Index (SPI) that is more than 1 (>1) means the time taken to complete the work is faster than the planned schedule. Meanwhile, a Schedule Performance Index (SPI) that is less than 1 (<1) indicates that the time required to carry out the work is longer than the planned time. In this project, the Schedule Performance Index (SPI) from the 22^{nd} to the 28^{th} week has shown a continuous decline, indicating that project performance is deteriorating over time. The average Schedule Performance Index (SPI average) from the 22^{nd} week to the 28^{th} week is 1.0096, which means that the performance aligned with the plan during these weeks.

5. Conclusion

This study analyzed road pavement work completion optimization with earned value concepts. It concluded that the cost variance (CV) is positive (> 0), and the average cost performance index (CPI average) is 1.2118. It can indicate that the actual costs incurred do not exceed the planned budget for the project. Furthermore, the schedule variance (SV) from the 22^{nd} week to the 23^{rd} week is positive (> 0); however, from the 24^{th} week to the 28^{th} week, it is negative (< 0). The schedule performance index (SPI average) is 1.0096, which means the time to complete the work is faster than the planned schedule.

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