

Analysis of Project Implementation Costs Using the Crashing Method in the Construction Work of Sunan Ampel Jombang Junior High School

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Keywords	ABSTRACT
Project acceleration, Crashing method, critical path, bridge project.	The development of educational infrastructure is a crucial aspect in supporting the improvement of the quality of learning and human resource development in Indonesia. However, in its implementation, construction projects often face challenges in the form of delays in completion and cost inefficiencies, which impact the disruption of the educational process and increase the budget. This study aims to analyze the cost efficiency and acceleration of the implementation time of the Sunan Ampel Jombang Junior High School construction project through the crashing method approach, which is a technique in project management used to accelerate project completion time by selectively adding resources to critical activities. The delay in the start of a project is the main problem faced by the implementers of the Sunan Ampel Jombang Junior High School construction project, resulting in delays in final completion and an inflated project value. Based on the analysis conducted, this study also provides solutions to overcome this. The results of the analysis of the Sunan Ampel Jombang Junior High School construction project show an additional cost of Rp. 163,845,745.00 from the normal work cost to Rp. 2,623,114,845.00, an increase of 0.93%. This research provides practical contributions for project managers and contractors in making strategic decisions related to controlling project time and costs and can be a reference in managing the risk of project delays in the future.

INTRODUCTION

The development of educational infrastructure, such as schools, is a strategic investment in improving the quality of human resources. In construction projects like the *Sunan Ampel Jombang* Junior High School building, project success depends heavily on effective cost and time management. These two factors are key indicators in assessing the efficiency of construction project implementation (Kannimuthu & Karthikeyan, 2018; Kim & Lee, 2020; Santos et al., 2025). However, in practice, construction projects often encounter obstacles such as delays, cost overruns, and discrepancies between planned schedules and actual field performance. Conventional planning methods that rely solely on initial estimates are often insufficiently flexible to address changing field conditions. Therefore, a project management approach is needed that can provide alternative solutions to optimize project completion time without significantly sacrificing cost efficiency (Al-Battaineh, 2019; Al-Zwainy & Mohammed, 2020; Basil & Waruguru, 2024; Chen et al., 2025; Huseynov, 2025). One method that can be applied to overcome this problem is the crashing method, which is a method of accelerating project time by adding resources to critical activities at a measurable additional cost (Solís-Carcaño & Martínez-Martínez, 2015).

The implementation of the *Sunan Ampel Jombang* Junior High School construction project, with CV. *IDEA KARYA NUSA* as the implementing contractor, has a contract value of Rp 2,608,373,702.00 (Two Billion Six Hundred Eight Million Three Hundred Seventy-Three Thousand Seven Hundred Two Rupiah) and is scheduled to be completed within a period of 150 (One Hundred and Fifty) days. In the implementation of the *Sunan Ampel Jombang* Junior High School construction project, obstacles occurred due to the influence of the weather and other technical matters. These problems caused the work progress in the 3rd (Third) week to be delayed by 11.65% (minus eleven point sixty-five percent). This significant percentage of delay has the potential to exceed the total completion time of the work according to the contract, which is 150 days. Cost and time planning and control are part of overall construction project management. In addition to assessment in terms of quality, project performance can also be evaluated in terms of cost and time. Costs incurred and the time spent completing a project must be continuously measured for deviations from the plan. Significant cost and time deviations indicate poor project management. Having project performance indicators in terms of cost and time allows for preventative measures to ensure project implementation proceeds according to plan. One method that can be applied to overcome this problem is the crashing method, which is a method of accelerating project time by adding resources to critical activities at a measurable additional cost (Ariyanto, Tjendani, & Witjaksana, 2023).

The crashing method is a project management approach used to accelerate project implementation by adding resources to certain activities, particularly those on the critical path. This addition can take the form of increased labor, overtime, faster equipment utilization, or parallel material procurement. While this method has the potential to increase costs, crashing is carried out selectively so that the additional costs incurred are commensurate with the benefits of reducing project implementation time. When a project faces potential delays, the project manager must be able to take quick and appropriate steps to anticipate and resolve the problem (Aminatuz Zuhriyah & Oetomo, 2022; Armalisa, Triana, & Sari, 2020; Budianto & Husin, 2021; Wijanarko & Oetomo, 2019). One approach that can be used is the crashing method, a project scheduling technique that adds resources (labor, equipment, overtime, etc.) to critical path activities to accelerate project completion with the consequence of measurable cost increases. Implementing the crashing method requires careful calculation, especially in identifying critical project activities, calculating the possible acceleration time, and estimating the additional costs required (Eliatun & Tjitradi, 2022; Budianto & Husin, 2021; Mandiyo & Zhafira, 2017; Ningru, Hartono, & Sugiyarto, 2017; Yaqin, Tjendani, & Witjaksana, 2023). By analyzing the combination of time and cost, the project implementer can determine the best crashing alternative that provides maximum efficiency.

Previous studies such as Mukti, Purnamasari, and Wasono (2019) and Firdaus, Tjendani, and Witjaksana (2023) have demonstrated that the crashing method can be an effective solution for accelerating school construction projects facing delays. However, both studies relied primarily on deterministic CPM calculations and focused mostly on direct labor costs, overlooking indirect costs, risks of weather disruptions, and potential impacts on quality and productivity. This creates a research gap, as real-world projects often encounter uncertainties and multidimensional trade-offs between time, cost, and quality.

The present study on the *Sunan Ampel Jombang* Junior High School project addresses this gap by integrating both direct and indirect cost components, incorporating weather-related risks, and applying a probabilistic CPM-PERT approach combined with Monte Carlo simulation to provide a more comprehensive and realistic time–cost–quality analysis. The aim is to identify the most efficient and feasible crashing strategies to mitigate an 11.65% delay while maintaining project quality

standards. The expected benefits include generating evidence-based strategies for cost-effective acceleration, providing a decision-making framework that can be replicated in similar construction projects, and supporting contractors in minimizing risks of cost overruns and schedule slippages.

METHOD

The steps in the data analysis techniques used in this study are:

1. Processing Research Data
2. Establishing relationships between activities
3. Creating a network diagram using
4. Calculating normal daily productivity and hourly productivity.

$$\text{Produktivitas harian normal} = \frac{\text{volume}}{\text{durasi}}$$

$$\text{Produktivitas per jam} = \frac{\text{produktivitas harian normal}}{\text{waktu kerja normal}}$$

1. Calculate crash duration
2. Calculate crash cost
3. Calculate cost slope

$$\text{Cost slope} = \frac{\text{crash cost} - \text{normal cost}}{(\text{normal duration} - \text{crash duration})}$$

1. Crashing is performed on the critical path activity that has the smallest cost slope.
2. Cost analysis due to time acceleration

RESULTS AND DISCUSSION

Critical Path of Work Based on the S-Curve

At the time of the research, the Sunan Ampel Jombang Middle School Development project did not have a work network diagram where the self-managed party only had a Cost Budget Plan (RAB), Time Schedule in the form of an S curve, so the Critical Path was obtained by looking at the network diagram in Microsoft Project 2016. The Critical Path is shown in the following table.

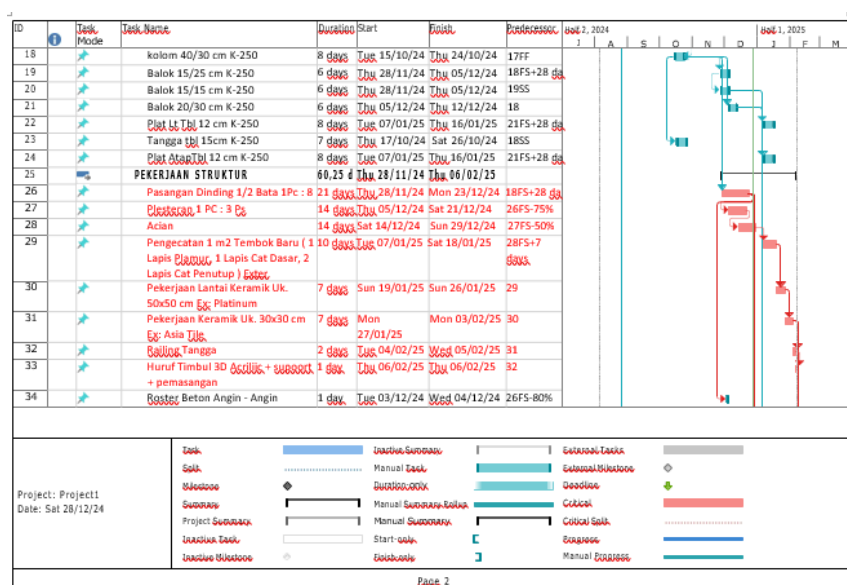


Figure 1. Critical path tasks for the Sunan Ampel Middle School project

Table 1. Crashed tasks

No	Type of work	Beginning of Work	End of Work
1	1/2 Brick Wall Pair 1Pc : 8Ps	28/03/2025	23/04/2025
2	Plastering 1 PC : 3 Ps	05/04/2025	21/04/2025
3	Acian	14/04/2025	29/04/2025
4	Painting 1 m2 of New Wall	17/05/2025	18/05/2025
5	Ceramic Work Size 50x50 cm	19/05/2025	26/05/2025
6	Ceramic Work Size 30x30 cm	27/05/2025	05/06/2025

Determining the Number of Resources and Wages in Normal Work

Calculation of the number of resources per day for 1/2 brick wall masonry work: 8 workers.

Work Volume: 725.12 m2 Normal Duration (Dn): 21 Days

Resource Requirement per Day for Normal Work: Labor Coefficient

- Workers: 0.300 Oh
- Craftsmen: 0.100 Oh
- Foreman: 0.010 Oh
- Foreman: 0.015 Oh

Number of Resources per Day (Volume x Coefficient)/Dn

- Workers: $(725.12 \times 0.300)/21 = 10.359 \approx 11$ people
- Craftsmen: $(725.12 \times 0.100)/21 = 3.453 \approx 4$ people
- Foreman: $(725.12 \times 0.010)/21 = 0.345 \approx 1$ person
- Foreman: $(725.12 \times 0.150)/21 = 0.518 \approx 1$ person

2. Wages for Normal Work

- Worker: Rp. 106,000.00
- Worker: Rp. 130,000.00
- Foreman: Rp. 142,000.00
- Foreman: Rp. 159,000.00

Wages per Day (Number of Workers per Day x Worker's Daily Wage)

- Workers: $11 \times 106,000.00 = \text{Rp. } 1,166,000.00$
- Workers: $4 \times 130,000.00 = \text{Rp. } 520,000.00$
- Foreman: $1 \times 142,000.00 = \text{Rp. } 142,000.00$
- Foreman: $1 \times 159,000.00 = \text{Rp. } 159,000.00 +$
 $= \text{Rp. } 1,987,000.00$

Total wages for 1/2-brick wall installation: 8 workers

$= \sum \text{daily wages} \times \text{normal duration (Dn)} = \text{Rp. } 1.987.000,00 \times 21 \text{ Hari}$
 $= \text{Rp. } 41.727.000,00$

The same calculation method for the number of resources and wages for normal work on other critical paths can be seen in the following table.

Table 2. Number of resources and wages in normal work

No	Type of work	Work Volume an	Duration (Days)	Daily Wage	Total Wages Normal work
1	1/2 Brick Wall Pair 1Pc : 8Ps	725,12	21	Rp1.987.000	Rp41.727.000
2	Plastering 1 PC : 3 Ps	1450,24	14	Rp6.074.000	Rp85.036.000
3	Acian	1450,24	14	Rp3.957.000	Rp55.398.000
4	Painting 1 m2 of New Wall	1450,24	10	Rp1.919.000	Rp19.190.000
5	Ceramic Size 50x50 cm	617,82	7	Rp4.364.000	Rp30.548.000
6	Ceramic Size 30x30 cm	25	7	Rp537.000	Rp3.759.000

Crash Cost (Cc)

Crashing analysis by adding work hours can be an alternative way to accelerate a project if the required resources are unavailable. This calculation uses an additional 3 hours of work to complete the normal workload.

The following is the crash cost calculation for a 1/2 Brick Wall Pair: 8Ps.

Normal Cost (Cn) of Work = Rp. 76,137,963.00 Normal Duration (Dn) = 21 Days

Crash Duration (Dc) = 16 Days Crash Cost (Cc) of Work

1. Normal Hourly Wage

a. Laborer = Rp. 106,000.00 7 Hours Per Day
= Rp. 15,143.00

b. Laborer = Rp. 130,000.00 7 Hours Per Day
= Rp. 18,571.00

c. Foreman = Rp. 142,000.00
7 Hours Per Day = Rp. 20,286.00

d. Foreman = Rp. 159,000.00 7 Hours Per Day
= Rp. 22,714.00

2. Overtime Pay for the 1st Hour

a. Worker = Rp. 15,143.00 x 1.5
= Rp. 22,714.00

b. Craftsman = Rp. 18,571.00 x 1.5
= Rp. 27,857.00

c. Foreman = Rp. 20,286.00 x 1.5
= Rp. 30,429.00

d. Foreman = Rp. 22,714.00 x 1.5
= Rp. 34,071.00

3. Overtime Pay for the 2nd and 3rd Hours

a. Worker = Rp. 15,143.00 x 2 x 2
= Rp. 60,571.00

b. Craftsman = Rp. 18,571.00 x 2 x 2
= Rp. 74,286.00

c. Foreman = Rp. 20,286.00 x 2 x 2
= Rp. 81,143.00

d. Foreman = Rp. 22,714.00 x 2 x 2
= Rp. 90,857.00

4. Total cost per day (daily wage + overtime pay for the first hour + overtime pay for the second and third hours)

a. Workers = Rp. 189,286.00

b. Workers = Rp. 232,143.00

c. Foreman = Rp. 253,571.00

d. Foreman = Rp. 283,929.00

5. Cost on time (number of workers x total cost per day)

a. Workers = Rp. 189,286.00 x 11
= Rp. 2,082,143.00

b. Foreman = Rp. 232,143.00 x 4
= Rp. 928,571.00

c. Foreman = Rp. 253,571.00 x 1
= Rp. 253,571.00

d. Foreman = Rp. 283,929.00 x 1
= Rp. 283,929.00 +
= Rp. 3,548,214.00

6. Total cost of additional man-hours

$$= \sum \text{cost on time} \times \text{crash duration}$$

$$= \text{Rp. } 3,548,214.00 \times 16$$

$$= \text{Rp. } 56,771,429.00$$

$$\text{Cost Slope (Rp/hour)} = \text{crash cost} - \text{normal cost}$$

$$\text{normal duration} - \text{crash duration}$$

$$= \text{Rp. } 11,354,286.00$$

Using the analysis method above, the analytical value of additional labor wage costs due to the acceleration of the project duration by adding 3 hours of work per day for work on other critical paths can be seen in the following table.

Table 3. Recapitulation of time and costs of acceleration with additional working hours.

No	Type of Work	Normal	Alternative (Crashing)	di = Dn - Dc	Cost Slope = (Cc - Cn) / di
		Duration (Dn)	Cost (Cn)	Duration (Dc)	Cost (Cc)
1	Half Brick Wall Installation 1 Pc: 8 Ps	21	Rp 76,137,963	16	Rp 83,873,307
2	Plastering 1 PC: 3 Ps	14	Rp 111,389,309	11	Rp 120,640,468
3	Smoothing (Acian)	14	Rp 67,136,685	11	Rp 77,530,033
4	Painting 1 m ² New Wall	10	Rp 76,122,169	8	Rp 101,353,942
5	Ceramic Work 50x50 cm	7	Rp 96,794,477	6	Rp 143,037,334
6	Ceramic Work 30x30 cm	7	Rp 3,368,075	6	Rp 5,753,496

Additional Costs Due to Increased Working Hours

The additional costs were calculated due to the accelerated project duration using a three-hour workweek extension, from 4:00 PM to 7:30 PM WIB. The overtime costs were calculated for the accelerated duration, which is 135 days, or 15 days faster than the normal duration. The following is an analysis of the additional costs due to overtime.

1. Additional lighting costs

a. Required data

1) 250-400 Watt Philco spotlight, Quantity = 1

Price = Rp. 1,100,000.00

2) Supreme cable (NYM 2 x 2.5), Length = 150 m

Price = Rp. 984,000.00

3) Neewgee 13310 plug (Broco), Quantity: 4 pieces, Price = Rp. 8,000.00

4) Standard 15340 socket (Broco), Price = Rp. 38,000.00

5) Installation cost (per point): Price = Rp. 70,000.00

6) Electricity during the acceleration period: Specification = 400 watts

= 0.4 kilowatts

Quantity = 1 unit

Price per kWh = Rp 1,444.70 (source: pln.co.id, October 2024. Electricity tariff group for small households (R-1/TR) with a capacity of 1,300 VA)

Acceleration Duration = 15 days

Overtime Per Day = 3 Hours (4:00 PM – 7:30 PM)

b. Calculation

1) Lamp Cost = Lamp Price x Number of Lamps

$$= \text{Rp } 1,100,000 \times 1$$

$$= \text{Rp } 1,100,000.00$$

2) Cable Cost (150 m) = Rp 984,000.00

3) Plug Cost = Plug Price x Number of Switches

= 1 x Rp 8,000.00

= Rp 8,000.00

4) Socket Cost = Rp 38,000.00

5) Installation Cost = J. Lamp x Installation Price per Point

= 1 x Rp 70,000.00

= Rp 70,000.00

6) Electricity Cost During the Acceleration Period

Electricity Cost = Price per kWh x Electricity Usage Specification x Overtime Hours x Number of Lamps x Acceleration Duration

= Rp 1,444.70 x 0.4 x 3 x 1 x 15

= Rp 6,934.56

c. Total Lighting Cost

1) Lamp Cost = Rp 1,100,000.00

2) Cable Cost = Rp 984,000.00

3) Plug Cost = Rp 8,000.00

4) Socket Cost = Rp 38,000.00

5) Installation Cost = Rp 70,000.00

6) Accelerated Electricity Cost = Rp 6,934.56 + Total Cost = Rp 2,226,005.00

2. Additional Management Fees

a. Required Data:

1) Number = 2 people/day (interview with the implementer)

2) Overtime pay/hour = Rp 15,000.00

3) Overtime = 3 hours/day

4) Accelerated duration = 15 days

b. Calculation:

Overtime pay/day = Rp 15,000.00 x 3 hours x 2 people

= Rp 90,000.00 Wages/day

Total Cost = Rp 90,000.00 x 15 Days

= Rp 1,350,000.00

Table 4. Additional costs due to additional working hours

Additional Lighting Costs	Rp. 2.226.005,00
Additional Management Fees	RP. 1.350.000,00
Total Additional Costs Due to Overtime	Rp. 3.576.005,00

(Source: Research Processed, 2025)

Additional Costs Due to Increased Working Hours

From the results of the calculation of additional labor wage costs and additional costs for management and project lighting due to the acceleration of the project with the addition of 3 hours of working hours, can be seen in tables 4.5 and 4.6, then the total acceleration costs can be calculated by adding 3 hours of working hours each day with a reduction in duration of 4 days from the normal time of 150 days to 135 days as shown in the following table.

Table 5. Total cost of accelerating additional working hours

Labor wage acceleration costs	Rp.145.528.597,00
Management and night lighting costs	Rp. 3.576.005,00
Total project cost	Rp.149.104.602,00

Crash Cost (CC)

Crash cost analysis for 1/2 Brick Wall: 8 pieces. Normal cost (Cn) = Rp. 76,137,963.00

Normal duration (Dn) = 21 days, crash duration (Dc) = 14 days, crash cost (Cc) of work

1. Labor coefficient

- a. Worker = 0.300
- b. Mason = 0.100
- c. Foreman = 0.010
- d. Foreman = 0.015

2. Daily labor wages

- a. Worker = Rp. 106,000.00
- b. Mason = Rp. 130,000.00
- c. Foreman = Rp. 142,000.00
- d. Foreman = Rp. 159,000.00

3. Normal duration labor requirement (Sn)

- a. Worker = 16 people
- b. Mason = 6 people
- c. Head Mason = 1 Person
- d. Foreman = 1 Person

4. Labor requirement per crash duration per day (Sc) = (volume x coefficient)/Dc

- a. Labor = 15.538 $\square$ 16 Persons
- b. Laborers = 5.179 $\square$ 6 Persons
- c. Head Mason = 0.518 $\square$ 1 Person
- d. Foreman = 0.777 $\square$ 1 Person

5. Additional labor per day = Sc - Sn

- a. Workers = 16 – 11 = 5 people
- b. Workers = 6 – 4 = 2 people
- c. Foreman = 1 – 1 = 0 people
- d. Foreman = 1 – 1 = 0 people

6. Additional labor cost (X) = Sc x Daily Wage

- a. Workers = Rp. 1,696,000.00
- b. Workers = Rp. 780,000.00
- c. Foreman = Rp. 142,000.00
- d. Foreman = Rp. 159,000.00 + Rp. 2,777,000.00

7. Total additional labor cost = $\sum X \times \text{Crash duration}$

= Rp. 2,777,000.00 x 14

= Rp. 38,878,000.00

Cost Slope (Rp/hour) = crash cost – normal cost

normal duration – crash duration

= -Rp 5,322,852.00

The calculation analysis above can also be used to analyze other work items on the critical path. The following table summarizes the values of the work items on the critical path for the construction of Sunan Ampel Junior High School, Jombang.

Table 5. Time and Cost Summary.

No	Type of Work	Normal Duration (Dn)	Alternative (Crashing) Cost (Cn)	di = Dn – Dc Duration (Dc)	Cost Slope = (Cc – Cn) / di Cost (Cc)
1	Half Brick Wall Installation 1 Pc: 8 Ps	21	Rp 76,137,963	14	Rp 81,460,815
2	Plastering 1 PC: 3 Ps	14	Rp 111,389,309	9	Rp 115,284,496
3	Smoothing (Acian)	14	Rp 67,136,685	5	Rp 73,044,650
4	Painting 1 m ² New Wall	10	Rp 76,122,169	7	Rp 94,984,490
5	Ceramic Work 50x50 cm	7	Rp 96,794,477	5	Rp 130,271,716
6	Ceramic Work 30x30 cm	7	Rp 3,368,075	5	Rp 5,241,538

Accelerated crash duration was achieved by extending the project completion time by adding additional labor, which was 122 days, or 28 days faster than the normal duration, using Ms. Project 2016 software. The crash cost for additional labor, including labor wages incurred due to the additional labor for 28 days, was Rp. 163,845,745.00.

CONCLUSION

Based on the results of the acceleration (crashing) analysis on the *Sunan Ampel Jombang* Middle School development project, it can be concluded that the total work time was reduced through acceleration (crashing), resulting in an additional work cost. This additional cost amounted to Rp. 163,845,745.00, increasing the total cost from Rp. 2,459,269,100.00 to Rp. 2,623,114,845.00, or an increase of 0.93% of the total normal work cost.

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