Application of Time Cost Trade Off Method in Optimizing Time and Cost on Ship Refurbishment Projects KMP Dharma Rucitra 1 and MT Triaksa 17

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***Abstract*— Delays that occur in the KMP Dharma Rucitra 1 ship refurbishment project have an impact on the MT Trikasa 17 ship refurbishment project, so that the project work must be accelerated in order not to exceed the contract. This study aims to overcome the delays that occur by finding the most optimal time acceleration value and the minimum cost. The time cost trade off method is often used in scheduling the repair of two or more ship units simultaneously to optimize project time and cost, so this method is considered to be able to overcome the problems that occur. Based on the repair list and main schedule data, the critical trajectory and productivity values of each job were obtained. The work on the critical trajectory was treated with variations of additional working hours (overtime) and variations of additional workers. The analysis shows that the addition of working hours (overtime) provides effective results, namely the addition of 1 working hour (overtime) with a reduction in time by 12.5% and a cost of Rp. 253,236,000 (4.35% increase). While the addition of labor provides effective results, namely the addition of 4 workers with a 25% reduction in time and costs of Rp. 245,140,000 (0.78% increase). Based on the two effective results, the most efficient result to overcome the delays that occur is the addition of 4 workers.**

Keywords— critical trajectory, improvement list, time cost trade-off

I. Introduction

A project generally has a predetermined processing time and budgeted project costs, in other words, the project must be completed exactly according to the predetermined time or faster, and the costs incurred are in accordance with what has been budgeted or more economical [1].

Looking at ship refurbishment projects, in the planning process there is scheduling that is useful to ensure that the project runs smoothly in accordance with the predetermined time and cost [2]. The scheduling is created as a guideline for project implementation and serves as a basis for monitoring the project's progress [3]. Scheduling becomes a crucial aspect of a project as it organizes the timeline and sequence of various phases, while also managing the interconnections between tasks. This ensures that the project proceeds in accordance with the agreed contract, or even completes ahead of schedule, potentially reducing the costs incurred [4].

However, in realization, there are often delays caused by several factors, such as unfavorable weather, errors in material specifications, delays in the material delivery process, design changes and others [5].

Time and cost management is needed in solving the problem of project delays to prevent losses that will occur. One of the ways that can be used in solving delay problems is the time cost trade off method. The time-cost trade-off is a planned, systematic, and analytical process conducted by examining tasks within a project. Its purpose is to find a balance between time and cost, allowing the project to be completed efficiently without exceeding the time limit or budget [6]. This method involves analyzing the work on the critical trajectory as well as alternatives such as adding working hours (overtime), adding labor, to changing or adding equipment to speed up the project time [7].

Looking at previous research in the field of shipping carried out on the construction project of the 7900 DWT Tank Transport Ship. The project experienced a delay of 22 days and applied the time cost trade off method to accelerate project time. The findings and discussion demonstrate that the project can be enhanced by implementing an alternative that adds 4 hours of work (overtime), leading to a reduction of 22 days in duration and an increase in costs amounting to Rp. 37,498,629 [8].

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An examination of other research pertaining to the refurbishment project of the KT Tirtayasa II ship, which encountered a delay of 15 days, reveals that the project employed the time-cost trade-off method to expedite its timeline. The findings and discussion indicate that the alternative of adding 3 hours of overtime is deemed the most optimal approach, resulting in a 15-day reduction in project duration while incurring a cost increase of 0.53% compared to normal expenses [9].

Previous research was also conducted on the Mooring Boat construction project. The application of the time cost trade off method with the alternative of adding 4 hours of work (overtime) is considered optimal to overcome the delay that occurred for 5 days. The results and discussion show that the project has decreased time by 5 days with an increase in costs of Rp. 3,600,000 [10].

Research in the civil engineering domain has yielded findings that align with those in the shipping sector. One such study focused on the construction project of the Convention Hall Building in Deli Serdang Regency, which faced significant delays. The application of the time cost trade off method with the addition of labor results in an acceleration of time for 14 days with an additional cost of Rp. 35,900,381 [11].

Another study was conducted on an ammunition warehouse construction project, where the time cost trade off method provided an acceleration of project time by 34.69% and cost optimization by 4.24% [12].

Based on several previous studies, the use of the time cost trade off method in overcoming the problem of delay is considered optimal. The research in this final project was conducted on the KMP Dharma Rucitra 1 and MT Triaksa 17 ship refurbishment projects, where the KMP Dharma Rucitra 1 ship refurbishment process experienced delays. To address the delays experienced in both projects, this research employs the time-cost trade-off method in conjunction with alternative variations, including additional working hours (overtime) and increased labor. The aim of this study is to determine the optimal time acceleration that incurs the least cost for the two projects in question. While prior research has utilized the time cost trade off method in ship repair and construction projects, this study investigates the simultaneous optimization of two ship refurbishment projects, emphasizing both the extension of working hours and variations in labor to yield a more efficient solution.

II. Methods

A. Object of the Research

The object of the research was the ship refurbishment projects of KMP Dharma Rucitra 1 and MT Triaksa 17 involving ship data obtained from PT Janata Marina Indah Shipyard 2, Semarang City. Principal dimensions of KMP Dharma Rucitra 1 and MT Triaksa 17 can be seen in table 1.

TABLE 1.
PRINCIPAL DIMENSION OF MT DHARMA RUCITRA 1 AND MT TRIAKSA 17

Dimension	KMP Dharma Rucitra 1	MT Triaksa 17
LOA	134.60 meters	90 meters
LPP	125 meters	84 meters
BM	21 meters	15.20 meters
T	5.70 meters	5 meters
GRT	11,479 tons	2,908 tons
DWT	3,334 tons	3,575 tons

B. Data Collection

Repair list and main schedule as secondary data were obtained from PT Janata Marina Indah Shipyard 2, Semarang City. This research is also complemented by supporting data obtained from books, journals, and previous research.

C. Research Stages

The purpose of scheduling in the process of planning a ship project is to obtain a rational schedule at a logical cost. However, when delays occur, a solution is needed to accelerate the project time so that losses can be minimized. The time cost trade off method is considered to be one way to accelerate project time. This method compresses the time of work on the critical trajectory by using alternatives. The following are the stages of data processing:

1. Merging the main schedule of KMP Dharma Rucitra 1 and MT Triaksa 17 in Microsoft Project.
2. Identifying predecessors and successors for each job.
3. Identifying the tasks that lie on the critical path for subsequent analysis using the time-cost trade-off method.
4. Calculation of daily productivity and productivity per hour for tasks located on the critical path.

$$PHN = \frac{\text{Workload}}{\text{Duration}} \quad (1)$$

$$PPJ = \frac{PHN}{JKN} \quad (2)$$

PHN = Normal daily productivity
PPJ = Productivity per hour
JKN = Normal working hours

5. Calculating the cost of normal project work.

$$NC = UPH \; x \; TKN \; x \; ND \quad (3)$$

NC = *Normal cost*
UPH = Worker's wage per day
TKN = normal workforce
ND = *Normal duration*

6. Performing acceleration calculations with alternative variations can be seen in table 2 as follows.

TABLE 2.
WORK SCHEME

Work Scheme	Overtime Hour	Workforce
A1	1 hour	-
A2	2 hours	-
A3	3 hours	-
A4	4 hours	-
B1	-	1 Person
B2	-	2 People
B3	-	3 People
B4	-	4 People

7. Calculating the productivity of additional working hours (overtime) or additional manpower.

$$PPJL = PHN + (PPJ\ x\ PK\ x\ WL) \tag{4}$$

$$PPTK = PHN + (PHN\ x\ PTK) : TKN \tag{5}$$

PPJL = Productivity of additional overtime hours
PK = Decreased percentage of work
WL = Overtime Duration
PPTK = Productivity of additional labor
PTK = Number of additional workers

8. Calculating the acceleration of processing time for alternatives of additional working hours (overtime) or additional labor.

$$CD = \frac{VP}{PPJL} \tag{6}$$

CD = crash duration
VP = Work Volume

9. Calculation of crash costs related to increased labor hours (overtime) and costs incurred from employing additional workforce.

$$CCH = UPH + BLH \tag{7}$$

$$CCJL = CCH\ x\ CD\ x\ TKN \tag{8}$$

$$CCTK = UPH\ x\ WP\ x\ TTK \tag{9}$$

CCH = daily crash cost
BLH = daily overtime cost
CCJL = additional working hours (overtime) crash cost
CCTK = additional labor crash cost
TTK = Total workforce after the addition

10. Calculating the cost slope for additional working hours (overtime) or additional labor.

$$CS = \frac{CC - NC}{ND - CD} \tag{10}$$

CS = Cost slope

11. Calculation of daily overtime costs according to the Regulation of the Minister of Manpower and Transmigration of the Republic of Indonesia number KEP. 102/MEN/VI/2004 article 11 [13].
12. Performing analysis by comparing the time acceleration and cost changes of each scheme.

III. RESULTS AND DISCUSSION

A. Main Schedule Merge

The time cost trade off method emphasizes the compression of time associated with tasks on the critical path. The identification of activities on the critical path begins with the integration of the primary schedules for the KMP Dharma Rucitra 1 and MT Triaksa 17 projects, facilitated by Microsoft Project software. This process is subsequently followed by the identification of predecessor and successor tasks.

B. Critical Trajectory

A critical trajectory is a trajectory that contains work that must be completed on time, or in other words, the work cannot be delayed, because it will affect the project as a whole [1]. The critical path is derived from the Critical Path Method (CPM), which utilizes a work network with a linear balance between time and cost. This technique involves constructing a work network that identifies the sequence of tasks and applies simple time estimates for each task [14]. A study [15] was conducted focusing on the evaluation and review of project performance using the Program Evaluation Review Technique (PERT) and CPM, applied within a construction company. The study details various activities involved in the construction project, including identifying the starting, finishing, and completion of tasks through forward and backward calculations in CPM. The critical path is then determined using both CPM and PERT methods. The work on the critical trajectory in this study can be seen in table 3.

TABLE 3.
CRITICAL WORK ON THE SCHEDULE OF KMP DHARMA RUCITRA 1 AND MT TRIAKSA 17

Code	Tasks	Volume	Duration	Workforce
B1	Scrap	200 m^2	1 day	2 people
B2	Fresh Water Cleaning	3,193 m^2	1 day	6 people
B3	Sand Blasting	807 m^2	2 days	5 people
B4	Hull Painting	1,877 m^2	4 days	10 people
B6	Draft and Plimsoll Mark Painting	1 set	2 days	2 people
B12	Anchor and Anchor Chain	2 unit	8 days	4 people
B7	Sea Chest and Valve	65 pieces	8 days	6 people
B11	Piping	2,256 kg	8 days	5 people
B9	UT	1 ls	2 days	2 people
B10	Replating	58,018 kg	7 days	37 people
B13	Tank Cleaning	682.5 m^3	8 days	7 people
G1	Scrap	1,320 m^2	1 day	5 people
G2	Fresh Water Cleaning	2,082 m^2	1 day	10 people
G3	Sand Blasting	2,082 m^2	2 days	5 people
G4	Hull Painting	6,246 m^2	3 days	17 people
G6	Draft and Plimsoll Mark Painting	1 ls	2 days	2 people
G7	Sea Chest and Valve	15 pieces	6 days	2 people
G9	UT	1 ls	2 days	2 people
G10	Replating	2,000 kg	5 days	4 people
G11	Piping	98.51 kg	5 days	2 people
G12	Anchor and Anchor Chain	2 units	6 days	5 people
G13	Tank Cleaning	682 m^3	6 days	10 people
H1	Propeller shaft removed and replaced	1 unit	4 days	8 people
H3	Stern Tube Rubber Seal removed	1 unit	3 days	2 people
H4	Propeller Cleaning	1 unit	6 days	5 people

C. Calculation Analysis

The time cost trade off analysis begins with the calculation of daily productivity and hourly productivity which is carried out to determine the level of work efficiency achieved in one day and per hour under normal conditions without acceleration. In an effort to accelerate the project, additional working hours (overtime) are often used as an alternative. It is because the contractor can utilize the existing workforce and skills that do not need to be doubted. However, the addition of working hours (overtime) can result in a decrease in the quality of workers, one of which is caused by fatigue. Every additional working hour (overtime), labor will experience a decrease in productivity of 0.1 [16]. It is inversely related to the option of increasing labor, which has a higher productivity rate compared to extending working hours (overtime). provided that the workspace is adequate in accordance with the addition of labor. From the resulting accelerated productivity figures, the crash duration, which is the duration of work after being treated with alternatives, can be known. The results of productivity calculations to crash duration can be seen in Table 4.

The approach taken for tasks on the critical path will affect the changes in associated costs. This adjustment in costs is referred to as crash cost. According to the Decree of the Minister of Manpower and Transmigration of the Republic of Indonesia, number KEP. 102/MEN/VI/2004, Article 11, wages for the first hour of overtime are set at 1.5 times the normal hourly wage, while the subsequent two hours and any additional hours are compensated at twice the normal hourly rate. The results of the overtime calculations are presented in Table 5.

The rise in costs and the decrease in construction time will be analyzed against the standard costs and durations of each task. This analysis is commonly referred to as the cost slope. Prior to calculating the cost slope, it is essential to determine the normal cost for each task. Given that this study emphasizes labor costs, the normal cost can be derived by multiplying the daily wages of workers by the total number of standard workers and the normal duration of the tasks. The findings from this cost calculation are presented in Table 6.

TABLE 4.
ANALYSIS OF CALCULATIONS FOR ALTERNATIVE OF 4 ADDITIONAL WORKERS

Code	Daily Productivity	Productivity per hour	Productivity Acceleration	Crash Duration
B1	200	25	600	1 day
B2	3,193	399,12	5,321	1 day
B3	403.28	50.41	725.9	1 day
B4	469.40	58.67	657.16	3 days
B6	0.50	0.06	1.5	1 day
B12	0.25	0.03	0.5	4 days
B7	8.13	1.01	13.54	5 days
B11	282	35.25	507.6	5 days
B9	0.5	0.06	1.5	1 day
B10	8,288	1,036	9,184	6 days
B13	85.31	10.66	134.06	5 days
G1	1,320	165	2,376	1 day
G2	2,082	260,25	2,914	1 day
G3	1,041	130.12	1,873	1 day

Code	Daily Productivity	Productivity per hour	Productivity Acceleration	Crash Duration
G4	2,082	260.25	2,571	2 days
G6	0.5	0.06	1.5	1 day
G7	2.5	0.31	7.5	2 days
G9	0.5	0.06	1.5	1 day
G10	400	50	800	3 days
G11	19.7	2.46	59.1	2 days
G12	0.33	0.04	0.6	3 days
G13	113.67	14.2	159.13	4 days
H1	0.25	0.03	0.37	3 days
H3	0.33	0.04	1	1 day
H4	0.17	0.02	0.3	3 days

TABLE 5.
ANALYSIS OF OVERTIME COST CALCULATION

	Rp. 5,000,000/month = Rp. 238,000/day	Daily Crash Cost
1 hour	1.5 x overtime hour x 1/173 x salary/month = Rp. 43,000	Rp. 281,000
2 hours	2 x overtime hour x 1/173 x salary/month = Rp. 116,000	Rp. 354,000
3 hours	2 x overtime hour x 1/173 x salary/month = Rp. 173,000	Rp. 411,000
4 hours	2 x overtime hour x 1/173 x salary/month = Rp. 231,000	Rp. 469,000

TABLE 6.
ANALYSIS OF COST CALCULATIONS FOR ALTERNATIVE OF 4 ADDITIONAL WORKERS

Code	Normal Cost	Crash Cost	Cost Slope
B1	Rp. 476,000	Rp. 1,428,000	-
B2	Rp. 1,428,000	Rp. 2,380,000	-
B3	Rp. 2,380,000	Rp. 2,142,000	(-) Rp. 238,000
B4	Rp. 9,520,000	Rp. 9,996,000	Rp. 476,000
B6	Rp. 952,000	Rp. 1,428,000	Rp. 476,000
B12	Rp. 7,616,000	Rp. 7,616,000	-
B7	Rp. 11,424,000	Rp. 11,900,000	Rp. 158,667
B11	Rp. 9,520,000	Rp. 10,710,000	Rp. 396,000
B9	Rp. 952,000	Rp. 1,428,000	Rp. 476,000
B10	Rp. 61,642,000	Rp. 58,548,000	(-) Rp. 3,094,000
B13	Rp. 13,328,000	Rp. 13,090,000	(-) Rp. 79,333
G1	Rp. 1,190,000	Rp. 2,142,000	-
G2	Rp. 2,380,000	Rp. 3,332,000	-
G3	Rp. 2,380,000	Rp. 2,142,000	(-) Rp. 283,000
G4	Rp. 12,138,000	Rp. 9,996,000	(-) Rp. 2,142,000
G6	Rp. 952,000	Rp. 1,428,000	Rp. 476,000
G7	Rp. 2,856,000	Rp. 2,856,000	-
G9	Rp. 952,000	Rp. 1,428,000	Rp. 476,000
G10	Rp. 4,760,000	Rp. 5,712,000	Rp. 476,000
G11	Rp. 2,380,000	Rp. 2,856,000	Rp. 158,667
G12	Rp. 7,140,000	Rp. 6,426,000	(-) Rp. 238,000
G13	Rp. 14,280,000	Rp. 13,328,000	(-) Rp. 476,000
H1	Rp. 7,616,000	Rp. 8,568,000	Rp. 952,000
H3	Rp. 1,428,000	Rp. 1,428,000	-
H4	Rp. 7,140,000	Rp. 6,426,000	(-) Rp. 238,000

D. Time Cost Trade Off Analysis

The analysis results for the refurbishment projects of the KMP Dharma Rucitra 1 and MT Triaksa 17, utilizing the time-cost trade-off method with alternative variations of additional working hours (overtime) or extra labor, are presented in Table 7. Complemented by time acceleration charts and additional costs contained in figures 1 and 2, with the following elaboration :

Under normal circumstances, the project is completed in 16 days with a total cost of Rp. 243,236,000. By implementing the alternative of adding 1 hour of overtime, the project duration is reduced by 12.5%, resulting in an increased cost of Rp. 254,230,000, which represents a 4.52% rise. When 2 hours of overtime are added, there is a similar 12.5% reduction in project time, but costs increase to Rp. 297,126,000, reflecting a 22.16% increase. Adding 3 hours of overtime leads to an 18.75% reduction in project duration, with total costs rising to Rp. 319,035,000, marking a 31.16% increase. Finally, the option of adding 4 hours of work results in the same 18.75% reduction in time, but costs increase to Rp. 338,744,000, amounting to a 39.27% increase.

The results of the analysis with the addition of labor found that the alternative of adding 1 labor resulted in a time reduction of 12.5% at a cost of Rp. 247,282,000 or an increase of 1.66%. The alternative of adding 2 workers resulted in a time reduction of 12.5% at a cost of Rp. 246,092,000 or an increase of 1.17%. The alternative of adding 3 workers resulted in a time reduction of 18.75% at a cost of Rp. 246,330,000 or an increase of 1.27%. The alternative of adding 4 workers provides a 25% reduction in time at a cost of Rp. 245,140,000 or an increase of 0.78%.

Project costs usually consist of direct costs and indirect costs. In this study, direct costs on the KMP Dharma Rucitra 1 project are estimated at Rp. 3,519,192,978 and indirect costs are estimated at Rp. 305,450,000. While direct costs on the MT Triaksa 17 project are estimated at Rp. 579,584,000 and indirect costs are estimated at Rp. 229,950,000. Direct costs are assigned to everything that will be a permanent component of the final project result, therefore the calculation of costs on labor changes is calculated in the direct costs of the project. The faster the project progresses, the indirect costs will decrease, but there will be an increase in direct costs. Direct costs will become normal costs if carried out efficiently and at normal project time. Indirect costs affect the sustainability of the project but are not directly related to the physical components of the project deliverables, such as overheads, taxes and provision of temporary facilities.

The total project cost is calculated by adding direct costs and indirect costs incurred throughout the project. This cost is heavily impacted by the project's duration and fluctuates with the schedule and progress of the work. The optimal project cost is realized by reducing total project expenditures. The graph depicting this optimum can be found in Figure 3. Project acceleration can also be done with other methods such as fast track. The fast track method is a method of accelerating projects by changing the relationship between jobs and providing overlapping or parallel scenarios to accelerate completion time without additional costs. The fast track method has been applied to the phase 1 of the Vocational Laboratory and Creative Industries building project at Brawijaya University. The project was delayed in the second week of the project. The implementation of the fast-track method demonstrates that the project can achieve a time savings of 14 days, although this comes with additional expenses of Rp. 10,324,470 due to the incorporation of additives to expedite the concrete hardening process [17].

Another study was conducted on the construction project of the Biology Laboratory building at UNESA Ketintang Campus, which encountered delays in the 18th week. This research employed both the fast-track method and the crashing method, where the fast track approach accelerated the project timeline from 213 days to 191 days, resulting in a reduction of indirect costs by 1.55%. However, the reduction in time achieved through the fast track method did not meet the project's target completion date. Consequently, further acceleration was implemented using the crashing method, which involved adding 3 working hours (overtime) to the tasks on the critical path. The crashing method provides an acceleration of time from 191 days to 177 days with an additional cost of 0.11% of the project cost. This schedule has met the project completion target [18].

Based on the aforementioned comparisons, it can be concluded that project acceleration can be achieved through various methods and strategies, either without incurring additional costs or with the inclusion of extra costs. The strategy that incurs no additional expenses can be implemented using the fast track method, as illustrated in this paper [19][20].

TABLE 7.
TIME COST TRADE OFF ANALYSIS RESULTS

Scheme	Duration	Cost	Time Percentage	Cost Percentage
Normal	16 Days	Rp. 243,236,000	100%	100%
A1	14 Days	Rp. 254.230.000	87,50%	104,52%
A2	14 Days	Rp. 297.126.000	87,50%	122,16%
A3	13 Days	Rp. 319.035.000	81,25%	131,16%
A4	13 Days	Rp. 338.744.000	81,25%	139,27%
B1	14 Days	Rp. 247,282.000	87,50%	101,66%
B2	14 Days	Rp. 246.092.000	87,50%	101,17%
B3	13 Days	Rp. 246.330.000	81,25%	101,27%
B4	12 Days	Rp. 245.140.000	75,25%	100,78%

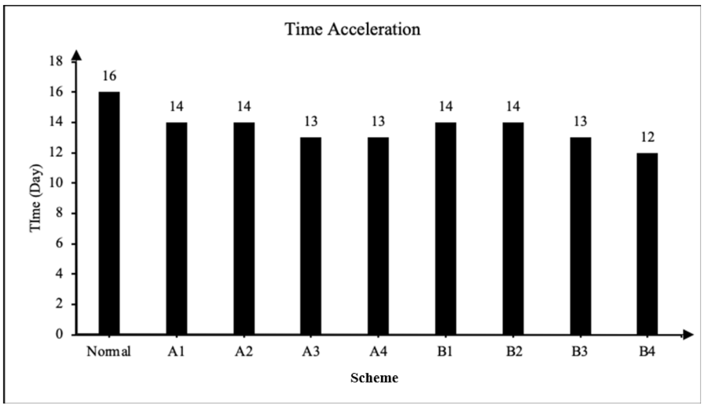

Figure 1. Time Acceleration Graph

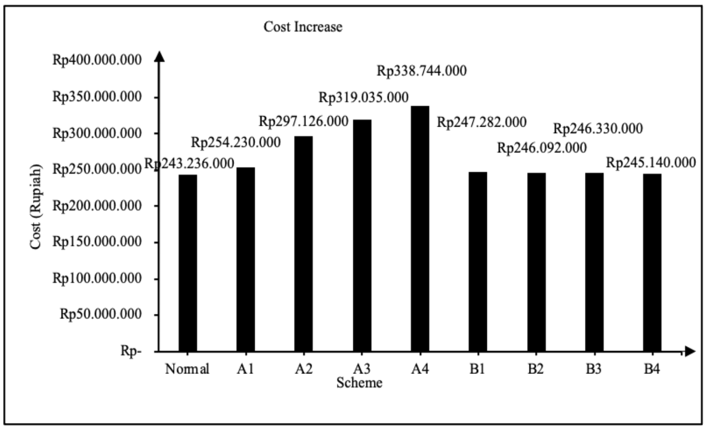

Figure 2. Cost Increase Graph

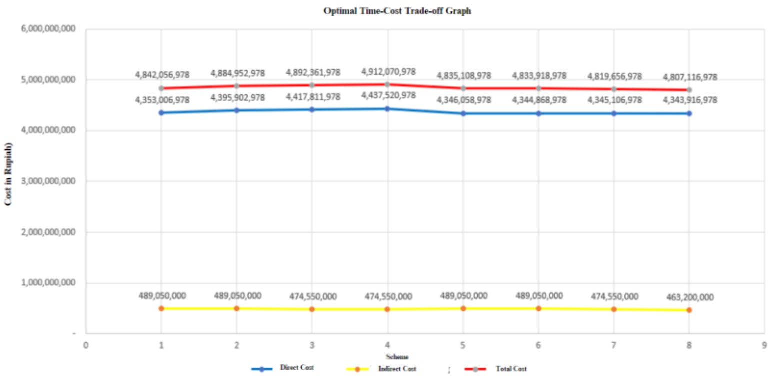

Figure 3. Optimal cost graph

IV. CONCLUSION

A. Conclusion

The analysis in this study focuses on the ship refurbishment project of KMP Dharma Rucitra 1 and MT Triaksa 17 conducted at PT Janata Marina Indah Shipyard 2, Semarang City. Based on the analysis, it is found that the effective result of adding working hours (overtime) is the addition of 1 working hour (overtime) with a reduction in days by 12.5% and a cost of Rp. 254,230,000 (4.52% increase). It is also found that the effective result of additional labor is the addition of 4 workers with a 25% reduction in time and a cost of Rp. 245,140,000 (0.78% increase).

Based on the effective results obtained from the two alternatives, it can be concluded that the most efficient result of the two effective results is the addition of 4 workers. The addition of 4 workers is considered to be able to compress more work, with faster processing time and a small increase in cost. So it can be concluded, the project can more efficiently overcome the problem of delays by adding 4 workers, with a reduction in days by 25% and an increase in cost of 0.78%.

B. Recommendation

In order to improve the results of further research, the authors provide suggestions. It is necessary to analyze the facilities and infrastructure available at the shipyard to support the work under study.

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