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Analysis of the Time Cost Trade-Off Method Application on Tug Boat 135 GT Repair Projects Owned by PT. Pelabuhan Indonesia II

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Abstract

In the project implementation process, there is still the possibility of delays, as in the case of the Tanjung Buyut I Tug Boat ship repair project - 206 135 GT calculations are needed to accelerate the project to determine the optimum time and cost. One method that can be used in accelerating projects / crashing projects is the Time Cost Trade-Off method. This method can be used to solve this problem by adding specific alternatives such as working hours, labor, and other things with the minimum additional cost. In this study, an alternative acceleration was carried out by adding human resources and working hours, lasting 1 to 4 hours, which would be applied to the Hull repair project for the Tug Boat Tanjung Buyut I-206 135 GT. Based on the results of the analysis that has been carried out on the work of the Hull section, which is included in the critical activity, it is obtained that the most optimum duration acceleration is the addition of working hours (overtime) for 3 hours and an additional workforce of 24 peoples which results in an acceleration of time of 17 days from the average duration of 60 days to 43 days with a time efficiency of 28%, as well as a cost reduction of IDR 19,700,000 or around 3.34% compared to the average duration fee of IDR 571,950,000 to IDR 552,250,000.

Keywords: *crashing project; duration acceleration; time cost trade-off*

1. Introduction

The increasing need for sea transportation has made the shipyard industry experience more projects, such as building new ships and repairing ships. In general, planning a project depends on the main success factors of a project, namely time, budget, quality, and client satisfaction (Ashari, 2011). The project runs well if the work is completed according to the planning time, produces good quality and quality, and according to the allocated cost.

However, it can be accepted that in the project implementation process, there is still the possibility of delays, both from internal and external factors. This variety of possibilities requires the shipyard to provide alternative solutions to complete the project on time (Howick et al., 2009).

Delays in a project can have several consequences, including increasing work costs and disrupting the timeline. Acceleration of project completion can be one way to anticipate project delays. However, accelerating the time will cause problems affecting project costs. Therefore, the acceleration of project completion must be carefully designed and calculated. Each project needs control measures regarding costs and deadlines so that the budget spent is not wasted and project time can be completed within the deadline.

Project acceleration/crashing is a method to shorten the project time by reducing the time of one or more essential project activities to less than the usual activity time (Rachman, 2013). One method that can be used to accelerate a project/crashing project is the Time Cost Trade-off or the exchange of time and costs. This method is an alternative that can be used to overcome project delays and develop the best plan to optimize the time and cost of project implementation. This can be achieved by adding more workers, increasing hours or overtime, using materials that are used more quickly, adding tools, and changing construction methods.

Referring to research that applies the Time Cost Trade-Off to Indonesian Building Construction projects, it is found that adding an alternative to accelerated working hours (overtime) for 1 hour a day results in a time efficiency of 24 days (9.02%) and a cost efficiency of IDR 43,019. 556.39 or decreased by 0.41%. (Priyo & Aulia, 2016). Another study entitled Optimizing the Acceleration of Class I Navigation Shipbuilding Projects using the Time Cost Trade-Off with an alternative

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Table 1. Critical Path Activity at Hull Work Section

No	Job Name	EF	LF	TF
1	Docking	30	30	0
2	Undocking	56	56	0
3	Classification (BKI) survey and enclosed certificate	59	59	0
4	Sea Trial	60	60	0
5	Dry docking charge per day	56	56	0
6	Floating charge for floating repair per day	29	29	0
7	Replating for hull construction, estimate	42	42	0
8	Hull scraping, including sea chest, skeg, and rudder/kort nozzle	33	33	0
9	Hull cleaning with high-pressure washing, bottom until bulwark	33	33	0
10	Hull blasting SA 2½, bottom until external bulwark	37	37	0
11	Hull Coating, flat bottom until bottom side	45	45	0
12	Hull Coating, top side, external bulwark	51	51	0
13	Draft Marking, Plimsol Mark, Tank Marking, Ship Name, Port Register, etc	55	55	0

acceleration, namely, the addition of overtime hours and additional workforce, obtained an acceleration of 25 days from the total normal duration of 225 days, shortened to 200 days with additional costs—an initial project of IDR 233,000,000,000 to IDR 234,889,654,211 (Muharani et al., 2020).

The ship repair project Tug Boat Tanjung Buyut I-206 135 GT is in progress, and delays in hull repairs are occurring. The project should have been completed 60 to 78 days or 18 days late. Reviewing these conditions, the author will research speeding up schedules in ship repair projects with an optimized number of workers from each overtime hour. The variation of overtime that will be analyzed is the addition of 1 hour, 2 hours, 3 hours, and 4 hours. The analysis was carried out to obtain the most cost-effective way to minimize losses caused by cost and time overruns to anticipate delays in the Tug Boat 135 GT repair project.

2. Research Method

The research data needed in this study uses the Tug Boat Tanjung Buyut I-206 135 GT ship repair project belonging to PT. Pelabuhan Indonesia II. This research uses the Time Cost Trade-Off method. This Time Cost Trade-Off is one method that can solve the delay problems by adding certain variables or alternatives, such as working hours and labor, as well as other things with minimal additional costs. Time Cost Trade-Off is a deliberate, systematic, and analytic process that tests all activities in a project centered on activities on the critical path (Ervianto, 2004).

The data that has been obtained is then analyzed with the help of the Microsoft Project application so that results and discussions can be obtained. The following are the results and discussion based on the analysis conducted in this study.

3. Result and Discussion

3.1. Arrangement of Activity Sequences

The first step in planning scheduling is to determine the work activity sequences. The arrangement of activities is carried out based on predecessors and successors. Work done before the work in question begins is called a predecessor, while a successor is a work that begins to be done after the work in question has taken place. In the relationship between activities, there are various terms to make it easier to plan a dependency relationship, including start to start (SS), finish to start (FS), start to finish (SF), and finish to finish (FF). The data obtained will later be carried out to organize activities assisted by Microsoft Project software and produce several critical activities on the Tug Boat Tanjung Buyut I-206 135 GT. Microsoft Project is a program that can help in optimizing project management, such as managing and analyzing workloads and developing schedules in project management (Maddeppungeng & Suryani, 2015).

3.2. Determining the Network Diagram and Critical Path

A network diagram is a group of networks containing the trajectory and the sequence of activities used to help visualize all the activities in the project. In drawing a network diagram, the first thing to do is determine the relationship between jobs and the duration of each job. In the network diagram, it can be seen that the values of ES (Earliest Start Time), EF (Earliest Finish Time), LS (Latest Allowable Start Time), and LF (Latest Allowable Finish Time) (I. Soeharto, 1999). From these data, the critical path can be known by calculating each job's total slack.

Activity on the critical path or critical activity has a total slack time value of zero (slack = 0) (Angelia et al., 2021). The repair project for the Tug Boat involves several critical activities, and this activity can be seen in

Table 2. Calculation of Normal Daily Productivity in the Hull Work Section

No	Job Name	Job Volume	Duration (Days)	Daily Productivity
1	Classification (BKI) survey and enclosed certificate	30	30	0
2	Replating for hull construction, estimate	56	56	0
3	Hull scraping, including sea chest, skeg, and rudder/kort nozzle	59	59	0
4	Hull cleaning with high-pressure washing, bottom until bulwark	60	60	0
5	Hull blasting SA 2½, bottom until external bulwark	56	56	0
6	Hull Coating, flat bottom until bottom side	29	29	0
7	Hull Coating, top side, external bulwark	42	42	0
8	Draft Marking, Plimsol Mark, Tank Marking, Ship Name, Port Register, etc	33	33	0

Table 1. Furthermore, activity on the critical path will be analyzed using the Time Cost Trade-Off method to obtain a more optimal project work duration.

3.3. Daily Productivity Calculation

Productivity is the comparison/ratio between output (produced) and input (resources used). With productivity, it is hoped that planning can run efficiently and effectively (Sutrisno, 2009).

Index for productivity progress using different measurements depending on the job (weight, welding parameters, cable length, etc.) per unit of time (Richard Lee Storch et al., 1995). The magnitude of each value of average daily productivity can be determined using Equation 1.

$$Daily\ Productivity = \frac{Job\ Volume}{Normal\ Duration} \quad (1)$$

The calculation of normal daily productivity for each work on the Hull, which is to be analyzed, is shown in Table 2.

3.4. Alternative Acceleration

The acceleration process can also be called the Crash Project. Several alternatives can be used to speed up the execution of a project to avoid delays in the execution of work. The alternative acceleration that will be carried out in this study is as follows:

3.4.1. Additional Working Hours (Overtime)

Alternative additional working hours (overtime) outside of regular working hours can be used to shorten the completion of a project. However, additional hours (overtime) can cause a decrease in productivity. This decrease was caused by various factors such as worker fatigue, etc. The difference between the productivity indices due to overtime work is 0.1 per hour or a decrease in productivity of 0.1 per hour.

The average working time for this project is 8 hours per day (08.00 – 17.00) with one hour break (12.00 – 13.00). As previously explained, additional working hours (overtime) can lead to decreased productivity. Therefore, in this study, additional working hours (overtime) will be carried out for 1, 2, 3, and 4 hours after regular working hours are over. The value of productivity after acceleration by adding working hours (overtime) can be obtained from Equation 2.

$$PAWH = NDP + (NHP\ x\ PR\ Coef.\ x\ DOH) \quad (2)$$

where PAWH: Productivity of Additional Working Hours, NDP: Normal Daily Productivity, NHP: Normal Hourly Productivity, PR Coef.: Productivity Reduction Coefficient, and DOH: Duration of Overtime Hours

The results of productivity calculations after adding working hours (overtime) for 1-4 hours for each job in the Hull section can be seen in Table 3 (for information on notations 1-8, see Table 2).

3.4.2. Additonal Labor

A project's duration can also be shortened with the addition of labor other than the addition of working hours (overtime). This study assumes an additional workforce based on increased daily productivity due to additional working hours (overtime).

The magnitude of the increase in daily productivity due to additional working hours is obtained from Equation 3.

$$\frac{(PAWH - NDP)}{NDP}\ x\ 100\% \quad (3)$$

where PAWH is Productivity of Additional Working Hours, and NDP is Normal Daily Productivity.

The magnitude of the increase in daily productivity with additional labor alternatives can be determined by equation 4.

$$PAL = NDP + \frac{(NDP \times AW)}{NW} \quad (4)$$

where PAL is Productivity of Additional Labor, NDP is Normal Daily Productivity, AW is Accelerate Workforce, and NW is Normal Workforce.

The productivity value after adding labor for each job in the Hull section is shown in Table 4 (for information on notations 1-8, see Table 2).

3.5. Crash Duration

Crash Duration is the duration of the work that has been shortened from the average project duration. Increased productivity will occur if a job is accelerated by

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Table 3. Productivity Calculation Results After Additional Working Hours for 1 – 4 Hours

Job Name	1 Hour	2 Hour	3 Hour	4 Hour
1	1,11	1,20	1,26	1,30
2	855,77	923,08	971,15	1000
3	59,16	63,81	67,13	69,13
4	96,57	104,16	109,59	112,84
5	96,57	104,16	109,59	112,84
6	29,58	31,91	33,57	34,56
7	18,70	20,18	21,23	21,86
8	0,28	0,30	0,32	0,33

adding an alternative acceleration. The crash duration can be calculated using Equation 5.

$$Crash\ Duration = \frac{Job\ Volume}{Accelerated\ Productivity} \quad (5)$$

The crash duration value for each job on the Hull section can be seen in Table 5 (for information on notations 1-8, see Table 2).

3.6. Crash Cost

Productivity The cost that must be incurred directly to complete the activity after acceleration is called Crash Cost (Hutapea et al., 2020). In this research, the calculation of crash cost is caused by two alternatives that have been applied, namely the addition of hours of work from one hour to four hours and the addition of manpower.

The calculation of Crash Cost is caused by the addition of working hours and labor in each job. The value of the crash cost can be determined by equation 6.

$$Crash\ Cost = CCWD\ x\ CD\ x\ TM \quad (6)$$

where CCWD is Crash Cost Workers Per Day, CD is Crash Duration, and TM is Total Manpower.

3.6.1. Crash Cost of Adding Working Hours (Overtime)

Determination of overtime pay needs to pay attention to the number of costs that will be issued, based on Government Regulation No. 35/2021 Article 31 explains that companies that employ workers/laborers beyond their working hours, as referred to in Article 2 paragraph (2) are required to pay Overtime Wages with the provisions (Government Regulation No. 35/2021) :

a. for the first overtime hours of 1.5 times the hourly wage.

b. for each subsequent overtime hour, two times the hourly wage.

The explanation above shows that the crash cost with the alternative of adding working hours (overtime) for 1 to 4 hours can be found by equation 7.

$$Crash\ Cost = OFD\ x\ CD\ x\ TMN \quad (7)$$

where OFD is the Overtime Fee per Day, and TMN is the Total Manpower Normal.

3.6.2. Crash Cost of Adding Labor

The crash cost with an alternative of adding labor can be found in equation 8.

$$Crash\ Cost = NLC\ x\ CD\ x\ TAM \quad (8)$$

where NLC: Normal Labor Cost and TAM: Total Additional Manpower.

After knowing the crash cost values of the two alternatives that have been applied, the total crash cost value can be determined by adding the crash cost values of the two alternatives. The following is the value of the crash cost with the alternative of adding labor and working hours (overtime) for each additional hour on the work of the Hull section, which can be seen in Table 6.

3.7. Cost Slope

The cost Slope is a high additional cost to be incurred to reduce the duration of each work on a project (Eirgash & Toğan, 2019). The value of the cost slope for each job can be calculated by:

$$Cost\ Slope = \frac{CC-NC}{ND-CD} \quad (9)$$

Table 4. Productivity Calculation Results of Additional Labor based on Increased Productivity of Overtime Hours for 1 – 4 Hours

Job Name	1 Hour	2 Hour	3 Hour	4 Hour
1	1,5	1,5	1,5	1,5
2	671,79	923,08	974,36	974,36
3	58,49	63,81	63,81	69,13
4	95,48	104,16	104,16	112,84
5	98,37	104,16	109,95	109,95
6	17,25	31,91	33,23	34,56
7	10,49	20,18	21,02	21,86
8	0,31	0,31	0,31	0,31

Table 5. Crash Duration Calculation Result with the Addition of Labor & Working Hours for 1 – 4 Hours

Job Name	Crash Duration (Days)			
	1 Hour	2 Hour	3 Hour	4 Hour
1	1	1	1	1
2	7	6	5	5
3	2	2	2	2
4	2	2	2	2
5	2	2	2	2
6	5	4	3	3
7	5	4	3	3
8	2	2	2	1

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Table 6. Total Crash Cost Value for each Additional Overtime Hour

No	Job Name	Crash Cost Total (IDR)			
		1 Hour	2 Hour	3 Hour	4 Hour
1	Classification (BKI) survey and enclosed certificate	510.000	590.000	670.000	750.000
2	Replating for hull construction, estimate	18.000.000	22.500.000	22.500.000	25.500.000
3	Hull scraping, including sea chest, skeg, and rudder/kort nozzle	3.900.000	5.000.000	5.800.000	6.900.000
4	Hull cleaning with high-pressure washing, bottom until bulwark	3.900.000	5.000.000	5.800.000	6.900.000
5	Hull blasting SA 2½, bottom until external bulwark	6.000.000	7.500.000	9.000.000	10.200.000
6	Hull Coating, flat bottom until bottom side	15.600.000	20.000.000	17.850.000	20.700.000
7	Hull Coating, top side, external bulwark	15.600.000	20.000.000	17.850.000	20.700.000
8	Draft Marking, Plimsol Mark, Tank Marking, Ship Name, Port Register, etc	1.740.000	2.060.000	2.380.000	1.350.000
	Total	76.050.000	82.650.000	81.850.000	93.000.000

Table 7. Total Crash Cost Calculation

Job Name	Crash Cost (IDR)			
	1 Hour	2 Hour	3 Hour	4 Hour
1	-195.000	-155.000	-115.000	-75.000
2	-1.375.000	-964.286	-843.750	-468.750
3	-1.050.000	-500.000	-100.000	450.000
4	-1.050.000	-500.000	-100.000	450.000
5	-1.500.000	-750.000	0	600.000
6	-1.500.000	-1.000.000	-1.230.000	-660.000
7	-1.500.000	-1.000.000	-1.230.000	-660.000
8	-330.000	-170.000	-10.000	-350.000

where CC is Crash Cost, NC is Normal Cost, ND is Normal Duration, and CD is Crash Duration.

The value of the Cost Slope for each work on the Hull section with the alternative of adding workforce and working hours for one to four hours can be seen in Table 7 (for information on notations 1-8, see Table 2).

3.8. Analysis Result of Time Cost Trade-Off Method

Calculation and analysis using the Time Cost Trade-Off method for each Hull, included in critical activities with an alternative acceleration of additional working hours (overtime) for one to four hours and additional manpower, with the result of accelerated duration and the optimal costs obtained (can be seen in Table 8) are as follows:

It can be concluded that the addition of labor and working hours for 1 hour results in a time acceleration of 14 days from the average duration of 60 days to 46 days and a time efficiency of 23%. There was also a cost reduction of IDR 25,500,000 (4.45%) compared to the standard duration fee. In comparison, adding labor and working hours for 2 hours increases time acceleration by 16 days from the average duration (from 60 to 44 days). Thus, the time efficiency is 26%, and the cost reduction of IDR is 18,900,000 (3.30%). Adding manpower and working hours for 3 hours results in time acceleration by 17 days from the normal duration of 60 days to 43 days. The time efficiency is 28%, while the cost reduction is IDR 19,700,000 (3.34%). Adding manpower and working hours of 4 hours results in an accelerated time of 18 days from the normal duration of 60 days to 42 days. The time efficiency is 30%, while the cost reduction is IDR 8,550,000 (1.49%).

Based on the duration and cost calculation of the four alternatives above, the average acceleration duration is 43.75 days, and the average acceleration cost is IDR

Table 8. Calculation Results of Duration, Labor, and Costs

Additional Overtime Hours	Duration	Additional Workforce	Cost (IDR)	Reduced Costs (IDR)
0 Hour (Normal)	60 Days	0 people	571.950.000	0
1 Hour	46 Days	12 people	546.450.000	25.500.000
2 Hour	44 Days	20 people	553.050.000	18.900.000
3 Hour	43 Days	24 people	552.250.000	19.700.000
4 Hour	42 Days	28 people	563.400.000	8.550.000

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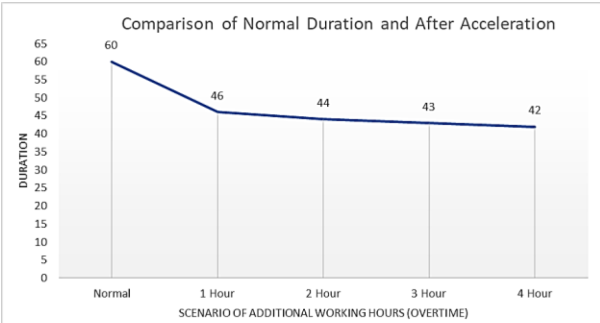

Figure 1. Graph of Comparison of Normal Duration and After Acceleration

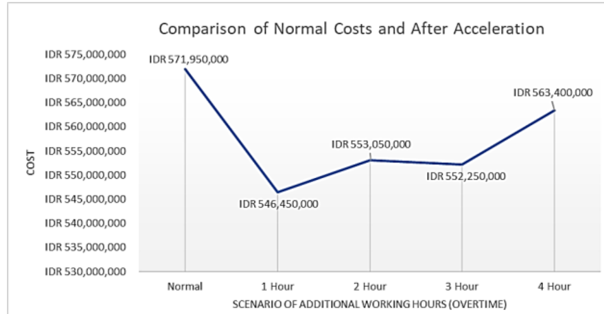

Figure 2. Graph of Comparison of Normal Costs and After Acceleration

553,787,500. Therefore, referring to Table 7, the most optimal acceleration alternative is the addition of labor and working hours (overtime) for 3 hours because it has a duration value and acceleration costs below the average. Therefore, referring to Table 7, the most optimal acceleration alternative is the addition of labor and working hours (overtime) for 3 hours because it has a duration value and acceleration costs below the average. For a comparison of normal costs and normal duration with those after acceleration, see Figures 1 and 2.

4. Conclusion

Calculations and analysis using the Time Cost Trade-Off method carried out on the Tanjung Buyut I-206 Tug Boat Reparation Project owned by PT Pelabuhan Indonesia II are concluded as follows: (1) Adding labor and working hours for 1 hour resulted in an acceleration of time by 14 days from the normal duration of 60 days to 46 days (23% time efficiency) and the cost reduction is Rp 25,500,000 (4.45% compared to the cost of the normal duration). 2) Adding labor and working hours for 2 hours resulted in an acceleration of time by 16 days from the normal duration of 60 days to 44 days (26% time efficiency), while the cost reduction is Rp 18,900,000 (3.30%). 3) Adding labor and working hours for 3 hours resulted in time acceleration by 17 days, from the normal duration of 60 days to 43 days (28% time efficiency), while the cost reduction is Rp 19,700,000 (3.34%). 4) Adding labor and working hours for 4 hours resulted in time acceleration by 18 days from the normal duration of 60 days to 42 days (30% time efficiency), while the cost reduction is Rp 8,550,000 (1.49%). Based on these average values, the most optimum value between accelerated working hours and overtime hours for 1 to 4 hours is an alternative to adding working hours (overtime) for 3 hours and adding a workforce of 24 people because the most efficient duration and good costs in terms of time and costs that do not increase, namely producing a duration of 17 days from the normal duration of 60 days to 43 days and time efficiency of 28%, as well as a cost reduction of Rp. 19,700,000 or about 3.34% compared to the normal duration fee of Rp. 571,950,000 to Rp. 552,250,000.

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