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ACCELERATION ANALYSIS USING THE CRASHING METHOD ON THE PROBOLINGGO-BANYUWANGI TOLL ROAD PACKAGE 1 PROJECT

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ABSTRAK

Jalan Tol Probolinggo-Banyuwangi Paket 1 adalah salah satu proyek pemerintahan yang dibangun untuk melengkapi Jalan Tol Trans Java. Berdasarkan jadwal rencana, proyek ini seharusnya selesai pada 2024, namun dikarenakan beberapa factor, proyek ini mengalami keterlambatan. Karena permasalah tersebut, penelitian ini bertujuan untuk menemukan solusi efektif untuk mempercepat berdasarkan waktu dan biaya. Salah satu cara efektif untuk menyelesaikan masalah ini dengan menggunakan metode crashing, dimana hanya mempercepat pekerjaan yang berada pada jalur kritis menggunakan Microsoft Project. Setelah menemukan jalur kritis makan akan di buat 5 skenario dengan pilihan pekerjaan yang berbeda untuk di percepat, setiap scenario akan di target untuk dapat mempercepat selama 4 minggu atau 1 bulan. Semua skenario akan dibandingkan untuk menemukan skenario paling efektif berdasarkan aspek biaya. Setelah dilakukannya analisis, penelitian ini menghasilkan 1) Skenario 1 membutuhkan biaya percepatan sebesar Rp6.548.955.840,05. 2) Skenario 2 membutuhkan biaya percepatan sebesar Rp6.549.764.555,46. 3) Skenario 3 membutuhkan biaya percepatan sebesar Rp6.895.340.767,67. 4) Skenario 4 membutuhkan biaya percepatan sebesar Rp7.368.457.309,22. 5) Skenario 5 membutuhkan biaya percepatan sebesar Rp6.371.649.065,18. Dari kelima skenario, skenario paling efektif dalam aspek biaya adalah skenario 5 dimana hanya membutuhkan biaya sebesar Rp6.371.649.065,18 dengan pekerjaan yang dipercepat adalah pekerjaan Common Borrow Material; Saluran U Tipe DS-6A; U Ditch 1×1,5; Saluran U Tipe DS-8A; Pekerasan Beton Semen; Beton Struktur Kelas C-1; Guardrail Kendaraan Tipe A; Concrete Barrier Tipe B yang dapat mempercepat proyek selaman 4 minggu atau 1 bulan.

Kata kunci : percepatan, crashing, jalur kritis

ABSTRACT

Probolinggo-Banyuwangi Toll Road Package 1 is one of the government projects to complete the Trans Java Toll Road. Based on the plant schedule, it must be finished in 2024, but because of many factors, this project has some delays. Because of those problems, this research aims to find an effective approach to accelerate based on time and cost. One of the effective ways to solve this problem is by using the crashing method, which only accelerates the critical activity using the Microsoft Project. After determining the critical path, five scenarios will be created with different activity options, each scenario targeted to accelerate 4 weeks or 1 month. All scenarios will be compared to find the most effective scenario based on the cost. The analysis results are as follows: 1) Scenario 1 requires an acceleration cost of IDR 6.548.955.840,05; 2) Scenario 2 requires an acceleration cost of IDR 6.549.764.555,46; 3) Scenario 3 requires an acceleration cost of IDR 6.895.340.767,67; 4) Scenario 4 requires an acceleration cost of IDR 7.368.457.309,22; 5) Scenario 5 requires an acceleration cost of IDR 6.371.649.065,18. From those five scenarios, the most effective is scenario 5, which only requires IDR 6.371.649.065,18, and the activity that has been accelerated is Common Borrow Material; U Channel Type DS-6A; U Ditch 1×1,5; U Channel Type DS-8A; Rigid Pavement Concrete; Structural Concrete Class C-1; Vehicle Guardrail Type A; and Concrete Berries Type B, allowing the project finish earlier by 4 weeks or 1 month.

Keywords: acceleration, crashing, critical path

1. INTRODUCTION

Project delays can harm the contractors in terms of time and cost. To prevent those problems, an acceleration can be conducted. There are many methods to accelerate a project, one of the crashing methods, by determining the critical path in the project that can be accelerated by additional equipment/workers and additional working hours. This acceleration needed an additional cost to be incurred.

The construction of the Probolinggo-Banyuwangi Toll Road Package 1 project has been delayed. There are several problems causing delays to this project, such as workload overflow from the previous project, delayed arrival of materials, and unfavorable weather. With regard to the workload overflow transferred from the previous toll construction, the Pasuruan Probolinggo toll construction starts from STA-3+881 to STA 0+000. This work was transferred to the contractor due to the inability of the previous contractor to complete the construction. The delay in material delivery significantly affects the project's progress, causing the project to not proceed according to the planned schedule, resulting in substantial delays. The weather is the last problem that is difficult to control. The constant weather changes have a considerable impact on the construction process, particularly with embankment and rigid pavement.

Using the crashing method is one way to make up for time that has been lost on the project. Crashing a project is where we find the critical path that contains the tasks we can increase productivity so that we can speed up their completion. There are a few ways to increase productivity, such as additional labor and heavy equipment, and additional working hours.

It is expected that this project can be completed in 660 days, as per Addendum 4 contract. However, based on the project schedule, it can be seen that there is a delay of -27,78% at Week 74 or Month 18. Given the negative schedule variance, it can be concluded that the project has been delayed. Therefore, this research will analyze acceleration with a target of 4 weeks.

From the background can be concluded that the construction of the Probolinggo-Banyuwangi toll road package 1 needs acceleration. This research aims to find the cost needed to accelerate the project, find the most effective activities to accelerate, and also find the differences before and after acceleration on the project schedule.

2. METHODOLOGY

This chapter outlines the research to know the objective of the study, including data collection and analytical methods.

A. Data Collection

Accurate data is required in the research process to support the study's implementation. There are several data that need to be collected from the research object, such as time schedule, budget planning, and unit price analysis.

B. Crashing Method

Delays are a significant problem during construction. The process requires valid and strategic measures. The acceleration may increase costs, and shortening the project timeline will not be a helpful solution if the shortened activities are not critical activities. The crashing method provides a logical and analytical manner to accommodate project acceleration. According to Arsjad and Sibi (2020), the crashing method is an approach of approximating the variable cost in calculating the maximum time reduction with the most economic cost for activities that still have scope to be shortened.

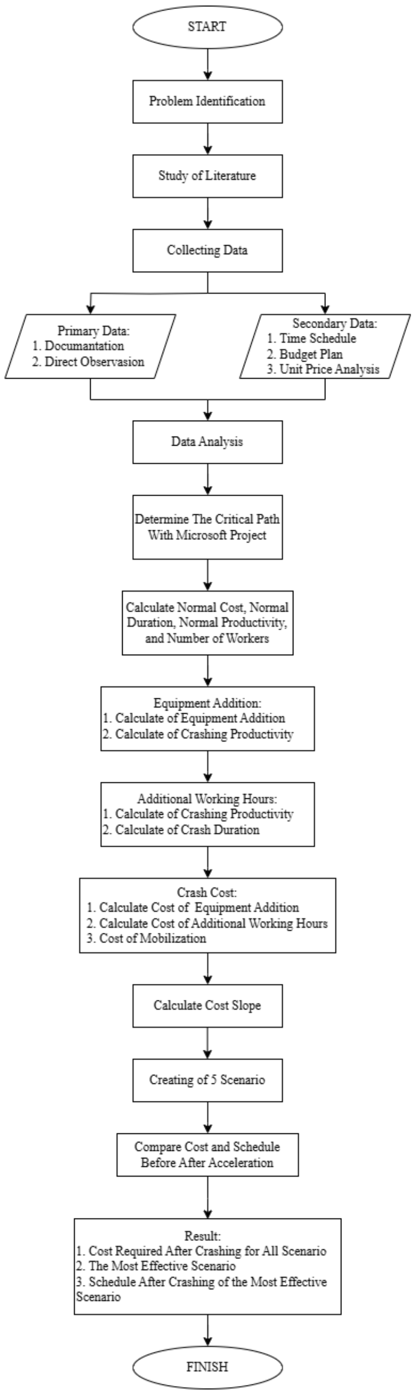

Figure 1. Research Flowchart

C. Additional Number of Equipment and Labour

Another factor that can be optimized in the project acceleration is by additional number of labor and heavy equipment. This additional aims to project finishing more earlyer or catch up the delays that alreasy hace accurred. The work load can be divided by adding the number of laborers and heavy equipment, so the work can be accomplished in a shorter period of time.

D. Additional Working Hours

The overtime in the crashing method extends the working hours. The aims of extending the working hours are to increase production within the period of 24 hours, to facilitate the work to be accomplished quicker, or to catch up on the delays. Overtime can help a project to speed up, but overtime can lead to some risks, such as decreased worker productivity and increased cost because overtime wages are higher than regular wages. Below is the folowchart of this research:

3. RESULTS AND DISCUSSION

This chapter presents the results from the data analysis and calculation. The following is the calculation to find the aims of this research:

A. Determine Critical Path

The crash program method is an acceleration technique that increases productivity on activities that are on the critical path. The critical path activities are those that significantly impact other activities. As activities on the critical path are accelerated, the remaining activities will finish sooner. In this research, the identification of the critical path will use the Microsoft Project software. There are several processes necessary to transfer the project schedule information into Microsoft Project.

Table 1. Critical Path

No	Activities
1	Tree cutting diameter > 75 cm
2	Demolition of concrete structure
3	Common borrow material
4	Class B-1-1a Structural Concrete
5	Class B-1-2 structural concrete
6	Class B-1 non-shrinkage structural concrete
7	Class C-1 structural concrete
8	PC-I beam nominal span 20.00 m to 22.00 m, h=1.25 m, installation
9	Stone masonry with mortar type DS-2
10	Stone masonry with mortar type DV-2
11	Vehicle guardrail type A
12	Concrete barrier, type B

B. Pre-Acceleration

Data needed to calculate the acceleration is normal cost and normal duration that can be obtained in the project s-curve. For the example of the calculation will be using the Common Borrow Material task. The normal productivity can be calculate using:

$$\text{Normal productivity} = \frac{\text{Volume}}{\text{Duration}} \quad (1)$$

$$= \frac{2439597\text{M3}}{474\text{ days}} = 5147\text{ M3/days}$$

The calculation of the number of equipment and labor is the starting point for calculating the project acceleration analysis. The compannents that needed in this calculation can be obtained from the unit price analysis of each task.

$$\text{Number of labor} = \frac{\text{volume} \times \text{coefficient}}{\text{normal duration}} \quad (2)$$

$$\text{Number of worker} = \frac{2439597 \times 0{,}0226}{3318\text{ hour}} \approx 17$$

$$\text{Number of foreman} = \frac{2439597 \times 0{,}0057}{3318\text{ hour}} \approx 5$$

$$\text{Number of equipment} = \frac{\text{normal productivity}}{\text{equipment productivity}} \quad (3)$$

$$\text{Excavator} = \frac{5147}{1443{,}47} \approx 4$$

$$\text{Dump truck} = \frac{5147}{129{,}60} \approx 40$$

$$\text{Motor grader} = \frac{5147}{1302} \approx 4$$

$$\text{Sheepfoot roller} = \frac{5147}{733{,}53} \approx 8$$

$$\text{Tandem roller} = \frac{5147}{1347{,}92} \approx 4$$

$$\text{Water tank} = \frac{5147}{996{,}03} \approx 6$$

C. Additional Number of Heavy Equipment

The increase will be carried out to 10% of the initial amount, where the first addition will be to heavy equipment, while the increase in the workers will be dependent on the productivity result after acceleration.

$$\text{Crash Productivity} = (\text{N} + \text{A}) \times \text{PC} \quad (4)$$

N = Number of equipment
A = Additional equipment
PC = Production capacity of equipment

$$\text{Excavator} = (4 + 1) \times 1443 = 7217\text{ M3/days}$$
$$\text{Dump truck} = (40 + 4) \times 130 = 5698\text{ M3/days}$$
$$\text{Motor grader} = (4 + 1) \times 1302 = 6511\text{ M3/days}$$
$$\text{Sheepfoot roller} = (8 + 1) \times 734 = 6602\text{ M3/days}$$
$$\text{Tandem roller} = (4 + 1) \times 1348 = 6740\text{ M3/days}$$
$$\text{Water tank} = (6 + 1) \times 996 = 6972\text{ M3/days}$$

D. Additional Working Hours

Productivity will increase after the addition of heavy equipment, but productivity will increase more by increasing working hours. During the construction, the daily hours of work per day are 7 hours. In this analysis, the hours of work will only increase by 1 hour. Since the workers will be working more than 7 hours, productivity decreases will become 90% due to fatigue.

$$\text{Crash productivity} = \text{DP} + (\text{OD} \times \text{HP} \times 90\%) \qquad (5)$$

DP = Daily productivity of equipment (M3/days)
OD = Overtime duration (Hours)
HP = Hourly productivity (M3/hours)

$\text{Excavator} = 7217 + (1 \times 1031 \times 90\%) = 8145$
$\text{Dump truck} = 5698 + (1 \times 814 \times 90\%) = 6431$
$\text{Motor grader} = 6511 + (1 \times 930 \times 90\%) = 7348$
$\text{Shepfoot roller} = 6602 + (1 \times 943 \times 90\%) = 7451$
$\text{Tandem roller} = 6740 + (1 \times 963 \times 90\%) = 7606$
$\text{Water tank} = 6972 + (1 \times 996 \times 90\%) = 7869$

From the crash productivity, the crash duration can be calculated.

$$\text{Crash productivity} = \frac{\text{Volume}}{\text{Crash productivity}} \qquad (6)$$

$$= \frac{2439597}{7348} = 332 \text{ days}$$

Based on the unit price analysis the number of workers can be calculated based on the equipment productivity. After determining the crash duration, the number of labors can be calculated.

$$\text{Number of labor} = \frac{\text{volume} \times \text{coefficient}}{\text{crash duration}} \qquad (7)$$

$$\text{Number of worker} = \frac{2439597 \times 0{,}0226}{332 \times 7} \approx 24$$

$$\text{Number of foreman} = \frac{2439597 \times 0{,}0057}{332 \times 7} \approx 6$$

$$\text{Additional labor} = \text{TN} - \text{NW} \qquad (8)$$

TN = Total number of labourers
NW = Number of labourers before the addition

$\text{Additional worker} = 24 - 17 = 7$
$\text{Additional foreman} = 6 - 5 = 1$

E. Crash Cost

The calculation of crash cost will start with calculating the cost needed for the addition of labour and heavy equipment.

$$\text{Cost} = \text{AW} \times \text{W} \times \text{CD} \qquad (9)$$

AW = Additional labour and heavy equipment
W = Wages (IDR/days)
CD = Crash duration (Days)

$\text{Worker} = 7 \times 120.000 \times 332$
$= 278.880.000$
$\text{Foreman} = 1 \times 168.000 \times 332$
$= 22.776.000$
$\text{Excavator} = 1 \times 3.570.000 \times 332$
$= 1.185.240.000$
$\text{Dump truck} = 4 \times 4.301.500 \times 332$
$= 5.712.392.000$
$\text{Motorgrader} = 1 \times 4.461.888 \times 332$
$= 1.481.346.975$
$\text{Sheepfotroller} = 1 \times 3.269.000 \times 332$
$= 1.085.308.000$
$\text{Tandem roller} = 1 \times 2.323.808 \times 332$
$= 1.767.504.256$
$\text{Water tank} = 1 \times 2.702.000 \times 33$
$= 897.064.000$

Then calculate the cost needed for the overtime wages. In this research, the additional working hours will be extended by 1 hour. Overtime cost will be calculated based on the regulations, where in the first hour of overtime, the hourly wages are multiplied by a factor of 1,5.

$$\text{Cost} = 1{,}5 \times \text{W} \times \text{TW} \times \text{CD} \qquad (10)$$

W = Wages (IDR/hours)
TW = Total of labour and equipment
CD = Crash duration (Days)

$\text{Worker} = 1{,}5 \times 17.143 \times 24 \times 332$
$= 204.891.429$
$\text{Foreman} = 1{,}5 \times 24.000 \times 6 \times 332$
$= 71.712.000$
$\text{Excavator} = 1{,}5 \times 510.000 \times 5 \times 332$
$= 1.269.900.000$
$\text{Dump truck} = 1{,}5 \times 614.500 \times 44 \times 332$
$= 13.464.924.000$
$\text{Motorgrader} = 1{,}5 \times 637.413 \times 5 \times 332$
$= 1.587.157.473$
$\text{Sheepfotroller} = 11{,}5 \times 467.000 \times 9 \times 332$
$= 2.093.094.000$
$\text{Tandem roller} = 1{,}5 \times 760.544 \times 5 \times 332$
$= 1.893.754.560$
$\text{Water tank} = 1{,}5 \times 386.000 \times 7 \times 332$
$= 1.345.596.000$

Mobilisation cost can be calculated based on the travel distance and the weight of each equipment. For the Common Borrow Material equipment mobilisation cost is IDR 16.500.000,00.

From all calculations, the total crash cost can be calculated.

$$\text{Crash cost} = \text{C1} + \text{C2} + \text{NC} + \text{M} \quad (11)$$

C1 = Cost for additional labour and heavy equipment (IDR)
C2 = Cost for additional working hours (IDR)
NC = Normal cost (IDR)
M = Mobilisation cost (IDR)

$$\text{Crash cost} = 12.463.511.231 + 21.931.029.462 + 691.692.607.824 + 16.500.000 = 726.106.648.517,93$$

F. Cost Slope

Finding the cost slope is necessary to find the cost needed to accelerate for each day or week.

$$\text{Cost slope} = \frac{\text{CC} - \text{NC}}{\text{ND} - \text{CD}} \quad (12)$$

CC = Crash Cost
NC = Normal Cost
ND = Normal Duration
CD = Crash Duration

$$\text{Cost slope} = \frac{726.103.648.517 - 691.692.607.824}{474 - 332} = \frac{34.411.040.693}{142} = 242.331.272,49$$

G. Creating Scenarios

Scenario options are selected activities that will be accelerated in order to meet the target of acceleration within 30 days or 4 weeks. Using Microsoft Project, a weekly acceleration simulation is developed to show that the selected activities are impactful on project duration. The project was originally 94 weeks, then after acceleration to 90 weeks. The simulation will be run 4 times for each scenario, and from the 5 scenarios will be choosen the most effective scenario.

Table 2. Acceleration Scenarios from Critical Activities

Scenarios	Activities	Weeks	Total Additional Cost
Scenario 1	Common Borrow Material	1	IDR 6.548.955.840,05
	U Ditch @1,5×1,5	2	
	U Channel Type DS-8A	2	
	Concrete Rigid Pavement	1	
	Structure Concrete Class C-1	4	
	Vehicle Guardrail Type A	4	
	Concrete Barrier Type B	4	
Scenario 2	Common Borrow Material	1	IDR 6.549.764.555,46
	U Ditch @1×1,5	1	
	U Ditch @1,5×1,5	1	
	U Channel Type DS-8A	2	
	Concrete Rigid Pavement	1	
	Structure Concrete Class C-1	4	
	Stone Masonry with Mortar Type DV-2	2	
	Vehicle Guardrail Type A	2	
Scenario 3	Common Borrow Material	4	IDR 6.895.340.767,67
	U Ditch @1×1,5	1	
	U Ditch @1,5×1,5	1	
	U Channel Type DS-8A	1	
	Asphalt Concrete Binder Course	2	
	Structure Concrete Class C-1	1	
	Stone Masonry with Mortar Type DV-2	4	
	Concrete Barrier Type B	4	
Scenario 4	Common Borrow Material	4	IDR 7.368.457.309,22
	U Channel Type DS-6A	1	
	U Ditch @1×1,5	2	
	U Ditch @1,5×1,5	1	
	Asphalt Concrete Binder Course	1	

Scenarios	Activities	Weeks	Total Additional Cost
Scenario 5	Structure Concrete Class C-1	1	IDR 6.371.649.065,18
	Stone Masonry with Mortar Type DV-2	4	
	Vehicle Guardrail Type A	3	
	Concrete Barrier Type B	1	
	Common Borrow Material	4	
	U Channel Type DS-6A	1	
	U Ditch @1×1,5	1	
	U Channel Type DS-8A	1	
	Concrete Rigid Pavement	1	
	Structure Concrete Class C-1	1	
	Vehicle Guardrail Type A	4	
	Concrete Barrier Type B	4	

H. Analysis of Acceleration Proof

Analysis of acceleration proof is conducted to demonstrate whether the acceleration in this research is done rationally and effectively. This analysis cundected by comparing the situation on the site before an after the additional equipment. The following is the analysis of the acceleration proof on the Common Borrow Material (CBM) task.

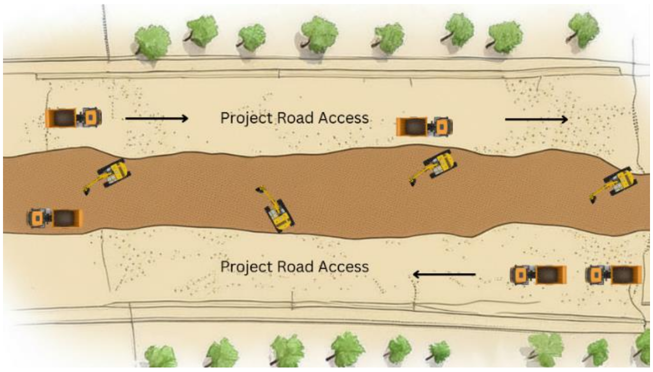

Figure 2. Site Condition Before Acceleration

Previously, the work was carried out using only 4 excavators and 40 dump trucks to transport the embankment material. The addition of 1 excavator and 4 dump trucks was made to accelerate the project duration.

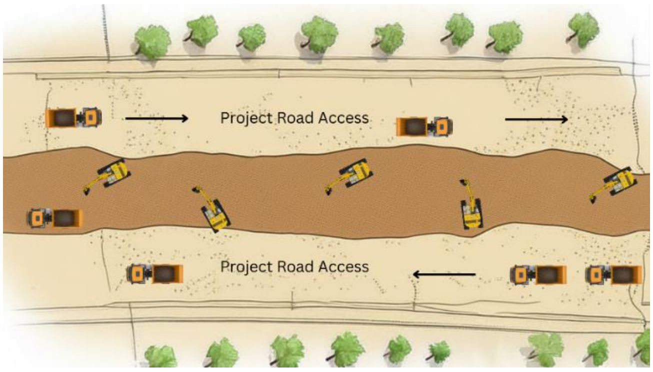

Figure 3. Site Condition Before Acceleration

It can be concluded from a sample proof of CBM work that the acceleration process in this study remains effective and rational. The zone division aids in efficiency and the allocation of heavy equipment, supporting the work process to avoid obstacles. Supported by visual evidence, the addition of 1 excavator and 4 dump trucks in the CBM work is still effective.

4. CONCLUSION

From the results of the acceleration analysis using the crashing program method on the Probolinggo-Banyuwangi Toll Road Project Package 1, the following conclusion is obtained:

1. The costs required to accelerate in each scenario
   Scenario 1 : IDR 6.548.955.840,05
   Scenario 2 : IDR 6.549.764.555,46
   Scenario 3 : IDR 6.895.340.767,67
   Scenario 4 : IDR 7.368.457.309,22
   Scenario 5 : IDR 6.371.649.065,18
2. Out of the five scenarios, Scenario 5 requires the minimal cost. All scenarios aim to accelerate the project work by 1 month or 4 weeks. Since each scenario has the same target for duration reduction, the aspect used to evaluate the most effective scenario is the one that requires the least cost, which is Scenario 5 with a cost of IDR 6.371.649.065,18.
3. Comparison of the schedule from the most efficient scenario, which is scenario 5. After implementing the acceleration using scenario 5, there will be significant changes in the schedule. In the scenario 5 the can be seen in Divisionon 4 (embankment work) initially requiring 84 weeks will be shortened to 83 weeks; Divisionon 6 (drainage) originally 62 weeks will be accelerated to 60 weeks; Divisionon 9

(pavement) initially 83 weeks will become 82 weeks; Divisionon 10 (concrete structures) initially 88 weeks will be reduced to 84 weeks; and Divisionon 11 (other activity) originally 61 weeks will be shortened to 57 weeks. This can be concluded that only accelerating the critical path can affect many other activities.

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