Analysis of Time and Cost Acceleration with Crashing Method on Apartment Construction Project in Bekasi City

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ABSTRACT

In the implementation of construction projects, problems are often found, such as delays. One of the solutions is by accelerating. Acceleration is not only done to overcome delays, but can also be done if there is a special request from the owner. This study discusses the acceleration of time and cost using the crashing method in an apartment construction project in Bekasi City, which aims to determine the optimal time and cost of the three alternatives used. The work that is accelerated is some structural work that is on the critical path. Acceleration is carried out with three alternatives, namely the addition of working hours, the addition of labor, and the combination of additional working hours and additional labor. The results showed that with the alternative of adding working hours, the implementation time was 298 days at a cost of Rp. 140,751,032,332, obtaining a time efficiency of 5.7% and a cost efficiency of 0.42%. With the alternative of adding labor, the implementation time is 292 days at a cost of Rp. 140,092,976,595, 7.59% time efficiency and 0.89% cost efficiency are obtained. With the alternative of adding working hours and additional labor, the implementation time is 290 days at a cost of Rp. 139,912,527,724, 8.23% time efficiency and 1.02% cost efficiency are obtained. Then it can be concluded that the alternative with the most optimal time and cost is the combined alternative of adding working hours and adding labor.

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1. INTRODUCTION

Project activities can be defined as temporary activities that allocate certain resources, take place over a limited period of time, and aim to produce products or results with clear quality standards [1]. The factors that determine the success of a project are cost, time, and quality which are interrelated. These three factors need to be handled as well as possible in order to generate profits in accordance with planning [2]. In the implementation of construction projects, it is not uncommon to find problems, such as delays. Some of the most common causes of delays include weather changes, shortages of labor, materials, or equipment [3]. One of the solutions is to accelerate [4]. Acceleration is not only done to overcome delays, but can also be done if there is a special request from the owner. However, acceleration requires consideration of quality standards and costs, the increase in costs incurred is expected to be minimal [5]. This research discusses the acceleration of time and cost with the crashing method on an apartment construction project in Bekasi City, which aims to determine the optimal time and cost of the three alternatives used. The crashing method is one of the programs that can be used to shorten the project duration [6]. Crashing can be done on activities that are on the critical path, the application of crashing on the project to get the optimum duration can be done with several alternatives [7]. These alternatives include additional labor, additional working hours, the use of a shift work system, the use of materials that are faster to install, the use of more effective construction methods, and the use of more productive tools [8].

Construction projects can be characterized in three ways: they are unique, resource intensive, and require organization [9]. Project activities can be defined as an activity that takes place within a limited period of time with the allocation of certain resources and aims to produce a product with a set quality standard [1]. Project management is a process of planning, organizing, implementing, and controlling by utilizing resources efficiently [10]. Based on PMBOK 3rd Ed (Project Management Body of Knowledge), the management science areas for planning are project scope planning, quality planning, time planning, cost planning, and resource planning [11]. Scheduling is the allocation of available time to utilize existing resources for the completion of a project to achieve optimal results by considering existing constraints [12]. Some commonly used project scheduling techniques are as follows:

a. Chart and S Curve, Bar Chart is a list of work organized in vertical columns and the time scale is shown in horizontal columns. The start and end of the activity are shown on the bar chart, and the length of the activity can be seen from the length of the bar chart [13]. The S curve is usually combined with a Bar Chart, showing the total type of work, its volume in units of time, and the ordinate is the sum of the percentage of work on the timeline [14].
b. Program Evaluation and Review Technique (PERT), PERT is used for implementation projects where time estimation is more important than cost. In PERT there are three time estimates: pessimistic time (b), most likely time (m), and optimistic time (a). The three time estimates are used to calculate the expected time (te) [15].
c. Critical Path Method (CPM), In the CPM method, it is known that there is a critical path, which is the path that has the longest total time for a set of activity components and the fastest time to complete the project. This path includes activities that, if implemented late, will delay the entire project [1].
d. Precedence Diagram Method (PDM), in PDM overlapping activities can be carried out without delaying activities (dummy) so as to accelerate the completion of the project [16]. The activities of the events are written in the form of rectangular nodes. Common attributes included in PDM diagrams include activity duration (D), activity identity (number and name), and the start and end of activities such as Earlies Start (ES), Latest Start (LS), Earlies Finish (EF), and Latest Finish (LF) [17].

Acceleration of project time is an attempt to complete the project earlier than the completion time under normal conditions. The kinds of acceleration of project duration include.

a. Fast track is a method of accelerating project duration by significantly increasing the average productivity of the project by utilizing highly skilled workers [18].
b. Project crashing is done in such a way that the work is completed at the expense of time and cost by increasing work shifts, the number of working hours, the number of workers, and other alternatives. Project crashing or crash program is done by improving scheduling using network planning on the critical path [2].

Activities in a project can be accelerated in various ways such as additional working hours (overtime), additional labor, and work shifts.

a. Overtime is work performed that exceeds normal working hours. Based on the Decree of the Minister of Manpower Number KEP.102/MEN/VI/2004, the standard wage for overtime is for the first overtime to be paid at 1.5 times the hourly wage and for each subsequent hour of overtime work must be paid at 2 times the hourly wage [19].

b. Additional labor, additional resources (labor) can affect the efficiency of the project if planned realistically and taking into account field conditions [20].
c. The work shift system is a work arrangement system that provides an opportunity to utilize all available time to operate a job [21].

Financial resources are an important factor in project implementation. The costs in question include all costs associated with the project, both direct and indirect. Direct costs are costs that directly affect the physical implementation of the project, such as labor costs, material costs, and equipment. Indirect costs are expenses for management, where these costs are incurred to smooth project implementation such as profits, management fees, supervision, and services required during the project development process [22].

2. METHODS

2.1 Data Collection Technique

In this study the data used is secondary data, namely data collected from previous research or publications from various other institutions. Usually indirect sources are official archives and documentation data. The secondary data used in this study such as project time schedule, work volume, and unit price list of work used.

2.2 Data Analysis Technique

In accelerating the project, it is carried out with alternatives to increase working hours, labor, and a combination of the two alternatives, so it is expected that more work volume will be produced in one day. The application of Time Cost Trade Off requires the calculation of costs and time after acceleration, the instrument in this study uses the Precedence Diagram Method (PDM) with the help of the Microsoft Project 2016 program.

After entering the relevant data to be analyzed into the Microsoft Project 2016 program, it will automatically calculate the calculations according to what is in this program. With the help of Microsoft Project 2016, the data input process tests each activity. Furthermore, the results of the analysis of the acceleration of project time before and after between the addition of working hours, the addition of labor, and the combination of the two alternatives are compared.

2.2.1 Acceleration Duration Analysis

The stages of calculating worker productivity and acceleration duration, using the following equation [23][24]:

a. Daily productivity

$$\textit{Daily productivity} = \frac{\textit{Volume}}{\textit{Normal duration}} \quad (1)$$

or

$$\textit{Daily productivity} = \frac{1}{\textit{Labor coefficient}} \quad (2)$$

b. Productivity per hour

$$\textit{Productivity per hour} = \frac{\textit{Daily productivity}}{\textit{Working hours per day}} \quad (3)$$

c. Overtime productivity

$$\textit{Overtime productivity} = a \times b \times \textit{Productivity per hour} \quad (4)$$

Description:

a = duration of additional working hours
b = coef. decrease in productivity of additional working hours

d. *Crash duration*

$$\text{Crash duration} = \frac{\text{Volume}}{\text{Daily productivity} + \text{Productivity of overtime hours}} \quad (5)$$

or

$$\text{Crash duration} = \frac{\text{Volume}}{\text{Daily productivity} \times \text{Total labor}} \quad (6)$$

2.2.2 Acceleration Cost Analysis

The stages of calculating the normal cost of resources and the cost of accelerating the addition of working hours, using the following equation [19][23]:

a. Worker overtime cost

Worker overtime cost = 1,5 × Normal hourly wage for the first overtime hour worked + 2 × n × Normal hourly wage for the next hour worked (7)

Description:
n = number of additional working hours (overtime)

b. *Crash cost* of workers per day

Crash cost of workers per day = *(Working hours per day × Normal cost of workers) + (n × Hourly overtime cost)* (8)

c. Overtime resource cost

Overtime resource cost = Resource requirement × Hourly overtime cost (9)

d. Daily total resource cost

Daily total resource cost = Normal cost × ∑Overtime resource cost (10)

e. Total cost of acceleration

Total cost of acceleration = (Total cost of daily resources × Duration of acceleration) + Material cost (11)

The stages of calculating the normal cost of resources and the cost of accelerating the addition of labor on each work item, using the following equation [23]:

a. Normal resource requirements

$$\text{Normal resource requirements} = \frac{\left(\frac{\text{labor coefficient} \times \text{Volume}}{\text{normal duration}}\right)}{\text{working hours}} \quad (12)$$

b. Resource cost per day

Resource cost per day = (Working hours × Resource requirement × Cost of resource unit price)
Resource cost per day = (Working hours × Resource requirement × Cost of resource unit price)(13)

c. Daily total resource cost

Total cost of daily resources = ∑Daily resource costs (14)

d. Total resource cost

Total resource cost = (Daily total resource cost × Duration) + Material cost (15)

The stages of calculating Cost Variance, Duration Variance, and Cost Slope, using the following equations [23]:

a. Cost Variance

Cost variance = Accelerated cost - Normal cost (16)

b. Duration Variance

Duration variance = Normal duration - Accelerated duration (17)

c. Cost Slope

$$\text{Cost slope} = \frac{\text{Accelerated cost - Normal cost}}{\text{Normal duration - Accelerated duration}} \quad (18)$$

or

$$\text{Cost slope} = \frac{\text{Cost variance}}{\text{Duration variance}} \quad (19)$$

2.2.3 Project Cost Analysis

The stages of calculating direct costs, indirect costs, and total costs, using the following equation [22]:

a. Direct Costs

$$\textit{Direct cost} = \textit{Material cost} + \textit{Labor cost} + \textit{Equipment cost} \tag{20}$$

$$\textit{Cumulative direct cost} = \textit{Previous cumulative cost} + \textit{Cost variance} \tag{21}$$

b. Indirect Cost

$$\textit{Indirect Cost} = \textit{Value of overhead \& profit} \times \textit{Direct cost} \tag{22}$$

$$\textit{Cumulative indirect cost} = \frac{\textit{Previous cost}}{\textit{Previous cumulative duration}} \times \textit{Cumulative duration} \tag{23}$$

Description:
Overhead & profit value = 15% (Unit Price Analysis of Work 2022)

c. Total cost

$$\textit{Total cost} = \textit{Direct cost} + \textit{Indirect cost} \tag{24}$$

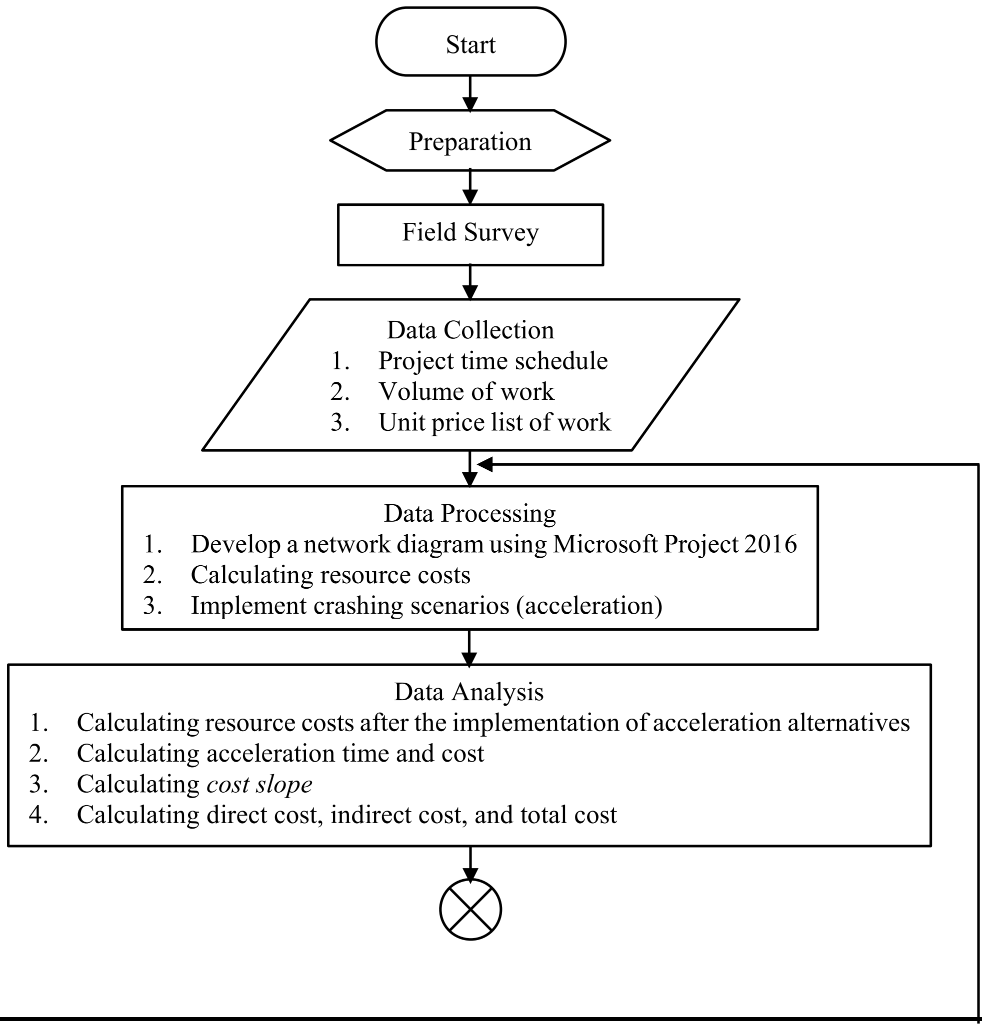
d. Time efficiency

$$Te = \left(\frac{\textit{Project duration - Cumulative duration of work}}{\textit{Project duration}}\right) \times 100\% \tag{25}$$

e. Cost efficiency

$$Ce = \left(\frac{\textit{Total project cost -Cumulative total cost of work}}{\textit{Total project cost}}\right) \times 100\% \tag{26}$$

2.3 Research Stages



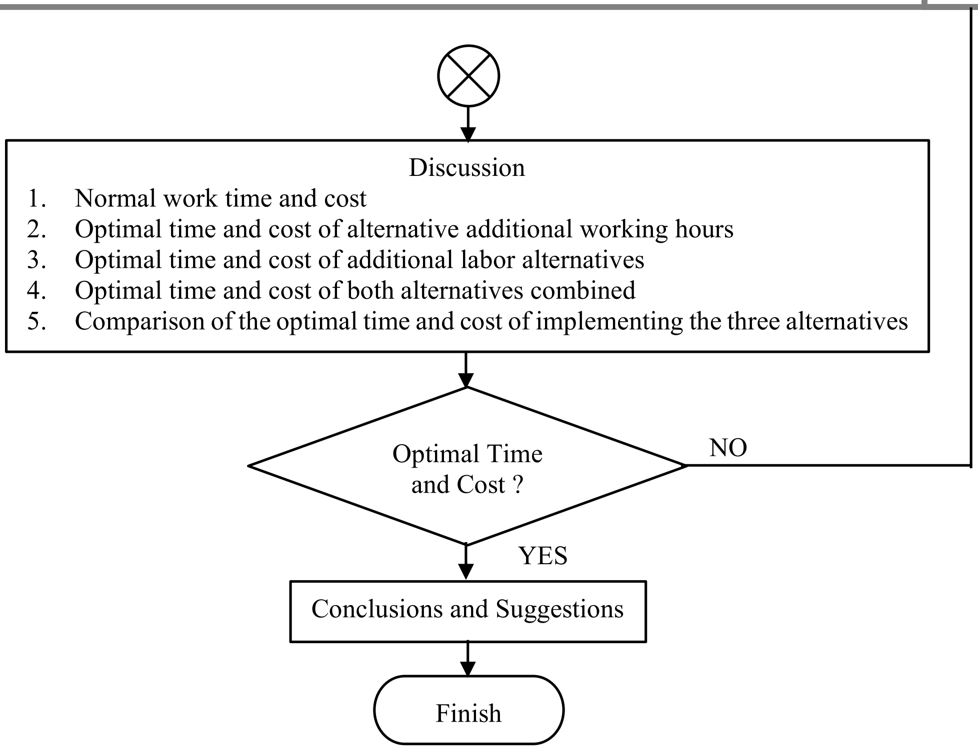


Figure 1. Research Flow Chart

3. RESULTS AND DISCUSSION

3.1 Research Data

The case study reviewed in this research is the Tower 3 Apartment in the Apartment and Mall development project in Bekasi City, with the following details:

a. Project Name : Tower 3 Apartment Construction Project
b. Project Location : Bekasi, West Java
c. Scope of Work : Structure Work
d. Budget : Rp. 122,913,080,933
e. Starting Time : December 5, 2022
f. Completion Time : March 8, 2024

Based on the recapitulation of the cost budget plan with reference to Bekasi City unit prices [25], it can be seen that the value of direct costs in this project is Rp. 122,913,080,933. For indirect costs obtained from the percentage of overhead and profit, in this project the percentage value of overhead and profit is 15% which is obtained based on the analysis of the unit price of work in 2022 [24]. So that the calculation of indirect costs obtained the following results:

Indirect cost = 15% × Direct cost
= 15% × Rp. 122,913,080,933
= Rp. 18,436,962,140

The total cost calculation is obtained from the following results:

Total cost = Direct cost + Indirect cost
= Rp. 122,913,080,933 + Rp. 18,436,962,140
= Rp. 141,350,043,073

3.2 Critical Path Activities Data

Based on the job description in Table 1, a critical path analysis is carried out, in this study the critical path is obtained by creating a network diagram using the Precedence Diagram Method (PDM) with Microsoft Project.

Table 1. Work Description

No	Work items	Duration	Predecessor	Successor
1	Substructure B1-GF	34 days		3SS+15 days;6FS+10 days
2	Frame and Upper Structure LG - L31	249 days	1SS+15	4SS+12 days;5
3	Upper Floor UG - L31	243 days	2SS+12	
4	Roof Structure	26 days	2FS	
5	Staircase Structure B1 - L31	272 days	1FS+10	

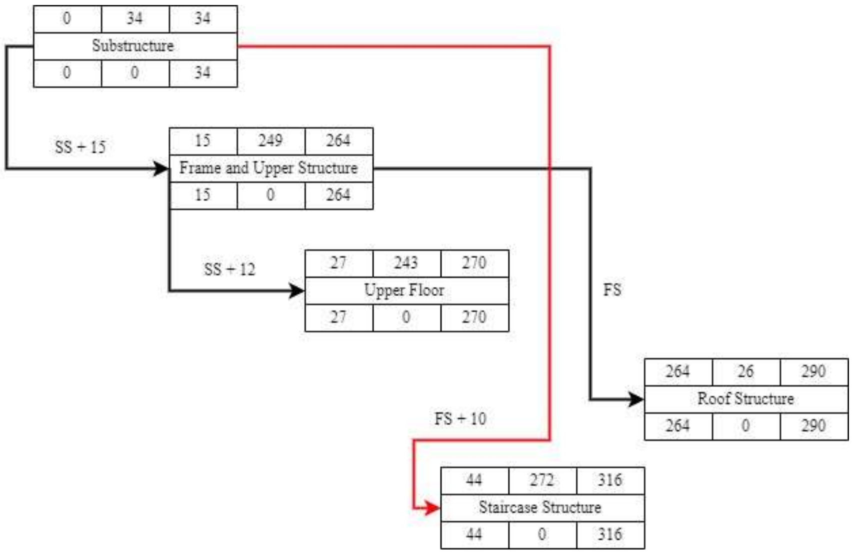


Figure 2. Diagram Precedence Diagram Method (PDM)

Based on Figure 2, it can be seen that the normal duration of project work is 316 days with activities on the critical path to be accelerated as in Table 2.

Table 1. Accelerated Critical Path Activities

ID	Work items	Duration	Predecessor	Successor
	Column Work B1	**8 days**		
9	Reinforcement	4 days	5SS+2 days	10SS+1 day;13SS
10	Formwork	5 days	9SS+1 day	11
11	Foundry	2 days	10	18FS-1 day
	Shearwall Work B1	**8 days**		
13	Reinforcement	4 days	9SS	14SS+1 day
14	Formwork	5 days	13SS+1 day	15
15	Foundry	2 days	14	18FS-1 day
	Staircase Work B1 - GF	**8 days**		
774	Reinforcement	5 days	24FS+28 days	775SS
775	Formwork	6 days	774SS	776
776	Foundry	2 days	775	778
	Staircase Work UG - P8	**9 days**		
786	Reinforcement	6 days	571;784	787SS
787	Formwork	7 days	786SS	788
788	Foundry	2 days	787	790
	Staircase Work L1	**10 days**		

834	Reinforcement	6 days	631;832	835SS
835	Formwork	8 days	834SS	836
836	Foundry	2 days	835	838

3.3 Acceleration Analysis with Additional Working Hours (Alternative 1)

In this research, the alternative of adding working hours was carried out for 3 hours, with the analysis results presented in Table 3.

Table 2. Time and Cost Efficiency of Accelerating the Addition of Working Hours

Code	Work items	Cumulative Duration	Total Cost	Time Efficiency	Cost Efficiency
PN	Normal Work	316	Rp. 141.350.043.073	0%	0%
PK B1	Column Work B1	315	Rp. 141.303.927.779	0,32%	0,03%
PS B1	Shearwall Work B1	314	Rp. 141.257.601.047	0,63%	0,07%
PT B1 - GF	Staircase Work B1 - GF	311	Rp. 141.160.289.268	1,58%	0,13%
PT UG - P8	Staircase Work UG - P8	299	Rp. 140.771.042.153	5,38%	0,41%
PT L1	Staircase Work L1	298	Rp. 140.751.032.332	5,70%	0,42%

Based on the analysis results in Table 3, it can be seen that after acceleration with the addition of working hours for 3 hours, the project implementation time is obtained to be 298 days with a time efficiency value of 5.7%, and obtained a total cost of Rp. 140,751,032,332 with a cost efficiency value of 0.42%.

3.4 Acceleration Analysis with Additional Labor (Alternative 2)

In this research, the alternative of adding labor is done by adding the number of workers considering the conditions in the field, with the analysis results presented in Table 4.

Table 3. Time and Cost Efficiency of Accelerating Labor Addition

Code	Work items	Cumulative Duration	Total Cost	Time Efficiency	Cost Efficiency
PN	Normal Work	316	Rp. 141.350.043.073	0%	0%
PK B1	Column Work B1	314	Rp. 141.230.809.442	0,63%	0,08%
PS B1	Shearwall Work B1	312	Rp. 141.120.187.348	1,27%	0,16%
PT B1 - GF	Staircase Work B1 - GF	306	Rp. 140.790.627.096	3,16%	0,40%
PT UG - P8	Staircase Work UG - P8	294	Rp. 140.199.988.034	6,96%	0,81%
PT L1	Staircase Work L1	292	Rp. 140.092.976.595	7,59%	0,89%

Based on the analysis results in Table 4, it can be seen that after acceleration with the addition of labor, the project implementation time is obtained to be 292 days with a time efficiency value of 7.59%, and obtained a total cost of Rp. 140,092,976,595 with a cost efficiency value of 0.89%.

3.5 Acceleration Analysis with Additional Working Hours and Labor (Alternative 3)

In this research, acceleration was carried out by combining both alternatives of additional working hours and additional labor, with the analysis results presented in Table 5.

Table 4. Time and Cost Efficiency of Accelerating the Addition of Working Hours & Labor

Code	Work items	Cumulative Duration	Total Cost	Time Efficiency	Cost Efficiency
PN	Normal Work	316	Rp. 141.350.043.073	0%	0%

PK B1	Column Work B1	314	Rp. 141.260.234.536	0,63%	0,06%
PS B1	Shearwall Work B1	312	Rp. 141.173.716.933	1,27%	0,12%
PT B1 - GF	Staircase Work B1 - GF	306	Rp. 141.019.036.620	3,16%	0,23%
PT UG - P8	Staircase Work UG - P8	282	Rp. 140.048.304.299	10,76%	0,92%
PT L1	Staircase Work L1	279	Rp. 139.912.527.724	11,71%	1,02%

Based on the analysis results in Table 5, it can be seen that after acceleration with the addition of working hours for 3 hours and additional labor, the project implementation time is obtained to 279 days with a time efficiency value of 11.71%, and obtained a total cost of Rp. 139,912,527,724 with a cost efficiency value of 1.02%. After analysis with the Precedence Diagram Method (PDM) diagram, it is found that the critical path has changed so that the project implementation time after acceleration with the addition of working hours for 3 hours and additional labor becomes 290 days with a cost efficiency value of 8.23%.

3.6 Comparison of Time and Cost of Acceleration

After conducting an acceleration analysis with the alternative of adding working hours for 3 hours, adding labor, and a combination of the two alternatives, a comparison of time and cost is obtained as in Table 6.

Table 5. Recapitulation of Time and Cost Comparison

Alternative	Duration (days)	Direct Costs	Indirect Costs	Total Cost	Time Efficiency	Cost Efficiency
Normal conditions	316	Rp. 122.913.080.933	Rp. 18.436.962.140	Rp. 141.350.043.073	0%	0%
Additional working hours	298	Rp. 123.364.276.896	Rp. 17.386.755.436	Rp. 140.751.032.332	5,70%	0,42%
Additional labor	292	Rp. 123.056.290.061	Rp. 17.036.686.534	Rp. 140.092.976.595	7,59%	0,89%
Additional working hours & labor	290	Rp. 123.634.323.809	Rp. 16.278.203.915	Rp. 139.912.527.724	8,23%	1,02%

Based on the recapitulation of time and cost comparisons in Table 6, a comparison graph of the time and cost of normal work with three acceleration alternatives can be presented in Figure 3.

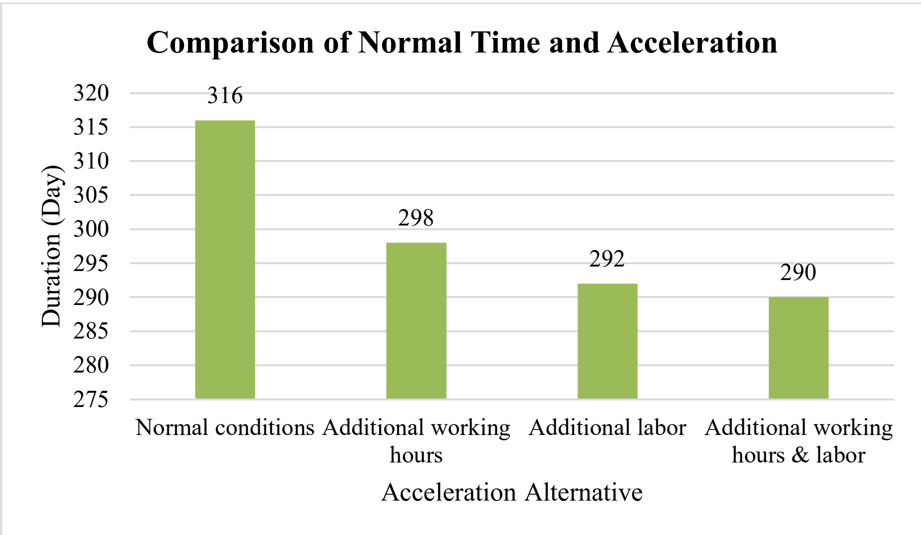


Figure 3. Normal and Accelerated Time Comparison Chart

Based on the comparison chart of normal and accelerated time, it can be seen that normal work takes 316 days to complete the project. After acceleration using the alternative of adding working hours for 3 hours the duration of work can be accelerated to 298 days with a time difference of 18 days and a time efficiency of 5.7% of normal time, with the alternative of adding labor can be accelerated to 292 days with a time difference of 24 days with a time efficiency of 7.59% of normal time, and with the combined alternative of adding working hours and labor can be accelerated to 290 days with a time difference of 26 days and a time efficiency of 8.23% of normal time.

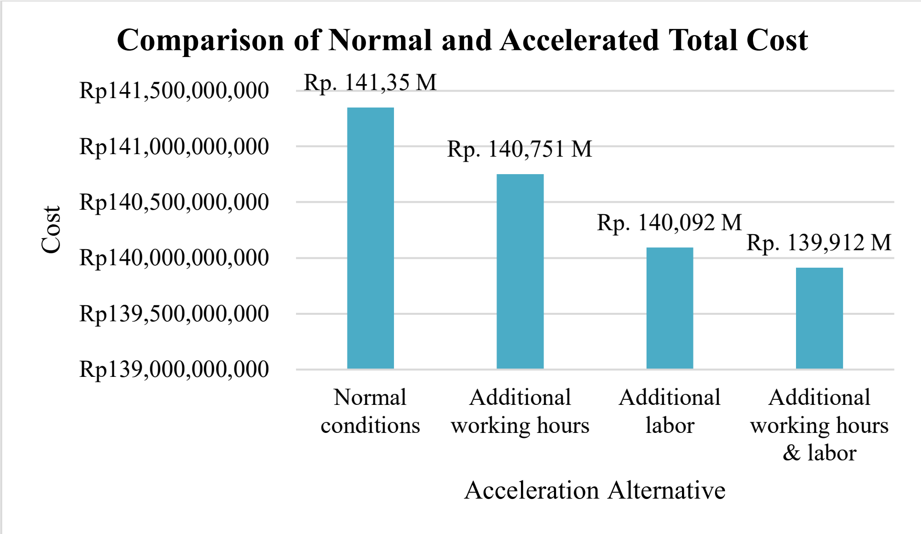


Figure 4. Normal and Accelerated Total Cost Comparison Chart

Based on the comparison chart of normal and accelerated total costs, it can be seen that normal work requires a total cost of Rp. 141,350,043,073. After acceleration with the alternative of adding working hours for 3 hours requires a total cost of Rp. 140,751,032,332, with a cost difference of Rp. 599,010,741 and a cost efficiency of 0.42% of normal costs. With the alternative of additional labor requires a total cost of Rp. 140,092,976,595, with a cost difference of Rp. 1,257,066,478 and a cost efficiency of 0.89% of normal costs. With the combined alternative of increasing working hours and increasing labor requires a total cost of Rp. 139,912,527,724, with a cost difference of Rp. 1,437,515,349 and a cost efficiency of 1.02% of normal costs.

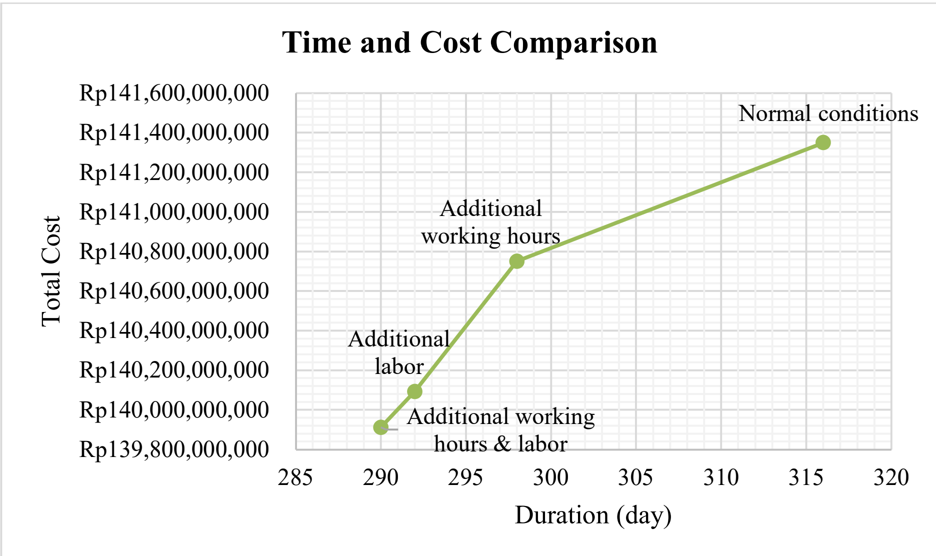


Figure 5. Time and Cost Comparison Chart

Based on the time and cost comparison chart, it can be seen that the acceleration alternative with optimal time and cost is the alternative of adding working hours and labor (alternative 3), the time required is 290 days with a time difference of 26 days and a time efficiency of 8.23% of normal time, and the cost required is Rp. 139,912,527,724, with a cost difference of Rp. 1,437,515,349 and a cost efficiency of 1.02% of normal costs.

4. CONCLUSION

Based on the results of data analysis and discussion of research results, it can be concluded that:

a. By applying acceleration to project implementation using the alternative of adding working hours for 3 hours (alternative 1), the duration of project implementation is 298 days with a cost of Rp. 140,751,032,332, thus obtaining a time efficiency of 5.7% and a cost efficiency of 0.42%.
b. By applying acceleration to project implementation using alternative labor additions (alternative 2), the project implementation duration is 292 days with a cost of Rp. 140,092,976,595, thus obtaining a time efficiency of 7.59% and a cost efficiency of 0.89%.
c. By applying acceleration to project implementation using a combined alternative of adding working hours for 3 hours and adding labor (alternative 3), the duration of project implementation is 290 days with a cost of Rp. 139,912,527,724, thus obtaining a time efficiency of 8.23% and a cost efficiency of 1.02%.
d. Of the three acceleration alternatives carried out when compared to the normal implementation time of 316 days at a cost of Rp. 141,350,043,073, the acceleration alternative with the optimal time and cost is the combined alternative of adding working hours for 3 hours and adding labor (alternative 3), the time required is 290 days with a time difference of 26 days and a time efficiency of 8.23% of normal time, and the required cost is Rp. 139,912,527,724, with a cost difference of Rp. 1,437,515,349 and a cost efficiency of 1.02% of normal costs.

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