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COST AND TIME EVALUATION WITH TIME COST TRADE OFF (TCTO) METHOD IN TIJ TUNNEL CONSTRUCTION (JOYOBOYO INTERMODA TERMINAL)

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ABSTRACT

Infrastructure development is an important element in supporting the progress of a city, especially in a metropolitan area like Surabaya. One of the strategic projects designed is the construction of a pedestrian tunnel connecting Joyoboyo Intermodal Terminal (TIJ) with Surabaya Zoo (KBS). This research aims to optimize the cost and time of project completion by using Time Cost Trade Off (TCTO) method. This method is used to analyze alternatives to accelerate the project implementation time by considering the impact on cost. Based on the contract, the project is scheduled to be completed within 156 calendar days, starting on May 30, 2024 until November 21, 2024. From the analysis of activities on the critical trajectory and cost slope calculation, it was found that the addition of 1 m² of PHT (one-time use) formwork installation was the most effective acceleration option. This alternative was able to cut the project duration to 145 days with an optimum total cost of Rp14,104,336,624.21. This resulted in a time efficiency of 4.49% and cost savings of Rp55,643,591.83 compared to normal conditions. In conclusion, the TCTO method proved to be effective in assisting decision-making to accelerate project implementation time without incurring significant cost spikes.

Keywords: Cost and Time, Time Cost Trade Off (TCTO), Tunnel

1. INTRODUCTION

A project is a collection of various resources consolidated in a temporary organizational structure in order to realize certain goals. Activities or work in a project can include construction or repair of facilities, as well as research and development activities. Based on this understanding, a project can be categorized as an activity that has a temporary nature (with time limits), is not repetitive, is not carried out routinely, has a clear start and finish time, uses certain resources, and is directed to achieve predetermined goals.(Hudaya et al., 2024)

Infrastructure development is one of the important indicators in supporting city growth, especially in metropolitan areas, such as Surabaya. One of the strategic projects being planned is the construction of a pedestrian tunnel connecting Joyoboyo Intermodal Terminal (TIJ) with Surabaya Zoo (KBS). The project aims to improve the accessibility and convenience of the community in using public facilities as well as supporting the development of the surrounding area.

This research has a formulation of the problem, including what is the ohow to evaluate the results of optimizing the duration and cost of the project after applying the Time Cost Trade Off (TCTO) method. In this study also has problemptimum duration of the project, what is the optimum cost of the project, and restrictions, including this research was conducted on the construction of the Joyoboyo Intermodal Terminal

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Pedestrian Tunnel - Surabaya Zoo, and does not include the calculation of equipment overtime costs.

This research aims to optimize the cost and duration of project completion through a case study of the construction of a pedestrian tunnel connecting Joyoboyo Intermodal Terminal (TIJ) with Surabaya Zoo (KBS). In accordance with the provisions in the contract, the project implementation time is set for 156 calendar days, starting on May 30, 2024 and ending on November 21, 2024. This research was conducted as a cost and time efficiency effort by applying the Time Cost Trade Off (TCTO) method.

With this approach, it is expected that the TIJ tunnel project can be completed within the target time without overburdening the budget. This research is expected to make a real contribution to construction project management, especially in facing a challenge of delay and efficient cost management.

2. LITERATURE REVIEW

Types of Projects

According to (Rantung et al., 2020), in terms of the main activities, various projects can be grouped into:

1. Construction Engineering Project
2. Manufacturing Engineering Project
3. Research and Development Project

Project Delay

Ketidakpastian dalam proyek; Dalam proyek konstruksi atau pengembangan, sering kali terdapat banyak faktor yang dapat menyebabkan keterlambatan, seperti cuaca buruk, keterlambatan pengiriman material, masalah teknis, atau perubahan perencanaan. Ketidakpastian ini dapat menempatkan proyek pada risiko keterlambatan, keputusan strategis, dan keputusan strategis.(Muin, 2023)

Time Cost Trade Off Method (TCTO)

Time Cost Trade Off (TCTO) analysis is an analysis method used to accelerate project completion time through schedule compression, with the aim of producing a more efficient project in terms of time (duration) and cost. The goal of this method is to achieve a project with an acceptable duration and minimize the total cost of the project. Reduction of project duration is done by selecting activities that are on the critical path.(Saragi, 2022)

In the Time Cost Trade Off (TCTO) method analysis, changes in project completion time will affect the costs incurred. If the implementation time is accelerated, the direct costs of the project will increase while the indirect costs of the project will decrease.(Setiawan et al., 2021)

Direct Costs

Direct costs are all expenses that are specifically related to the project activities being implemented. These costs are categorized as normal costs if the work is carried out efficiently within the planned project implementation timeframe. If the project must be completed in a shorter period of time than the normal duration (imposed duration).(Mela, 2019)

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Indirect Costs

Indirect Costs include costs incurred for managing, monitoring, and paying for materials and services used in procuring project components. These components are not part of the permanent equipment or product, but are required to support the project development process.(Nurabidin & Beatrix, 2024)

Additional Working Hours (Overtime)

The addition of working hours (overtime) is often used as an alternative because it allows optimization of the utilization of resources that are already available in the field, and only requires additional cost adjustments that are relatively efficient for the contractor. In general, the normal working duration for labor is 8 hours per day (starting at 08.00 to 16.00, including one hour of rest time), while overtime is carried out after the regular working hours have ended.(Laras Titi Nawang Wulan, Isradinas Mirajhusnita, 2021)

Table 2.1 Decrease in Productivity Index

Overtime Duration	Decreased Productivity Index	Work performance (%)
1 hour	0,1	90
2 hour	0,2	80
3 hour	0,3	70

Source: Hendryani, quoted Endriastuti & Triana, 2024

1. Daily Productivity (DP)

$$DP = \frac{\text{Volume}}{\text{Normal Duration}} \quad (2.1)$$

Dimana:

Volume = The unit volume of each work item

Normal Duration = The time required with a normal level of productivity

2. Hourly Production (HP)

$$HP = \frac{\text{Daily Productivity}}{\text{Working Hours Per day}} \quad (2.2)$$

Where:

Daily Productivity = A measure of how efficiently and effectively a person or team completes a task within a given time.

Working Hours Per Day = The required duration of time to work in one day.

3. *Crash Duration*

$$\textit{Crash Duration} = \frac{\text{Volume}}{\text{Daily productivity after crash}} \quad (2.3)$$

Where:

Work Volume = Unit volume of each item

Daily productivity after crash = Process to speed up project completion by adding working hours.

Crash Cost

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Acceleration costs (crash costs) are direct costs that arise as a consequence of efforts to accelerate the completion of a job. With the acceleration of time, the direct cost for each work item will increase compared to the direct cost in the previous normal condition.(Endriastuti & Triana, 2024)

The calculation formula for determining additional labor costs can be presented as follows:

1. Normal Labor Costs Per Day
   = Daily productivity × Unit price of worker wages (2.4)
2. Normal Hourly Labor Cost
   = Hourly productivity × Unit wage rate of workers (2.5)
3. Worker Overtime Costs
   = 1.5 × normal hourly wage for the first additional working hours (overtime) + 2 × n × normal hourly wage for the next additional working hours (overtime) (2.6)
4. Crash Cost
   = (Working hours per day × Normal cost of workers) + (n × Overtime cost per hour) (2.7)
5. Cost Slope

$$= \frac{Crash\ Cost - Normal\ Cost}{\text{Durasi Normal} - Durasi\ Crash} \tag{2.8}$$

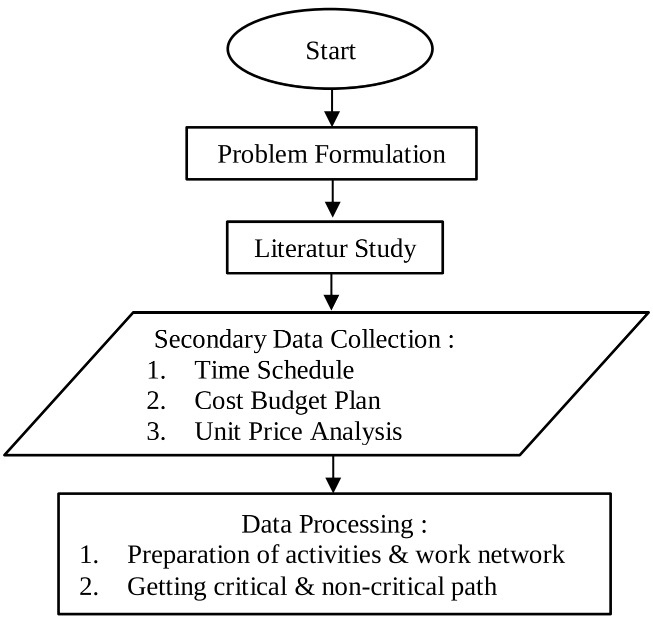
Where:

Crash Cost = Direct costs incurred to complete activities in accelerated time.
Normal Cost = Direct costs incurred to complete activities in normal time
Normal = Time required with normal productivity rate
Crash Duration = Time required with accelerated productivity rate

3. RESEARCH METHODOLOGY

Flowchart

The following is a flow chart of this research as follows:



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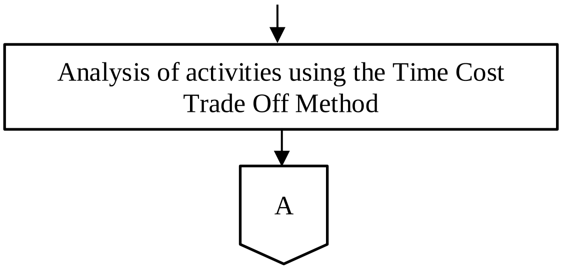

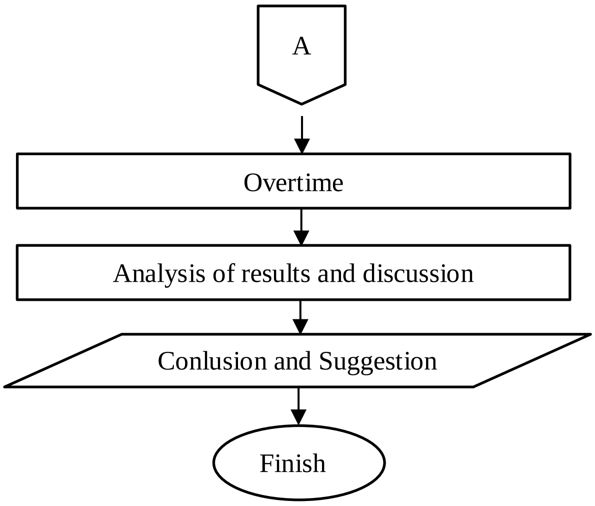

Research Location

This research is a cost and time evaluation using the Time Cost Trade Off (TCTO) method as an acceleration effort so that the project can be completed efficiently in terms of time and cost.

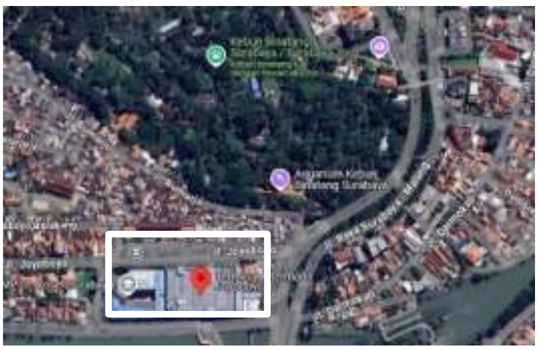

Figure 3.2 Research Location

Data collection

The data required in this Final Project is secondary data obtained from the contractor, including

1. Project Scheduling

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Project scheduling is needed to determine the normal duration in accordance with the project implementation schedule

2. Project Cost Budget
   Cost budget details are used to determine the normal costs made as a reference in calculating acceleration costs. In this study, normal cost data from the Bill of Quantity (BoQ) of each job is used.
3. Supporting Data
   Other supporting data is needed so that the analysis carried out can be more accurate. The supporting data required include: interviews with related parties, Basic Unit Prices of Activities, and others.

Data processing

The steps taken in processing this research data are as follows:

1. Preparation of Work Network
   Activities were grouped based on the main work items from the project schedule and Budget Plan (RAB). Dependencies and durations were identified using project progress reports, enabling the determination of normal time and cost for each activity. Critical path activities served as the basis for time and cost acceleration analysis. The work network was then developed using Microsoft Project to efficiently perform scheduling calculations and generate the project network diagram..
2. Determining Critical and Non-Critical Paths
   The work network diagram was developed based on the project time schedule to identify the critical path. By inputting activity durations and relationships into the system, a precedence diagram was generated, showing ES, EF, LS, and LF times. This allowed the identification of the critical path through analysis of total float values, which then served as the basis for time and cost acceleration.

Analysis using the Time Cost Trade Off (TCTO) Method

The following are the stages in the analysis using the TCTO method:

1. Developing an Acceleration Scenario (Crashing)
   The first step is to determine the acceleration alternative that will be applied, namely through the addition of working hours (overtime) for 1 hour, 2 hours, and 3 hours per day, respectively.
2. Determine the Duration and Cost of Acceleration (Crash Duration and Crash Cost)
   After that, the productivity under accelerated conditions is calculated. This productivity value varies depending on the choice of acceleration scenario used. Crash duration is calculated by dividing the work volume by the crashing productivity value obtained.
3. Calculating Cost Slope Value
   Cost slope is the ratio between additional cost and reduction in project completion time due to acceleration. The greater the crash cost value, the higher the cost

slope, and vice versa.

4. Iteration Process
   Compression is carried out on activities that are on the critical path by selecting the work that has the lowest cost slope value. Then, reschedule all activities based on the new duration after acceleration.
5. Evaluation of TCTO Analysis Results
   After the Time Cost Trade Off (TCTO) analysis is carried out, several new alternative project times and costs will be obtained. From the overtime alternatives of 1 hour, 2 hours, and 3 hours, the most optimal activity will be selected based on the combination of time and cost of project completion.

4. ANALYSIS AND DISCUSSION

Critical Path Job List

The following are details of the critical activities that will be examined in this study:

Table 4.1 Critical Path Job List

No.	Work Items	Volume	Duration (hour)
1	Concrete Fc'35 Mpa	34,36	36
2	S13 Threaded Reinforcement Iron	2.705,83	30
3	Installation of 1 m2 of Formwork for PHT (1 time use)	16,78	36
4	Concrete Raft Foundation 60 cm Fc'35 MPa (PC 450)	646,48	36
5	Concrete Wall Concrete 60 cm thick Fc'35 MPa (PC 450)	524,82	54
6	Concrete Plate 60 cm thick Fc'35 Mpa (PC 450)	548,30	36
7	Voute Concrete Plate 20 cm thick Fc'35 MPa (PC 450)	29,08	24

Source: Researcher's Processed Results, 2025

Calculating Crash Duration

Crash Duration is the time required to complete a job after additional working hours (overtime). In finding crash duration, the daily productivity, hourly productivity, and daily productivity after acceleration must be calculated.

The following is an example of the calculation of crash duration on an Fc'35 Mpa concrete work item with an alternative of adding overtime duration of 1 hour, 2 hours, and 3 working hours.

Concrete Work Item Fc’35 Mpa Alternative crashing overtime 1 hour:

Volume	= 34,36 m3
Normal Duration	= 36 day
Normal Duration (hour)	= 288 hour

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Normal Productivity (day)	= Volume / Normal Duration (day)
	= 34,36 / 36
	= 0,954 m3/day
Normal Productivity (hour)	= Volume / Normal Duration (hour)
	= 34,36 / 288
	= 0,119 m3/hour
Crash Duration	= Volume / ((Prod.Normal (days) + (overtime duration x Prod. Normal (hours) x productivity coefficient))
	= 34,36/(0,954+(1 x 0,119 x 0,9))
	= 32,36 days
Then the Maximum Acceleration	= Normal Duration – *Crash Duration*
	= 36-32,36
	= 3,64 = 4 days

Concrete Work Item Fc'35 Mpa
Alternative crashing overtime 2 hour:

Volume	= 34,36 m3
Normal Duration	= 36 day
Normal Duration (hour)	= 288 hour
Normal Productivity (day)	= Volume / Normal Duration (day)
	= 34,36 / 36
	= 0,954 m3/day
Normal Productivity (hour)	= Volume / Normal Duration(hour)
	= 34,36 / 288
	= 0,119 m3/hour
Crash Duration	= Volume / ((Prod.Normal (days) + (overtime duration x Prod. Normal (hours) x productivity coefficient))
	= 34,36/(0,954+(2 x 0,119 x 0,8))
	= 30 day
Then the Maximum Acceleration	= Normal Duration – Crash Duration
	= 36-30
	= 6 day

Concrete Work Item Fc'35 Mpa
Alternative crashing overtime 3 hour:

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Volume	= 34,36 m3
Normal Duration	= 36 day
Normal Duration (hour)	= 288 hour
Normal Productivity (day)	= Volume / Normal Duration (day)
	= 34,36 / 36
	= 0,954 m3/day
Normal Productivity (hour)	= Volume / Normal Duration (hour)
	= 34,36 / 288
	= 0,119 m3/hour
Crash Duration	= Volume / ((Prod.Normal (days) + (overtime duration x Prod. Normal (hours) x productivity coefficient))
	= 34,36/(0,954+(3 x 0,119 x 0,7))
	= 28,51 day
Then the Maximum Acceleration	= Normal Duration – Crash Duration
	= 36 – 28,51
	= 7,49 = 7 day

Based on the previous example of calculating the duration of acceleration (Crash Duration) on concrete work Fc'35 MPa, the results show that with the addition of working time (overtime) for 1, 2, and 3 hours, the maximum acceleration that can be achieved is 4 days, 6 days, and 7 days, respectively.

For the calculation of crash duration of other work items can be seen in Table 4.2 below:

Table 4.2 Recapitulation of Overtime Alternative Crashing

No.	**Duration (day)**	***Crash Duration* (day)**			***Crashing* (day)**		
		1 hour	2 hour	3 hour	1 hour	2 hour	3 hour
1	36	32,36	30,00	28,51	3,64	6,00	7,49
2	30	26,97	25,00	23,76	3,03	5,00	6,24
3	36	32,36	30,00	28,51	3,64	6,00	7,49
4	36	32,36	30,00	28,51	3,64	6,00	7,49
5	54	48,54	45,00	42,77	5,46	9,00	11,23
6	36	32,36	30,00	28,51	3,64	6,00	7,49
7	24	21,57	20,00	19,01	2,43	4,00	4,99

Source: Researcher's Processed Results, 2025

Calculating Crash Cost

Crash Cost is a direct cost arising from the acceleration of the implementation of a job. With acceleration, the direct cost for each work item will automatically be higher than the previous normal cost. In this study, based on the cost budget plan data from the project, the labor component is included in the labor cost category. Labor costs include

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all expenses related to the payment of workers or staff involved in carrying out work on the project. Therefore, in calculating overtime costs for each work item, this study uses labor costs, not based on the unit price of wages.

Example of calculating overtime costs required in 1 day for Fc'35 Mpa concrete work in tunnel structure work with a duration of 1 hour, 2 hours, and 3 hours:

Daily labor costs	= Rp 4.593.588
Hourly labor costs	= Labor cost per day/hour of work = Rp 4.593.588/8 = Rp 574.199
1 hour overtime fee	= Labor cost per hour x 1.5 = Rp 574.199 x 1,5 = Rp 861.298
2 hour overtime fee	= (Labor cost per hour x 1.5) + (Labor cost per hour x 2) = (Rp 861.298) + (Rp 574.199 x 2) = Rp 2.009.695
3 hour overtime fee	= (Labor cost per hour x 1.5) + (Labor cost per hour x 2 x 2) = (Rp 861.298) + (Rp 574.199 x 2 x 2) = Rp 3.158.092
Normal Duration	= Rp 47.162.871
1 hour Expediting Fee	= Normal fee + 1 hour overtime fee = Rp 47.162.871 + Rp 861.298 = Rp 48.024.169
2 hour Expediting Fee	= Normal rate + 2 hours overtime rate = Rp 47.162.871 + Rp 2.009.695 = Rp 49.172.566
3 hour Expediting Fee	= Normal rate + 3 hours overtime rate = Rp 47.162.871 + Rp 3.158.092 = Rp 50.320.963

From the above calculation example, it is obtained for overtime costs per day for a duration of 1 hour, 2 hours, and 3 hours, namely the hourly labor cost multiplied by 1.5 for the first 1 hour, then for the next 2 hours the hourly labor cost multiplied by 2 multiplied by 2 hours.

The normal cost for concrete work fc'35 Mpa is Rp. 47,162,87 then added to the total cost of overtime results in an acceleration cost of 1 hour of Rp. 48,024,169, 2 hours of Rp. 49,172,566 and 3 hours of Rp. 50,320,963. The results of the acceleration cost calculation for other work items can be seen in Table 4.3

Table 4.3 Summary of Acceleration Costs

No	Normal Duratio n (Rp)	Total Overtime Costs (Rp)			Acceleration Fees (Rp)		
		1 hour	2 hour	3 hour	1 hour	2 hour	3 hour
1	47.162.871	861.298	2.009.695	3.158.092	48.024.169	49.172.566	50.320.963
2	38.963.880	347.429	810.667	1.273.905	39.311.309	39.774.547	40.237.785
3	3.897.761	617.835	1.441.616	2.265.396	4.515.596	5.339.377	6.163.157

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4	2.404.403.655	16.205.233	37.812.211	59.419.189	2.420.608.888	2.442.215.866	2.463.822.844
5	3.930.121.720	13.155.597	30.696.394	48.237.190	3.943.277.317	3.960.818.114	3.978.358.910
6	2.121.343.434	13.744.168	32.069.724	50.395.281	2.135.087.602	2.153.413.158	2.171.738.715
7	310.433.420	728.945	1.700.871	2.672.797	311.162.365	312.134.291	313.106.217

Source: Researcher's Processed Results, 2025

Calculating Cost Slope Value

Cost slope is the ratio between the increase in cost and the reduction in project time duration due to acceleration. The increase in cost is in line with the magnitude of the crash cost. The higher the crash cost value, the greater the cost slope value, and vice versa. The following is an example of cost slope calculation for Fc'35 Mpa concrete work in tunnel structure work with maximum acceleration duration.

Cost Slope calculation for Fc'35 Mpa Concrete work in 1 hour overtime:

Cost Slope/day = ((acceleration cost-normal cost)/(normal duration-crash duration))
= ((Rp 48.024.169 – Rp 47.162.871) / (36 –32,36))
= Rp 236.591,07

Cost Slope calculation for Fc'35 Mpa Concrete work in 2 hour overtime:

Cost Slope/day = ((acceleration cost-normal cost)/(normal duration- crash duration))
= ((Rp49.172.565,93 - Rp 47.162.871) / (36 – 30))
= Rp 334.949,15

Cost Slope calculation for Fc'35 Mpa Concrete work in 3 hour overtime:

Cost Slope/day = ((acceleration cost-normal cost)/(normal duration- crash duration))
= ((Rp50.320.963,03 - Rp 47.162.871) / (36 – 28,51))
= Rp 421.914,41

Based on the example calculation above for concrete work with quality fc'35 MPa, the cost slope value per day (additional cost due to acceleration) is Rp 236,591.07 for 1 hour overtime, Rp 334,949.15 for 2 hours overtime, and Rp 421,914.41 for 3 hours overtime, respectively.

Furthermore, the cost slope values for other Tunnel Structure work items can be seen in Table 4.4.

Table 4.4 Cost Slope Recapitulation

No.	Cost Slope Value (Rp)		
	1 hour	2 hour	3 hour
1	236.591,07	334.949,15	421.914,41
2	114.522,75	162.133,33	204.229,18
3	169.714,05	240.269,32	302.652,18
4	4.451.437,56	6.302.035,19	7.938.277,89
5	2.409.152,60	3.410.710,42	4.296.257,68
6	3.775.404,05	5.344.954,05	6.732.702,89
7	300.352,22	425.217,76	535.620,10

Source: Researcher's Processed Results, 2025

Compression Against Cost and Time

After identifying the activities that are on the critical trajectory, the project duration is accelerated starting from the work that has the lowest cost slope value. This step aims to obtain the fastest completion time with the minimum total cost possible.

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Table 4.5 Job Sequence according to Lowest Cost Slope

Stage	Lowest Cost Slope Job Order	***Cost Slope* (Rp)**		
		1 hour	2 hour	3 hour
1	S13 Threaded Reinforcement Iron	114.522,75	162.133,33	204.229,18
2	Installation of 1 m2 of Formwork for PHT (1 time use)	169.714,05	240.269,32	302.652,18
3	Concrete Fc'35 Mpa	236.591,07	334.949,15	421.914,41
4	Voute Concrete Plate 20 cm thick Fc'35 MPa (PC 450)	300.352,22	425.217,76	535.620,10
5	Concrete Wall Concrete 60 cm thick Fc'35 MPa (PC 450)	2.409.152,60	3.410.710,4	4.296.257,7
6	Concrete Plate 60 cm thick Fc'35 Mpa (PC 450)	3.775.404,05	5.344.954,1	6.732.702,9
7	Concrete Raft Foundation 60 cm Fc'35 MPa (PC 450)	4.451.437,56	6.302.035,2	7.938.277,9

Source: Researcher's Processed Results, 2025

The following is an example of acceleration calculation with the optimal alternative of adding working hours (overtime) and maximum acceleration duration:

Normal Condition

Normal Duration = 156 Days

Direct Costs = Rp 12.872.709.287,34

Indirect Costs = Rp 1.287.270.928,70

Total Normal Cost = Rp 12.872.709.287,34 + Rp 1.287.270.928,70
= Rp 14.159.980.216,04

The calculation of indirect costs is obtained from overhead costs of 5%, and profit of 5%. The calculation of indirect costs in this study is based on overhead costs of 5% and profit of 5%. Both components are accumulated from the direct costs of the analyzed work, especially the tunnel structure work included in the critical trajectory. This information refers to the journal excerpt entitled “Comparison of Work Acceleration Methods on Direct Costs and Indirect Costs” by (Desembardi et al., 2024)

Compression calculation for fc’35 Mpa concrete work with 1 hour overtime:

Cost Slope/day = Rp 236.591,07

Normal Duration = 36 Days

Accelerated Duration = 32,36 = 32 day

Total Acceleration = Normal Duration – Crash Duration
= 36 – 32,36
= 3,64 = 4 day

Total Project Duration = Normal Duration – Crash Duration
= 156 – 4
= 152 Day

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Additional Fees	= Cost Slope x Total Acceleration
	= Rp 236.591,07 x 4
	= Rp 946.364,28
Direct Costs after Acceleration	= Normal Direct Cost + Additional Cost
	= Rp 12.872.709.287,34 + Rp 946.364,28
	= Rp 12.873.655.651,62
Indirect Costs after Acceleration	= (Normal Indirect Costs / Normal Duration) x Total Project Duration
	= (Rp 1.287.270.928,70 /156) x 152
	= Rp 1.254.263.981,81
Total cost	= Rp 12.873.655.651,62 + Rp 1.254.263.981,81
	= Rp 14.127.919.633,43

Compression calculation for fc'35 Mpa concrete work with 2 hour overtime:

Cost Slope/day	= Rp 334.949,15
Normal Duration	= 36 Days
Accelerated Duration	= 30 Days
Total Acceleration	= Normal Duration – Crash Duration
	= 36 – 30
	= 6 Days
Total Project Duration	= Normal Duration – Crash Duration
	= 156 – 6
	= 150 Days
Additional Fees	= Cost Slope x Total Acceleration
	= Rp 334.949,15 x 6
	= Rp 2.009.694,93
Direct Costs after Acceleration	= Normal Direct Cost + Additional Cost
	= Rp 12.872.709.287,34 + Rp 2.009.694,93
	= Rp 12.874.718.982,27
Indirect Costs after Acceleration	= (Normal Indirect Costs / Normal Duration) x Total Project Duration
	= (Rp 1.287.270.928,70 /156) x 150
	= Rp 1.237.760.508,37
Total cost	= Rp 12.874.718.982,27 + Rp 1.237.760.508,37
	= Rp 14.112.479.490,63

Compression calculation for fc'35 Mpa concrete work with 3 hour overtime::

Cost Slope/day	= Rp 421.914,41
Normal Duration	= 36 day
Accelerated Duration	= 28,51
	= 29 day

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Total Acceleration	= Normal Duration – Crash Duration = 36 – 29 = 7 day
Total Project Duration	= Normal Duration – Crash Duration = 156 – 7 = 149 day
Additional Fees	= Cost Slope x Total Acceleration = Rp 421.914,41 x 7 = Rp 2.953.400,88
Direct Costs afterAcceleration	= Normal Direct Cost + Additional Cost = Rp 12.872.709.287,34 + Rp 2.953.400,88 = Rp 12.875.662.688,22
Indirect Costs after Acceleration	= (Normal Indirect Costs / Normal Duration) x Total Project Duration = (Rp 1.287.270.928,70 /156) x 149 = Rp 1.229.508.771,64
Total cost	= Rp 12.875.662.688,22 + Rp 1.229.508.771,64 = Rp 14.105.171.459,86

Thus compression is done until all work in the tunnel structure work gets optimum cost and time. The results of compression (emphasis) on time and cost can be seen in table 7 below.

Table 4.6 Recapitulation of Direct Costs, Indirect Costs, and Total Costs

Work Items	Duration	Direct Costs (Rp)	Indirect Costs (Rp)	Total cost (Rp)
1 Hour				
S13 Threaded Reinforcement Iron	153	12.873.052.855,59	1.262.515.718,53	14.135.568.574,13
Installation of 1 m2 of Formwork for PHT (1 time use)	152	12.873.388.143,53	1.254.263.981,81	14.127.652.125,34
Concrete Fc'35 Mpa	152	12.873.655.651,6	1.254.263.981,8	14.127.919.633,4
Voute Concrete Plate 20 cm thick Fc'35 MPa (PC 450)	154	12.873.309.991,79	1.270.767.455,26	14.144.077.447,04
Concrete Wall Concrete 60 cm thick Fc'35 MPa (PC 450)	151	12.884.755.050,33	1.246.012.245,09	14.130.767.295,42

Source: Researcher's Processed Results, 2025

Concrete Plate 60 cm thick Fc'35 Mpa (PC 450)	152	12.887.810.903,55	1.254.263.981,81	14.142.074.885,36
Concrete Raft Foundation 60 cm Fc'35 MPa (PC 450)	152	12.890.515.037,56	1.254.263.981,81	14.144.779.019,37
2 Hour				
S13 Threaded Reinforcement Iron	151	12.873.519.954,01	1.246.012.245,09	14.119.532.199,10
Installation of 1 m2 of Formwork for PHT (1 time use)	150	12.874.150.903,29	1.237.760.508,37	14.111.911.411,65
Concrete Fc'35 Mpa	150	12.874.718.982,27	1.237.760.508,37	14.112.479.490,63
Voute Concrete Plate 20 cm thick Fc'35 MPa (PC 450)	152	12.874.410.158,37	1.254.263.981,81	14.128.674.140,18

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Table 4.6 Recapitulation of Direct Costs, Indirect Costs, and Total Costs

Work Items	Duration	Direct Costs (Rp)	Indirect Costs (Rp)	Total cost (Rp)
Concrete WallConcrete 60 cm thickFc'35 MPa (PC 450)	147	12.903.405.681,13	1.213.005.298,20	14.116.410.979,33
Concrete Plate 60 cm thick Fc'35 Mpa (PC 450)	150	12.904.779.011,65	1.237.760.508,37	14.142.539.520,02
Concrete Raft Foundation 60 cm Fc'35 MPa (PC 450)	150	12.910.521.498,49	1.237.760.508,37	14.148.282.006,86
3 Hour				
S13 Threaded Reinforcement Iron	150	12.873.934.662,40	1.237.760.508,37	14.111.695.170,76
Installation of 1 m2 of Formwork for PHT (1 time use)	149	12.874.827.852,57	1.229.508.771,64	14.104.336.624,21
Concrete Fc'35 Mpa	149	12.875.662.688,22	1.229.508.771,64	14.105.171.459,86
Voute Concrete Plate 20 cm thick Fc'35 MPa (PC 450)	151	12.875.387.387,83	1.246.012.245,09	14.121.399.632,92
Concrete Wall Concrete 60 cm thick Fc'35 MPa (PC 450)	145	12.919.968.121,87	1.196.501.824,75	14.116.469.946,62
Concrete Plate 60 cm thick Fc'35 Mpa (PC 450)	149	12.919.838.207,59	1.229.508.771,64	14.149.346.979,24
Concrete Raft Foundation 60 cm Fc'35 MPa (PC 450)	149	12.928.277.232,56	1.229.508.771,64	14.157.786.004,20

Source: Researcher's Processed Results, 2025

5. CONCLUSION AND SUGGESTIONS

Conclusion

Based on the results of the analysis of cost efficiency and duration of project implementation by applying the Time Cost Trade Off (TCTO) method to the construction of the Pedestrian Tunnel connecting the Joyoboyo Intermodal Terminal and the Surabaya Zoo, several conclusions can be drawn as follows:

1. The most optimal acceleration was achieved in the installation of 1 m² Formwork for PHT (single-use), where the best result occurred with 3 hours of daily overtime, reducing the project duration to 149 days. This alternative shortens the project by 7 days compared to the normal schedule, resulting in a time efficiency of 4.49%.
2. The most cost-efficient acceleration was also found in the installation of 1 m² Formwork for PHT (single-use), with the lowest total cost of Rp14,104,336,624.21 achieved by applying 3 hours of daily overtime. This alternative saves Rp55,643,591.83 compared to the normal cost, resulting in a cost efficiency of 0.39%.

Suggestions

Based on the results of the discussion analysis, the advice that can be given to future researchers is to include the calculation of equipment overtime costs so that the results of the calculation of the total cost of acceleration become more accurate and realistic.

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