Project Acceleration Analysis Using the Time Cost Trade Off Method in the Phase II Construction of the Serayu Pegalongan – Mandirancan River Bridge, Banyumas Regency

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ABSTRACT

The Serayu River Bridge is a bridge that connects Pegalongan Village with Mandirancan Village, Banyumas Regency, Central Java Province. This bridge has a total length of 140 meters divided into three spans using steel and reinforced concrete structures and has a road width of 8 meters. The implementation of the Serayu River Bridge phase II project has a planned duration of 150 calendar days from July 26, 2021, to December 22, 2021. However, in its implementation, there was a delay of 30 working days from the initial plan. The delay occurred because October had entered the rainy season and several other causes of delay. This study aimed to analyze the acceleration of the Serayu River Bridge phase II project to get the optimum time and cost. Acceleration was carried out by Time Cost Trade Off (TCTO) analysis based on conditions in the field. The alternative used was by adding work shifts and labor. Thus, with the acceleration analysis using these two alternatives, it is expected to produce a more optimum alternative in the project implementation if it experiences delays in terms of time and cost. After the acceleration analysis, it was found that the acceleration alternative with the addition of work shifts could be accelerated from 30 working days to 120 working days (down 20.00%). The project's total cost, which initially amounted to IDR 10.794.871.204 to IDR 10.766.272.352, then there was a difference of IDR 28.598.851 from the project implementation before acceleration (down 0.26%). Meanwhile, the acceleration alternative with additional labor could be accelerated from 12 working days to 138 working days (down 8.00%). The total project cost, which initially amounted to IDR 10.794.871.204 to IDR 10.763.795.717, then there was a difference of IDR 31.075.486 from the project implementation before acceleration (down 0.29%).

INTRODUCTION

The new bridge construction project on the Serayu River is a bridge that connects Pegalongan Village, Patikraja Subdistrict, with Mandirancan Village, Kebasen Subdistrict, Banyumas Regency, Central Java Province. The new bridge on the Serayu River has a total length of 140 meters divided into three spans using steel and reinforced concrete structures and has a road width of 8 meters. The longest span of the steel structure is 60 meters, and the bridge approach uses a reinforced concrete structure with a length of 20 meters. The first phase of the new bridge on the Serayu River has been carried out as abutment foundation work and bridge pillars with the 2020 Budget of 14.5 Billion for 120 calendar days. As for now, the construction of a new bridge on the Serayu River is entering the second phase with a contract value of 16.5 billion for 150 calendar days from July 26, 2021, to December 22, 2021. October is entering the rainy season, so it can affect work performance in the field.

The project was delayed for 60 days from the specified contract. Therefore, one of the solutions is to use the Time Cost Trade Off (TCTO) method, which can shorten the time but cause a swelling of costs and labor for this project.

In carrying out the construction of this bridge, controlling the implementation time is very crucial. Therefore, systematic project management is required to ensure the implementation time is in accordance with the contract or even faster. Thus, the project can be successful, and the costs incurred can bring maximum profit.

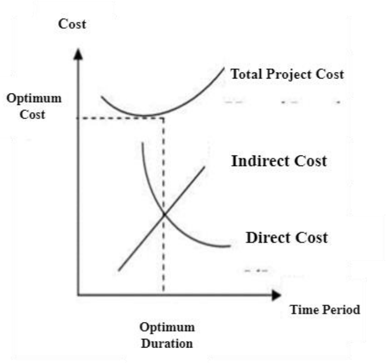

Figure 1. Relationship between time and total cost, direct cost, and indirect cost

This final project will discuss the acceleration analysis using the Time Cost Trade Off (TCTO) method in the Phase 2 construction of the Pegalongan – Mandirancan Serayu River Bridge. Meanwhile, the implementation scheduling calculation for this project uses a results diagram of the processing with Microsoft Project tools. This tool contains coefficients for workers and materials needed, the weight of each work to the whole work, the duration of each work, and the relationship between one work and another.

RESEARCH DESCRIPTION

A. General

In a literary work, a literature review functions as a theoretical basis in the literary work discussion. Thus, this chapter will discuss all the theories used in carrying out a Time Cost Trade Off analysis in the implementation of bridge construction.

B. Calculation of Work Volume and Duration

What is meant by the volume of work is to calculate the number of work volumes in one unit. How to describe the volume of work is to calculate in detail the volume of each work according to the *bestek* drawings and detailed drawings. The duration of each work on the construction of the Serayu River Bridge is used based on the book Analysis (the modern way) Budget Implementation by Ir. A. Soedrajat S. 1984.

C. Equipment Used

The equipment and the number of units used in each item of this bridge structure work are as follows:

1. Excavator (backhoe)
2. Dump Truck
3. Truck Mixer
4. Concrete Pump
5. Piling Hammer Cranes
6. Crane Service
7. Crane Erection
8. Tools

D. Project Objectives and Three Constraints

In achieving the goals and objectives of the project that have been determined, there are limitations in a project, namely the Triple Constraint or three constraints consisting of Cost/Budget (Cost), Time/Schedule (Time), and Quality. From a technical perspective, the measure of project success is related to the extent to which these three objectives can be met. Therefore, a good arrangement is needed so that the combination between the three is as desired, namely with project management [1].

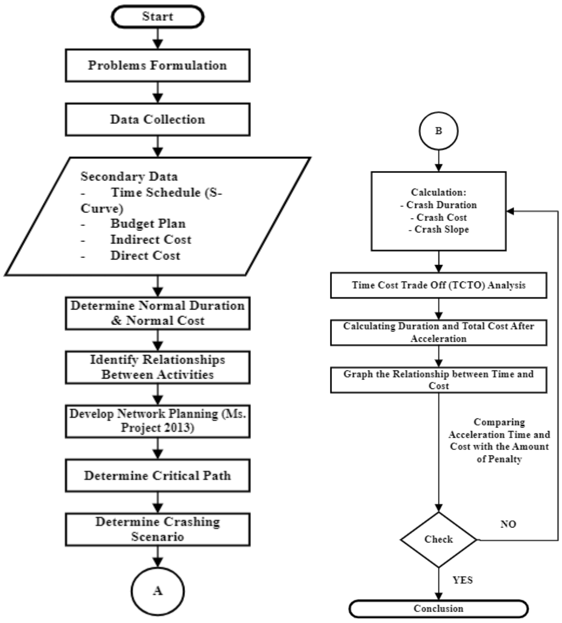

Figure 2. Methodology Flowchart

E. Cost

Cost is one of the most important things in implementing a project. It is because all project entities, such as materials, labor, equipment, and others, depending on the availability of existing costs. In a construction implementation, costs can be divided into two types, namely direct costs and indirect costs.

1. *Direct Costs*

Items included in direct costs include material costs, labor costs, and equipment costs.

2. *Indirect Costs*

Items included in indirect costs include overhead costs, employee salaries, incidental expenses, etc.

F. Implementation Scheduling

Scheduling can be defined as planning the implementation of activities by identifying and managing the division of time and sequence of construction work in a systematic and detailed manner.

1. Network Planning

Network planning, in principle, is a dependency relationship between parts of the work described in the network diagram so that it is known which parts of the work must take precedence and which work must wait for the completion of other work [1].

2. Precedence Diagramming Method

In the PDM diagram, the relationship between activities develops into several possibilities in the form of constraints. Constraints show the relationship between activities with one line from the previous node to the next node. One constraint can only connect two nodes. Since each node has two ends, namely start (S) and finish (F), then there are four kinds of constraints, namely start to start (SS), start to finish (SF), finish to start (FS), and finish to finish (FF). On the constraint line, an explanation of the lead or lag time is attached [2].

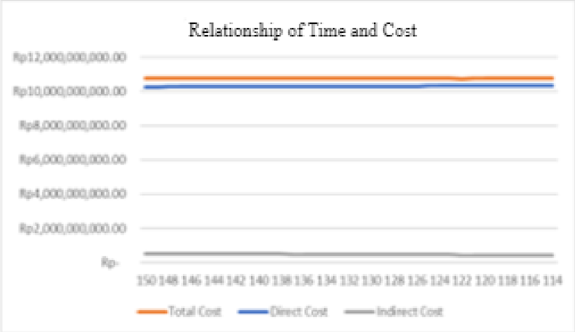

Figure 3. Graph of Relationship between Cost and Duration of Alternative Work Shifts

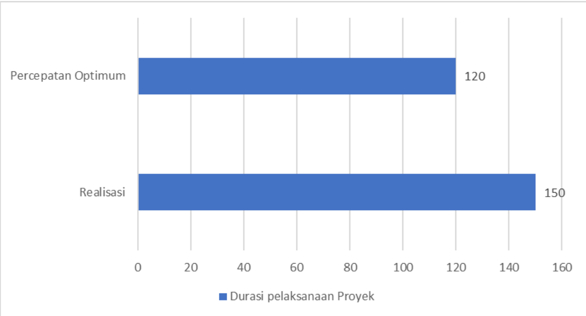

Figure 4. Illustration of Project Duration Acceleration of Alternative Work Shifts

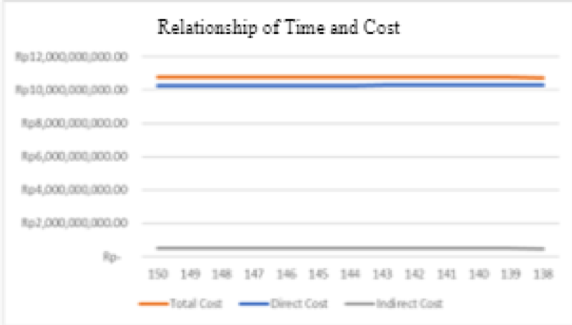

Figure 5. Graph of Relationship between Cost and Duration of the Alternative Additional Labor

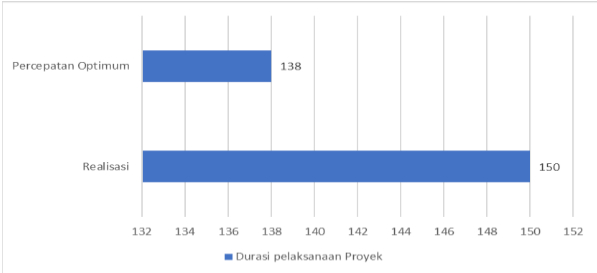

Figure 6. Illustration of Duration Acceleration of Alternative Additional Labor

G. Acceleration of Project Implementation

Accelerating the project completion duration is an attempt to complete the project earlier than the completion time under normal circumstances. With the project acceleration, there will be a reduction in the duration of activities that will be held in the crash program. The maximum crashing duration of an activity is the shortest duration to complete an activity that is technically still possible, assuming resources are not a constraint. The maximum acceleration duration is limited by the size of the project or work site. However, there are four factors that can be optimized to accelerate activity, which include increasing the number of workers, scheduling overtime work, using heavy equipment, and changing construction methods in the field [2]

1. Additional Work Shifts

In this final project, an alternative to adding work shifts will be used in the normal shift (08:00 – 17:00) and the next shift (19:00 – 04:00).

2. Additional Labor

Besides additional work shifts, an alternative addition of labor will also be used, where the addition is taken 50% of normal labor, considering the conditions of the project field.

H. Crashing Calculation

The crashing process is a way of estimating variable costs in determining the maximum and most economical duration reduction of an activity that is still possible to reduce [2]. To further analyze the relationship between costs and the time of an activity, several terms are used, namely Normal Duration (ND), Crash Duration (CD), Normal Cost (NC), and Crash Cost (CC).

I. Time-Cost Relationship

The total cost is highly dependent on the overall duration of the project implementation. Direct costs of the project will increase as the project duration shortens due to the optimization process. In contrast, indirect costs are stagnant and continuous throughout the project, so a reduction in project duration will result in a reduction in indirect costs. The following figure explains the relationship between direct costs, indirect costs, and total project costs. Optimum project costs are obtained by finding the lowest total project cost.

J. Time Cost Trade Cost

In accelerating the completion of a project by compressing the duration of activities, it is sought that the addition in terms of cost is as minimal as possible. Cost control carried out is direct costs because these costs will increase if the duration is reduced. This compression is carried out on activities on the critical cross with the lowest cost slope [2].

The procedure of shortening the time [1] can be described as follows:

1. Calculate project completion time and identify float using normal timeframe.
2. Determine the normal cost of each activity.
3. Determine the accelerated cost of each activity.
4. Calculate the cost slope of each activity component
5. Shorten the activity period, starting from the critical activity that has the lowest cost slope.
6. If a new critical path is formed in the process of accelerating the project time, then accelerate the critical activities that have the lowest cost slope combination.
7. Continue to shorten the activity time until the point the project is shortened.
8. Make a cost versus time tabulation, draw it on a graph and connect the normal points (normal costs and time), the points formed every time the activity is shortened, up to the SPP points (Shorten Project Points).
9. Calculate the project's indirect costs and draw it on

the graph above.
10. Sum direct and indirect costs to find the total cost before the desired time period.
11. Check on the total cost graph to achieve the optimum time i.e. the period of project completion with the lowest cost.

METHODOLOGY

The flowchart can be seen in Figure 2.

RESULTS AND DISCUSSIONS

A. Project Overview

The general data of the Serayu river bridge construction project are as follows:

1. Project Name :Phase II Construction of Serayu River Bridge
2. Project Location :Banyumas District, Central Java
3. Project Type :Phase II Construction of Serayu River Bridge
4. Contractor :PT. SBPS-AMA-HD KSO
5. Span Length :140 Meters
6. Contract Value :IDR 16.500.000.000
7. Plan Time :150 Calendar Days
8. Scope of Work : Earthwork and geosynthetics, graded pavement, bridge superstructure, bridge safety structure, and bridge approach/oprit structure.

B. Normal Duration

Normal duration is the time required to complete the project, along with the schedule of each activity during implementation. This data was obtained from the project Time Schedule in the form of S Curve diagram.

C. Work Volume

Volume calculation was carried out on each work item based on the WBS that has been made. Volume was obtained by multiplying the length, width, and height according to the working drawings on the project.

D. Productivity and Work Duration

Productivity and duration calculations were carried out on each work item based on the WBS that has been made. Productivity was obtained from the production capacity of labor and heavy equipment for work items. Work duration was obtained from the division between volume and work productivity.

The following is an example of a calculation on the productivity of concrete floor slab formwork fabrication.

Volume = 66.90 m2

Fabrication Time = $\frac{5.5\ hours}{10\ m2}$

(1 working day = 8 hours)

Foreman = 1 x 8 = 8 hours/day

Chief Builder = 1 x 8 = 8 hours/day

Carpenter = 5 x 8 = 40 hours/day

Labor = 5 x 8 = 40 hours/day

Total labor = 96 hours/day

Productivity $=\frac{96\ hours/day}{5{,}5\ hours}\ x\ 10\ m2 =\ 175\ m2/day$

Duration $= \frac{66{,}90\ m2}{175\ m2/day} = 1\ day$

E. Implementation Budget Plan

After obtaining the productivity and duration of each work, the Implementation Budget Plan is calculated. The Implementation Budget Plan is obtained based on the Work Unit Price Analysis (WUPA) on each work.

F. Network Planning

Network planning or diagram is the first step that must be taken in conducting Time Cost Trade Off analysis. In preparing the network diagram, it is necessary to know the relationship between activities and the duration of each activity according to the project schedule or called Normal Duration.

G. Acceleration Scenario

Before calculating crash duration and crash cost, it is first necessary to form a crashing/acceleration scenario for the work on the critical path. This acceleration scenario is carried out based on the resource requirements of each work to get a more optimum duration. Scenario selections are based on work items with a long duration and high cost. The acceleration method to be used is the addition of work shifts and additional labor.

H. Crashing Productivity Analysis

Productivity acceleration is the ability to complete an activity with a certain volume after acceleration. The following is an example of detailed calculations for productivity acceleration:

1. Alternative Work Shift Addition= Normal Productivity x Total Shifts

Example of calculation on Pegalongan Retaining Wall excavation work:

Normal daily productivity = 780 m3/day

Number of normal shifts = 1 shift (afternoon)

Number of additional shifts = 1 shift (night)

Productivity acceleration = 780 x 2

= 1560 m3 / day.

2. Alternative Labor Addition = $\frac{Normal\ daily\ productivity\ x\ Number\ of\ acceleration\ labours}{Number\ of\ normal\ labours}$

Example of calculation on Steel Floor Plate Reinforcement Fabrication work:

Normal daily productivity =24111 pieces/day

Number of normal labor = 12 OH

Additional labor (50%) = 6 OH

Number of acceleration labor = 18 OH

Productivity Acceleration $=\frac{24111\ pieces/day\ x\ 18}{12}$

= 36166 pieces/day

I. Crash Duration Calculation

Once productivity increases, the time required to complete the activity will be faster than before. In the rash duration calculation, the productivity after acceleration will be summed up between the productivity of the first acceleration and the productivity of the second acceleration. Example of the calculation details can be seen as follows:

Crash Duration = Volume / Productivity Acceleration

1. Alternative Work Shift Addition

Work = Pegalongan Retaining Wall Excavation

Volume =1712 m^3

Productivity =1560 m3/day

Crash Duration $=\frac{1712\ m3}{1560\ m3/day}$ = 1 day

2. Alternative Labor Addition

Work =Demolition of Pegalongan Retaining Wall Formwork

Volume =839 m2

Productivity =421 m2/day

Crash Duration $=\frac{839\ m2}{421\ m2/day}$ = 2 day

J. Crash Cost Calculation

Crash cost is the amount of direct cost to complete work after acceleration. In this study, there are two acceleration alternatives used, namely work shifts addition and labor addition, according to the scenario that has been prepared. The following is a detailed example of Crash Cost calculations of each acceleration alternative:

1. Acceleration by adding shifts

a. Work shifts addition

Pegalongan Retaining Wall Reinforcement Fabrication Work

Normal Costs = IDR 587.854.738

Acceleration Duration = 3 days

a) Labor needs (shift 08.00-17.00)

Labor = 5 x IDR 85.000 =IDR 425.000

Builder = 5 x IDR 95.000 =IDR 475.000

Chief Builder = 1 x IDR 100.000 = IDR 100.000

Foreman = 1 x IDR 105.000=IDR 105.000

Total = IDR 1.105,000

b) Labor Needs (shift 19.00-04.00)

Labor = 5 x IDR 85.000 =IDR 425.000

Builder = 5 x IDR 95.000 = IDR 475.000

Chief Builder = 1 x IDR 100.000 = IDR 100.000

Foreman = 1 x IDR 105.000=IDR 105.000

Total = IDR 1.105.000

Crash Cost = Normal Costs + (Additional labor wages x Acceleration duration)

= IDR 587.854.738+ (IDR 1.105.000 x 3)

= IDR 595.617.238

b. Addition of work shifts and heavy equipments

Pegalongan Retaining Wall Excavation Work

Normal Costs = IDR 10.202.500

Acceleration Duration = 2 days

a) Labor Needs (shift 08.00-17.00)

Labor = 2 x IDR 85.000= IDR 170.000

Foreman = 1 x IDR 105.000= IDR 105.000

Excavator = 1 x IDR 4.800.000=IDR 4.800.000

Dumptruck = 1 x IDR 4.200.000=IDR 4.200.000

Total = IDR 9.275.000

b) Labor Needs (shift 19.00-04.00)

Labor = 2 x IDR 85.000= IDR 170.000

Foreman = 1 x IDR 105.000= IDR 105.000

Excavator = 1 x IDR 4.800.000=IDR 4.800.000

Dumptruck = 1 x IDR 4,200,000=IDR 4,200,000

Total = IDR 9.275.000

Crash Cost = Normal Costs + (Additional tool & labor wages x Acceleration duration)

= IDR 10.202.500 + (IDR 9.275.000 x 2)

= IDR 28.752.500

2. Acceleration by adding labor

Demolition of Pegalongan Retaining Wall Formwork

Normal Costs = IDR 2.332.000

Acceleration Duration = 2 days

a) Normal labor needs

Labor = 5 x IDR 85.000 = IDR 425.000

Builder = 5 x IDR 95.000 = IDR 475.000

Chief Builer = 1 x IDR100.000 = IDR 100.000

Foreman = 1 x IDR 105.000=IDR 105.000

Total = IDR 1.105.000

b) Additional labor needs (50%)

Labor = 3 x IDR 85.000 = IDR 425.000

Builder = 3 x IDR 95.000 = IDR 475.000

Chief Builer = 1 x IDR 100.000 = IDR 100.000

Foreman = 1 x IDR 105.000 = IDR 105.000

Total = IDR 745.000

Crash Costs = Normal Costs + (Additional labor wages x Acceleration duration)

= IDR 2.332.000+ (IDR 745.000 x 2)

= IDR 3.792.500

K. Crash Slope Calculation

Cost slope is the addition of direct costs in accelerating an activity per unit of time. In carrying out an acceleration duration, there will be additional costs due to the acceleration duration, where the value of the cost slope depends on the results of the Crash Duration and Crash cost obtained previously.

The greater the crash cost, the greater the cost slope value. The following is an example of Cost Slope calculation for each activity:

$$Cost\ Slope = \frac{Crash\ Cost - Normal\ Cost}{Normal\ Duration - Crash\ Duration}$$

1. Alternative Work Shift Addition

Pegalongan Retaining Wall Reinforcement Fabrication Work

Crash Cost = IDR 595.617.238

Normal Cost = IDR 587.854.738

Crash Duration = 3 days

Normal Duration = 5 days

Cost Slope $=\frac{\text{IDR 595.617.238} - \text{IDR 587.854.738}}{5-3}$

=IDR 3.105.000

2. Alternative Labor Addition

Steel Floor Plate Reinforcement Installation Work

Crash Cost = IDR 7.594.166

Normal Cost = IDR 6.352.500

Crash Duration = 3 days

Normal Duration = 5 days

Cost Slope $=\frac{\text{IDR 7.594.166} - \text{IDR 6.352.500}}{5-3}$

= IDR 745.000

L. Additional Costs

1. Lighting Cost = IDR 2.460.937
2. Electricity Cost = IDR 11.557/day
3. Security = IDR 140.000/day
4. Overtime Management team = IDR 1.293.750/day
5. Additional Consumption = IDR 270.000/day

M. Indirect Cost

1. Management team salary = IDR 2.120.000/day
2. General expenses = IDR 832.000/day
3. Fixed indirect costs = IDR 76.500.000/year

N. Time Cost Trade Off (TCTO) Analysis

1. Alternative Work Shift Compression

From the results of the crashing analysis conducted with the addition of the work shift system, the project can be accelerated or reach the saturation point at the 36th acceleration, with the result that the optimum duration is at the 310th acceleration or 120 working days. The following is the calculation of the total acceleration cost:

a. Direct cost calculation:
 = Normal Direct Cost + Additional Cost +Cost Slope
 = IDR 10.265.231.204 + IDR 51.459.228 + IDR 8.501.920
 = IDR 10.335.532.352
b. Indirect cost calculation:
 = Variable Cost (120 days) + Fixed Cost
 = IDR 354.240.000 + IDR 76.500.000
 = IDR 430.740.000
c. Thus, the total cost:
 = Direct Cost (120 days) + Indirect Cost (120 days)
 = IDR 10.335.532.352+ IDR 430.740.000
 = IDR 10.766.272.352

2. Alternative Labor Addition Compression

From the results of the crashing analysis conducted with the addition of labor, the project can be accelerated or reach a saturation point at the 12th acceleration. With the optimum duration results that occur at the maximum acceleration of 138 working days. The following is the calculation of the total acceleration cost:

a. Direct Cost Calculation:
 = Direct Cost Normal + Cost Slope
 = IDR 10,279,919,717 + IDR 4,348,513
 = IDR 10,271,171,346
b. Indirect cost calculation:
 = Variable Cost (138 days) + Fixed Cost
 = IDR 407.376.000 + IDR 76.500.000
 = IDR 483.876.000
c. Thus, the total cost:
 = Direct Cost (138 days) + Indirect Cost (136 days)
 = IDR 10.271.171.346 + IDR 483.876.000
 = IDR 10.763.795.717

O. Relationship of Time and Cost

1. Alternative Work Shift

After obtaining a recapitulation of the total project cost during acceleration, a time and cost relationship graph is made as shown in Figure 3 and Figure 4.

Efficiency Calculation of Cost and Project Time with Night Shift Addition:

a. Time Efficiency Calculation

$$=\frac{Normal\ Duration - Acceleration\ Duration}{Normal\ Duration} x\ 100\%$$

$$= \frac{150-120}{150} x\ 100\% = 20.00\%$$

b. Cost Efficiency Calculation

$$=\frac{Total\ Normal\ Cost - Total\ Acceleration\ Cost}{Total\ Normal\ Cost} x\ 100\%$$

$$= \frac{\text{IDR } 10.784.531.304 - \text{IDR } 10.766.272.352}{\text{IDR } 10.784{,}531.304} x\ 100\%$$

= 0.26%

2. Alternative Labor Addition

After obtaining a recapitulation of the total project cost during acceleration, a time and cost relationship graph is made as shown in Figure 5 and Figure 6.

Efficiency Calculation of Cost and Project Time with Labor Addition

a. Time Efficiency Calculation

$$= \frac{Normal\ Duration - Acceleration\ Duration}{Normal\ Duration} x\ 100\%$$

$$= \frac{150-138}{150} x\ 100\% = 8.00\%$$

b. Cost Efficiency Calculation

$$= \frac{Total\ Normal\ Cost - Total\ Acceleration\ Cost}{Total\ Normal\ Cost} x\ 100\%$$

$$= \frac{\text{IDR } 10.784.531.204 - \text{IDR } 10.763.795.717}{\text{IDR } 10.784.531.204} x\ 100\%$$

= 0.29%

P. Delay Cost

Next is to compare the amount of fine costs before acceleration with after carried out acceleration:

TD = Delay Duration x 0.001 x Total Contract

a. Before Acceleration
 The 150th day with a delay duration of 30 working days
 TD = 30 x 0.001 x total contract
 = 30 x 0.001 x IDR 16.500.000.000
 = IDR 495.000.000
b. After Acceleration
 a) Alternative Work Shift
 The 120th day with optimum duration without delay.
 b) Alternative Labor Addition
 The 138th day with optimum duration without delay.

CONCLUSIONS

Based on data analysis and discussion of the research results, several conclusions are obtained as follows:

1. Alternative Work Shift Addition:
 a. Duration: Can be crashed up to 36 times to 114 working days with an optimum duration at the 31st acceleration, which is 120 working days or a decrease of 20.00%.
 b. Costs: Required a total cost of IDR 10.766.272.352 or a decrease of 0.26% after crashing (acceleration).
2. Alternative Labor Addition:
 a. Duration: Can be crashed up to 12 times to 138 working days with the optimum duration at the maximum acceleration (12th), which is 138 working days or a decrease of 8.00%.
 b. Costs: Required a total cost of IDR 10.763.795.717 or a decrease of 0.29% after crashing (acceleration).

The cost of accelerating the project duration is cheaper than the cost that must be incurred if the project is delayed and subject to fines.

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