Optimizing Time and Costs of Building Construction Projects with the Alternative of Additional Overtime Hours and Additional Workers

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Abstract. This study was conducted on a new classroom construction project at SMKN 1 Kertak Hanyar, Tatah Amuntai District, at the request of the project owner to accelerate completion. The objective was to ensure the project is finished according to the initial schedule without disrupting the teaching and learning process. Two acceleration alternatives were evaluated in terms of cost and time efficiency: (1) extending working hours (overtime) and (2) increasing labor resources. The analysis began by identifying the critical path using the Precedence Diagram Method (PDM), followed by a crashing process to determine the cost slope of activities on the critical path. Under normal conditions, the project duration was 72 days with a total cost of IDR 298,406,296.70. Extending working hours by 2 hours on critical path activities reduced the duration to 62 days, with an increased cost of IDR 317,096,296.70. Meanwhile, adding four workers to critical path activities reduced the duration to 54 days at a cost of IDR 305,171,296.70. The results indicate that increasing labor resources provides a more optimal acceleration strategy compared to extending working hours, considering both cost and time efficiency.

Keywords: PDM, crashing, time and costs acceleration, overtime analysis, additional workers analysis.

1 Introduction

Efficient project scheduling requires accurate and comprehensive analysis of time and cost, particularly in construction projects, which are expensive and time-constrained. From a managerial perspective, understanding the mechanisms for achieving performance is crucial in multitasking environments such as construction projects, especially when activities are restricted by strict time constraints [1]. This necessitates the development of multiple scheduling alternatives to identify optimal solutions by considering project lead times [2]. Optimization is a systematic effort to achieve improved performance and optimal outcomes under specific conditions. In this context, cost optimization refers to achieving a real and sustainable reduction in unit service costs without compromising the intended functionality or quality of the project [3].

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The process of accelerating time is called the crashing project. The main objective of the time acceleration program is to shorten the schedule for completing activities or projects with minimal cost increases [4]. Crashing project is carried out on every job that is on the critical path, so this needs to be known before crashing. Project completion within minimum time incurring minimum cost is desirable in every project [5].

Currently, infrastructure development projects, particularly educational facilities, require timely completion to minimize disruption to the surrounding environment, especially when located near residential areas. Many project owners expect construction work to be completed faster than the predetermined schedule while maintaining cost efficiency [6]. However, discrepancies often arise between the quality of services delivered by contractors and the owner's expectations [7].

In this study, an analysis is conducted on the new classroom construction project at SMKN 1 Kertak Hanyar, Tatah Amuntai District. The project requires accelerated completion at an efficient cost, as requested by the owner. This urgency is further driven by the project's proximity to existing classroom buildings that remain in use for teaching and learning activities, as well as its location on peatland, which is prone to fire hazards during certain months [8], [9].

This analysis aims to evaluate the impact of project duration acceleration through additional overtime working hours and increased labor resources, and to identify the most optimal crashing method for reducing project duration.

2 Methods

A construction project is a series of one-time activities that are generally short-term in nature. It involves specific resource allocation and possesses unique characteristics, requiring resources such as labor, materials, equipment, capital, and work methods [10].

This study was conducted using small-scale field surveys to collect visual data on site conditions, workforce, and construction methods. The data were then analyzed systematically through the following procedures:

a. Dependency logic modeling
b. Determine the normal duration and critical path
c. Analysis of direct cost and indirect costs based on interviews
d. Crash method with additional working hours (overtime)
   1. Daily productivity analysis

      $$\text{Daily Productivity} = \frac{\text{volume}}{\text{Normal working Duration}} \quad \ldots\ldots\ldots\ldots\ldots\ldots \; 1$$

   2. Hourly productivity analysis

      $$\text{Hourly Productivity} = \frac{\text{Daily Productivity}}{\text{Daily working Hours}} \quad \ldots\ldots\ldots\ldots\ldots\ldots \; 2$$

   3. Daily productivity analysis after the crash method (PHSC) at 1 hour, 2 hours and 3 hours overtime

$$\text{PHSC} = (\text{normal working hours} \cdot \text{hourly productivity}) + (\text{overtime working hours} \cdot \text{overtime productivity decline index} \cdot \text{hourly productivity}) \quad \ldots\ldots 3$$

The productivity decline index can be seen in figure 1 below:

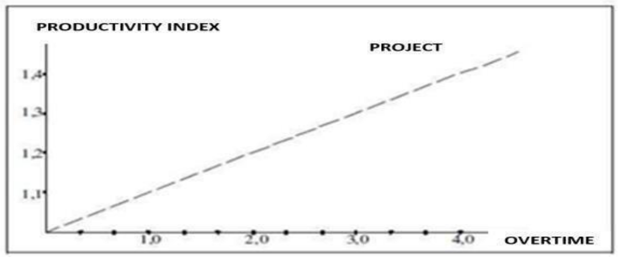

Figure 1. Overtime productivity decline index [11]

4. Analysis crash duration at 1 hour, 2 hours and 3 hours overtime

$$\text{Crash Duration} = \frac{\text{volume}}{\text{PHSC}} \quad \ldots\ldots 4$$

5. Analysis crash cost at 1 hour, 2 hours and 3 hours overtime

$$\text{Crash cost} = \text{normal cost} + (\text{overtime pay coefficient} \cdot \text{hourly wage costs} \cdot \text{crash duration}) \quad \ldots\ldots 5$$

The overtime wage coefficient is taken based on Government Regulation of the Republic of Indonesia number 35 of 2021 [12] juncto Decree of the Minister of Manpower number KEP. 102/MEN/VI/2004 concerning overtime working time and work wages. This regulation explains that for additional work vary, for the first hour of additional work wages, workers are entitled to a wage of 1.5 times the normal hourly wage and for additional hours of work the worker gets 2 times the normal hourly wage [13].

6. Analysis cost slope

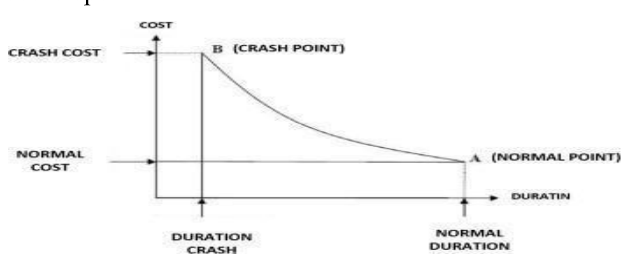

Figure 2. Time and Cost Relationship

From Figure 2, slope of the activity can be defined as the slope of the line which is joining from Normal Time and Crash Time [14]. Mathematically, cost slope can be written as:

$$\text{Cost Slope} = \frac{(\text{crash cost} - \text{normal cost}}{(\text{normal duration} - \text{crash duration})} \quad \ldots\ldots\ldots\ldots \quad 6$$

7. Network diagram analysis after crash

Crash method with additional workers:

1) Daily productivity analysis.

$$\text{Daily Productivity} = \frac{\text{Volume}}{\text{Normal working duration}} \quad \ldots\ldots\ldots\ldots \quad 7$$

2) Analysis of worker productivity.

$$\text{Worker Productivity} = \frac{\text{Daily productivity}}{\text{Number of workers}} \quad \ldots\ldots\ldots\ldots \quad 8$$

3) Daily productivity analysis after the crash method (PHSC) with the addition of 2 workers, 4 workers and 6 workers.

$$\text{PHSC} = \text{worker productivity} \cdot (\text{Number of workers} + \text{additional workers}) \ldots\ldots \quad 9$$

4) Analysis crash duration with the addition of 2 workers, 4 workers and 6 workers.

$$\text{Crash Duration} = \frac{\text{volume}}{\text{PHSC}} \quad \ldots\ldots\ldots\ldots \quad 10$$

5) Analysis crash cost with the addition of 2 workers, 4 workers and 6 workers.

$$\text{Crash cost} = \text{Normal cost} + (\text{additional worker costs} \cdot \text{Crash duration}) \ldots\ldots \quad 11$$

6) Analysis cost slope.

$$\text{Cost Slope} = \frac{(\text{crash cost} - \text{normal cost}}{(\text{normal duration} - \text{crash duration})} \quad \ldots\ldots\ldots\ldots \quad 12$$

7) Network diagram analysis after crash.

3 Results and Discussion

3.1 Normal Duration and Critical Path

From the results of the analysis of dependency relationships and PDM, it is found that the normal project duration is 72 days with a critical path on jobs A, B, C, D, H, I, J, N,O and job P. this can be seen in figure 3 below:

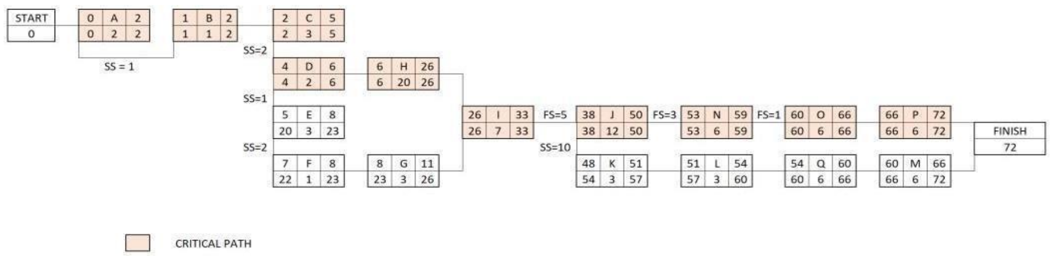

Figure 3. Normal Network Diagram

3.2 Crash Method with Additional Overtime Hours

The crash method with an additional 1 hour of overtime is only applied to job H and job J, with a duration of 69 days, 3 days faster than the normal duration. This can be seen in figure 4 below:

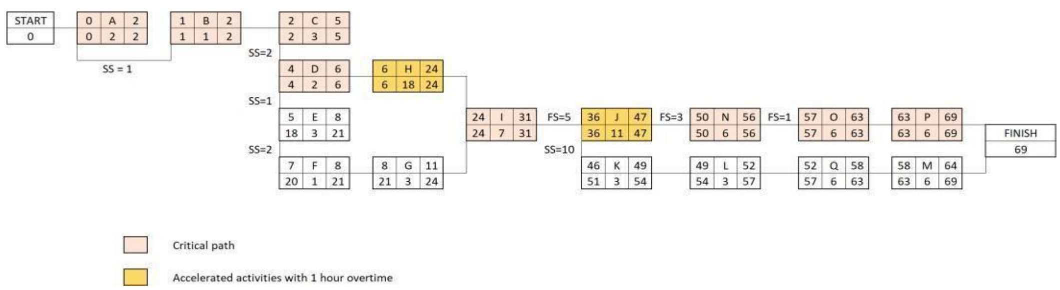

Figure 4. Acceleration with 1 Hour Overtime

Likewise for acceleration with the addition of 2 hour of overtime, carried out on jobs H, I, J, N, O and job P. with a duration of 62 days, 10 Days faster than the normal duration. This can be seen in figure 5 below:

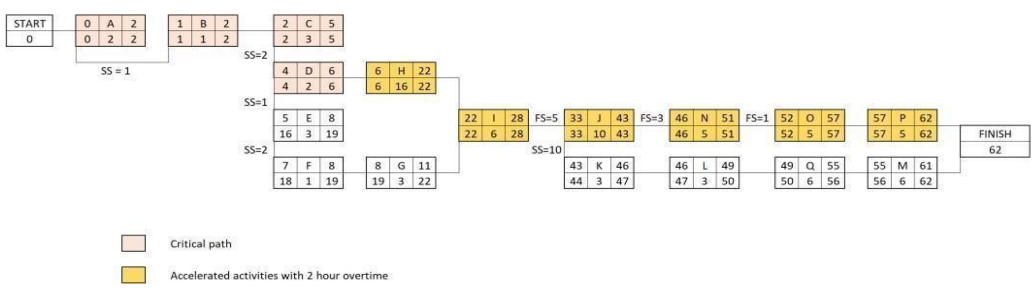

Figure 5. Acceleration with 2 Hour Overtime

Acceleration with the addition of 3 hours of overtime is only carried out on jobs H, I and job J. the implementation duration is 58 days, 14 days faster than the normal duration. This can be seen in figure 6 below:

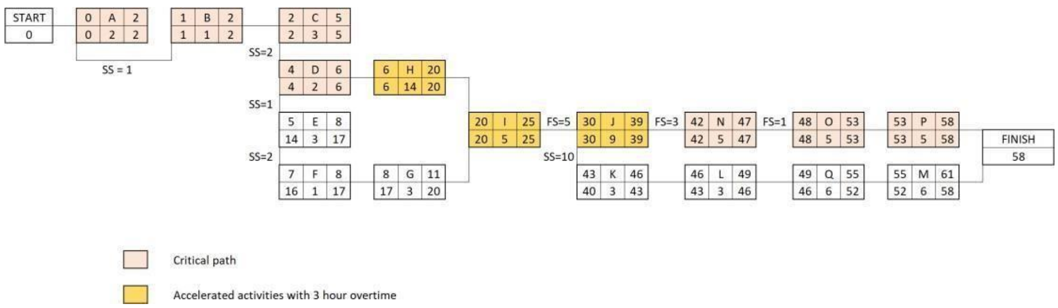

Figure 6. Acceleration with 3 hour overtime

3.3 Crash Method with Additional Workers

Acceleration by adding two workers (one construction worker and one helper) was applied only to activities H, I, J, K, M, N, and P. The resulting project duration is 56 days, which is 16 days faster than the normal schedule. This result is illustrated in Figure 7.

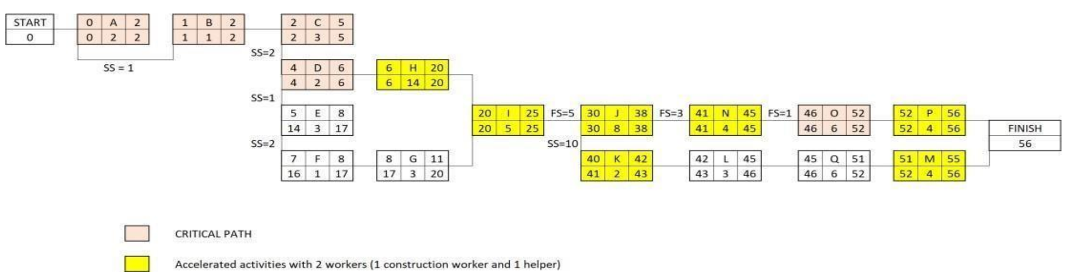

Figure 7. Acceleration with the Addition of 2 Worker

Acceleration by adding four workers (two construction workers and two helpers) was applied only to activities H, I, J, M, N, P, and Q. The resulting project duration is 47 days, which is 25 days faster than the normal schedule. This result is illustrated in Figure 8.

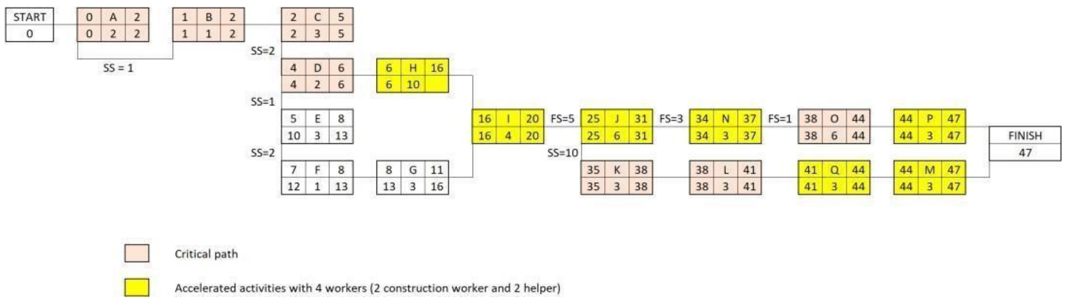

Figure 8. Acceleration with the addition of 4 worker

Finally, acceleration with the addition of 6 workers (3 construction workers and 3 helpers), was carried out on jobs D, H, I, J, L, N,M, P and job Q. The implementation duration was 42 days, 30 days faster than with normal duration. This can be seen in figure 9 below:

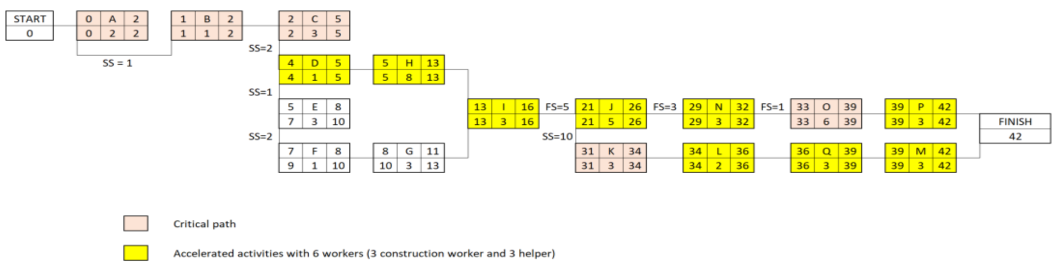

Figure 9. Acceleration with the Addition of 6 Worker

3.4 Comparison of Time and Cost Analysis

Analysis of the comparison of time and cost is used to determine the difference between normal costs, costs due to acceleration due to additional working hours and costs due to acceleration due to the addition of labor and duration of each acceleration result. This aims to determine which acceleration has the most optimum results.

a. Normal Cost
   Normal costs are costs before the acceleration, with 5 workers (1 foremen, 2 construction workers and 2 helpers) and 72 days of completion time. Total Cost IDR298,406,296.70.
b. Comparation of Time-Costs to Accelerate Addition of Working Hours
   Figure 10(a) shows that acceleration through the addition of 1 hour of overtime results in a crash duration of 69 days with a direct cost of IDR 314,606,297.00. Similarly, Figure 10(b) indicates that adding 2 hours of overtime reduces the duration to 62 days with a crash cost of IDR 317,096,297.00. Meanwhile, as shown in Figure 10(c), adding 3 hours of overtime results in a crash duration of 58 days with a crash cost of IDR 345,706,297.00.

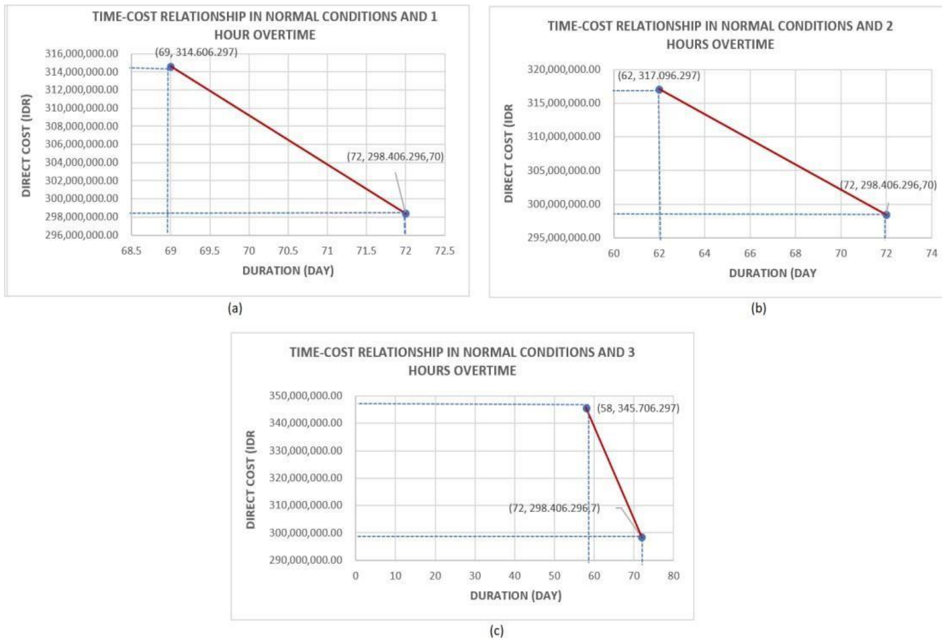

Figure 10. Project Direct Cost-Duration Relationship (Overtime)

The results of the acceleration analysis with alternative additional working hours can be seen in figure 11 the following is the analysis:

a. Addition for 1 working hour resulted in a decrease in the duration of work by 4% or 3 days from the normal duration. For an increase in costs due to addition during 1 working hour is as much as 5% or IDR16,200,000.00 from normal cost.

b. Addition for 2 hours of work resulted in a decrease in the duration of work by as much as 14% or 10 days from the normal duration. For an increase in costs due to additions for 2 hours of work, it is 6% or IDR18,890,000.00 from normal cost.

c. Additions for 3 hours of work resulted in a decrease in the duration of work by 19% or 14 days from normal duration. For an increase in costs due to addition for 3 hours of work is as much as 14% or IDR47,300,000.00 from normal cost.

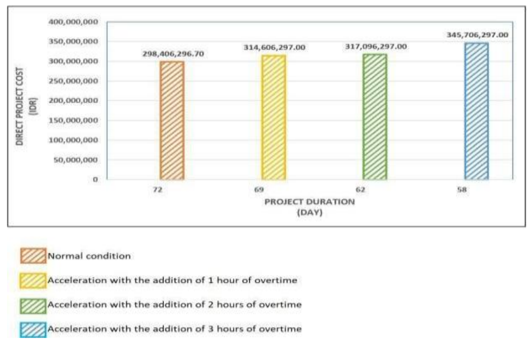

Figure 11. Acceleration Results with Overtime Hours

d. Comparation Time-Costs to Accelerate Addition of Workers

Figure 12(a) shows that acceleration by adding two workers results in a crash duration of 56 days with a crash cost of IDR 305,171,297.00. Similarly, Figure 12(b) indicates that adding four workers reduces the duration to 47 days with a crash cost of IDR 307,976,297.00. Meanwhile, as shown in Figure 12(c), adding six workers results in a crash duration of 42 days with a crash cost of IDR 313,751,297.00.

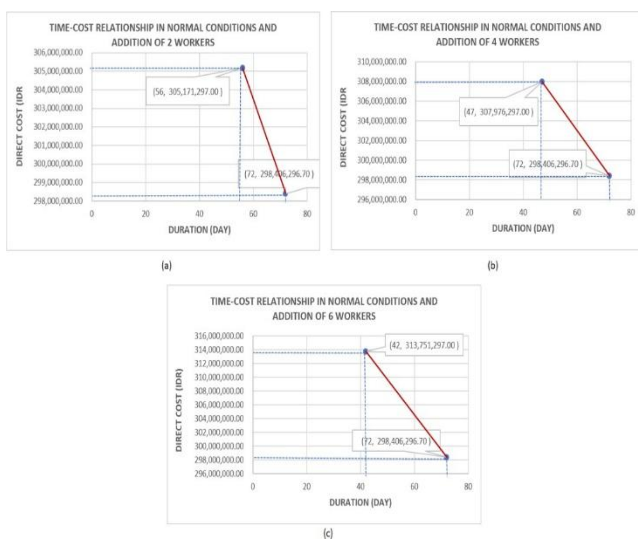

Figure 12. Project Direct Cost-Duration Relationship (Additional Workers)

Through the chart shown in figure 13 it can be analyzed:

a. Addition of 2 workers resulted in a decrease in the duration of work by 22% or 16 days from the normal duration. For the increase in costs due to addition for 2 people, the workforce is as much as 2% or IDR6,275,000.00 from normal cost.

b. Addition of 4 workers resulted in a decrease in the duration of work by 35% or 25 days from the normal duration. For the increase in costs due to the addition of 4 people the workforce is as much as 3% or IDR9,570,000.00 from normal cost.

c. Addition of 6 workers resulted in a decrease in the duration of work by 42% or 30 days from the normal duration. For the increase in costs due to the addition of 6 people, the workforce is 5% or IDR15,345,000.00 from normal cost.

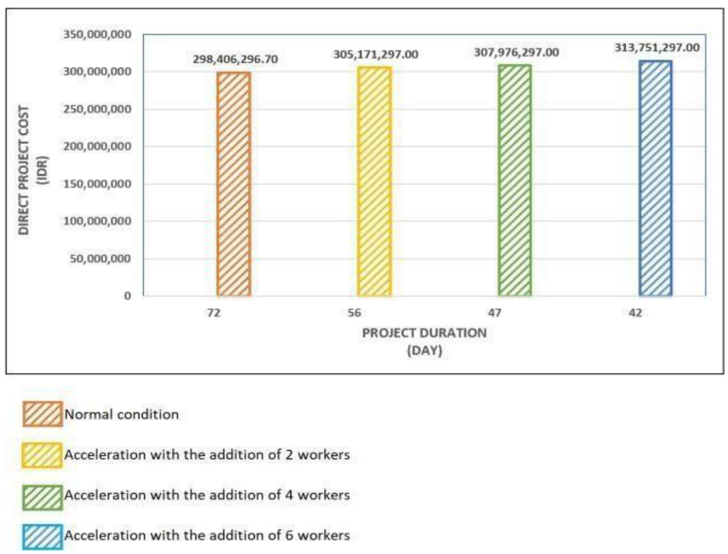

Figure 13. Acceleration Results with Additional Workers

4 Conclusion

The most optimal crash method using overtime is achieved by adding 2 hours of overtime, resulting in a total cost of IDR 317,096,296.70 and a project duration of 62 days. In contrast, the most optimal crash method using additional labor is obtained by adding four workers (two construction workers and two helpers), resulting in a lower total cost of IDR 305,171,296.70 and a shorter duration of 54 days.

Overall, the results indicate that the crash method involving additional workers is more optimal than the method based on extended overtime, in terms of both cost and time efficiency.

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