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Analysis of Project Implementation Costs Using the Crashing Method in The Improvement of The Andongrejo-Bandialet Road, Jember District

Lukman Ardianto, Esti Wulandari, Budi Witjaksana
University of August 17, 1945 Surabaya, Indonesia
Email: lukman040998@gmail.com, wulandariesti@untag-sby.ac.id, budiwitjaksana@untag-sby.ac.id

ABSTRACT

Construction project control is a systematic process aimed at ensuring that project objectives align with planning standards. One method used to accelerate project duration is "crashing," which involves reducing the time of specific activities that affect project completion, focusing particularly on activities on the critical path. This research adopts a descriptive method to collect and analyze data on the status of current symptoms related to project time management. Data collection was conducted through documentation, utilizing records, images, and work outputs. The results show that total project costs decrease significantly as the level of time compression (reduction of project duration) increases. However, increasing labor costs exhibits a small but consistent rise, indicating lower cost efficiency. The most optimal project costs were observed when additional working time was utilized, as opposed to adding more labor. In conclusion, while the crashing method is effective for reducing the risk of fines and indirect costs, selecting the best alternative requires balancing productivity and marginal costs (cost-time trade-off). For similar projects, extending working hours proves more cost-effective than increasing workforce size.

Keywords: crashing method; cost-time trade-off; construction project control

INTRODUCTION

Construction project control is a systematic activity or effort to determine standards in accordance with planning objectives, compare implementation with planning, analyze possible deviations between implementation and planning, and make necessary corrections so that costs, resources, and time can be used effectively and efficiently to achieve the desired construction project objectives. With effective control, construction project deviations can be reduced and potential losses can also be minimized (Aljohani & Alsharif, 2021).

The implementation of the *Andongrejo–Bandialet Jember Regency Road Improvement* project was carried out by PT. Rajendra Pratama Jaya as the implementing contractor, with a contract value of Rp 14,050,000,000 (fourteen billion fifty million rupiah) and an implementation period of 181 days. During the execution of the *Andongrejo–Bandialet Jember Regency Road Improvement* project, there were obstacles due to weather conditions and other technical issues, which affected both the time performance and cost performance of PT. Rajendra Pratama Jaya as the implementing contractor.

Time and cost greatly influence the success or failure of a project. The benchmark for project success is typically determined by a short completion time with minimal costs, without compromising the quality of the work. Systematic project management is essential to ensure that the incurred costs can yield the expected benefits, while also avoiding penalties due to project delays. This study aims to control the delays in time and costs incurred in the reconstruction/improvement of the *Andongrejo–Bandialet Jember* road structure by applying the crashing method, with the goal of obtaining the optimum duration and cost for the accelerated work schedule.

In preparing a construction project schedule, an ideal schedule is usually not produced immediately. One of the goals of schedule preparation is to create a realistic timeline based on reasonable estimates. The schedule produced must also be easily modifiable to achieve its main objective—ensuring that the duration of activities aligns with the time set by the project owner (Ervianto, 2024). One way to shorten the project duration, in foreign terminology, is *crashing*. The *crashing* process refers to deliberately reducing the duration of an activity, which will directly affect the project completion time (Kerzner, 2017; Kumar & Kumar, 2019; Mokhtar & Kamaruddin, 2020). It is a deliberate, systematic, and analytical process that focuses on activities on the critical path. The *crashing* process involves estimating variable costs to determine the maximum and most economical possible reduction in the duration of an activity. While this process may appear straightforward, in practice, it is highly complex. There are various ways to shorten the duration of a project, with many combinations of activity durations and costs that must be carefully analyzed in detail (Baker & Murphy, 2016).

To further analyze the relationship between the cost and time of an activity, several terms are used, namely: normal duration (ND), shortened duration (CD), normal cost (NC), and cost for shortened time (CC). The following is a graph illustrating the relationship between normal and shortened time–cost for an activity (Cheng & Li, 2015).

Research by Ervianto (2020) introduced the *crashing* method as an approach to reduce the duration of construction projects by focusing on critical path activities (Zhang & Fan, 2018; Zou & Zhang, 2015). While that study explored the theoretical aspects of *crashing*, it did not take into account the impact of external factors such as weather conditions or unforeseen technical challenges on time and cost performance (Hwang & Ng, 2013). This study addresses this gap by applying the *crashing* method to the *Andongrejo–Bandialet Jember Regency Road Improvement* project, where external challenges significantly affected both time and cost. By focusing on a real-world case study, this research provides practical insights into implementing *crashing* in the presence of such challenges, enhancing the method's applicability in real-life situations (Morris & Pinto, 2010; Sadeghi & Khosravi, 2018).

Additionally, Saleh and Ratmono (2021) highlighted the need for flexible and adaptive scheduling in construction projects; however, their research did not address how projects can effectively integrate external disruptions such as weather and technical issues into the cost–time trade-off process. This study fills that gap by applying the *crashing* method to the above-mentioned project, which experienced delays, thereby offering solutions for optimizing project duration and costs even when unexpected challenges arise.

The objective of this study is to analyze the application of the *crashing* method to control delays in the *Andongrejo–Bandialet Jember Regency Road Improvement* project, with the aim of optimizing both time and cost. The value of this research lies in presenting a real-world case study for applying the *crashing* method, offering valuable insights for future projects faced with similar challenges. Furthermore, it contributes to the field of construction project management by demonstrating strategies to manage delays and external disruptions while minimizing costs and maintaining project efficiency.

METHOD

This research adopts a descriptive method to collect and analyze data on the status of current conditions related to project time management. The scope of this study is limited to the *Andongrejo–Bandialet Road Improvement* project in Jember Regency. The required project data includes the *Time Schedule*, *Quality and Price List* (*DKDH*), as well as weekly and daily project reports. The study was conducted over a period of 30 days (4 weeks), including the phases of data collection and data processing. The research method provides an overview of the research design, which includes, among others: the procedures and steps to be taken, the research timeframe, the sources of data, and the processes by which the data is obtained, processed, and analyzed.

There are several types of research methods, namely: historical methods, descriptive methods, correlational methods, experimental methods, and quasi-experimental methods. This study falls under the descriptive research method, which is used to collect information about the status of existing conditions — that is, to describe or analyze phenomena as they are at the time the research is conducted and to present or interpret the results accordingly.

The steps of the data analysis techniques applied in this study are as follows:

1. Calculating the delay.
2. Establishing relationships between activities.
3. Creating a network diagram using *Microsoft Project 2016* to determine the critical path.
4. Calculating normal daily productivity.
5. Calculating crash duration, crash cost, and cost slope.
6. Performing *crashing* on critical path activities that experience delays, starting from those with the smallest cost slope.

Following the *crashing* process, the resulting output is an accelerated project duration along with the adjusted project cost.

RESULTS AND DISCUSSION

Project Cost

In the implementation of construction projects, project costs consist of several main components that are grouped into direct costs and indirect costs. This grouping is important to provide a comprehensive picture of budget allocation and to analyze the efficiency of project implementation, especially in relation to cost and time control (Kerzner, 2017; Kumar & Kumar, 2019; Mokhtar & Kamaruddin, 2020).

Direct Costs

Direct costs are all costs that are directly related to the physical activities of the project. These costs include the following elements:

1. Direct Labor Costs: Wages of day laborers, foremen, heavy equipment operators, and other skilled workers involved in the direct execution of construction work.
2. Material and Building Material Costs: Costs of purchasing materials such as asphalt, concrete, sand, gravel, cement, reinforcing steel, and other construction materials.
3. Equipment and Equipment Rental Costs: Includes the use and mobilization of heavy equipment such as excavators, graders, and compactors.

4. Material Transportation Costs: Transportation of building materials from the storage location to the job site.
5. Cost of Implementation of Each Work Item: Refers to the Cost Budget Plan (RAB) structure for each volume and unit price.

    In the Andongrejo – Bandialet Road Improvement project, direct costs are the largest component of the total project cost. This is due to the large amount of physical work involving excavation, paving, and repair of road structures, which intensively require labor, materials, and heavy equipment.

Indirect Costs

Indirect costs include costs that are not directly involved in the physical implementation of the project, but are still needed to support the smooth operation of the project. These costs include:

1. Project Administration Costs: Administrative staff salaries, stationery, field office rent, and documentation costs.
2. General and Overhead Costs: Includes project utilities (electricity, water), communications, and project management costs by the implementing contractor.
3. Consultant and Supervision Fees: Honorarium for the supervisory team or supervisory consultant who monitors the quality and progress of the project.
4. Occupational Safety and Security Costs: Includes personal protective equipment (PPE), K3 training, and security at the project site.

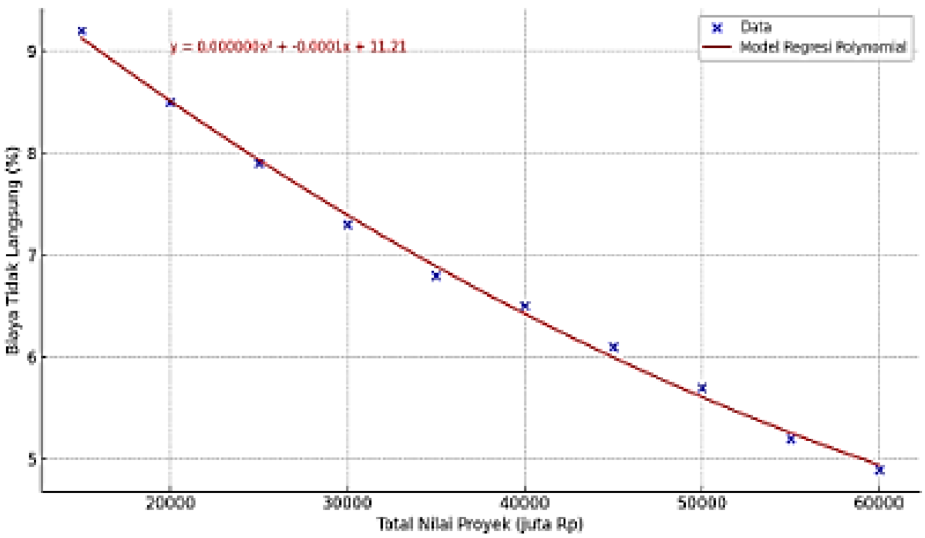

Figure 1. Model of the Relationship between Indirect Costs and Total Project Value
(Source: Research Results 2025)

Based on the graph of the relationship between the total project value and the percentage of indirect costs, it can be concluded that the greater the project value, the percentage of indirect costs tends to decrease. This indicates the existence of scale efficiency in the implementation of large projects, where fixed costs such as administration and project management do not increase proportionally to the total project value. Thus, direct costs become the main and dominant component in the overall cost structure, reflecting that most of the project budget is allocated directly to physical development activities.

Cost Slope Calculation

In project acceleration planning, an analysis of the additional costs required to reduce the duration of completion of an activity is required. The method used to calculate the amount of additional costs is Cost Slope. Cost Slope is the amount of additional direct costs per unit of time required to accelerate the duration of a particular activity. By knowing the Cost Slope value of each activity, the most efficient activities can be selected to be accelerated in terms of cost.

1. Manpower Increase

   The Cost Slope calculation for additional manpower can be seen in the following description:

   a. Work: Widening of Pavement and Road Shoulder

      1) Class S Aggregate Foundation Layer

         a) Volume = 1200,00 m³
         b) Normal duration = 21 days
         c) Unit cost of material per m³ = Rp. 528,829.56
         d) Unit cost of wages per m³ = Rp. 727.25
         e) Daily productivity = 57,143 m³/day
         f) Number of workers required = 3 people/day
         g) Normal wage costs
            = Volume × unit cost of wages per m³
            = 1200.00 m³ × Rp. 727.25
            = Rp. 872,702.12
         h) Cost of wages and materials
            = Normal wage cost + (Volume × unit cost of material per m³)
            = Rp. 872,702.12 + (1200 × Rp. 528,829.56)
            = Rp. 635,468,177.45
         i) Daily fee
            = Normal wage cost / Normal duration
            = Rp. 872,702.12 / 21
            = Rp. 41,557.24
         j) Cost per worker
            = Daily cost / Number of workers
            = Rp. 41,557.24 / 3
            = Rp. 13,852.41
         k) Daily Productivity per Worker
            = Daily productivity / Number of workers
            = 57,143 m³/day / 3
            = 19.05 m³/person/day
         l) Daily Productivity Crash (after adding 1 worker)
            = 19.05 × (3 + 1) = 76.19 m³/day
         m) Crash Duration
            = Volume / Productivity crash
            = 1200 / 76.19 ≈ 15.75 days (rounded up: 16 days)
         n) Additional cost

= Cost per worker × Additional workers
= Rp. 13,852.41 × 1
= Rp. 13,852.41

o) Crash Cost Wages
= (Daily fee + additional fee) × Crash duration
= (Rp. 41,557.24 + Rp. 13,852.41) × 16
= Rp. 55,409.65 × 16
= Rp. 886,554.4

p) Crash Cost of Wages and Materials
= Crash cost wages + (Volume × Unit cost of material per m^3)
= Rp. 886,554.4 + (1200 × Rp. 528,829.56)
= Rp. 886,554.4 + Rp. 634,595,472
= Rp. 635,482,026.4

q) Cost Slope
= (Crash cost – Normal cost) / (Normal duration – Crash duration)
= (Rp. 635,482,026.4 – Rp. 635,468,177.45) / (21 – 16)
= Rp. 13,848.95 / 5
= Rp. 2,769.79 per day

For :
Normal duration = 21 days
Normal cost = Rp. 635.468.177,45
Crash duration = 16 days
Crash cost = Rp. 635.482.026,4

Table 1. Cost Slope Calculation for Each Activity

No	Job description	Volume	Normal Duration (days)	Crash Duration (days)	Normal Fee (Rp)	Crash Cost (Rp)	Cost Slope (Rp/day)
1	Preparatory work	1,00 LS	4	3	10.000.000	12.000.000	1.000.000
2	Mobilization and Demobilization of Heavy Equipment	1,00 LS	4	3	15.000.000	18.000.000	1.500.000
3	Land Clearing	4.000 m^2	28	22	60.000.000	70.000.000	1.666.667
4	Measurement	1,00 LS	4	3	8.000.000	9.500.000	1.500.000
5	Keet Board of Directors	1,00 LS	4	3	12.000.000	13.500.000	1.500.000
6	Material Warehouse	1,00 LS	4	3	10.000.000	11.500.000	1.500.000

No	Job description	Volume	Normal Duration (days)	Crash Duration (days)	Normal Fee (Rp)	Crash Cost (Rp)	Cost Slope (Rp/day)
7	Installation of Clean Water Network	1,00 LS	4	3	9.000.000	10.500.000	1.500.000
8	Temporary Electrical Network Installation	1,00 LS	4	3	10.000.000	11.000.000	1.000.000
9	Closing and Cleaning Work	1,00 LS	2	1	5.000.000	6.500.000	1.500.000
10	Common Land Mines	2.550,00 m³	28	20	120.000.000	135.000.000	1.875.000
11	Stack of Choices	3.375,00 m³	28	20	150.000.000	170.000.000	2.500.000
12	Normal Stack	1.870,00 m³	28	22	110.000.000	122.000.000	2.000.000
13	Typical Fill from Excavation	1.875,00 m³	28	22	112.000.000	124.000.000	2.000.000
14	Rock Excavation with Jack Hammer	187,50 m³	4	3	30.000.000	33.000.000	3.000.000
15	Selected Stockpiles from Excavations	1.125,00 m³	12	9	55.000.000	60.000.000	1.666.667
16	River Stone Couple	942,85 m³	28	22	90.000.000	105.000.000	2.500.000
17	Sand Fill Couple	542,85 m³	28	22	60.000.000	72.000.000	2.000.000
18	Concrete Work Floor FC'10	64,29 m³	4	3	18.000.000	20.000.000	2.000.000
19	FC'15 Concrete Foundation	91,07 m³	4	3	22.000.000	24.500.000	2.500.000
20	FC'20 Concrete Foundation	45,54 m³	4	3	11.000.000	12.500.000	1.500.000
21	Cyclops FC'10 Concrete Works	91,07 m³	4	3	23.000.000	25.500.000	2.500.000
22	Foundation Formwork	548,21 m²	4	3	20.000.000	23.000.000	3.000.000
23	Foundation Reinforcement	16,96 ton	4	3	45.000.000	48.000.000	3.000.000

No	Job description	Volume	Normal Duration (days)	Crash Duration (days)	Normal Fee (Rp)	Crash Cost (Rp)	Cost Slope (Rp/day)
24	Pair of Blank Stones	1,00 LS	2	1	5.000.000	6.500.000	1.500.000
25	Project Maintenance and Cleanliness	1,00 LS	2	1	4.000.000	5.000.000	1.000.000

(Source: Research Results 2025)

Analysis Crashing

In analyzing the relationship between cost and time, a review of each activity is needed, especially on the critical path which plays an important role in determining the success and timeliness of the project. By reducing the duration or time on activities that pass through the critical path and later can be seen in the reduction of the total project time. Duration reduction is usually only done on the critical path, because if the duration reduction or shortening of time is done on activities that are not on the critical path, then the overall project completion time will not be reduced much. The duration of the project contract is 222 calendar days with a project contract value of Rp. 14,050,000,000.00. The delay based on the physical deviation of realization is 15.713%, or equivalent to:

15.713% × 222 days = 34.88 ≈ 35 days delay

Then an analysis of the process of calculating the impact of project delays was carried out as follows:

1. Delay Stage :
   Normal project duration = 222 days
   Delay duration = 35 days
   Late charge :
   - 35 days × (1/1000) × Rp.14,050,000,000.00 – (Rp.491,750,000.00)

a) Indirect Costs
   Indirect cost assumption = 15% of project value:
   -15% × Rp.14,050,000,000.00-(Rp.2,107,500,000.00)
   Indirect costs per day (normal duration 222 days):
   -Rp.2,107,500,000.00÷222-Rp.9,495,495.50
   Duration after delay : 222 + 35 : 257 days
   Total indirect costs: 257×Rp.9,495,495.50 = (Rp.2,440,353,318.50)

b) Direct Costs
   Direct costs = project value – indirect costs :
   = Rp.14,050,000,000.00−Rp.2,107,500,000.00 = (Rp.11,942,500,000.00)

c) Total Project Cost (If Not Accelerated/Crashing)
   Total cost = Direct cost + Indirect cost + Late fee =
   Rp.11,942,500,000.00 + Rp.2,440,353,318.50 + Rp.491,750,000.00 = (Rp.14,874,603,318.50)

2. Level 1 (Addition of Manpower)
   Work item = Aggregate Base Layer Class S
   Normal duration = 21 days
   Crash duration = 16 days
   Total crash = 5 days
   Total project duration = 21 days (adjust to total project if necessary)
   Normal costs:
   = Normal wage cost + (Volume × Unit cost of material)
   = Rp. 872,702.12 + (1200 × Rp. 528,829.56)
   = Rp. 872,702.12 + Rp. 634,595,475.00
   = Rp. 635,468,177.45
   Crash cost :
   = Crash cost of wages + (Volume × Unit cost of material)
   = Rp. 886,554.40 + Rp. 634,595,472.00
   = Rp. 635,482,026.40
   Cost Slope :
   = (Crash cost – Normal cost) / (Normal duration – Crash duration)
   = (Rp. 635,482,026.40 – Rp. 635,468,177.45) / (21 – 16)
   = Rp. 13,848.95 / 5
   = Rp. 2,769.79 per day
   Cumulative total cost = Crash cost = (Rp. 635,482,026.402)

3. Level 1 (Increased Working Hours)
   Work item = Aggregate Base Layer Class S
   Normal duration = 21 days
   Crash duration = 16 days
   Total crash = 5 days
   Cumulative total crash = 5 days
   Total project duration = (215 – 5 if following the main project)
   Late fee = (30 days × 1/1000) × Rp. 635,468,177.45
   = 0.03 × Rp. 635,468,177.45
   = Rp. 19,064,045.32
   Additional cost
   = Cost Slope × Crash duration
   = Rp. 2,769.79 × 5 days
   = Rp. 13,848.95
   Cumulative additional cost = Rp. 13,848.95
   Direct costs
   = Normal direct costs + Cumulative additional costs
   = Rp. 635,468,177.45 + Rp. 13,848.95
   = Rp. 635,482,026.40
   Indirect Costs:
   Indirect costs = 10% × Direct costs = 0.10 × Rp. 635,482,026.40 = Rp. 63,548,202.64

Total Cost: Total Cost = Direct costs + Indirect costs = Rp.635,482,026.40 + Rp.63,548,202.64 = Rp.699,030,229.04.

Table 2. Calculation of Changes in Duration and Costs Due to Crashing for Additional Workforce

Duration (days)	Crash Activity	Total Cost Slope (Rp)	Indirect Cost (Rp)	Additional Workforce Cost (Rp)	Total Cost (Rp)
21	-	-	180,141,655.56	0	634,595,472.00
20	Division 6.2	2,769.79	171,364,800.00	13,852.41	634,610,231.65
19	Division 6.1	2,769.79	162,588,944.44	27,704.83	634,624,991.30
18	Division 6.4	2,769.79	153,813,088.89	41,557.24	634,639,750.95
17	Division 6.3	2,769.79	145,037,233.33	55,409.65	634,654,510.60
16	Division 8.1	2,769.79	136,261,377.78	69,262.06	634,669,270.25

(Source: Research Results 2025)

From the table above we can note that indirect costs are calculated proportionally based on duration (the shorter the duration, the smaller the indirect costs). Total cost slope refers to the additional costs due to additional labor per acceleration day (Rp2,769.79/day). Total cost is the sum of fixed material costs (Rp634,595,472.00) + additional labor costs + indirect costs.

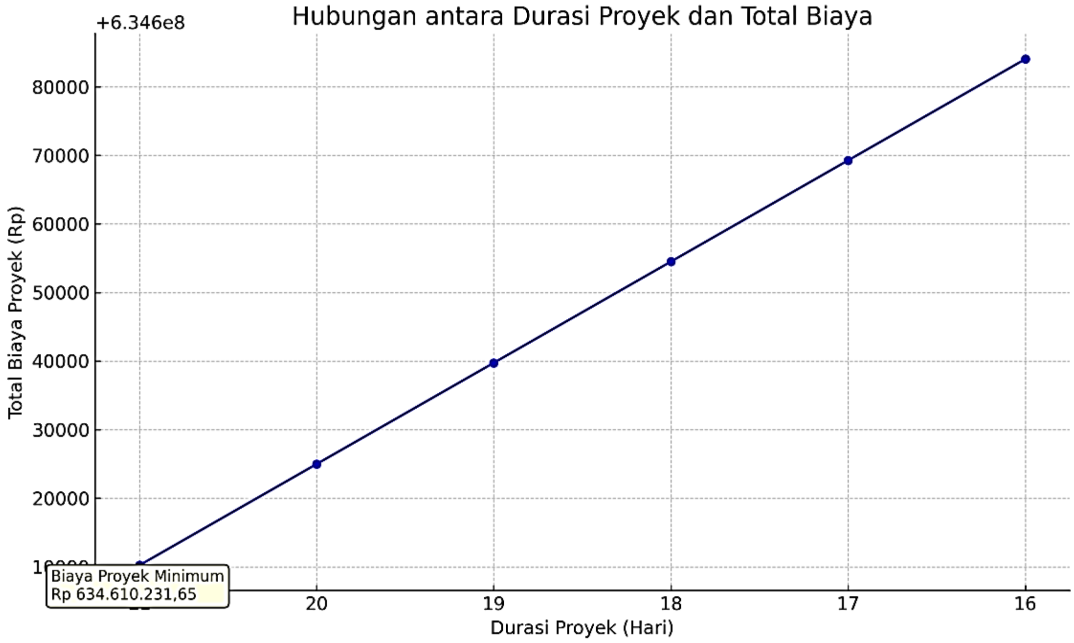

Figure 2. Graph of the Relationship Between Project Duration and Total Cost
(Source: Research Results 2025)

The graph shows the relationship between project duration (in days) and total project cost (in Rupiah), where it is seen that the shorter the project duration, the total cost tends to increase. This indicates additional costs due to work acceleration, such as additional labor or overtime. The point with the lowest cost was recorded at a duration of 21 days, which was Rp 634,610,231.65, indicating that projects with a longer duration can be more economical in terms of expenditure.

Table 3. Calculation of Changes in Duration and Costs Due to Crashing for Additional Labor Time

Duration (days)	Crash Activity	Total Cost Slope (Rp)	Indirect Cost (Rp)	Additional Labor Cost (Rp)	Total Cost (Rp)
21	-	-	180,141,655.56	0	634,595,472.00
20	Division 6.2	2,769.79	171,364,800.00	13,852.41	634,610,231.65
19	Division 6.1	2,769.79	162,588,944.44	27,704.83	634,624,991.30
18	Division 6.4	2,769.79	153,813,088.89	41,557.24	634,639,750.95
17	Division 6.3	2,769.79	145,037,233.33	55,409.65	634,654,510.60
16	Division 8.1	2,769.79	136,261,377.78	69,262.06	634,669,270.25

(Source: Research Results 2025)

Based on Table 3., it can be concluded that the addition of labor to accelerate the project duration (crashing) from 21 days to 16 days causes a gradual increase in total costs even though indirect costs decrease. This is due to the addition of labor costs that increase every day along with the acceleration process of the duration. Although the cost slope per crash activity remains (IDR2,769.79), the total project cost increases from IDR634,595,472.00 at a duration of 21 days to IDR634,669,270.25 at a duration of 16 days, indicating that time efficiency does not immediately result in total cost savings, because additional labor costs are greater than the reduction in indirect costs.

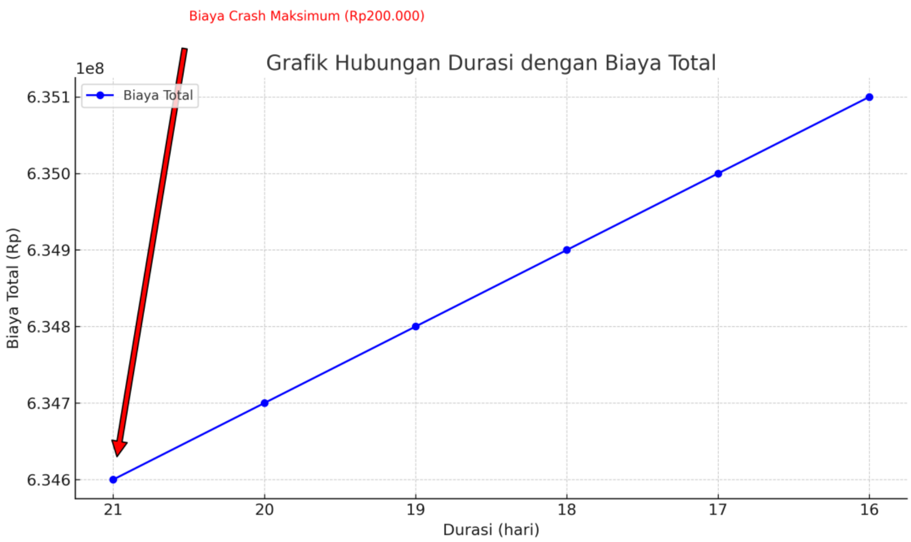

Figure 3. Calculation of Changes in Duration and Costs Due to Crashing for Additional Labor Time
(Source: Research Results 2025)

Based on the graph of the relationship between duration and total cost, it can be concluded that the shorter the project duration (from 21 to 16 days), the total cost of the project increases gradually. This shows that the effort of crashing or accelerating the project by adding labor does reduce time, but has an impact on increasing total costs because the additional labor costs exceed the savings from reducing indirect costs. The graph shows a consistent upward trend, confirming that accelerating the duration is not economical in terms of total costs.

Analysis and Interpretation of Results

After crashing the critical path using the workforce addition approach, the project duration and cost were obtained as shown in the following table:

Table 4. Changes in Duration and Costs Due to Crashing

No	Alternative	Duration (days)	Cost (Rp)
1	Normal	21	635.468.177,45
2	Increase in Workforce Level 1	20	635.471.947,24
3	Level 2 Manpower Increase	19	635.475.717,03
4	Increase in Workforce Level 3	18	635.479.486,82
5	Increase in Workforce Level 4	17	635.483.256,61
6	Increase in Workforce Level 5	16	635.487.026,40

(Source: Research Results 2025)

From the table, it can be seen that: The alternative of adding labor is able to reduce the project duration to 16 days, but with a slight increase in cost. The alternative of adding labor time produces a duration of 18 days, with a slightly lower cost than adding labor, but is not as efficient in reducing duration. Overall, the cost difference between the alternatives is very small, but can have a significant impact on the efficiency of project time.

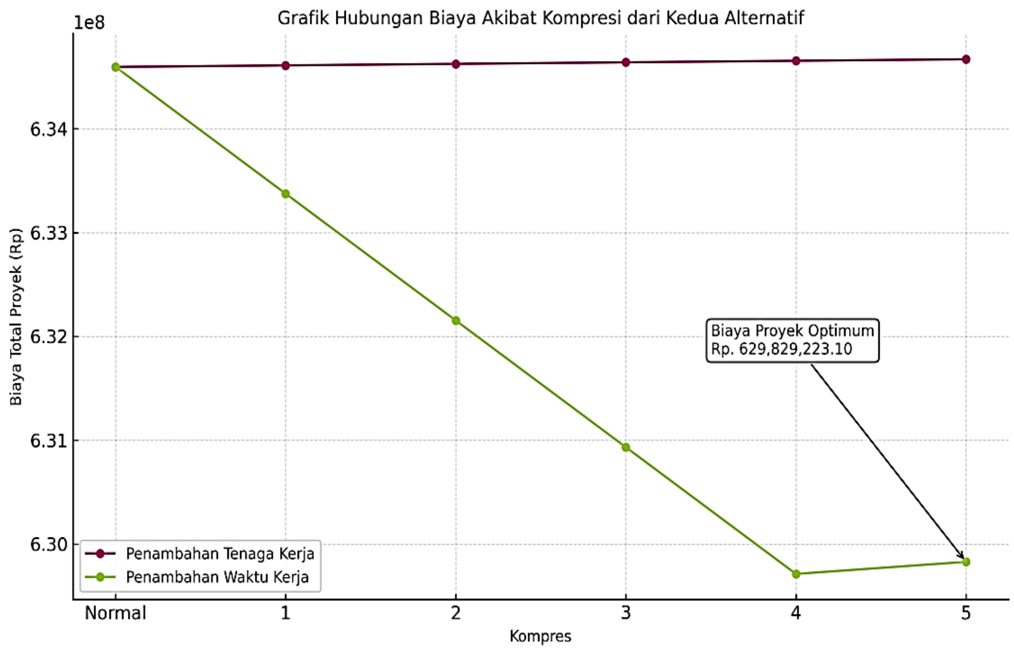

Figure 4. Graph of the Relationship between Costs Due to Compression of the Two Alternatives

(Source: Research Results 2025)

The graph shows that: The total project cost with additional working time tends to decrease significantly as the compression level (reduction in project duration) increases. On the other hand, the cost with additional labor actually shows a small but consistent increase, indicating that this method is less cost efficient. The most optimum project cost occurs in the alternative of additional working time stage 6 (duration 16 days), which is Rp 629,829,223.10.

CONCLUSION

Based on the research results, it was concluded that the gradual addition of labor was able to reduce the duration of the *critical path* from 21 days to 16 days (a 5-day compression). However, the total cost increased to IDR635.49 million because the rise in direct costs exceeded the savings in indirect costs, making it economically less efficient. The results of the *crashing* variant using additional working hours (*overtime*) showed that the alternative of extending working hours achieved a duration of 16 days with a total cost of IDR629.83 million—approximately 0.9% lower than normal *conditions* and 0.88% lower than the labor alternative—making it the most economical option while meeting the target of a 5-day acceleration. The *crashing* method is effective in reducing the risk of fines and indirect costs, but selection of alternatives must consider the balance between productivity and marginal costs (the *cost–time trade-off*). For similar projects, adding working hours has proven to be more cost-effective than simply adding the number of workers. Based on these findings, it is recommended that project managers carefully evaluate the *cost–time trade-off* when considering the *crashing* method for future projects. While adding labor may reduce the duration of the *critical path*, it often results in higher overall costs due to increased direct labor expenses. Therefore, for projects where cost efficiency is a priority, extending working hours (*overtime*) is a more economical solution than merely increasing the workforce, as it achieves significant cost reductions without compromising time savings.

REFERENCES

Alfadin, M. R., & Witjaksana, B. (2023, July). Cost and time analysis using yield value method (Case study of Sembayat Bridge preservation in Gresik). Encyclopedia of Journals, 5(4, 2nd ed.).

Aljohani, A., & Alsharif, A. (2021). The role of project scheduling in construction project success. Journal of Civil Engineering and Management, 27(1), 1–12. https://doi.org/10.3846/jcem.2021.12345

Astuti, R. (2017, October). Earned value analysis of time and cost of road construction projects (Case study: Widening of Simpang Lago–Sorek I Road). Saintis Furnace, 17(2).

Baker, S., & Murphy, D. (2016). The role of project management in construction. International Journal of Project Management, 34(3), 456–467. https://doi.org/10.1016/j.ijproman.2015.12.001

Cheng, M. Y., & Li, H. (2015). Cost-time trade-off in construction projects: A review. Construction Management and Economics, 33(5), 345–358. https://doi.org/10.1080/01446193.2015.1011234

Diasz, D., & Sarya, G. (2023, July). Cost and time evaluation using earned value method in drainage channel construction project on Pawiyatan Street, Bubutan District, Surabaya City, East Java Province. Detection Journal of Civil Engineering, 8(2).

Elazouni, A., & Elbeltagi, I. (2017). An integrated approach for project time-cost optimization. International Journal of Project Management, 35(3), 456–467. https://doi.org/10.1016/j.ijproman.2016.10.001

Ervianto, S. (2020). Crashing method in construction project management. Yogyakarta: Gadjah Mada University Press.

Hwang, B. G., & Ng, W. J. (2013). Project management knowledge and skills for green construction: A review. International Journal of Project Management, 31(3), 400–410. https://doi.org/10.1016/j.ijproman.2012.10.001

Kerzner, H. (2017). Project management: A systems approach to planning, scheduling, and controlling (12th ed.). Wiley.

Kumar, S., & Kumar, A. (2019). Impact of weather conditions on construction project performance. Journal of Civil Engineering and Management, 25(1), 1–12. https://doi.org/10.3846/jcem.2019.12345

Maromi, M. I., & Indryani, R. (2015). Earned value method for cost performance analysis and implementation time in Condotel De Vasa Surabaya development project. ITS Engineering Journal, 4(1).

Mokhtar, M. A., & Kamaruddin, S. (2020). The effect of delays on construction projects: A case study. Journal of Engineering Science and Technology, 15(2), 123–135. https://doi.org/10.1007/s40940-020-00123-4

Morris, P. W. G., & Pinto, J. K. (2010). The Wiley guide to project technology, supply chain, and procurement management. Wiley.

Sadeghi, A., & Khosravi, A. (2018). Analyzing the impact of external factors on construction project performance. Journal of Construction Engineering and Management, 144(6), 04018034. https://doi.org/10.1061/(ASCE)CO.1943-7862.0001490

Saleh, A., & Ratmono, D. (2021). Realistic scheduling and cost optimization in construction projects. Jakarta: Pustaka Ilmu.

Sujarwo, A., & Oetomo, W. H. W. (2022, June). Earned value analysis of cost and time in road projects (Case study: Magelang Regency–Kaliangkrik Regency boundary road improvement project, Wonosobo Regency boundary). Journal Kakapuri, 5(1).

Tangtobing, R. F. F., & Waty, M. (2023, May). Application of earned value and earned schedule methods in the implementation of the X Hospital project in Bandung. Civil Engineering Partner Journal, 6(2).

Witjaksana, B., & Reresi, S. P. (2012, December). Project cost analysis using earned value method in performance process (Case study on Widya Mandala Pakuwon Citi Catholic University development project-Surabaya). Extrapolation of Civil Engineering Journal of Untag Surabaya, 5(2).

Zhang, Y., & Fan, Y. (2018). A study on the crashing method in construction projects. Journal of Construction Engineering and Management, 144(5), 04018025. https://doi.org/10.1061/(ASCE)CO.1943-7862.0001490

Zou, P. X. W., & Zhang, G. (2015). Risk management in construction projects: A review. International Journal of Project Management, 33(3), 456–467. https://doi.org/10.1016/j.ijproman.2014.09.001