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Scheduling and Network Analysis on Cooling Water Pipe Fabrication Project

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ABSTRACT

Optimizing costs and time and manpower planning are very important in project management. The case study raised in this research is a cooling water pipe fabrication project with a processing time duration of 231 days and a project cost allocation of Rp. 306,545,488,000. The method used to control project delays is earned value analysis, and to optimize the project is done by shortening the project duration and minimizing project cost losses using the crash program method. The results of the earned value analysis stated that the project experienced delays, exceeded budget costs and was subject to project delays penalties, which was 340 days of completion time more than 111 days from the planned time and with a total final project cost of Rp. 331,813,410,524.46 more than Rp. 25,267,922,524.44 of the costs that have been prepared. Then an effort was made to accelerate the duration of the project with three scenario options. From the results of the crash cost calculation, it is found that the final total cost estimate for scenario 1 with 3 hours overtime is Rp. 289,043,553,541. Scenario 2, the estimated total final cost with 4 hours overtime is Rp. 289,051,063,021 and scenario 3 the estimated total final cost with the addition of workers is Rp. 289,310.359,861. So, the scenario that can be used by PT. X in order to minimize losses is to impose 3 hours overtime with an estimated total final cost of Rp. 289,043,553,541.

Keywords: *Earned Value Analysis, Crash Program, Project Control*

1. INTRODUCTION

Cooling water pipe or abbreviated as CWP is a cooling pipe for the PLTU turbine cooling system in the Kendal area, Central Java. The fabrication project of the CWP is divided into two types of pipes, namely the outfall pipe and the intake pipe. In the construction of this fabrication project, there were few obstacles to the work arrangement. The schedule that has been prepared by the fabricator does not go according to plan, based on this, project control and appropriate planning are required. An important part of implementing the project itself is controlling in terms of cost and time. The inconsistency between costs and time in the field with the scheduling plan can be said that the project management is in the bad or inadequate category. In a situation like this, it is possible to make preventive measures so that project implementation goes according to plan.

PT. X is a national heavy construction company engaged in the EPCI (Engineering, Procurement, Construction, Installation) sector. This company is in charge of the CWP fabrication project. The CWP project is planned to be completed within 231 days (February 2019 - October 2019), in this project the company only makes pipes until its delivered. However, it doesn't rule out the possibility that this project will experience delays in its construction, if it refers to the schedule that has been prepared. The inconsistency between the cost budget plan and also the working time in the field with the scheduled plan, shows a lack of management coordination as a control function.

2. METHODOLOGY

After collecting the data, the research can proceed to the data analysis and discussion stage. The steps taken are as follows:

1. Analyzing Project Performance

There are three indicators that need to be done to analyze project performance in terms of costs and schedules, namely:

- **Planned Value (PV)**

PV = Plan weight (%) x Total contract costs	(1)

Plan weight (%) is the scheduled percentage of each work item to the total cost of the entire contract without including tax.

- **Earned Value (EV)**

EV = weight of progress x Total contract costs	(2)

The realization weight above is the percentage that has been done from each particular work item to the total contract cost without including tax.

- **Actual Cost (AC)**

It is calculated by adding up all direct or indirect expenses in a given review period.

- ***Cost Variance*** **(CV)**

CV = EV – AC	(3)

- ***Schedule Variance*** **(SV)**

SV = EV – PV	(4)

- ***Cost Performance Index*** **(CPI)**

$CPI = \frac{EV}{AC}$	(5)

- ***Schedule Performance Index*** **(SPI)**

$SPI = \frac{EV}{PV}$	(6)

2. Determine Estimated Time and Cost by calculating Estimate at Completion (EAC) and estimating the project completion time.

3. Reschedule PDM
Reschedule using PDM to find critical paths from all activities.

4. Acceleration of Project Time
Calculate the acceleration of the project time using a crash program by calculating the cost of overtime or additional workers.

5. Determine the most optimal scenario.

3. RESULT AND DISCUSSION

3.1 Earned Value Analysis

3.1.1 Progress Project Report

The project progress report is data that contains the progress of each work item per period (per-week) and is accumulated by weight per work item. The following is a table of actual project progress report recapitulation:

Table 1. Recapitulation of Project Progress

Period	Actual Weight (%)
15 Feb '19	0.0
22 Feb '19	0.01
15 Mar '19	2.16
Period	Actual Weight (%)
29 Mar '19	6.28
12 Apr '19	14.14
26 Apr '19	25.16
17 May '19	34.53
31 May '19	43.54
14 Jun '19	48.09
28 Jun '19	58.79
05 Jul '19	64.20
19 Jul '19	74.82

The tables should be centered. Descriptions and numbers inside the table should be typed with font size 9 or less (but they should be readable). Table's background may be colored as necessary. Tables should be explained in the text as close to the tables as possible. Citation remark should be given by end of the label if the table is taken from a reference. An example of table and its label as shown in Table 1.

3.1.2 Earned Value and Planned Value Calculations

Planned value is the budget of a job that is compiled based on a work activity schedule. This calculation is used to determine the budget for a job that has been adjusted based on the work plan that has been prepared. Calculation of planned value using the formula according to equation 1.

Meanwhile, earned value is the result of actual weight to total project cost. The actual weight is obtained from the project progress report according to data in the field. The calculation of earned value uses the formula in according with equation 2.

- PV calculation for the period of 22 February 2019:

PV = 0.2% x IDR 306,545,488,000 = IDR613,090,976

- EV calculation for the period of 22 February 2019:

EV = 0,01% x Rp. 306.545.488.000 = Rp. 30.654.458

The following is the recapitulation of planned value and earned value in graph form:

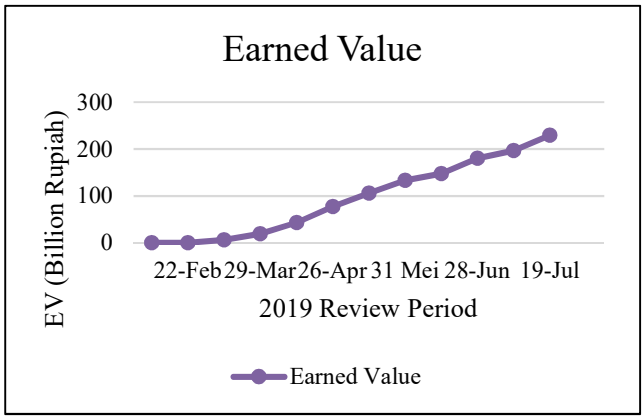

Figure 1. Earned Value Curve

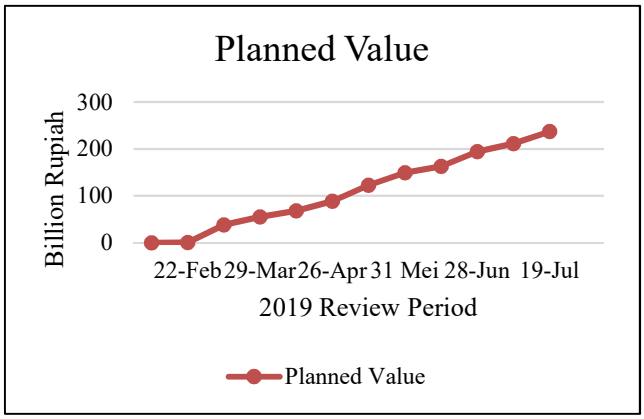

Figure 2. Planned Value Curve

3.1.3 Actual Cost Calculations

Actual cost is the actual expense incurred in a project in a certain period. The actual cost value can be a cumulative calculation of the work in a certain period. The following is the recapitulation of actual cost in graph form:

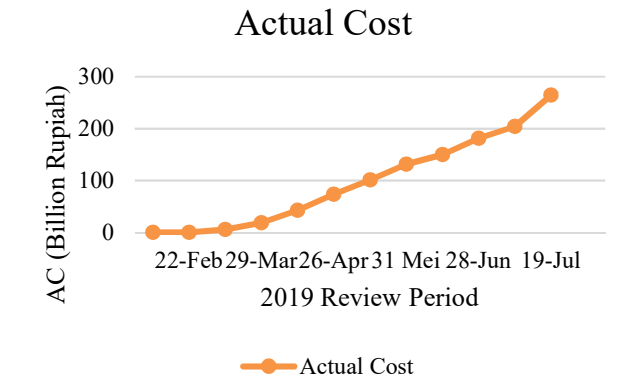

Figure 3. Actual Cost Curve

After obtaining the results of the earned value, planned value and actual cost calculations, then plotted into a combined graph between EV, PV, and AC in Figure 3.4 below:

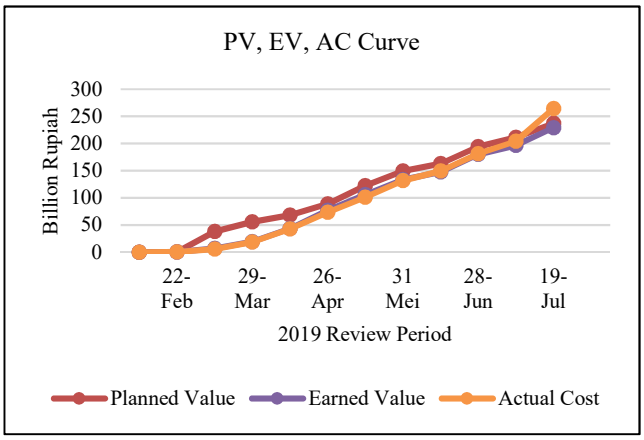

Figure 4. PV, EV, AC Curve

3.1.4 Schedule Variance Calculations

Table 2. Schedule Variance Calculation

Period	EV	PV	SV = EV - PV
15 Feb '19	Rp. -	Rp. -	Rp. -
22 Feb '19	Rp. 30.654.458	Rp. 613.090.976	-Rp. 582.436.517
15 Mar '19	Rp. 6.621.382.540	Rp. 37.980.985.963	-Rp. 31.359.603.422
29 Mar '19	Rp. 19.251.056.646	Rp. 55.576.696.974	-Rp. 36.325.640.328
12 Apr '19	Rp. 43.345.532.003	Rp. 68.2677.680.177	-Rp. 24.922.148.174
26 Apr '19	Rp. 77.126.844.780	Rp. 88.683.609.678	-Rp. 11.556.764.897
17 May '19	Rp. 105.850.157.006	Rp. 122.526.231.553	-Rp. 16.676.074.547
31 May '19	Rp. 133.469.905.475	Rp. 149.318.307.204	-Rp. 15.848.401.729
14 Jun '19	Rp. 147.417.725.179	Rp. 162.959.581.420	-Rp. 15.541.856.241
28 Jun '19	Rp. 180.218.092.395	Rp. 194.073.948.452	-Rp. 13.855.856.057
05 Jul '19	Rp. 196.802.203.296	Rp. 211.669.659.464	-Rp. 14.867.456.168
19 Jul '19	Rp. 229.357.334.121	Rp. 237.266.207.712	-Rp. 7.908.873.590

- SV calculation for the period 22 February 2019 with the EV result for the 22 February 2019 period is Rp. 30,654,458 and the cost of PV is Rp. 613,090,976.
  Schedule Variance results:

SV = Rp. 30,654,458 - Rp. 613.090.976 = -Rp. 582,436,517

- The calculation of SV for the period March 15 2019 with the EV result for the period March 15 2019 was Rp. 6,621,382,540 and the cost of PV is Rp. 37,980,985,963.
  Schedule Variance results:

SV = Rp. 6,621,382,540 - Rp. 37,980,985,963 = -Rp. 31,359,603,422

The difference between EV and PV is negative. Shows that progress in the field is less than the project plan.

3.1.5 Cost Variance Calculations

Table 3. Cost Variance Calculation

Period	EV	AC	CV = EV – AC
15 Feb '19	Rp. -	Rp. -	Rp. -
22 Feb '19	Rp. 30.654.458	Rp. 25.246.183	Rp. 5.408.275
15 Mar '19	Rp. 6.621.382.540	Rp. 5.829.361.802	Rp. 792.020.738
29 Mar '19	Rp. 19.251.056.646	Rp. 18.518.221.473	Rp. 732.835.172
12 Apr '19	Rp. 43.345.532.003	Rp. 42.827.742.395	Rp. 517.789.607
26 Apr '19	Rp. 77.126.844.780	Rp. 75.472.206.149	Rp. 1.654.638.631
17 May '19	Rp. 105.850.157.006	Rp. 103.462.110.948	Rp. 2.388.046.058
31 May '19	Rp. 133.469.905.475	Rp. 131.593.612.229	Rp. 1.876.293.245
14 Jun '19	Rp. 147.417.725.179	Rp. 149.762.297.623	-Rp. 2.344.572.444
28 Jun '19	Rp. 180.218.092.395	Rp. 181.493.836.534	-Rp. 1.275.744.139
05 Jul '19	Rp. 196.802.203.296	Rp. 204.262.810.482	-Rp. 7.460.607.186
19 Jul '19	Rp. 229.357.334.121	Rp. 264.579.658.961	-Rp. 35.222.324.840

Cost variance is the difference between actual cost and earned value.

- CV calculation in the period 22 February 2019 with an EV result of Rp. 30,654,458 and AC Rp. 25,246,183.
  Cost variance results:

CV = Rp. 30,654,458 - Rp. 25,246,183 = Rp. 3,908,275

3.1.6 Schedule Performance Index

Schedule Performance Index is a performance efficiency factor in project completion. SPI calculation can be obtained which work results are right according to the plan and which are not according to the plan.

SPI = 1: project performance on time
SPI <1: project performance is late
SPI > 1: faster project performance

Table 4. Average SPI

Period	EV	PV	SPI = EV/PV
15 Feb '19	Rp. -	Rp. -	-
22 Feb '19	Rp. 30.654.458	Rp. 613.090.976	0,05
15 Mar '19	Rp. 6.621.382.540	Rp. 37.980.985.963	0,17
29 Mar '19	Rp. 19.251.056.646	Rp. 55.576.696.974	0,34
12 Apr '19	Rp. 43.345.532.003	Rp. 68.2677.680.177	0,63
26 Apr '19	Rp. 77.126.844.780	Rp. 88.683.609.678	0,87
17 May '19	Rp. 105.850.157.006	Rp. 122.526.231.553	0,86
31 May '19	Rp. 133.469.905.475	Rp. 149.318.307.204	0,89
14 Jun '19	Rp. 147.417.725.179	Rp. 162.959.581.420	0,90
28 Jun '19	Rp. 180.218.092.395	Rp. 194.073.948.452	0,93
05 Jul '19	Rp. 196.802.203.296	Rp. 211.669.659.464	0,93
19 Jul '19	Rp. 229.357.334.121	Rp. 237.266.207.712	0,97
Average SPI			**0,68**

The average SPI result is 0.68. It's indicating that the project performance in the field is lagging behind the project plan on schedule.

3.1.7 Cost Performance Index

Table 5. Cost Performance Index Calculation

Periode	EV	AC	CPI = EV/AC
15 Feb '19	Rp. -	Rp. -	-
22 Feb '19	Rp. 30.654.458	Rp. 25.246.183	1,21
15 Mar '19	Rp. 6.621.382.540	Rp. 5.329.961.802	1,24
29 Mar '19	Rp. 19.251.056.646	Rp. 18.518.221.473	1,03
12 Apr '19	Rp. 43.345.532.003	Rp. 42.827.742.395	1,04
26 Apr '19	Rp. 77.126.844.780	Rp. 72.172.206.349	1,06
17 May '19	Rp. 105.850.157.006	Rp. 103.462.110.948	1,02
31 May '19	Rp. 133.469.905.475	Rp. 131.593.612.229	1,01
14 Jun '19	Rp. 147.417.725.179	Rp. 149.762.297.623	0,98
28 Jun '19	Rp. 180.218.092.395	Rp. 181.493.836.534	0,93

Periode	EV	AC	CPI = EV/AC
05 Jul '19	Rp. 196.802.203.296	Rp. 204.262.810.482	0,96
19 Jul '19	Rp. 229.357.334.121	Rp. 264.579.658.961	0,86
Average CPI			**1,03**

The average CPI result is 1.03 indicating that the planned costs are greater than the costs in the field.

3.1.7 The Estimated Final Time and Cost of The Project

The results of calculating the estimated project time:

Estimated Project Time = $\frac{231}{0,68}$ = 340 days

Project Delay = 340 days - 231 days = 111 days

Estimated Project Cost = $\frac{AC+(BAC-EV)}{CPI}$

= $\frac{Rp.264.579.658.961+(Rp.306.545.488.000-Rp.229.357.334.121)}{1,03}$

= Rp. 331.813.410.524

3.1.8 Project Late Fee

Cost of Fine = Project Delay x ($\frac{1}{1000}$) x Total Project Cost

= 111 x ($\frac{1}{1000}$) x Rp. 306.545.488.000

= Rp. 34.026.549.168

Estimated total costs to be paid for the entire CWP project including project late fees are:

Overall Cost = Cost of Fine + Estimated Total Final Project Cost

= Rp. 34.026.549.168 + Rp. 331.813.410.524

= Rp. 365.839.959.692

3.2 Crash Duration Analysis

The following is the calculation of crash duration of Body assembly 36L-V activities with 4 hours of overtime:

Productivity per-hour = $\frac{Weight\ Factor}{Working\ Hours\ x\ Duration\ of\ Activities}$

= $\frac{0.0094}{8\ x\ 23}$ = 5.1 x 10^{-5}

Productivity with the addition of 4 hours of overtime:

= (Working Hours x Productivity per-hour) + (a x b x Productivity per-hour)

= (8 x 5.1 x 10^{-5}) + (8 x 0.4 x 5.1 x 10^{-5}) = 5.6 x 10^{-4}

Crash duration with 4 hours of overtime:

$\frac{(Weight\ Factor)}{(Productivity\ per-days\ after\ crashing)}$

= $\frac{0.0094}{0.00056}$ = 16 days

Then, for calculating crash duration with 3 hours of overtime work is as follows:

Productivity with the addition of 3 hours of overtime:

= (Working Hours x Productivity per-hour) + (a x b x Productivity per-hour)

= (8 x 5.1 x 10^{-5}) + (8 x 0.3 x 5.1 x 10^{-5}) = 5.2 x 10^{-4}

Crash duration with 4 hours of overtime:

$\frac{(Weight\ Factor)}{(Productivity\ per-days\ after\ crashing)}$

= $\frac{0.0094}{0.00052}$ = 18 days

3.2.1 Overtime Calculations

It is known that hourly workers wages are Rp. 75,000.00 and for the worker's overtime pay is Rp. 100,000.00.

1. Daily Wage Calculation:
   = $\frac{Rp.28.710.000}{23}$
   = Rp. 1.248.260
2. Calculation of Hourly Worker Wages:
   = $\frac{Rp.1.248.260}{8}$
   = Rp. 156.032
3. Calculation of Worker Overtime Wages = 4 x Rp. 100,000
   = Rp. 4,000,000
4. Calculation of Crash Cost:

Wage Crash Cost = 16 x (Rp. 1,248,260 + Rp. 4,000,000)
= Rp. 83,972,160

- 36L-V body assembly activity costs (4 hours overtime)

= Crash Cost + Sub-Contractor Cost + Material Cost

= Rp. 83.972.160 + Rp. 920.749.000 + Rp. 1.855.220.000

= Rp. 2.859.941.160

Total Overtime Costs for Cooling Water Pipe Fabrication Project

= Actual Cost + Activity Costs that have not been implemented

= Actual Cost + (Load Out Sea Fastening 4th Shipment + Grillage and Sea Fastening 5th Shipment + Load Out Sea Fastening 5th Shipment + Can Pipe Body Fabrication 36L-V + Appurtenances Pipe Body Fab 36L-V + Flange UWJ 36L-V + Body Assembly 36L-V + Can UWJ Fab 36L-V + UWJ Assembly 36L-V + UWJ Installation 36L-V + Appurtenances Pipe Body Assembly 36L-V + Blasting & Painting CWP 36L-V + Grillage and Sea Fastening 6th Shipment + Load Out Sea Fastening 6th Shipment)

= Rp. 264.579.658.961 + (Rp. 63.200.000 + Rp. 56.750.000 + Rp. 53.800.000 + Rp. 3.880.220.000 + Rp. 940.849.000 + Rp. 725.380.000 + Rp. 2.859.941.160 + Rp. 625.600.000 + Rp. 680.145.000 + Rp. 1.585.100.000 + Rp. 690.749.000 + Rp. 2.785.455.000 + Rp. 80.525.000 + Rp. 79.325.000)

= Rp. 289.051.063.021

- 36L-V body assembly activity costs (3 hours overtime)

= Crash Cost + Sub-Contractor Cost + Material Cost

= Rp. 76.468.680 + Rp. 920.749.000 + Rp. 1.855.220.000
= Rp. 2.852.437.680

Total Overtime Costs for Cooling Water Pipe Fabrication Project
= Actual Cost + Activity Costs that haven't been implemented
= Actual Cost + (Load Out Sea Fastening 4th Shipment + Grillage and Sea Fastening 5th Shipment + Load Out Sea Fastening 5th Shipment + Can Pipe Body Fabrication 36L-V + Appurtenances Pipe Body Fab 36L-V + Flange UWJ 36L-V + Body Assembly 36L-V + Can UWJ Fab 36L-V + UWJ Assembly 36L-V + UWJ Installation 36L-V + Appurtenances Pipe Body Assembly 36L-V + Blasting & Painting CWP 36L-V + Grillage and Sea Fastening 6th Shipment + Load Out Sea Fastening 6th Shipment)
= Rp. 264.579.658.961 + (Rp. 63.200.000 + Rp. 56.750.000 + Rp. 53.800.000 + Rp. 3.880.220.000 + Rp. 940.849.000 + Rp. 725.380.000 + Rp. 2.859.941.160 + Rp. 625.600.000 + Rp. 680.145.000 + Rp. 1.585.100.000 + Rp. 690.749.000 + Rp. 2.785.455.000 + Rp. 80.525.000 + Rp. 79.325.000)
= Rp. 289.043.553.541

3.2.2 Calculation of Additional Workers

After crash duration of 36L-V body assembly activities from 23 days to 16 days, then the calculation of additional working hours is carried out.

$$\frac{16}{23} = \frac{3184}{a}$$

a = 4577

$$\frac{4577}{8\ (work\ hours\ per-day)} = 572 \text{ workers}$$

Total Cost = Rp. 75,000 x 4577 = Rp. 343,275,000

- 36L-V body assembly activity costs (Manhours Add)

Manhours Addition Fee + Sub-contractor Fee + Material Cost
= Rp. 343.275.000 + Rp. 920.749.000 + Rp. 1.855.220.000
= Rp. 3.119.244.000

Total Manhours Addition Fee
= Actual Cost + Activity Costs that haven't been implemented
= Actual Cost + (Load Out Sea Fastening 4th Shipment + Grillage and Sea Fastening 5th Shipment + Load Out Sea Fastening 5th Shipment + Can Pipe Body Fabrication 36L-V + Appurtenances Pipe Body Fab 36L-V + Flange UWJ 36L-V + Body Assembly 36L-V + Can UWJ Fab 36L-V + UWJ Assembly 36L-V + UWJ Installation 36L-V + Appurtenances Pipe Body Assembly 36L-V + Blasting & Painting CWP 36L-V + Grillage and Sea Fastening 6th Shipment + Load Out Sea Fastening 6th Shipment)
= Rp. 264.579.658.961 + (Rp. 63.200.000 + Rp. 56.750.000 + Rp. 53.800.000 + Rp. 3.880.220.000 + Rp. 940.849.000 + Rp. 725.380.000 + Rp. 3.119.244.000 + Rp. 625.600.000 + Rp. 680.145.000 + Rp. 1.585.100.000 + Rp. 690.749.000 + Rp. 2.785.455.000 + Rp. 80.525.000 + Rp. 79.325.000)
= Rp. 289.310.359.861

Table 6. Recapitulation PDM Calculations

Scenario	Duration	*Manhours*	*Manpower*	Total Cost
Project running, increased duration and paid a fine	340 days	107.536	13.442	Rp. 365.839.959.692
Duration is accelerated by enforcing overtime hours (3 hours)	226 days	109.568	13.442	Rp. 289.043.553.541
Duration is accelerated by enforcing overtime hours (4 hours)	224 days	109.824	13.442	Rp. 289.051.063.021
The duration is accelerated by adding more workers	224 days	112.112	14.014	Rp. 289.310.359.861

From the 4 scenarios that have been calculated above, the scenarios that can be applied by PT. X in the cooling water pipe fabrication project with the lowest cost and minimizing losses is to apply a 3 hour overtime system (scenario 2) for workers with an estimated total final project cost of Rp. 289.043.553.541 with a duration of 226 days.

4. CONCLUSION

4.1 Conclusion

1. The results of the cost and time performance analysis on the CWP project using the earned value analysis method with no additional workers and volume of work added. Thus, the project performance is late from the plan indicated by the results of the schedule performance index is 0.68 indicating that the project performance is late from the scheduling plan and the result of the cost performance index is 1.03 indicating that the actual cost incurred is smaller than the work that has been or is being done.
2. The results of the calculation of total project final costs using earned value analysis without any change in scenario, the project will experience delays and project costs will swell, which is estimated to reach Rp. 331,813,410,524 and the duration of the project completion increased from 231 days to 340 days.

3. By using the Precedence Diagramming Method (PDM) on the CWP fabrication project, it is known that A1-E1-D2-H3-G5-W2-X3-AF1-AJ1-AK1-AK2 activities are at a critical path.
4. The results of calculations from several predetermined scenarios are as follows:
   - ✓ The first scenario; continue to carry out the project without any changes and is required to pay a project fine of Rp. 365,839,959,692 with a project completion duration of 340 days.
   - ✓ The second scenario; crash duration is carried out for activities located at critical points and 3 hours of overtime work is applied with a total final project cost of Rp. 289,043,553,541 and duration of project completion of 226 days.
   - ✓ The third scenario; Crash duration is carried out for activities located at critical points and 4 hours of overtime work are applied with a total final project cost of Rp. 289,051,063,021 and the duration of project completion was 224 days.
   - ✓ The fourth scenario; crash duration is carried out for activities located at critical points and additional workers are given with a total final project cost of Rp. 289,310.359,861 with a project completion duration of 224 days.

   So, it can be concluded that the scenario that will be applied by PT. X in the CWP fabrication project to minimize losses is the *second scenario*, namely by imposing 3 hours of overtime work with a total final cost of Rp. 289,043,553,541 and the duration of the project completion is 226 days.

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