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Earned Value Method Evaluation of Project Time and Cost Control on Crane Support Structure Construction Projects PT Pindad (Persero)

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Abstract

PT Pindad (Persero) is a manufacturer of heavy-duty equipment such as armoured vehicles. As a result, a crane facility is required to facilitate the material transportation operations, which is supported by a steel structure apart from the building structure. The crane support structure construction process was 19.75 percent delayed until the 12th week. The goals of this study were carried out to evaluate project control using the Earned Value method, which intends to identify project performance in terms of cost and time before and after evaluating project control and knowing the predicted cost and time of total project completion. Schedule Performance Index (SPI) of 0.85 shows a delay of 10.927 percent from the initial plan of 73.731 percent with a realization of 62.804 percent. Meanwhile, the Cost Performance Index (CPI) of 1.22 indicates that the costs incurred are still less than the estimated budget, with a potential profit of Rp. 1,144,245,992.81 or 11,425 percent of the total project budget. Based on the analysis of performance calculations, the estimated project completion time is 26 weeks, or longer than the planned schedule of 22 weeks. In terms of cost, the estimated cost of completing this project is Rp. 8,870,754,007,19. This means that, with the current project cost performance, the project will have a potential profit of Rp. 1,144,245,992.81 or 11,425% of the total project budget. Based on performance calculations, the estimated project completion time is 26 weeks, which is longer than the planned schedule of 22 weeks. The total cost of completing this project is projected to be Rp. 8,870,754,007,19. This means that, regarding the existing project cost performance, the project has a potential profit of Rp. 1,144,245,992.81, or 11.425% of the total project budget.

Keywords
Cost, Earned Value, Project Control, Time.

1. Introduction

The process of establishing facilities and infrastructure in the manufacturing industry is intimately connected to the world of construction, one of which is PT Pindad (Persero), which is involved in manufacturing. PT Pindad (Persero) is currently installing a crane support structure in a hangar building with a capacity of 20 T (1 unit), 10 T (1 unit), and 5T (1 unit) and a Runway Crane stretch of 150 meters for a contract value of Rp 10,015,000,000.00.

The crane support structure's construction is planned and expected to be completed within the budget and time constraints. Meanwhile, the contractor had a 19.75 percent delay in achieving the schedule and plan progress targets until the third reporting period, or 12 weeks after implementation. As a result, project control is important, particularly in terms of project time and cost.

The concept of earned value is one of the concepts that can be used to manage this construction project. Because it can be monitored to avoid cost overruns or schedule delays, this method is thought to be effective in complex construction projects.(Susanti, Melisah, and Juliantina 2019) As a result, the title of this Final Project is "Evaluation of Project Time and Cost Control Using Earned Value Method in the Construction of PT Pindad (Persero) Crane Supporting Structures." The objectives of this study are developed in light of this context.:

1. What is the contractor's time and cost performance with approaches or methods to improve project performance?
2. What is the estimated cost and duration of project completion if project performance is the same as in the latest analysis?

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2. Literature Review

2.1. Project management

Project management is the process of planning, organizing, leading, and controlling the activities of organizational members and other strategies to achieve set organizational goals. (Maromi and Indriyani 2015) Project management attempts to manage every sector of the project organization in order to achieve the optimal achievable results in accordance with the planning objectives. Meanwhile, project performance is a comparison between the project implementation system planned in the contractor's work program before to implementation and the implementation governance implemented by the contractor after the construction process begins. The performance of this project can be seen in terms of cost and time.

1. Time Performance, can be analyzed using indicators such as Schedule Variance (SV) and Schedule Performance Index (SPI) which are obtained from the amount of deviation of the result value (Earned Value) with the planned schedule.
2. Cost Performance, can be analyzed using indicators such as the planned budget (Planned Value), the value of the results (Earned Value), direct and indirect costs (Actual Cost) which produces Cost Variance (CV) and Cost Performance Index (CPI) as indicators.

2.2. Project Control

Project control is a system or method used to control the course of a construction project. In the process, project control is an effort made by the Contractor so that time and costs do not exceed the plan.

1. Time and cost management, In fact, time and cost control cannot be separated because they are intimately connected. This is evident when the Contractor is required to optimize time and costs by accelerating. The following graph represents the correlation between time and cost: Correlation betweenTime and Cost which is Normal and Shortened.

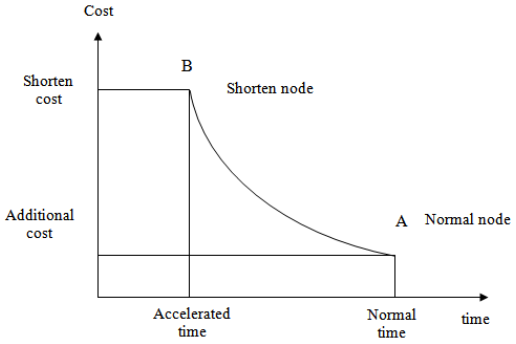


Figure 1. Normal and Shortened Time-Cost Relationship

2.3. Earned Value Method

The Earned Value method, commonly recognized as the concept of the value of the results, is the concept of calculating the amount of spending according to the budget in accordance with the work that has been completed.(Bryde, Unterhitzenberger, and Joby 2018) When regarded with relation to the amount of work completed, this concept regulates the number of units of work completed for the job.(Widayanti, Hartono, and Sugiyarto 2017). This Earned Value method is used during implementation and is repeatable in each reporting period (terms). Several indicators are calculated in the Earned Value method application to assess project performance and estimate the costs and time required for the remaining work, such as :

1. BCWS (Budgeted Cost of Work Schedule), is a budget allocation that is planned in accordance with the work plan (scheduling) and compiled against the time of activity or can be called PV (Planned Value).(Chen, Chen, and Lin 2016)
2. BCWP (Budgeted of Work Performance), is a budget that has been spent during the implementation process in a certain period or called EV (Earned Value).(Desi Rahmayanti, Faiza Renaldi 2017)
3. ACWP (Actual Cost of Work Planned), ACWP is the total cost budget incurred during the work implementation process for a certain period or AC (Actual Cost).

There are basic indicators that serve as a reference in analyzing the performance of the project based on the Earned Value concept, namely:

1. CV (Cost Variance), is the deviation obtained by comparing the value of the results obtained with the total costs that have been incurred during the implementation in a certain period.

$$\boldsymbol{CV = EV - AC} \quad \text{..... (1)}$$

2. SV (Schedule Variance), is the deviation obtained from the deviation value between BCWP and BCWS.

$$SV = EV - PV$$ ..... (2)

3. CPI (Cost Performance Index),is the index value obtained through the comparison of the value of the work that has been carried out (BCWP) with the actual costs that have been incurred during the implementation (ACWP).

$$CPI = \frac{EV}{AC}$$ ..... (3)

CPI = 1: cost according to plan
CPI > 1 : lower cost/saving
CPI < 1 : higher cost/wasteful

4. SPI (Schedule Performance Index) is a factor that shows the amount of work done against the planned work unit.

$$SPI = \frac{EV}{PV}$$ ..... (4)

Where,
SPI = 1: project on time
SPI > 1 : faster project
SPI < 1 : late project

2.4. Estimated Cost and Project Completion Time

1. ETC (Estimate to Complete), is an estimate of the cost required to complete the remaining work. (Dwi Septian, Gendam Prakoso, and Budiono 2016)assuming that the trend of project performance will remain (constant) until the end of the project. ETC for physical progress > 50%

$$ETC = \frac{(BAC - EV)}{CPI}$$ ..... (5)

Where, BAC (Budget at Completion) is the total project cost that has been budgeted.

2. EAC (Estimate at Complete), is an estimate of the total project cost until the final report. (Aryani, Rafie, and Syahruddin 2016)

$$EAC = ETC + AC$$ ..... (6)

3. Time Estimate (TE), is the estimated time for completion of the work

$$TE = ATE + \frac{(D - (ATE\ x\ SPI))}{SPI}$$ ..... (5)

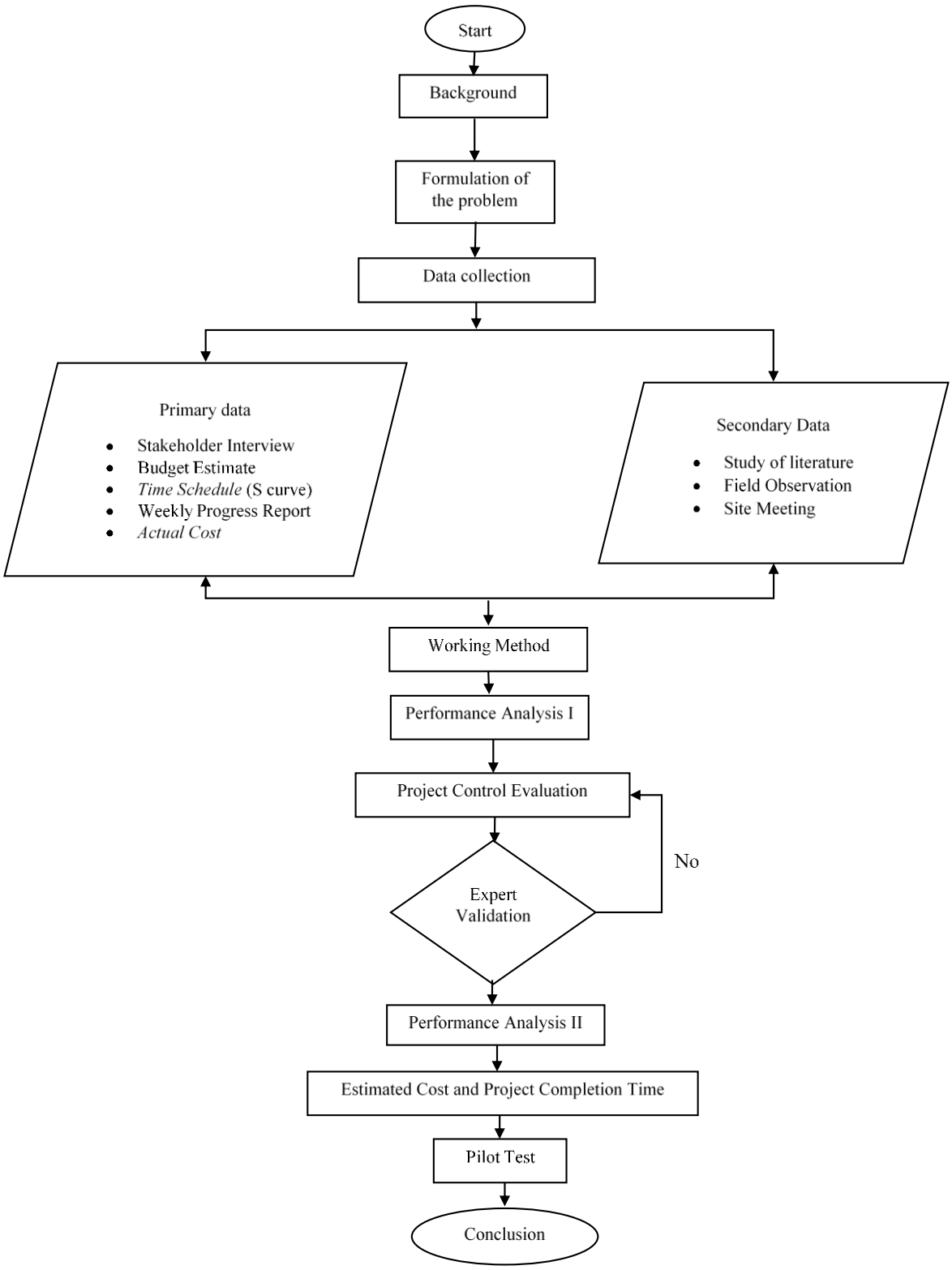
Where,
TE = Time Estimate
ATE = Actual Time Extended (Time Used)
D = Duration (Plan Time)

3. Methodology

This study will utilize descriptive quantitative and qualitative research methods. The quantitative method is carried out by analyzing data from observations and field observations using the Earned Value method. The performance of the work implementation will be known based on the results of the data analysis. In general, this research method is carried out with the following stages:

1) Determining the Background
2) Formulation of the problem
3) Data collection
4) Contractor Working Method
5) Project Performance Analysis I (Week 1 – Week 12)
6) Project Control Evaluation
7) Data Validation
8) Project Performance Analysis II (Week 12 – Week 16)
9) Estimated Cost and Project Completion Time
10) Test Pilot
11) Conclusion

The steps or processes carried out in this study are described by the following flow chart:



Flowchart 2. Research Flowchart

4. Results and Discussion

4.1. Project General Data

Table 1. Project General Data

Project name	:	Construction Project for Portal Crane Structure Building 100 PT Pindad (Persero)
Project owner	:	PT Pindad (Persero)
Project location	:	Jalan Gatot Subroto No. 517, Bandung, Indonesia, 40285
Planning consultant	:	PT Perintis Karya Pasundan
Contractor	:	PT Laverton Protection Technology
Contract value	:	Rp. 10,015,000,000,-
Execution time	:	150 Calendar Days (22 Weeks)
Contract Schedule	:	29 December 2020 to 31 May 2021
Construction Type	:	Bored Pile Foundation Structure Steel Structure

4.2. Earned Value I Analysis (Week 1-Week 12)

1. Earned Value Analysis (Week 1-Week 12)

The progress of the project achievement until the review in Week 12 is presented in Table 2. below :

Table 2. Week 12 Job Progress Data

Plan Progress	49,021%
Realization Progress	28,815%
Total Budget	Rp. 10,015,000,000,-

The calculation of Earned Value (EV) for Week 12 review is as follows:

EV (12th Week) = Realized Progress x BAC
= 29.271% x 10.015.000.000
= Rp. 2,885,835,023.25

2. Planned Value (PV) Analysis (Week 1- Week 12)

The Planned Value (PV) in this week's period can be calculated by multiplying the percentage of plans in the 12th week shown by the S-Curve by the total project budget or contract value as shown in table 2.

The 12th Week Planned Value (PV) calculation is obtained by the following formula:

PV (12th Week) = Planned Progress x BAC
= 49,021% x 10,015,000,000
= Rp. 4,909,403,641.59

3. Actual Cost (AC) Analysis (Week 1 – Week 12)

The actual costs incurred in this project are obtained from the contractor's financial statements, where payments are made according to the planned budget per weekly period.

Table 3. Actual Cost Week 1 – Week 12

Week-	Cumulative Actual Cost	Week-	Cumulative Actual Cost
1	Rp -	7	Rp 1,321,358,161.26
2	Rp 86,224,701.26	8	Rp 2,021,971,327.26
3	Rp 86,224,701.26	9	Rp 2,614,765,602.26
4	Rp 205.142.001.26	10	Rp 2,746,742,479.26
5	Rp 664,137,001,26	11	Rp 3,466.614,599.26
6	Rp 1.308.274.161.26	12	Rp 3,688.095,099.26

4.3. Project Performance Analysis I (Week 1 – Week 12)

1. Schedule Variance (SV)

Calculation of Week 12 Schedule Variance (SV), as follows:

SV (12th Week) = EV - PV
= 2,885,835,023.25 - 4,909,403,641.59
= -2,023,568,618.34

A negative value indicates that the project execution time is slower than the initial planning.

2. Schedule Performance Index (SPI)

Calculation of Week 12 Schedule Performance Index (SPI), as follows:

SPI (12th Week) = EV / PV
= 2,885,835,023.25 / 4,909,403,641.59
= 0.588

An SPI value of less than 1 indicates that the implementation time is behind the planned schedule.

3. Cost Variance (CV)

Calculation of Cost Variance (CV) Week 12, as follows:

CV (12th week) = EV - AC
= 2,885,835,023.25 -3,688.095,099.26
= -1,504,835,174.75

The Negative Cost Variance (CV) value indicates that the costs incurred are greater than the planned budget.

4. Cost Performance Index (CPI)

Calculation of the Cost Performance Index (CPI) Week 12, as follows:

CPI (12th Week) = EV / AC
= 2,885,835,023.25 /3,688.095,099.26
= 0.657

A CPI value less than 1 indicates spending is greater than the budget.

4.4. Project Control Evaluation

Based on the calculation of Earned Value and Performance Analysis I (Week 1 – Week 12) in general the current project description can be seen according to the following graph:

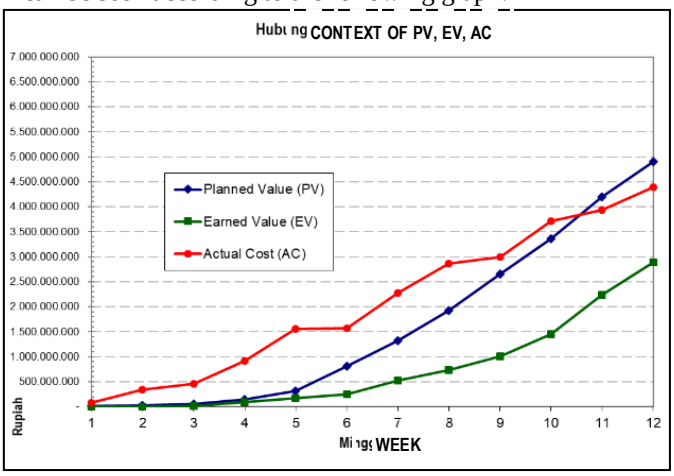


Figure 3. Context of PV, EV and AC

Based on the project's performance, the contractor conducts review actions such as adding bore pile and iron power, equipment, improving the method of carrying out bore pile and erection, and exploring design alternatives to save material by reducing material waste.

4.5. Earned Value II Analysis (Week 12 – Week 16)

1. Earned Value Analysis (Week 12-Week 16)

The progress of the project achievement until the review in Week 12 is presented in Table 2. below:

Table 4. Work Progress Week 12 to Week 16

No	Achievement	12th week	16th week	Deviation
1	Plan	49,021%	73,731%	24.71%
2	Realization	29.271%	62.569%	33,298%

The calculation of Earned Value (EV) for the 16th Week review is as follows:

EV (12th Week) = Realized Progress x BAC
= 62.569% x 10,015,000,000
= Rp. 6,266,309,092.24

2. Planned Value (PV) Analysis (Week 12- Week 16)

The calculation of the Planned Value (PV) in this week's period can be calculated by multiplying the percentage of plans in the 12th week which can be seen from the S-Curve with the total project budget or contract value presented in table 2.

The 12th Week Planned Value (PV) calculation is obtained by the following formula:

PV (12th Week) = Plan Progress x BAC
= 73.731% x 10.015.000.000
= Rp. 7,384,122,795.59

3. Actual Cost (AC) Analysis (Week 12 – Week 16)

The actual costs incurred in this project are obtained from the contractor's financial statements, where payments are made according to the planned budget per weekly period which is presented in the following recapitulation table:

Table 5. Actual Cost Week 12 - Week 16

Week	Actual Cost			AC(Cumulative)
	Direct Cost (1)	Overhead (2)	Total (3=1+2)	(4)
12	450,260,800,000	1,320,000.00	451,580,800,000	4,390,670,198.00
13	421,533,500.00	1,320,000.00	422.853.500.00	4,813,523,698.00
14	33,964,000.00	1,740,000.00	35,704,000.00	4,849,227,698.00
15	27,756.250.00	7,684,000.00	35,440,250.00	4,884,667,948.00
16	231,942,350.00	5,458,000.00	237,400,350.00	5,122,068,298.00

4.6. Project Performance Analysis II (Week 12 – Week 16)

To get the results of the evaluation of project time and cost control, a project performance analysis is carried out again to determine changes in performance after steps have been taken by the contractor with a 16th Week review. With the same calculation method and formula, a recapitulation of the project performance calculation is obtained, which is presented in table 4. Following:

Table 6. Calculation Recapitulation up to Sunday 16

No	Analysis	week 12	Sunday 16
1	ACWP	4,390,670,198.00	5,122,068,298.00
2	BCWS	4,909,403,641.59	7,384,122,795.59
3	BCWP	2,885,835,023.25	6,266,314,290.81
4	CV	- 1,504,835,174.75	1,144,245,992.81
5	SV	- 2,023,568,618.34	- 1,117,808,504.78
6	SPI	0.59	0.85
7	CPI	0.66	1.22

Based on the calculation of Table 4. It can be seen that project control has a good impact on project performance. This can be seen in terms of time where the SPI value has increased from 0.59 to 0.85, meaning that in terms of time the project has succeeded in minimizing time delays. Meanwhile, in terms of costs, the CPI value increased from 0.66 to 1.22, meaning that from a cost perspective the project managed to save costs so that the costs incurred were smaller than the planned costs. In general, the development of project performance can be seen in the following figure:

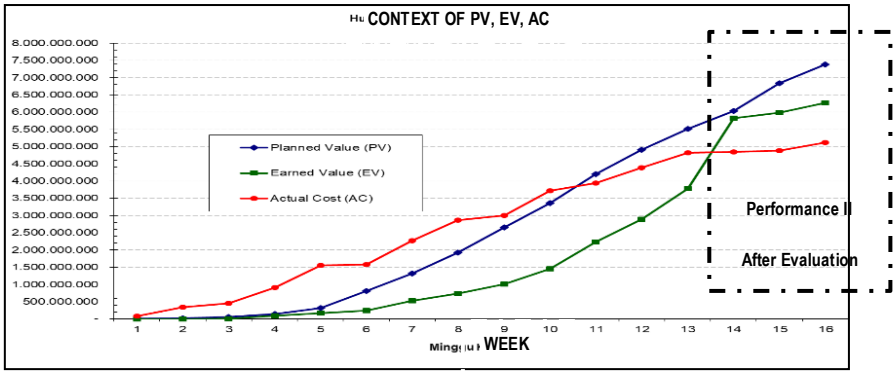


Figure 4. Context of PV, EV and AC until Sunday 16

4.7. Estimated Cost and Project Completion Time

Based on the calculation of project performance, it is possible to estimate the cost and time of completion of the 16th Week review project using 3 variants, namely Estimate To Complete (ETC), Estimate At Completion (EAC) and Time Estimate (TE).

1. Estimate To Complete (ETC)

Estimate To Complete (ETC)is the estimated cost to complete the remaining work. Calculation of Estimate To Complete (ETC) Week 16 with a progress of 62.569% (>50%) using the following equation:

ETC=((Budget Total-Earned Value (EV)))/CPI
ETC =((10,015,000,000-6,266,314,290.81))/1,223
ETC = IDR 3,748,690,907.76

2. Estimate At Completion (EAC)

Estimate At Completion (EAC)is the estimated cost to complete the entire project. Calculation of Estimate At Completion (EAC) Week 16 using the following equation:

EAC=ETC+Actual Cost (AC)
EAC=3.748.690.907.76+5.122.068.298.00
EAC= IDR 8,871,413,205.76

3. Time Estimate (TE)

Time Estimate (TE)is the estimated time required to complete the entire project. Calculation of the 16th Week Time Estimate (TE) using the following equation:

TE = ATE + ((D-(ATE x SPI)/SPI))
TE = 16 + ((22-(16 x 0.849)/0.849)
TE = 25,924 (rounded up to 26 Weeks)

By using the calculation formula, it is obtained a recapitulation of the calculation results of the estimated cost and final project completion time in the following table:

Table 7. Estimated Cost and Project Completion Time Week 12 and Week 16

No	Analysis	week 12	Sunday 16
1	ETC (Rp)	7,129,164,976.75	3,748,685,709.19
2	EAC (Rp)	11,519,835,174.75	8,870,754,007,19
3	TE (Sunday)	37.43	25.92

Based on the calculation of project performance, the estimated cost and time for the final project completion are shown in Table 5 which shows that there is an increase in terms of cost with the performance of the Week 12 project requiring a completion cost of Rp. 11,519,835,174.75 experienced a decrease in costs on Sunday 16 to Rp. 8,870,754,007,19. Meanwhile, in terms of project completion time, the project also increased from 38 weeks to 26 weeks with an increase in project performance in 16 weeks.

5. Conclusions and suggestions

5.1. Conclusion

1. The contractor adds bore pile and iron power, equipment, changes the method of carrying out bore pile and erection and tries design alternatives to save material by minimizing material waste. At the end of the

project review on week 16, the project performance in terms of time (SPI) was 0.85, indicating a delay of 10.927% from the initial plan of 73.731% with 62.804% realization. Meanwhile, the project cost performance (CPI) of 1.22 shows that the costs incurred are still below the planned budget.

2. Based on the analysis of performance calculations, the estimated project completion time is 26 weeks or 4 weeks longer than the planned schedule of 22 weeks. This shows a potential loss of Rp. 1,117,808,504.78 or 11,161% of the total project budget. This can be anticipated by improving the performance of the current project. In terms of cost, the estimated cost of completing this project is Rp. 8,870,754,007,19. This means that with the current project cost performance, the project will have a potential profit of Rp. 1,144,245,992.81 or 11,425% of the total project budget.

5.2. Suggestion

1. Using the Earned Value Method as a tool to measure project performance in terms of time and cost is very helpful for the Contractor to take project control measures to avoid delays and cost overruns. By using the Earned Value method, predictions of time and cost can be obtained to be able to complete the remaining work, so that corrective actions can be taken what will be done next.
2. Further studies on controlling project time and costs can be carried out by considering the quality and technical specifications of the materials used and may consider the cash flow control method used by the Contractor in dealing with market price fluctuations.

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Biography / Biographies (Optional)

Yopi Lutfiansyah ST, MT is an Assistant Professor in Construction Management the Department of Civil Engineering at Mercu Buana University, Jakarta, Indonesia. He has joined at Mercu Buana University since 2017. He earned Diploma in Civil Engineering from Polytechnic University of Indonesia, Profession Engineer from University of Muhammadiyah Surakarta and Master in Project Management from University of Indonesia in 2015 with the title thesis "Evaluation for time Controlling system at optical submarine project at PT. XYZ with approaching to risk management and PMBOK 2013 to improve time management with Structural Equation Modelling (SEM-PLS) method". His research interest include Optimisation, Scheduling, Costing, Quality and lean.

Wilhelmus Tarigan,is a student of Mercu Buana University, Jakarta, Indonesia who has conducted this research and made a journal on "Evaluation of Project Time and Cost Control Using the Earned Value Method in the Construction Project of PT Pindad (Persero) Crane Support Structures. He has had work experience in the civil construction sector for 4 years since completing the Diploma 3 program from the Medan State Polytechnic in 2013. From 2019 to July 2021 he still served PT Pindad (Persero) a government-owned defense industry company managed by the Ministry of SOEs as staff planning and control of fixed assets maintenance. He and his team are tasked with carrying out and controlling the construction process at PT Pindad (Persero).