TIME-COST TRADE-OFF ANALYSIS ON JETTY CONSTRUCTION PROJECT (CASE STUDY : INDONESIAN NAVY JETTY CONSTRUCTION PROJECT)

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ABSTRACT

The performance of a project can be assessed based on the aspects of time, cost, and quality. The project is said to be successful when it can achieve the goals in the form of these three aspects by the initial planning. But the reality on the ground, often project implementation is not following the plan, resulting in project delays. Contractors can overcome the delay through various methods of accelerating time. This study aims to determine the acceleration of time through the Time-Cost Trade-Off analysis on The Indonesian Navy Jetty Construction Project in Saumlaki (Phase I) by comparing alternative methods of overtime and additional manpower. The analysis was carried out by using a quantitative descriptive method. The data used is secondary data such as of related documents, Bill of Quantity, S Curve, work volume, list of wages, and a number of workers. The calculation results show that acceleration using overtime alternatives can reduce 18 days or 6.98% of the implementation duration with a reduction in costs of IDR. 1,220,546,167.00 of the total cost of implementation (efficiency 1.8%). Additional manpower can reduce the duration for 19 days or by 7.36% with a reduction of IDR. 1,076,481,972.00 (1.61% efficiency). So that in this study it was found that the alternative of working overtime was more efficient than the alternative of additional manpower.

Keywords : *Scheduling, PDM, Crashing,*

1. INTRODUCTION.

A port is one of the important infrastructures in the maritime world which consists of land and waters around it with certain boundaries as a place of activity for government and economic activities which is used as a place for ships to dock, anchor, pick up and drop off passengers and load and load-unload cargo equipped with shipping safety facilities and port support activities as well as a place for intramodal and intermodal transport, Widyatmoko (2008). The port serves as a gateway and facilitates relations between regions, islands, or even between continents and nations. With this function, the port construction project must be accountable socially, economically, and technically.

The project is said to be successful if the goals set are achieved and meet quality standards of time and cost. In general, project planning which consists of scheduling, budgeting and quality serves as the main basis that will lead a project to success. Scheduling is one component of planning results in terms of resource performance in the form of project duration, costs, manpower, materials and equipment that can provide information about the project implementation schedule and project progress. The work implementation schedule is planned in such a way as to be carried out on time, however in practice in the field often it is not in accordance with the determined planning so the project delays often occur. Project implementers need to accelerate time as a solution to the delay. The consequence of the accelerated project time is the increase in direct costs. Therefore, a Time-Cost Trade- Off (TCTO) analysis is needed in order to obtain optimal results. Crashing is a method that can be used to accelerate projects. Crashing is a deliberate, systematic and analytic process by testing all activities in a project that are focused on critical path activities (Soeharto, 1999). This research was conducted by analyzing the crashing method and using a case study on the Indonesian Navy Jetty Construction Project in Saumlaki Phase I which experienced delays. This project is targeted for completion on September 13, 2019, with an implementation time of 240 working days. With the acceleration, it is expected to be used as an evaluation material so that the continuation of the project for the next step can be completed on time even faster than the initial planning. Efforts to accelerate it are carried out by using the alternative of adding working hours and increasing the manpower.

Previous research that has a relationship with this problem / research was carried out by, among others, Ririh, K. R., & Hidayah, N. Y. (2020) in a study entitled Reducing Project Duration of an Apartment Project by Waskita Karya using the Crashing Method. Ballesteros-Perez, P., Elamrousy, K. M., & Gonzalez-Cruz, M. C. (2019) studied Non-Linear Time-Cost Trade-Off Models of Activity Crashing: Application to Construction Scheduling and Project Compression with Fast-Tracking. Feylizadeh, M. R., Mahmoudi, A., BagheIDRour, M., & Li, D. F. (2018) in a study entitled Project Crashing using a Fuzzy Multi-Objective Model Considering Time, Cost, Quality and Risk Under Fast Tracking Technique: A case study. Novitasari, AD, Sandora, R., & Lestari, RL (2018) in their research entitled Project Scheduling Analysis using Presedence Diagram Method (PDM). In another title, Scheduling Project Crashing Time Using Linear Programming Approach: Case Study was researched by Chitra, K., & Halder, P. (2017). Another study entitled Monitoring and Controlling RCC Work in Delayed Construction Projects by Gujarati, N., & Balapgol, B. S. (2016). In this study, a network analysis in the form of the Precedent Diagram (PDM) method was carried out using the Ms Project 2016 application in order to obtain jobs on the critical path. Work that falls into the critical trajectory will be carried out by crashing calculations by adding work hours (overtime) and additional manpower. From the two alternatives to calculate the project acceleration, the final result of this research will be obtained in the form of a more efficient project time acceleration and cost.

2. MATERIAL AND METHOD

Project scheduling is one of the elements of planning results, which can provide information about the schedule of plans and project progress in terms of resource performance in the form of costs, manpower, equipment and materials as well as project duration plans and time progress for project completion (Husen, 2009). The precedent diagram (PDM) method is a node which is generally in the form of a rectangle, while the arrows are only a pointer to the relationship between the various activities concerned (Nurjaman, K et al, 2014). Time cost trade off is a deliberate, systematic and analytical process by testing all activities in a project that are focused on critical path activities (Erwianto, 2004).

2.1. Project Costs

a. Direct costs for the project include direct costs for manpower (wages for manpowerers, foremen, workers), materials and materials needed, and costs for the use of equipment that are closely related to project activities. Direct costs of a project are the total amount of each activity.

b. Indirect Costs, including project fixed costs which include tractor rental, diesel-electric rental, night guard / security fees, depreciation of equipments, bank interest and so on.

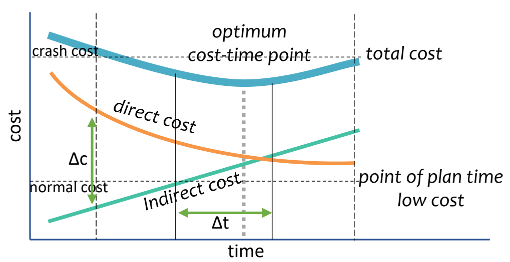

Figure 1. Graph of the Time and Cost Relationship

The method used is to review the slope of each line segment which can provide identification of the effect of costs on reducing project completion time (Nurjaman, K et al, 2014).

2.2. Preparation of Network Planning with the Precedence Diagram (PDM) Method

Precedence Diagram Method (PDM) is a network that is also known as an Activity on Node (AON) because the location of its activity is in the node section. The project schedule obtained is in the form of a block diagram, so that to make it a Network Diagram several steps must be taken to compile it, among others (Nurjaman, K et al, 2014):

- Identify the project scope and break it down into activity components.
- Arrange the components of activity according to the logical sequence of dependencies into a network.
- Provide an estimate of the time span for each job.
- Identification of critical paths, floats, and project completion timelines.
- Increase the efficiency and results in the use of resources.

Figure 2. Node symbol of activity in PDM

2.3. *Crashing the Duration*

There are ways to accelerate the duration of activities in the project, namely (Husen, 2014):

a. Organizing work shifts.
b. Increase working hours or overtime.
c. Use tools more productively.
d. Increase the number of workers.
e. Using faster materials.
f. Using a faster construction method.

2.4. The crashing method procedure is as arranged follows (Soeharto, 1999):

- Make a network planning a series of activities
- Calculate the duration of project completion and identification of PDM
- Determine the normal cost of each activity
- Determine the accelerating cost of each activity
- Determine the cost slope of each activity with the formula:

$$cost\ slope = \frac{crash\ cost - normal\ cost}{normal\ duration - crash\ duration} \quad (1)$$

- Shorten the duration of activities starting from the critical activity path with the lowest cost slope
- If a new critical path is formed during the acceleration process, it will accelerate the critical activities that have the lowest slope combination.
- Continue to reduce activity time until the point of PPC (Point of Project Crashing) or until there is no more critical path.
- Calculate and total direct and indirect costs to find total costs before reducing time.
- Comparing normal costs and acceleration costs with a percentage.

2.5. *Worker Productivity*

Productivity is defined as the ratio between output and input, or it can be said as the ratio between production output and total resources used. In a construction project, the ratio of productivity is the value measured during the construction process; which can be separated into manpower costs, material costs, methods, and tools. The success of a construction project depends on the effectiveness of resource management, and workers are one resource that is not easy to manage. The wages given really depend on the skills of each worker because each worker has their own character that is different from one another.

2.6. Implementation of Additional Working Hours (Overtime)

One strategy to speed up the project completion time is to increase the work hours (overtime) of the workers. The addition of working hours (overtime) is very often done because it can empower existing resources in the field and simply by streamlining the additional costs incurred by the contractor. The normal working time for workers on this project is 8 hours (starting at 08.00 and ending at 17.00 with one hour of rest), then overtime hours are carried out after normal working hours are finished.

Additional working hours (overtime) can be done by adding 1 hour, 2 hours, 3 hours, and 4 hours according to the desired addition time. The greater the addition of overtime hours can cause a decrease in productivity, an indication of the decrease in worker productivity towards the additional working hours (overtime) can be seen in Figure 3. This study uses the assumption of 1 hour of overtime per day.

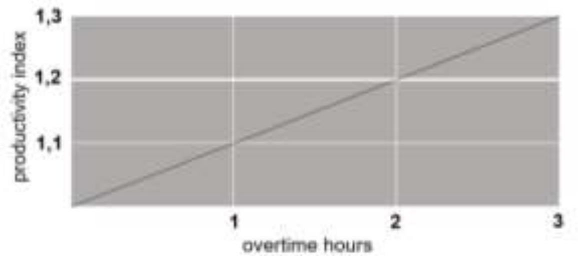

Figure 3. Graph of Decreased Productivity Indication

From the description above, it can be written as follows:

- Daily productivity

$$= \frac{volume}{normal\ duration} \tag{2}$$

- Hourly productivity

$$= \frac{daily\ productivity}{hours\ of\ work\ a\ day} \tag{3}$$

- Daily productivity after a crash

= (Hours of work per day × Hourly productivity) + (a × b × Hourly productivity) (4)

With:

a = duration of additional working hours (overtime)

b = productivity reduction coefficient due to additional working hours (overtime)

- *Crash duration*

$$= \frac{volume}{daily\ productivity\ after\ crash} \tag{5}$$

2.7 Additional Worker Costs (Crash Cost)

The additional working time will increase the cost for manpower from the normal cost of manpower. Based on the Decree of the Minister of Manpower and Transmigration of the Republic of Indonesia Number KEP. 102 / MEN / VI / 2004 that wages for additional work vary. In the addition of the first hour of work, the worker gets an additional wage of 1.5 times the normal hourly wage and in the next additional working hour, the worker will get 2 times the normal hourly wage.

The calculation for additional manpower costs can be formulated as follows:

- Normal manpower costs per day = Daily productivity × Unit price for workers' wages (6)
- Normal hourly manpower costs
  = Hourly productivity × Unit price for workers wages (7)
- Overtime costs for workers
  = 1,5 × the normal hour's wages for the first additional (overtime) hours worked + 2 × n × the normal hour's wages for the next additional hour of work (overtime) (8)

With :

n = the number of additional hours worked (overtime)

- Crash costs of workers per day= (Hours of work per day × Normal manpower cost) + (n × Hourly overtime cost) (9)

2.8. Additional Manpower

The increase in the number of workers will affect the efficiency of the project if it is planned realistically and takes into account several factors, namely the capacity of the job location, the ease and flexibility to do work, supervision of the manpower, and job security. The productivity of additional manpower can be calculated by the following formula:

Crashing productivity = (Normal daily productivity x Number of accelerated workers) / (Number of normal workers) (10)

This study uses the assumption of an additional manpower of 25% of the normal manpower considering the area of the project being undertaken.

2.9. Research methods

The data needed in this study are secondary data. In this study, the secondary data required is in the form of project documents, namely the S curve, details of the cost budget, work volume, list of wages, and the number of workers. After the required data is collected, the crashing process is then carried out. The acceleration process in this study is carried out by emphasizing the duration of activities on the critical path with additional treatment, namely the addition of working hours and additional manpower. After knowing the activities that are on the critical trajectory, then calculating the cost slope. Crashing is performed on activities with the lowest cost slope. The crashing process is repeated several times until it reaches saturation point.

3. RESULT AND DISCUSSION.

3.1. General Project Data

Project name : The Indonesian Navy Jetty Construction in Saumlaki (Phase I).

Project owner : Indonesian Navy

Contractor : X (Ltd)

Budget : IDR.79,367,378,000.00 (including 10% tax)

Time of execution : 240 working days

Start date of work : 17 January 2019

Delay : 18 working days

3.2. Critical Path

Based on data processing with the Ms Project 2016 application, the following critical path are obtained:

Table 1. Critical Path

No	Task Name	Normal Duration	ID	Predecessor
1	Steel Pile Ø 70 cm t 16 mm	42	5.1	1.6SS+53 days
2	Erection fee	42	5.2	5.2SS+33%
3	Pile peel & cut off	42	5.5	5.2SS
4	Pile filling concrete	105	5.6	55SS+50%
5	Single pile cap concrete	119	5.9	51;56ss+7%
6	Longitudinal beam 40/70, K-350	119	5.10	51SS;59
7	Transverse beam 40/70, K-350.	119	5.11	5.10
8	Platform concrete K-350	119	5.12	5.11SS+10%
9	Drainage pipe dia 3"	119	5.13	5.12
10	Cansteen + Ducting concrete	119	5.14	5.13+6%
11	Solar cell lighting lamp	14	5.17	5.14FF

The data above are activities that will be accelerated. Some reasons for selecting activity items in these critical activities are:

a. The selected critical activity has a resousce work or has workers so that it can be crashed.

b. In selected critical activities, acceleration can be done by adding overtime hours or by increasing the number of workers. If an additional manpower is carried out in other critical activities, the number of workers will not increase because these critical activities only have a small manpower index.

3.3. Calculation of Crash Duration and Crash Cost With The Overtime Method

Table 2. Overtime crashing calculations at First Itteration

No.	ID	Task Name	Normal Duration (Dn) (days)	Normal Cost (Cn) (IDR)	Crash Duration (Dc) (days)	Crash Cost (Cc) (IDR)	Cost Slope (Cc-Cn)/(Dn-Dc) (IDR)
1	5.1	Steel Pile Ø 70 cm t 16 mm	42	26.460.000	38	28.428.750	492.188
2	5.2	Erection fee	42	743.820.000	38	799.163.750	13.835.938
3	5.5	Pile peel & cut off	42	70.560.000	38	75.810.000	1.312.500
4	5.6	Pile filing concrete	105	132.300.000	94	140.647.500	758.864
5	5.9	Single pile cap concrete	119	257.040.000	107	274.455.000	1.451.250
6	5.10	Longitudinal beam 40/70, K-350	119	276.080.000	107	294.785.000	1.558.750
7	5.11	Transverse beam 40/70, K-350	119	188.020.000	107	200.758.750	1.061.563
8	5.12	Platform concrete K-350	119	345.100.000	107	368.481.250	1.948.438
9	5.13	Drainage pipe dia 3"	119	80.920.000	107	86.402.500	456.875
10	5.14	Cansteen + Ducting concrete	119	133.280.000	107	142.310.000	752.500
11	5.17	Solar cell lighting lamp	14	7.140.000	13	7.873.125	733.125
		Total		**2.260.720.000**		**2.419.115.625**	

In the first iteration, the results obtained from the acceleration of time to 227 days at a direct cost of IDR. 2,419,115,625.00. The calculation is continued with the second iteration of the new critical path because it has not reached PPC (Point of Project Crashing).

Table 3. Overtime crashing calculations at Second Itteration

ID	Task Name	Normal Duration (Dn) (days)	Normal Cost (Cn) (IDR)	Crash Duration (Dc) (days)	Crash Cost (Cc) (IDR)	Cost Slope (Cc-Cn)/(Dn-Dc) (IDR)
4.1	Rubble stone masonry	63	666.540.000	57	716.133.750	8.265.625
4.2	Armour stone stone masonry	63	1.111.320.000	57	1.194.007.500	13.781.250
4.3	Geotextile non woven	42	211.680.000	38	227.430.000	3.937.500
4.4	Land Fill CBR 30%	91	758.030.000	82	811.133.750	5.900.417
4.5	Lean concrete K-175 on cansteen	7	30.100.000	6	30.637.500	537.500
4.8	Ducting concrete	28	113.120.000	25	119.937.500	2.272.500
4.11	Rigid pavement-concrete K350	35	1.113.000.000	13	1.170.637.500	2.619.886
	Total		**4.003.790.000**		**4.269.917.500**	

The second iteration is carried out on activities 4.5, 4.8 and 4.11. The result of this iteration is that the time acceleration becomes 222 (has reached the Point of Project Crashing) with a direct cost of IDR. 4,269,917,500.00.

3.4. Calculation of Crash Duration and Crash Cost With The Method of Additional Manpower

In the first iteration, the results obtained from the acceleration of time to 233 with a direct cost of IDR. 2,486,400,000.00 according to table 4.

Table 4. Additional manpower crashing calculations at First Itteration

No.	ID	Task Name	Normal Duration (Dn) (days)	Normal Cost (Cn) (Rp)	Crash Duration (Dc) (days)	Crash Cost (Cc) (Rp)	Cost Slope (Cc-Cn)/(Dn-Dc)
1	5.1	Steel Pile Ø 70 cm t 16 mm	42	26.460.000	34	31.220.000	595.000
2	5.2	Erection fee	42	743.820.000	34	898.520.000	19.337.500
3	5.5	Pile peel & cut off	42	70.560.000	34	80.080.000	1.190.000
4	5.6	Pile filling concrete	105	132.300.000	93	145.320.000	1.085.000
5	5.9	Single pile cap concrete	119	257.040.000	105	286.440.000	2.100.000
6	5.10	Longitudinal beam 40/70, K-350	119	276.080.000	105	305.480.000	2.100.000
7	5.11	Transverse beam 40/70, K-350.	119	188.020.000	108	203.140.000	1.374.545
8	5.12	Platform concrete K-350	119	345.100.000	103	388.360.000	2.703.750
9	5.14	Cansteen + Ducting concrete	119	133.280.000	104	147.840.000	970.667
		Total		**2.172.660.000**		**2.486.400.000**	

Then the second iteration is continued to the new critical path because it has not reached the Point of Project Crashing with the results according to table 5.

Table 5. Additional manpower crashing calculations at Second Itteration

No.	ID	Task Name	Normal Duration (Dn) (days)	Normal Cost (Cn) (IDR)	Crash Duration (Dc) (days)	Crash Cost (Cc) (IDR)	Cost Slope (Cc-Cn)/(Dn-Dc)
1	4.5	Lean concrete K-175 on cansteen	7,00	30.100.000	6	36.220.000	6.120.000
2	4.8	Ducting concrete	28,00	113.120.000	23	136.580.000	4.692.000
3	4.11	Rigid pavement-concrete K350	35	1.113.000.000	28	1.344.280.000	33.040.000
		Total		1.256.220.000		1.517.080.000	

The second iteration is carried out on activities 4.5, 4.8 and 4.11. The result of this iteration is the time acceleration to 221 (has reached the Point of Project Crashing) with the required cost of IDR. 1,517,080,000.00.

3.5. Indirect Project Costs

Costs in a project consist of direct costs and indirect costs. Direct costs are costs for everything that will become a permanent component of the final project outcome. Determination of indirect costs based on the results of the project data obtained by the percentage for indirect costs of 2% of the total project value in detail, the calculation is as shown below:

Indirect Cost = 2% x IDR. 72,152,162,704.00 = IDR.1,443,043,254.00

Indirect Cost / day = Indirect Cost / Normal Project Duration = IDR. 1,443,043,254.00 / 240 days

= IDR. 6,012,680.00 / day

3.6. Project Cost and Time Analysis

Based on the analysis and calculation of the project time and costs, the results are in the following table 6. The results of the cost and time calculations can be displayed in a cost and time relationship graph as follows figure 4 :

Table 6. Time and cost analysis

	Normal	Real	Over time	Addition of Manpower
Duration (days)	240	258	222	221
Crast Duration (days)			18	19
Direct Cost (IDR)	64.936.946.434	64.936.946.434	65.361.469.559	65.511.546.434
Indirect Cost (IDR)	1.443.043.254	1.551.271.498	1.334.815.010	1.328.802.330
Indirect Cost/day (IDR)	6.012.680	6.012.680	6.012.680	6.012.680
Total Cost	66.379.989.688	66.488.217.932	66.696.284.569	66.840.348.763
Penalty (1/1000 per day)		1.428.612.804		
	66.379.989.688	67.916.830.736	66.696.284.569	66.840.348.763

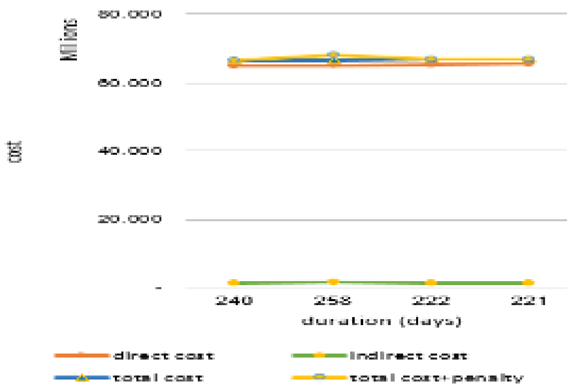

Figure 4. Graph of time and cost comparation

Furthermore, from the analysis results obtained the calculation of each project duration according to table 7.

Table 7. Recapitulation of Duration Project Analysis.

Project	Duration (days)				
	Plan	Real	Crash	Δ(days)	
Realization	240	258		-18	Delay
Overtime	240	240	222	0	Not Delay
Additional Manpower	240	239	221	1	Not Delay

4. CONCLUSIONS.

The real duration of project implementation is 258 days from the planned 240 days at a cost of IDR.66,379,989,688.00 from the planned cost of IDR.66,379,989,688.00. After crashing with the overtime alternative, the project duration is 240 days at a cost of IDR. 66,696,284,569.00 (efficiency 1.8%). In the alternative of adding manpower, the duration after crashing is 239 days at a cost of IDR.66,840,348,763.00 (efficiency 1.61%). So that in this study it was found that the alternative of working overtime was more efficient than the alternative of additional manpower.

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