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Predicting The Time And Cost of Fireboat Construction Using Earned Value Method (EVM)

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Abstract
Companies located in Surabaya which are mainly engaged in the production of commercial vessels, providing ship repair and maintenance services as well as general engineering with order-based specifications often experiencing problems of delays and cost overruns because of lack of supervision. Along with the development of the technology industry, ship production requires every shipyard to evaluate their system. Poor performance and lack of control and supervision have caused delays in the construction of new vessels. By using an Earned Value Method (EVM) calculation, it can predict the completion time and the remaining costs of fireboat construction, find deviations between plans and reality, and encourage to look for the causes. Based on the calculation analysis results of the fireboat construction, the researcher predicts the cost of remaining work as Rp. 23,616,760,065 and predicts the total cost at the end of the work of Rp. 157,383,943,827 and researchers also predicted project completion time of 381 days.

Keywords: Controlling, Planning, Cost Prediction, Time prediction, EVM, Schedule, Fireboat

1. INTRODUCTION

Companies located in Surabaya, which are mainly engaged in the production of commercial vessels, providing ship repair and maintenance services as well as general engineering with order-based specifications often experiencing problems of delays and cost overruns because of lack of supervision (Silvianita, 2018). Along with the development of the technology industry, ship production requires every shipyard to evaluate the system used. The new ship construction project is required to work fast according to the schedule. Poor performance, low quality, and cost overruns often occur in a project (Arica Dwi Susanto A. A., 2018).

The literature used in this paper were obtained to support the research. These literature includes paper titled A fuzzy pert approach to evaluate plant construction project scheduling risk under uncertain resources capacity (R.Lin, 2009). Earned Value Management Systems: Challenges and Future Direction (Wilson, 2013). CPM, PERT and Project Management With Fuzzy Logic Technique and Implementation On A Business (Mazlum, 2015). Integration of Building Information Modeling and Critical Path Method Schedules to Simulate the Impact of

Temperature and Humidity at the Project Level (Shan, 2014). Comparative Study of Management Operation System Techniques (MOST) and CPM in Construction Scheduling (Shailla, 2014). Extension of Time Determination in Construction Projects in Nigeria: The Critical Path Method (Andawei, 2014). Critical path analysis for the management of fractured neckof femur (Balla, 1995). The Critical Path Method In Estimating Project Duration (Nafkha, 2016). Critical Path Analysis for New Product Planning (Wong, 1964). Measuring the Actual Energy Cost Performance of Green Buildings: A Test of the Earned Value Management Approach (Dwaikat, 2016). Cost Control and Performance Review of Software Projects by Using the Earned Value Management (Alecu, 2014). Critical Path Method in Designing Feasible Solutions (Agarwal, 2013). Traditional Critical Path Method versus Critical Chain Project Management: A Comparative View (M, 2015). Project Planning And Control With Pert And Cpm (K.K.Khandelwal, 2002). Project Planning And Scheduling Using PERT And CPM Techniques With Linear Programming: Case Study (Agyei, 2015). Fast Missile Boat Project Planning using CPM and What If Analysis Method (Silvianita, 2018). CPM Schedule Summarizing Function of the Beeline Diagram Method (Kim, 2012). Earned value method as a tool for project control (Czarnigowska A., 2008). The Factors Affecting The Methods of Construction Projects Scheduling: An State of The Art and Overview (Fatemeh Nouban, 2017). Contruction Project Scheduling with Time, Cost and Material Restrictions Using Fuzzy Mathematical Models and Critical Path Method (Daniel Castro-Lacouture, 2009). Planning and Monitoring of industrial punch development processes (Y. Arslan, 2017).

By using an Earned Value Method (EVM) calculation, it can predict the completion time and the remaining cost of 60 Meter ship construction, finding deviations between plans and reality, and encouraging them to look for the causes. This Paper is organized as follows. Section 2 review about the basic ship theory. Section 3 gives result and section 4 discussion of research. Finally, in section 5 present conclusion this paper.

2. MATERIALS AND METHODS

A. Technical Concept

The indicators used in the concept of the yield value or earned value method are(Ibrahim, 1993):

1. Actual cost (AC) or Actual Cost of Work Performed (ACWP)
   Is the actual cost of work that has been carried out at a certain reporting period. This fee is obtained from the accounting or financial data of the project at the reporting date (for example, the end of the month), which is a record of all actual expenditure expenses from workload or accounting codes including overhead calculations and others.
2. Earned value (EV) or Budgeted Cost of Work Performed (BCWP)
   Is the result value from the point of view of the work value that has been completed on the budget provided to carry out the work. If the AC number is compared to EV, you will see a comparison between the costs incurred for the work carried out on the Costs that should have been incurred.

   EV = Physical progress weight x Plan budget

   - Cumulative physical progress weight for all work, which is obtained from monthly progress reports
   - The plan budget is obtained by the contract RAB

3. Planned Value (PV) or Budgeted Cost of Work Scheduled (BCWS)
   Is the budget value for a workload that is integrated with the implementation schedule. There's combination of costs, schedules and scope of work, where each element of the work has been given a cost and schedule allocation that can be a benchmark for reporting the implementation of work.

   PV = Plan weight x Plan budget.

   - Cumulative physical progress weight for all work, which is obtained from time schedule
   - The plan budget is obtained by the contract RAB

Based on (Czarnigowska A., 2008), Variance is obtained from 3 indicators, which are:

a. Cost Variance (CV)

Cost variance is the difference between the value obtained after completing workload with actual costs incurred during project implementation.

CV=EV–AC or CV=BCWP–ACWP

- Negative (-): Cost Overrun
- Zero (0): Accordance with the cost plan
- Positive(+): Cost Underrun

b. Schedule Variance (SV)

The schedule variance is used to calculate deviations between BCWS and BCWP.

SV=BCWP– BCWS

- Negative (-): Longer than the time schedule
- Zero (0): Accordance with the time schedule
- Positive (+): Faster than the time schedule

Table. 1 Integrated Variance Analysis

SCHEDULE VARIANCE SV=BCWP-BCWS	COST VARIANCE CV=BCWP-ACWP	NOTES
Positive	Positive	Work is carried out faster than the schedule with more costs than the budget
Zero	Positive	Work is carried out right on schedule with lower costs than the budget
Positive	Zero	Work is carried out according to the budget and completed faster than the schedule
Zero	Zero	Work is carried out according to schedule and budget
Negative	Negative	Work is finished late and costs more than the budget
Zero	Negative	Work is carried out on schedule with costs above the budget
Negative	Zero	Work is finished late and costs according to the budget
Positive	Negative	The work is completed faster than the plan with costs above the budget

Some terms related to this assessment are Cost Performance Index, Schedule Performance Index, Estimate at Completion dan Variance at Completion (Indraga, 2015).

a. Cost Performance Index (CPI)

The cost efficiency factors that have been spent can be shown by comparing the value of physically completed work (BCWP) with costs that have been incurred in the same period (ACWP).

CPI = EV : AC or CPI = BCWP : ACWP

- CPI = 1 means that the project cost is in accordance with the plan
- CPI > 1 means that the project cost is less than the plan
- CPI < 1 means that the project cost is more than the plan

b. Schedule Performance Index (SPI)

Performance efficiency factors in completing work can be shown by a comparison between the value of physically completed work (BCWP) and the planned expenditure issued based on the work plan (BCWS).

SPI = EV : PV or SPI = BCWP : BCWS

- SPI = 1 means that the project time is in accordance with the plan
- SPI > 1 means that the project time is faster than plan
- SPI < 1 means that the project time is lower than the plan

c. Estimate at Completion (EAC)
CPI and SPI are to predict the statistical costs needed to complete the project.

EAC = ACWP + ((BAC – BCWP) / (CPI x SPI))

From the EAC value, an estimate of the difference between the cost of the project completion plan (BAC) and the cost of completion of the project is based on achieved work performance (EAC) or variance at completion (VAC).

VAC = BAC – EAC

B. Time prediction and Project Completion Cost

Cost estimates or project completion schedules based on indicators obtained when reporting will provide clues to the cost at the end of the project (Estimate At Completion = EAC) and project completion time estimation (Estimate All Schedule = EAS) (Naderpour, 2011). Cost or schedule forecasts are useful because they provide early warning about things that will occur in the future, if the trends that exist at the time of reporting have not changed. If the remaining work is considered to be a fixed performance as at the time of reporting, the estimated cost for the remaining work (ETC) is (Heizer, 2009):

ETC = (BAC - BCWP) : CPI
EAC = ACWP - ETC

Meanwhile, the estimate time of the completion of the works:

ETS = (remaining time) : SPI
EAS = Completion time + ETS

C. Method of Research.

In the analysis of this research, these following steps will be carried out: Schedule Variance (SV), Cost Variance (CV), Cost Performance Index (CPI), Schedule Performance Index (SPI) and Estimate At Completion (EAC).

3. RESULT

After processing the data, they were subsequently analyzed the data that has been processed. This data analysis was conducted to find out which activities have increased costs due to shortening of time seen from the critical path, so that the direct costs calculated are labor salaries (overtime).

Table. 2 Schedule and Duration of the Fireboat Construction Project

No	Activity	Duration (Day)	Start	Finish
	Hull Construction		10/10/2016	06/06/2017
1	Hull Fabrication	70	10/10/2016	15/01/2017
2	Hull Sub Assembly	104	18/10/2016	11/03/2017
3	Hull Assembly	137	26/10/2016	06/05/2017
4	Hull Erection	137	25/11/2016	06/06/2017
	Painting anode Catodic Protection		01/10/2016	22/05/2017
5	Blasting and Painting Raw Material	48	10/10/2016	15/12/2016
6	Block Blasting and Painting	137	15/11/2016	31/05/2017
7	Finishing Hull	27	06/06/2017	12/07/2017

No	Activity	Duration (Day)	Start	Finish
8	Painting Outfitting	79	06/06/2017	22/09/2017
9	Anode	19	14/03/2017	07/04/2017
	Hull Outfitting		10/10/2016	05/10/2017
10	Seat and Foundation	86	10/10/2016	07/02/2017
11	Deck Machinery and Equipment	86	07/02/2017	07/06/2017
12	Interior	171	07/02/2017	05/10/2017
	Machinery Outfitting		10/10/2016	05/10/2017
13	Piping System Including Ducting	181	10/10/2016	20/06/2017
14	Shafting	51	20/06/2017	30/08/2017
15	Machinery Outfitting	25	31/08/2017	05/10/2017
	Electric, Electronic Outfitting		10/10/2016	05/10/2017
16	Cabling	172	10/10/2016	07/06/2017
17	Power Supply	172	02/11/2016	01/07/2017
18	Illuminiation	172	26/11/2016	26/07/2017
19	Communication and Instrumentation	178	21/12/2016	18/08/2017
20	Computing and Information	172	13/01/2017	12/09/2017
21	Nautical and Radio	172	07/02/2017	05/10/2017
	Function and Commisioning		05/10/2017	30/10/2017
22	Machinery Commisioning	9	05/10/2017	18/10/2017
23	Equipment Commisioning	8	10/10/2017	21/10/2017
24	Lighting Commisioning	4	18/10/2017	24/10/2017
25	System Control Commisioning	4	24/10/2017	30/10/2017
	HAT and SAT		02/11/2017	18/12/2017
26	Harbour Acceptance Test	31	02/11/2017	16/12/2017
27	Yard Trial	14	27/11/2017	18/12/2017
	Delivery		20/12/2017	20/12/2017
28	Delivery to Customer	0	20/12/2017	20/12/2017

Table. 3 Project Budget Plan for Fireboat Construction

No.	Job Description		Cost (Rupiah)
A	**Hull Construction**		
	1	Hull Fabrication	Rp 46.176.942
	2	Hull Sub Assembly	Rp 6.244.996
	3	Hull Assembly	Rp 8.286.629
	4	Hull Erection	Rp 8.286.629
B	**Painting anode Catodic Protection**		
	5	Blasting and Painting Raw Material	Rp 3.242.594
	6	Block Blasting and Painting	Rp 2.522.018
	7	Finishing Hull	Rp 1.621.297
	8	Painting Outfitting	Rp 4.743.795
	9	Anode	Rp 1.140.913
C	**Hull Outfitting**		
	10	Seat and Foundation	Rp 5.224.179
	11	Deck Machinery and Equipment	Rp 5.224.179
	12	Interior	Rp 10.388.311
D	**Machinery Outfitting**		
	13	Piping System Including Ducting	Rp 10.928.743
	14	Shafting	Rp 3.122.498
	15	Machinery Outfitting	Rp 1.561.249

No.	Job Description		Cost (Rupiah)
E	**Electric, Electronic Outfitting**		
	16	Cabling	Rp 4.203.363
	17	Power Supply	Rp 4.563.651
	18	Illuminiation	Rp 4.383.507
	19	Communication and Instrumentation	Rp 4.743.795
	20	Computing and Information	Rp 4.803.843
	21	Nautical and Radio	Rp 3.963.171
E	**Function and Commisioning**		
	22	Machinery Commisioning	Rp 600.480
	23	Equipment Commisioning	Rp 540.432
	24	Lighting Commisioning	Rp 120.096
	25	System Control Commisioning	Rp 420.336
F	**HAT and SAT**		
	26	Harbour Acceptance Test	Rp 1.921.537
	27	Yard Trial	Rp 900.721
G	**Delivery**		
	28	Delivery to Customer	Rp 120.096
	TOTAL		Rp 150.000.000

A. Gantt Chart Planning for The Fireboat Construction Project

The planning schedule making for a fireboat construction project used Gantt Chart to determine when the activities were started, postponed, and completed.

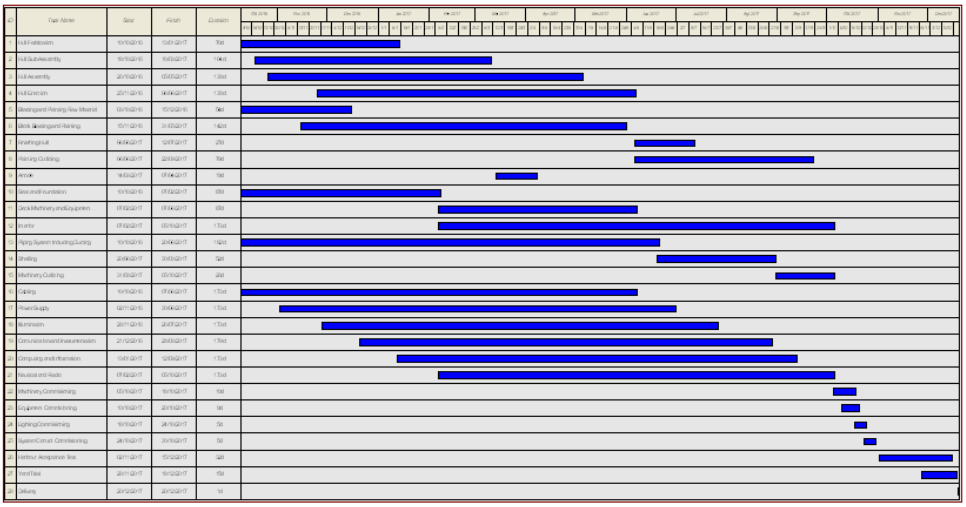

Fig. 1 Gantt Chart Planning for The Fireboat Construction Project

4. DISCUSSION

The calculation of the Earned Value Method (EVM) on this project resulted onBudget Cost Work Schedule (BCWS), Budget Cost Work Performed (BCWP), Actual Cost Work Performed (ACWP), Analysis of Cost Variances and Schedule Variances, Productivity and Performance Index.

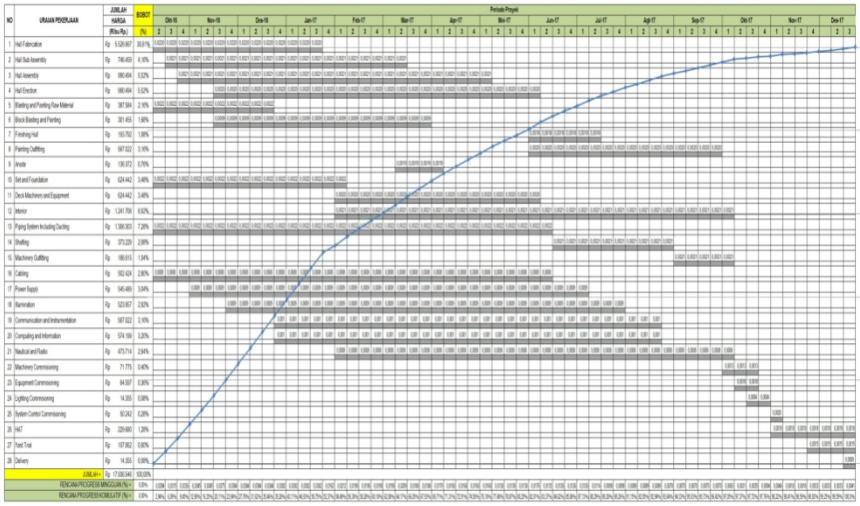

Fig. 2 S-Curve

Based on the S-curve depiction, it can be seen that the completion of the project was completed on day 314. Because this project is currently running, the project reporting period is made, where at the end of the period the work progress is submitted to the Contractor as presented in the following table:

Table. 4 Project Planning Period Date

Period	Day	Period Date	Plan Weight
1	16	10 Oct 16 – 31Oct 16	9,45%
2	38	1 Nov 16 – 30 Nov 16	14,50%
3	60	1 Dec 16 – 31 Dec 16	15,34%
4	82	1 Jan 16 – 31 Jan 17	13,09%
5	102	1 Feb 17 – 28 Feb 17	7,81%
6	125	1 Mar 17 – 31 Mar 17	7,75%
7	145	1 Apr 17 – 30 Apr 17	6,58%
8	168	1 May 17 – 31 May 17	5,75%
9	190	1 Jun 17 – 30 Jun 17	5,62%
10	211	1 Jul 17 – 31 Jul 17	4,38%
11	234	1 Agust 17 – 31 Agust 17	3,38%
12	255	1 Sep 17 – 30 Sep 17	2,78%
13	277	1 Oct 17 – 31 Oct 17	1,34%
14	299	1 Nov 14 – 31 Nov 17	1,16%
15	314	1 Dec 17 – 20 Dec 17	1,08%

Table. 5 BCWS Recapitulation

Period	Plan Weight	BCWS	BCWS Cumulative
1	9,45%	Rp14.166.232.836	Rp 14.166.232.836
2	14,50%	Rp21.734.606.133	Rp 35.900.838.970
3	15,34%	Rp23.001.259.607	Rp 58.902.098.577
4	13,09%	Rp19.625.219.490	Rp 78.527.318.067
5	7,81%	Rp11.719.419.104	Rp 90.246.737.171
6	7,75%	Rp11.624.092.843	Rp101.870.830.014
7	6,58%	Rp 9.868.688.520	Rp111.739.518.534
8	5,75%	Rp 8.627.310.802	Rp120.366.829.337
9	5,62%	Rp 8.440.159.436	Rp128.806.988.773
10	4,38%	Rp 6.578.035.155	Rp135.385.023.928
11	3,38%	Rp 5.069.612.508	Rp140.454.636.436
12	2,78%	Rp 4.174.521.435	Rp144.629.157.872

Period	Plan Weight	BCWS	BCWS Cumulative
13	1,34%	Rp 2.008.151.976	Rp146.637.309.848
14	1,16%	Rp 1.743.537.687	Rp148.380.847.535
15	1,08%	Rp 1.619.152.465	Rp150.000.000.000

Table. 6 BCWP Recapitulation

Period	Realization	Cumulative Realization	BCWP	Cumulative BCWP
1	7,98%	7,98%	Rp 11.970.466.747	Rp 11.970.466.747
2	12,86%	20,84%	Rp 19.278.595.640	Rp 31.249.062.387
3	13,15%	33,99%	Rp 19.712.079.484	Rp 50.961.141.870
4	11,80%	45,79%	Rp 17.701.947.980	Rp 68.663.089.850
5	7,02%	52,81%	Rp 10.535.757.775	Rp 79.198.847.625
6	6,11%	58,92%	Rp 9.171.409.253	Rp 88.370.256.878
7	5,84%	64,76%	Rp 8.763.395.406	Rp 97.133.652.284
8	4,39%	69,16%	Rp 6.591.265.453	Rp 103.724.917.737
9	4,46%	73,62%	Rp 6.693.046.433	Rp 110.417.964.170
10	3,20%	76,82%	Rp 4.808.543.699	Rp 115.226.507.869
11	2,93%	79,75%	Rp 4.395.354.045	Rp 119.621.861.913
12	2,54%	82,29%	Rp 3.815.512.592	Rp 123.437.374.505
13	1,25%	83,55%	Rp 1.879.630.250	Rp 125.317.004.755
14	1,02%	84,57%	Rp 1.532.569.627	Rp 126.849.574.382
15	0,79%	85,36%	Rp 1.186.838.757	Rp 128.036.413.139
16	7,40%	92,76%	Rp 11.100.000.000	Rp 139.136.413.139
17	3,10%	95,86%	Rp 4.650.000.000	Rp 143.786.413.139
18	4,14%	100,00%	Rp 6.210.000.000	Rp 150.000.000.000

Table. 7 ACWP Recapitulation

Period	ACWP	ACWP Cumulative
1	Rp 12.568.990.084	Rp 12.568.990.084
2	Rp 20.049.739.466	Rp 32.618.729.550
3	Rp 20.303.441.868	Rp 52.922.171.418
4	Rp 18.055.986.939	Rp 70.978.158.357
5	Rp 10.641.115.353	Rp 81.619.273.710
6	Rp 10.363.692.456	Rp 91.982.966.166
7	Rp 9.376.833.084	Rp 101.359.799.250
8	Rp 6.723.090.762	Rp 108.082.890.012
9	Rp 6.893.837.826	Rp 114.976.727.838
10	Rp 5.193.227.194	Rp 120.169.955.033
11	Rp 4.746.982.368	Rp 124.916.937.401
12	Rp 4.082.598.473	Rp 128.999.535.874
13	Rp 1.917.222.855	Rp 130.916.758.729
14	Rp 1.639.849.501	Rp 132.556.608.230
15	Rp 1.210.575.532	Rp 133.767.183.762

Table. 8 Cost Variance and Schedule Variance calculations

Period	Cost Variance	Schedule Variance
1	-Rp 598.523.337	-Rp2.195.766.090
2	-Rp 771.143.826	-Rp2.456.010.493
3	-Rp 591.362.385	-Rp3.289.180.124
4	-Rp 354.038.960	-Rp1.923.271.510
5	-Rp 105.357.578	-Rp1.183.661.330

Period	Cost Variance	Schedule Variance
6	-Rp1.192.283.203	-Rp2.452.683.590
7	-Rp 613.437.678	-Rp1.105.293.114
8	-Rp 131.825.309	-Rp2.036.045.349
9	-Rp 200.791.393	-Rp1.747.113.003
10	-Rp 384.683.496	-Rp1.769.491.457
11	-Rp 351.628.324	-Rp 674.258.464
12	-Rp 267.085.881	-Rp 359.008.843
13	-Rp 37.592.605	-Rp 128.521.726
14	-Rp 107.279.874	-Rp 210.968.060
15	-Rp 23.736.775	-Rp 432.313.708

Table. 9 Value of Project Performance in CPI and SPI

Period	CPI	SPI	Notes
1	0,95	0,85	Cost overrun &Schedule underrun
2	0,96	0,87	Cost overrun &Schedule underrun
3	0,96	0,87	Cost overrun &Schedule underrun
4	0,97	0,87	Cost overrun &Schedule underrun
5	0,97	0,88	Cost overrun &Schedule underrun
6	0,96	0,87	Cost overrun &Schedule underrun
7	0,96	0,87	Cost overrun &Schedule underrun
8	0,96	0,86	Cost overrun &Schedule underrun
9	0,96	0,86	Cost overrun &Schedule underrun
10	0,96	0,85	Cost overrun &Schedule underrun
11	0,96	0,85	Cost overrun &Schedule underrun
12	0,96	0,85	Cost overrun &Schedule underrun
13	0,96	0,85	Cost overrun &Schedule underrun
14	0,96	0,85	Cost overrun &Schedule underrun
15	0,96	0,85	Cost overrun &Schedule underrun
16	0,94	0,93	Cost overrun &Schedule underrun
17	0,94	0,96	Cost overrun &Schedule underrun
18	0,93	1,00	Cost overrun &Schedule underrun

A. Estimation of Project End Time and Costs

Estimation of the final time and costs of project completion can be done using indicators obtained at the time of reporting to provide a final project estimation. This estimation is useful in providing early warnings about things that will happen in the future, based on the assumption that the trends that exist and are revealed at the time the reporting has not changed. It is also useful to provide a forward-looking picture to the Contractor, so that it can take the necessary corrective steps.

1. ETC (Estimate to Completion):
Estimated costs for the remaining work, assuming that the trend of project performance will remain constant until the end of the project, obtained by:
ETC = (Project Total Anggaran Total Proyek - BCWP): CPI
ETC = (Rp. 150.000.000.000 - Rp. 128.036.413.139) : 0,93
ETC = Rp 23.616.760.065

2. EAC (Estimate at Completion): Estimated total cost at the end of the project, obtained by:
EAC = ACWP + ETC
EAC = Rp. 133.767.183.762 + Rp. 23.616.760.065
EAC = Rp. 157.383.943.827

3. ECD (Estimated Completion Date): Estimation of Project Completion Schedule.
   ECD = (Remaining Time : SPI) + time spent
   ECD = (57 : 0,85) + 314
   ECD = 381 days

5. CONCLUSION

Based on the results of the analysis that has been done by researchers that the calculation of ongoing activities of the fireboat project should be based on planning takes 314 days, because there is a delay in work the researchers estimate the addition of time to the completion of the project 67 days so the time needed for the fireboat project to finish is 381 days . With the addition of time, the cost to complete the work will increase Rp. 23,616,760,065, and the total cost at the end of the work is Rp. 157,383,943,827.

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