HEURISTIC
Vol. 21, No. 2, October 2024
ISSN(p) 1693-8232
ISSN(e) 2723-1585

Optimizing Project Duration and Cost of Support Ship through Time-Cost Trade-Off Analysis and Microsoft Project Application: A Case Study at PT XYZ

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Article history:
Received: 21 December 2024
Accepted: 8 January 2025
Published: 13 January 2025

Keywords:
Microsoft project;
Optimization;
Time cost trade off method

ABSTRACT
The construction of a ship project requires time control to avoid delays because late fines will be imposed. This control can be carried out using project management control tools, namely project scheduling. This research aims to optimize project duration and costs by finding the critical path using the help of Microsoft Project Software and accelerating to avoid project delays using the time cost trade off method. The data collection method was carried out by interviews and direct observation at the project location and obtained through PT XYZ internal parties. The research results showed that there was a delay of 12 days on the Support Ship construction project with 10 critical activities on the production floor. Alternative acceleration is done by adding working hours (overtime) by 2 hours, 3 hours and 4 hours. After calculating the acceleration for critical activities that have the lowest cost slope values, The optimal duration and costs were obtained by adding 3 hours of overtime so that the processing time could be accelerated from 236 days to 228 days with a total acceleration cost of IDR 53,295,000.

INTRODUCTION

Project activities are the process of converting a resource into development results that are in accordance with goals and expectations. All of them must be carried out within a limited time, limited costs but produce good quality [1]. Project scheduling is a way used to manage a project, large-scale projects will succeed if they use careful planning, scheduling and coordination of various interrelated activities [2]. Activities in project scheduling depend on each other in at least two ways. Firstly, they compete for the limited resources required to carry out the activity. Second, prioritisation constraints between pairs of activities require that each pair be performed in a predetermined order [3].

The object of this research is the Support Ship building project at PT XYZ. The owner of Support Ship has made a contract with PT XYZ worth IDR 21 billion to build a ship for 11 months and must be delivered maximum on 31 October 2025. However, in the scheduling it is estimated that the project will be late for 12 days. Because ship building projects are required to pay attention to timeliness, a method is needed to accelerate the project. If in the process of building a ship project there is one work activity that is late, it will affect the delay of the entire project or the main milestone and the delay of other projects due to limited manufacturing facilities. Referring to PERPRES Number 16 of

2018, if there is a delay in work, the shipyard will be subject to a fine of 1‰ (one per mile) of the contract value or the value of the contract portion for each day of delay.

Based on these problems, project scheduling and optimisation of project time and costs will be carried out to anticipate delays in the Support Ship project. Data processing in this study uses the help of Microsoft Project software, a computer programme that can process project planning and implementation data [4]. Microsoft Project is utilized to identify activity relationships and critical paths. Microsoft Project software uses 3 methods or basic concepts [5]. The first is the barchart method so that activities are arranged vertically and the time scale is arranged horizontally [6]. The second Critical Path Method to find out the critical path (critical path) [7]. The third Precedence Diagram Method so that work can be done overlapping [8]. This research also uses the Time cost trade off method which is used to analyse project acceleration so that time and cost can be optimized [9].

This research is motivated by the need for PT XYZ to optimise the construction of the Support Ship project. Therefore, researchers will accelerate the project duration as a way to avoid delays in the delivery of the ship project. In a study with the title "optimisation of the acceleration of the first class shipbuilding project with the time cost trade off analysis approach method" the optimum duration of 25 days was obtained at a cost of IDR 724,654,211.10. In the study, 2 acceleration alternatives were carried out, namely the addition of working hours and the addition of labour [10]. Because at PT XYZ it is not possible to add labour, so this research will only use the alternative of adding working hours for 2-4 hours. With the results of this analysis, it is hoped that it can help PT XYZ in optimising time and costs so that there is no delay in the Support Ship project so that it can be delivered on time and avoid late fees.

MATERIALS AND METHODS

Object of Research

This research object uses the Support Ship construction project at PT XYZ located in Surabaya for 1 month from 1 to 29 November 2024. Support Ship has the following main size:

Table 1. Main Size of Support Ship

Specifications	Size
Weight	74 tonnes
Length	17 meters
Beam	3,5 meters

Table 1 shows the main size of Support Ship which has a length of 17 meters, a beam of 3.5 meters, and a weight of 74 tonnes.

Data Collection

The data used in this research consists of primary data and secondary data. This data will later become input at the data processing stage. The explanation of the data is:

a. Primary Data

Primary data is a data source obtained directly from the field . [11]In this study, researchers obtained primary data through interviews and observations at the PT XYZ project site.

b. Secondary Data

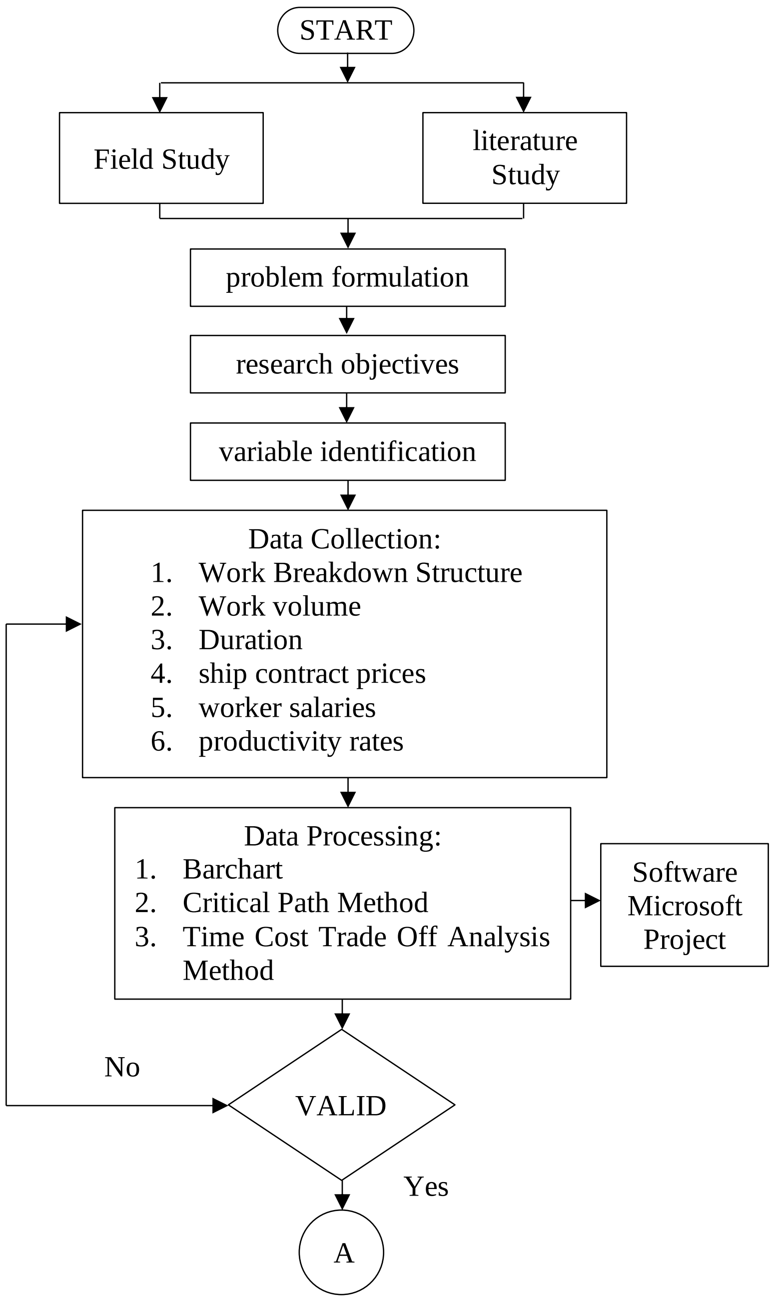
In this study, researchers obtained secondary data in the form of Work Breakdown Structure data, work volume, work duration, ship contract price, worker salary, and worker productivity obtained from PT XYZ.

Data Processing and Analysis

In this study, the data will be processed using Microsoft Project software and analysed using the Time Cost Trade Off method. The stages of data processing are:

1. Determining inter-activity relationships (predecessors) and critical path for Support Ship project using Microsoft Project software.
2. Calculating daily productivity rates along critical paths.
3. Calculate the crash duration on each critical path.
4. Calculate the crash cost based on the crash duration results.
5. Calculate the cost slope on each critical path to find out the smallest difference in time and cost.
6. Analyzing results using Time-Cost Trade-Off method.

Flowchart



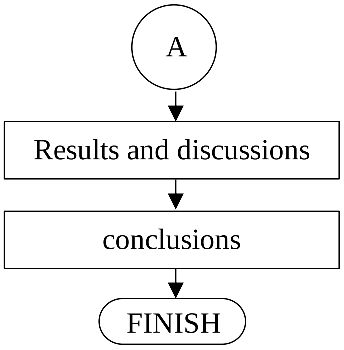


Figure 1. Flowchart

Based on Figure 1, the steps can be seen in the form of a diagram or what is commonly called a flowchart. Flowchart is an illustration of the flow of research stages from start to finish. This research begins with field studies and literature studies followed by formulating problems, looking for research objectives and identifying variables. Furthermore, data collection is carried out in the form of Work Breakdown Structure, work volume, work duration, ship contract price, worker salary, and worker productivity. The data is then processed using Microsoft project software to determine the critical path and using the time cost trade off analysis method. If the results obtained are valid, a discussion and conclusion will be made.

RESULTS AND DISCUSSIONS

Results

Predecessor and Critical Path Determination

Predecessor represents the interdependent connection between activities [12]. Predecessor activity networks enable detailed scheduling [13]. The Critical Path refers to the sequence of activities with the longest duration, where any delay would impact the overall project timeline [14]. Predecessors and critical paths can be determined using Microsoft Project software, which is a software product developed by the Microsoft company [15].

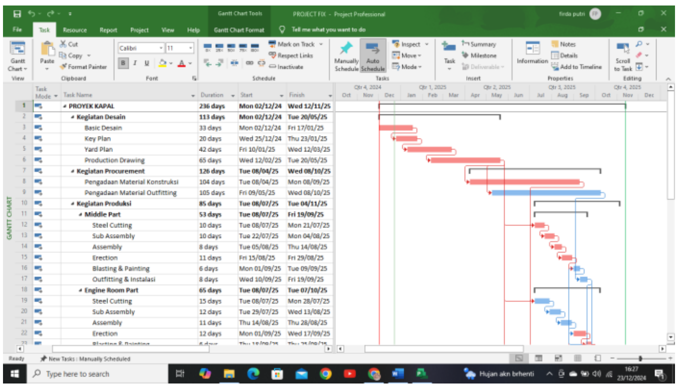


Figure 2. Critical Path Activities using Microsoft Project

Based on Figure 2, it can be seen that the activities that are on the critical path, in this processing it is known that the total project duration is 236 days starting from 02 December 2024 to 12 November 2025. So it can be concluded that the Support Ship building project is 12 days late so that project acceleration is needed.

Table 2. Critical Path Activities on the Production Floor

No.	Activities	Duration
1	**Middle Part**	
	Stell Cutting	10
	Sub Assembly	10
	Assembly	8
	Erection	11
2	**Engine Room Part**	
	Erection	12
	Blasting & Painting	6
3	**After Part**	
	Blasting & Painting	6
4	**Fore Part**	
	Blasting & Painting	6
	Outfiting & Instalasi	8
5	**Accomodation Part**	
	Outfiting & Instalasi	8

In table 2, it is known that there are 10 activities on the production floor that are on the critical path. It should also be noted that only activities on the production floor will be analysed by accelerating the project duration using the time cost trade off method.

Normal Daily productivity calculation

Productivity is the ratio between production output and total resources to obtain a normal daily productivity calculation value. Productivity can be measured based on the average output and input performed by workers each month [16]. The normal daily productivity equation is written as follows:

Normal Daily Productivity = Volume/Duration

Table 3. Normal Daily productivity

Activities	Duration	Volume (Tonnes)	Daily Prod
Middle Part			
Stell Cutting	10	12.92	1.292
Sub Assembly	10	10.64	1.064
Assembly	8	9.88	1.235
Erection	11	9.88	0.898
Engine Room Part			
Erection	12	11.36	0.947
Blasting & Painting	6	0.87	0.145
After Part			
Blasting & Painting	6	0.68	0.113
Fore Part			
Blasting & Painting	6	0.76	0.127

Outfiting & Instalasi	8	4.56	0.570
Activities	**Duration**	**Volume (Tonnes)**	**Daily Prod**
Accomodation Part			
Outfiting & Instalasi	8	0.72	0.090

Table 3 shows the results of normal daily productivity for each activity on the critical path. Normal daily productivity is estimated to determine the optimal productivity results of workers in a day. An example of calculating normal daily productivity in sub-assembly activities is as follows:

Volume of stell cutting activity = 12.92 tonnes
Duration of stell cutting activity = 10 days
Normal daily productivity
= 12.92 tonnes/10 days
= 1.292

Project Acceleration Alternative

Acceleration alternatives are used in order to complete the project so that it is completed faster than the scheduled time. In this study, an acceleration alternative is added in the form of additional working hours (overtime). Normal working time is done for 8 hours while overtime is done after normal working time for 2 hours to 4 hours. However, the addition of overtime hours reduces productivity to 75% of normal hours due to several things such as workers who already feel fatique and the air when it is late. The daily productivity equation after adding working hours (overtime) can be found as follows:

Productivity After Acceleration = Normal Daily Productivity + Daily Productivity per hour x Efficiency x Additional Working Hours (overtime)

Table 4. Productivity After Adding Overtime Hours

Activities	Prod 2 hours	Prod 3 hours	Prod 4 hours
Middle Part			
Stell Cutting	1.534	1.655	1.777
Sub Assembly	1.264	1.363	1.463
Assembly	1.467	1.582	1.698
Erection	1.067	1.151	1.235
Engine Room Part			
Erection	1.124	1.213	1.302
Blasting & Painting	0.172	0.186	0.199
After Part			
Blasting & Painting	0.135	0.145	0.156
Fore Part			
Blasting & Painting	0.150	0.162	0.174
Outfiting & Instalasi	0.677	0.730	0.784
Accomodation Part			

Outfiting & Instalasi	0.107	0.115	0.124

Table 4 shows the results of productivity after adding overtime hours for 2 hours, 3 hours, and 4 hours. An example of productivity calculation after adding overtime hours for 2 hours in stell cutting activities is as follows:

Normal Daily Productivity = 1.292
Daily Productivity per hour = 0.162
Efficiency = 75%
Additional Working Hours (overtime) = 2 hours
Productivity After Acceleration
= 1.292 + 0.162 × 75% × 2 hours
= 1.534

Crash Duration Calculation

Crash duration is the duration of the activity after a crash programme or acceleration of the activity [17]. The Crash Duration equation is written as follows:

Crash Duration = Volume/Productivity After Acceleration

Table 5. Crash Duration Calculation Results

Activities	**Crash Duration (Hour)**		
	2 hours	**3 hours**	**4 hours**
Middle Part			
Stell Cutting	8	8	7
Sub Assembly	8	8	7
Assembly	7	6	6
Erection	9	9	8
Engine Room Part			
Erection	10	9	9
Blasting & Painting	5	5	4
After Part			
Blasting & Painting	5	5	4
Fore Part			
Blasting & Painting	5	5	4
Outfiting & Instalasi	7	6	6
Accomodation Part			
Outfiting & Instalasi	7	6	6

In Table 5, it can be seen that the results of the crash duration calculation obtained the highest difference value in the addition of 4 working hours and the lowest in the addition of 2 working hours. An example of crash duration calculation with the addition of overtime hours for 2 hours in stell cutting activities is as follows:

Volume = 12.92 tonnes
Productivity After Acceleration = 1.534
Crash Duration
= 12.92 tonnes/1,534
= 8.421 = 8 days

Crash Cost Calculation

Crash Cost is the cost incurred due to the addition of working hours equal to the duration of the crash. The cost after crashing will be greater than the normal cost [18]. Referring to Government Regulation No. 35/2021 Article 31 paragraph (1) explains that companies that employ workers/labourers beyond the working time as referred to in Article 2l paragraph (2) are obliged to pay Overtime Salaries with the provisions:

a. First overtime hour at 1.5 times the hourly rate of pay.
b. For each subsequent hour of overtime, 2 times the hourly rate of pay.

In the data collection, it is known that the salaries of workers on the Support Ship construction project at PT XYZ are IDR 85,000 / hour so that the salaries of workers in a day are IDR 680,000. From this data, an overtime salaries of Rp 127,500 is obtained in the first hour and Rp 170,000 in each subsequent overtime hour. The number of workers is obtained from JO for each activity. This data will then be calculated using the Crash Cost equation which is written as follows**:**

Crash Cost = (Normal Salaries + Overtime Salaries) × Workers × Crash Duration

Table 6. Crash Cost Calculation Results

Activities	Crash Cost (IDR)		
	2 hours	**3 hours**	**4 hours**
Middle Part			
Stell Cutting	31,280,000	36,720,000	36,890,000
Sub Assembly	31,280,000	36,720,000	36,890,000
Assembly	27,370,000	27,540,000	31,620,000
Erection	35,190,000	41,310,000	42,160,000
Engine Room Part			
Erection	39,100,000	41,310,000	47,430,000
Blasting & Painting	19,550,000	22,950,000	21,080,000
After Part			
Blasting & Painting	19,550,000	22,950,000	21,080,000
Fore Part			
Blasting & Painting	19,550,000	22,950,000	21,080,000
Outfiting & Instalasi	27,370,000	27,540,000	31,620,000
Accomodation Part			
Outfiting & Instalasi	34,212,500	34,425,000	39,525,000

In Table 6, it can be seen that the lowest crash cost calculation results in the addition of 2 working hours and the highest crash cost occurs in the addition of 4 working hours. An example of crash cost estimation after adding 2 hours of overtime to the stell cutting activity is as follows:

Normal Salaries = IDR 680,000
Overtime Salaries = IDR 297,500
Crash Duration = 8 days
Workers = 4 people
Crash Cost
= (680,000 + 297,500) × 4 × 8
= 3,910,000 × 8
= IDR 31,280,000

Cost Slope Calculation

Cost Slope is the cost per day obtained from the comparison between the difference between normal cost and acceleration cost with the difference between normal duration and acceleration duration, calculated as needed in the project duration acceleration analysis [19]. Normal costs can be found by multiplying the normal duration by the normal salaries per day. So that the Cost Slope equation is written as follows:

Cost Slope = Crash Cost - Normal Cost/Normal Duration - Crash Duration

Table 7. Cost Slope Calculation Results

Activities	Cost Slope (IDR)		
	2 hours	3 hours	4 hours
Middle Part			
Stell Cutting	2,040,000	4,760,000	3,230,000
Sub Assembly	2,040,000	4,760,000	3,230,000
Assembly	5,610,000	2,890,000	4,930,000
Erection	2,635,000	5,695,000	4,080,000
Engine Room Part			
Erection	3,230,000	2,890,000	4,930,000
Blasting & Painting	3,230,000	6,630,000	2,380,000
After Part			
Blasting & Painting	3,230,000	6,630,000	2,380,000
Fore Part			
Blasting & Painting	3,230,000	6,630,000	2,380,000
Outfiting & Instalasi	5,610,000	2,890,000	4,930,000
Accomodation Part			
Outfiting & Instalasi	7,012,500	3,612,500	6,162,500

Table 7 shows cost slope that will be used to calculate the most optimal time and cost starting from the lowest cost slope, so it is known that the optimal cost and time is done with the addition of 3 hours of overtime and activities that will be carried out overtime on Assembly Middle Part, Erection Engine Room Part, Outfitting & Installation Fore Part, and Outfitting & Installation Accomodation Part.

Discussions

In this problem the project is scheduled to experience a delay of 12 days where the normal duration is 228 days to 236 days resulting in cost overruns due to delays, the total cost of delays that will be incurred can be calculated by the following equation:

Late fee = Initial contract cost + (0.001 × Initial contract cost × late day)

12-day Late Fee
= IDR 21,000,000,000 + (0.001 × IDR 21,000,000,000 × 12)
= IDR 21,000,000,000 + IDR 252,000,000
= IDR 21,252,000,000

With the alternative of adding overtime hours, the total cost of additional acceleration and optimal duration will be calculated in order to compare with the cost of late fees. Based on the results of the cost slope calculation, the activity with the lowest cost slope value is selected until the optimal duration and cost are achieved. Furthermore, the total crash duration and crash cost of the activity will be calculated using 3 scenarios of overtime time for 2 hours, 3 hours, and 4 hours.

Table 8. Total Crash Duration and Crash Cost

No.	Scenario	Total Crash Duration	Total Crash Cost (IDR)
1	2 hours Overtime	47	190,612,500
2	3 hours Overtime	27	139,995,000
3	4 hours Overtime	25	171,275,000

Table 8 shows the total crash duration and crash cost for activities with the lowest cost slope. The lowest total crash cost is obtained by adding 3 hours of overtime and the activities with the lowest cost slope that will be carried out by adding 3 hours of overtime are Assembly on the Middle Part, Erection on the Engine Room Part, Outfitting & Installation on the Fore Part, and Outfitting & Installation on the Accomodation Part. The crash cost data is a combination of normal wages and overtime wages, so to find overtime wages or total acceleration costs can be done with the following equation:

Final Acceleration Cost = Total Crash Cost – Normal salaries during acceleration

Table 9. Final Acceleration Duration and Cost

No.	Scenario	Duration	Cost
1	2 hours Overtime	228	58,012,500
2	3 hours Overtime	228	53,295,000
3	4 hours Overtime	227	63,750,000

Table 9 shows that the optimal duration and cost of acceleration is achieved by adding 3 hours of overtime, so that the total duration becomes 228 days and the cost of acceleration is IDR 53,295,000. The final duration can be known with the help of Microsoft Project by inputting the duration of the cost slope from the lowest to the optimal duration, this is due to the limitation of holidays. An example of the final cost calculation after adding 3 hours of overtime is as follows:

Total Crash Cost = IDR 139,995,000
Normal salaries during acceleration = IDR 77,520,000
Final Cost
= IDR 139,995,000 - IDR 77,520,000
= IDR 53,295,000

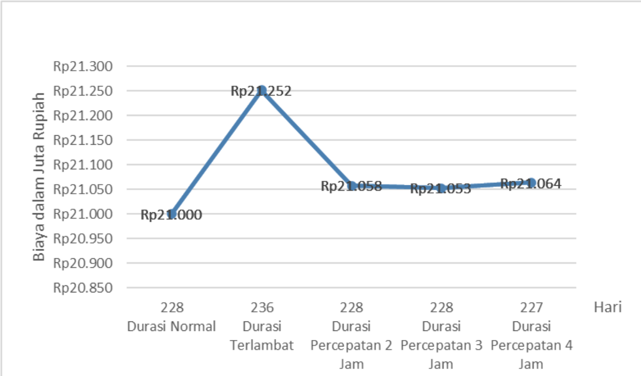


Figure 3. Comparison of Time and Cost

Based on Figure 3, it can be seen that if the duration of the work is accelerated, the cost will increase compared to the initial cost that has been determined before the acceleration process is carried out [20]. Initially the cost of Support Ship building was IDR 21,000,000,000 with a duration of 228 days, but there was a delay so that the total cost became IDR 21,252,000,000 and the duration of the work became 236 days. The increase in cost is due to a late penalty of 1‰ (one per mil) of the contract value. After acceleration, the duration of the work became 228 days with an acceleration cost of Rp 53,295,000 so that the total cost became Rp 21,053,295,000. However, the additional cost of this acceleration may not affect the initial cost/contract value that has been determined if the cost of this acceleration is borne by the company, but this can reduce company profits due to additional overtime hours. The normal wage for each worker if there is no delay is IDR 155,040,000, but because the project is late and acceleration is carried out, there will be additional overtime wages, so that the total worker wages after acceleration are IDR 208,335,000. In the previous study, the optimum duration was found to be 25 days with a cost of Rp 724,654,211.10. The study conducted 2 acceleration alternatives by adding working hours for 4 hours and adding labour [10]. Based on this research, researchers want to use another alternative by adding overtime hours but by comparing the addition of overtime hours for 2 hours, 3 hours, and 4 hours to find the most optimal addition of overtime hours.

CONCLUSION

After analysing with the time cost trade off method and data processing with Microsoft Project software, it was concluded that there was a delay of 12 days in the Support Ship building project with 10 production floor activities on the critical path. Alternative acceleration is done by increasing working hours (overtime) for 2 hours, 3 hours, and 4 hours. This acceleration is applied using the time cost trade-off method to critical activities with the lowest cost slope value, so as to obtain the optimal duration and cost with the addition of overtime for 3 hours so as to accelerate the processing time from 236 days to 228 days with a total acceleration cost of IDR 53,295,000. from here it can be seen that the cost of additional acceleration is smaller than the cost of a late penalty of IDR 252,000,000. This research has some limitations, such as the calculation of overtime is only done in the production section, so the analysis results may be the last option. In addition, the data used is an integrated schedule so that many activities are less detailed. For future research, it is recommended that the data coverage be expanded and use different analysis methods that can provide more in-depth and accurate results.

ACKNOWLEDGMENT

Thank you to PT XYZ for providing the opportunity to conduct research and provide relevant information to support the author's research topic.

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