

ANALYSIS OF DELAYS IN CONSTRUCTION TIME OF THE BANJARSARI WATER GATE PROJECT, SIDOARJO DISTRICT USING CRITICAL PATH METHOD

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ABSTRACT

The Banjarsari sluice gate, located on the Sidoarjo district's shipping river, faces various challenges that can affect its performance. These challenges include sedimentation, damage to building structures, and decreased water quality due to domestic and industrial waste. The implementation of the Banjarsari Water Gate maintenance project, especially the floor work, experienced seepage at the bottom of the water gate floor, resulting in structural failure of the water gate building. CPM method duration planning is a recommendation in choosing from the many methods available, because there is a calculation of the earliest time the project starts, the latest time the project begins, the earliest time completed, and the latest time completed, so that the time lag of all activities can be known. Analyze the acceleration of work duration by adding workers to the work on the critical path. The purpose of this research is to analyze the length of time required by the CPM (Critical Path Method) method for the work of the Banjarsari floodgate. In this study, the time analysis uses the CPM (Critical Path Method) method and is assisted by Microsoft Project 2021 Software. The analysis results obtained work through the critical path, namely demolition work and cyclope concrete casting, and obtained the results of the duration of work on the Banjarsari floodgate work after crashing to 66 working days from the initial duration of 72 working days.

Keywords: Cost; CPM; Microsoft Project; Schedule

INTRODUCTION

Construction projects have a relatively high level of complexity in their implementation, so projects often experience delays in project completion and cost overruns. Therefore, a management system is needed that is able to organize the project properly so that construction activities can achieve effectiveness and efficiency (Amirtash et al., 2021; Bakry et al., 2014; Hansen, 2023; Mohammadi et al., 2018; Naizghi, 2021; Shillito & Schaffer, 2020). In the construction world, this is known as construction project management activities. One of the scopes in construction management activities is project control estimation. Control is defined as a systematic effort to determine standards by planning goals and objectives, design information systems, compare implementation with standards, analyze possible deviations, then take the necessary corrective actions so that resources can be used effectively and efficiently to achieve goals and objectives. Based on this definition, project control is a systematic activity to regulate and control the process of construction activities to minimize deviations that may occur so that the results of project work can be appropriate or better than planned (Pradita et al., 2023).

Delays in construction projects are often caused by various factors, including the lack of human resources that impact work implementation, such as casting foundations, sloofs, columns, and other structures. According to Ervianto, project delays occur when implementation time is not used as planned, resulting in delayed subsequent activities. Delays also cause losses for owners and contractors because project implementation is not in accordance with the contract (Durdyev & Hosseini, 2020; Fashina et al., 2021; Gurgun et al., 2024; Rauzana & Dharma, 2022). For this reason, project management is needed, including planning, organizing, implementing, supervising, and maintaining to ensure the project is completed on time, within budget, and of the specified quality. Project success is greatly influenced by good time management, which includes scheduling projects to be on time, on cost, and of high quality.

One commonly used project scheduling method is the Critical Path Method (CPM), which helps plan and schedule project activities through a network system. CPM includes two types of planning: normal and accelerated time and cost planning (Khotimah et al., 2024; Ramani et al., 2022; Yoppie Fanny Ryandre, 2023; Zareei, 2018). The critical path is determined from the activity with the longest

time, which determines the overall project duration. This method includes forward pass (ES and EF) and backward pass (LS and LF) calculations to determine critical activities with zero float and non-critical activities with positive float. Activities are connected through constraint types such as FS, FF, SS, and SF, with the possibility of lag for network flexibility. The stages in building a CPM network include activity identification, sequence, duration, network, and critical path determination.

The case of the delayed construction of the Banjarsari Sluice Gate in Sidoarjo Regency illustrates the importance of good project management. This sluice gate is vital in regulating water flow for irrigation and drinking water supply. However, challenges such as sedimentation, structural damage, and sewage threaten its function. Delays in the maintenance project occurred during foundation casting as the kitsdam or dewatering system leaked and could not withstand the water discharge. As a result, the contractor had to repeat the dewatering process. At the same time, water regulation from upstream was not possible due to the irrigation and raw water needs managed by the IPAM, causing significant bottlenecks and project delays. This emphasized the importance of managing resources, equipment, weather, and natural conditions to keep the project running smoothly and efficiently.

This study analyzed the time and cost delays in the Banjarsari Sluice maintenance project in Banjarsari village, Taman sub-district, Sidoarjo district. They analyzed what caused the delay in the project and what the best solution was to get the most efficient cost and time. Where time analysis uses the CPM (Critical Path Method) method and is assisted by Microsoft Project Software. To avoid non-conformity with the plan, it is necessary to analyze time optimization using the Critical Path Method (CPM) method by crashing, namely using the most efficient cost analysis between additional workers or overtime work to get the optimal time at the end of the project, in the Banjarsari floodgate rehabilitation project with a completion time of 30 calendar days. The objectives to be achieved from this writing are to determine the value of project time optimization obtained when planned using the Critical Path Method (CPM) and to determine the difference in time between the plan and project optimization after analysis using the Critical Path Method (CPM).

This research analyzes the time required to implement the Banjarsari Water Gate Construction project using the Critical Path Method (CPM) to identify the critical path and optimal time estimation. Another objective is to compare the duration of time and cost between the scheduling of the Banjarsari Sluice Gate Construction project based on the initial plan with the results of calculations using the CPM method, to evaluate the efficiency of time and cost that can be achieved, and provide recommendations for improving project management in the future. The benefit of this research for construction service providers is finding out which activities must be completed first, especially in the Banjarsari floodgate project development work item.

METHOD

This research uses a descriptive approach that aims to systematically describe the existing conditions in the Krembangan Sluice Gate Construction project on the Pelayaran River, Sidoarjo Regency. This approach was chosen because the research focuses on analyzing project time duration using the Critical Path Method (CPM). The types of data used in this research include qualitative and quantitative data. Qualitative data provides information about the dependency relationship between project activities and the causes of delays, which are obtained through interviews, observations, and literature studies. Meanwhile, quantitative data is in the form of time, cost, and number of workers measurements obtained from project documents, such as working drawings, time schedules, unit price analysis (AHS), and direct observations in the field.

The primary data came from interviews with field workers and relevant company staff and observation of project activities. Secondary data was obtained from project documents and applicable regulations, including the Minister of Public Works and Housing Regulation 2023. The data collection techniques were interviews, observations, and literature studies, which aimed to obtain relevant and accurate information for further analysis.

In data analysis, researchers collected data from the Brantas River Basin Center, such as project working drawings, time schedules, and AHS. Next, the researcher inventoried the project activities and broke them into more detailed components. After that, each activity was coded, and duration and cost calculations were made based on field data and unit price analysis. Dependency relationships between activities were compiled based on the results of interviews and observations, and time calculations were carried out using Earliest Event Time (EET) and Latest Event Time (LET) through Microsoft Project 2021 software. The next step is to identify the critical path and, if needed, accelerate activities

on the critical path to optimize project completion time. This research is expected to provide insight into the efficiency of project scheduling and recommendations for improving project management in the future.

RESULTS AND DISCUSSION

Time Analysis Using Critical Path Method

Time analysis using the Critical Path Method (CPM) is an effective approach in project management. It is especially useful for identifying critical activities that affect the total duration of the project. With CPM, activities that require extra attention or need to be prioritized can be identified, resources allocated more efficiently, and anticipatory actions planned in case of delays.

Determination of Dependency Logic (Predecessor)

Determining dependency logic in the Critical Path Method (CPM) is essential in developing an effective project schedule. Dependency logic describes the relationship between activities in the project, which determines the sequence of activities based on logical dependency relationships.

Table 1. Dependency Logic List

Activity Code	Job Description	Predecessor	Duration of work
I	PREPARATORY WORK		
A	Measurement / Bouwplank	K FS	3 days
II	DEMOLITION WORK		
B	Demolition of Existing Concrete	Start	6 days
C	Demolition of Stone Masonry	E FS	3 days
D	Demolition of Existing Concrete Cyclops	C SS	10 days
E	Demolition of secondary sluice gates	B FS-3Days	3 days
III	DEWATERING WORK		
F	Earthen kistdam work	I SS+3Days	10 days
G	Retaining bamboo sectional work	I SS+3Days	10 days
H	Bamboo sectional anchoring framework	I SS+3Days	10 days
I	Hourly operation of the water pump	D SS	13 days
J	Kistdam demolition	Z SS	2 days
IV	STRUCTURAL WORK		
S	K175 Quality Concrete	N FS	7 days
L	K125 Quality Concrete (Concrete Rebate)	Q FS	2 days
M	Fixing with Plain Iron	D FS	4 days
K	Concrete Floor Scoop	D FS	12 days
N	Foundation and Sloof Formwork Installation	K FS	2 days

Source: Processed by Researcher, 2024

Table 2. List of Dependency Logic (Continued)

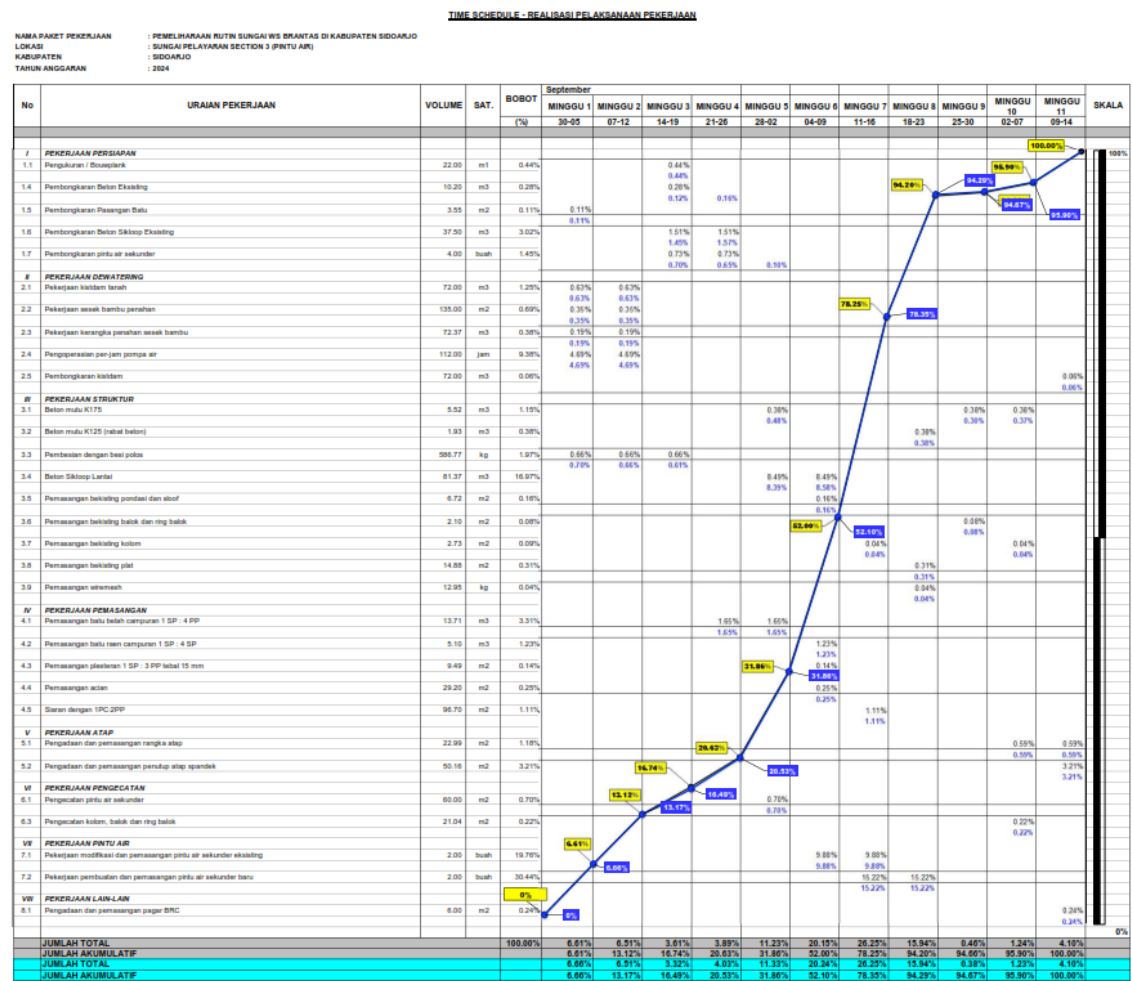
Activity Code	Job Description	Predecessor	Duration of work
O	Erection of Beam and Ring Beam Formwork	P FS	2 days
P	Erection of column formwork	N FS	1 day
R	Installation of plate formwork	T FS	2 days
Q	Wiremesh concreting	R FS	1 day
V	INSTALLATION WORK		
T	Installation of stone masonry mix 1 SP: 4 PP	K FS	6 days
U	Installation of Raen stone mix 1 SP: 4 SP	T FS	2 days
V	Plastering 1 SP: 3 PP 15 mm thick	S FS+3 Days	4 days
W	Installation of the acian	V FS	5 days
X	Broadcast with 1PC:2PP	W FS	3 days
VI	ROOFING WORK		
AC	Procurement and installation of roof trusses	L FS+2 Days	3 days
AD	Procurement and installation of spandex roof coverings	AC FS	1 day
VII	PAINTING WORK		
Y	Painting of secondary sluice gates	X FS	3 days
Z	Painting of columns, beams, and beam rings	Y FS	2 days
VIII	SLUICE GATE WORK		

Activity Code	Job Description	Predessor	Duration of work
AA	Modification work and installation of existing secondary sluice gates	0 FS +1 Days	8 days
AB	Construction and installation of new secondary sluice gates	AA FS + 3 Days	6 days
IX	MISCELLANEOUS WORK		
AE	Procurement and installation of BRC fence	Z FF	1 day

Source: Processed by Researcher, 2024

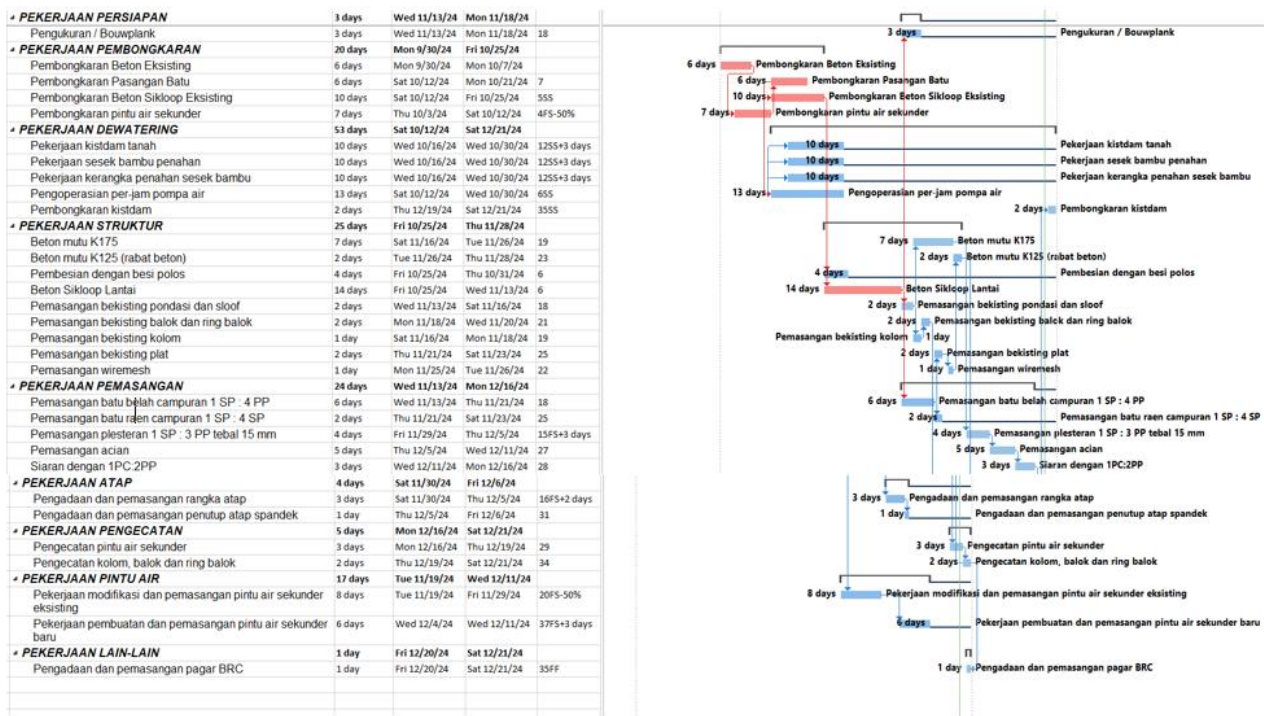
Project Activities and Time Schedule

In its implementation, the project is designed through several stages of activities summarized in a schedule. This time schedule aims to ensure that all project activities are carried out systematically, efficiently, and within the predetermined time target. This project time schedule is designed using methods such as the Critical Path Method (CPM) to map each stage in detail. The schedule shows the sequence of activities, estimated time, and the dependency relationship between one activity and another.

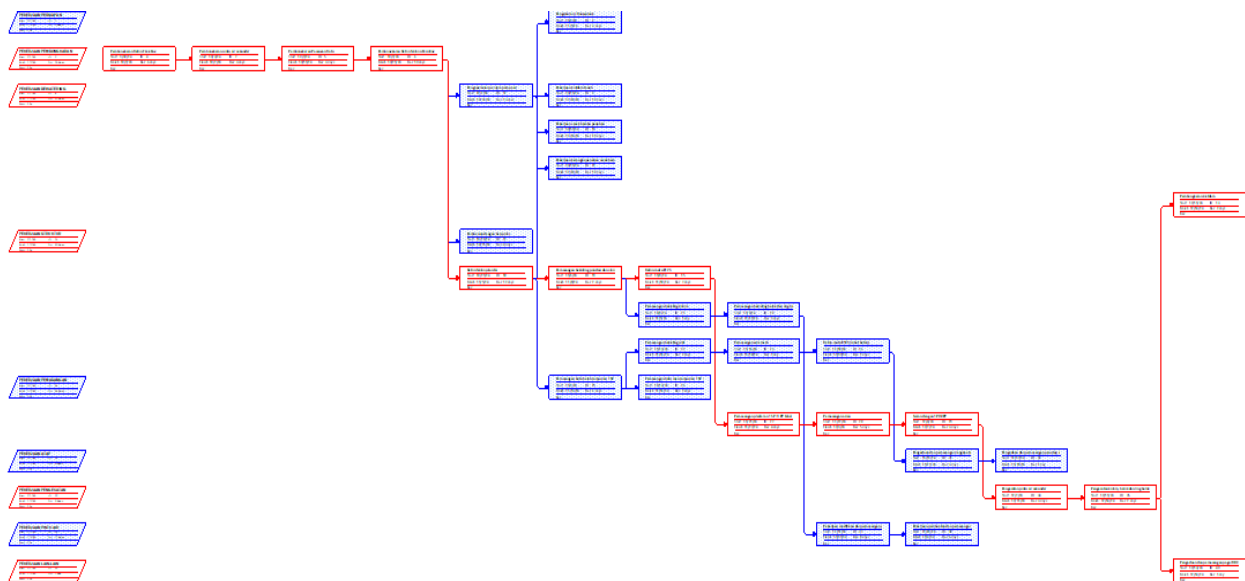


Source: OP SDA II Planner, 2024

Project scheduling for the construction of the Banjarsari sluice gate in Sidoarjo district using Microsoft Project 2021 starts with each activity given a realistic duration based on technical planning, then connected using dependencies such as start-to-start (SS) or finish-to-start (FS). Project scheduling using Microsoft Project is also used to visualize the sequence of work and determine the critical path, which is the set of activities that most affect the project's total duration. Microsoft Project also allows simulation in the event of delays, so the schedule can be updated to minimize the impact on project completion.



Scheduling using Microsoft Project 2021
Source: Processed by Researcher, 2024



Banjarsari Water Gate Network Diagram using Microsoft Project 2021
Source: Processed by Researcher, 2024

Analysis of Time and Cost Alternatives Due to Time Delays

The analysis of time and cost alternatives due to time delays in sluice gate projects is an evaluation process that aims to identify the impact of delays on the achievement of project targets and propose solutions to minimize the consequences. Delays in sluice gate construction projects can be caused by various factors, such as technical problems, lack of coordination, unfavorable weather, and material constraints. These delays not only affect the project schedule but also increase costs, including direct expenses (such as additional labor and equipment costs) and indirect costs (such as penalties or claims from other parties).

In this analysis, the Critical Path Method (CPM) is often used to identify the critical path in the project schedule and determine acceleration alternatives such as adding working hours (overtime), using additional resources, or changing work methods.

Time Analysis With the Addition of the Number of Workers on Items on the Critical Path

The first alternative, namely by increasing the number of workers on items on the critical path, is a strategy to accelerate the completion of the sluice gate project, which is experiencing delays due to demolition work and casting cyclopean concrete. This approach is carried out by adding labor to activities on the critical path, which is a series of jobs that determine the project's total duration. Adding labor allows the activity to be completed faster without changing the order of other work.

Table 8. Duration and Number of Workers on Critical Path Work

No.	Job Description	Number of workers	Duration of work
II	DEMOLITION WORK		16
2.1	Demolition of Existing Concrete	4	6
2.2	Demolition of Stone Masonry	3	6
2.3	Demolition of Existing Concrete Cyclops	4	10
2.4	Demolition of Existing Sluice Gate	3	5
IV	STRUCTURAL WORK		
4.1	Concrete Floor Stoops	6	12

Source: Processed by Researcher, 2024

Due to the delay in this work, each work item must be accelerated. Here are the work items that are on the critical path.

The longest work weight is on the critical path. The addition of workers at the Banjarsari sluice gate in the Sidoarjo district is calculated as follows:

A. Number of Workers in Existing Concrete Demolition Work

Workers = four people
 Duration of work = 6 days
 Duration of work to be achieved = 4 days
 Therefore, the addition of workers is :

$$6 \text{ days} \times 4 \text{ people} = 24 \text{ people} \times n$$

$$n = \frac{6 \times 4}{4} = 6 \text{ people}$$

$$\text{additional workers} = 6 - 4 = 2 \text{ people}$$

B. Number of Workers on Demolition Work of Stone Masonry

Workers = three people
 Duration of work = 6 days
 Duration of work to be achieved = 4 days
 Therefore, the addition of workers is :

$$6 \text{ days} \times 3 \text{ people} = 18 \text{ people} \times n$$

$$n = \frac{6 \times 3}{4} = 4.5 \text{ people} \sim 5 \text{ people}$$

$$\text{additional workers} = 6 - 5 = 1 \text{ person}$$

C. Number of Workers in Existing Cycloped Concrete Demolition Work

Workers = four people
 Duration of work = 10 days
 Duration of work to be achieved = 7 days
 Therefore, the addition of workers is

$$10 \text{ days} \times 4 \text{ people} = 40 \text{ people} \times n$$

$$n = \frac{10 \times 4}{7} = 5.71 \text{ people} \sim 6 \text{ people}$$

$$\text{additional workers} = 6 - 4 = 2 \text{ people}$$

D. Number of Workers on Demolition Work of Existing Sluice Gates

Workers = three people
 Duration of work = 5 days
 Duration of work to be achieved = 3 days
 Therefore, the addition of workers is :

$$5 \text{ days} \times 3 \text{ people} = 15 \text{ people} \times n$$

$$n = \frac{5 \times 3}{3} = 5 \text{ people}$$

$$\text{additional workers} = 5 - 3 = 2 \text{ people}$$

E. Number of Workers on Concrete Cycloop Floor

Workers = six people
 Duration of work = 12 days
 Duration of work to be achieved = 9 days
 Therefore, the addition of workers is :

$$12 \text{ days} \times 6 \text{ people} = 6 \text{ people} \times n$$

$$n = \frac{12 \times 6}{9} = 8 \text{ people}$$

$$\text{additional workers} = 8 - 6 = 2 \text{ people}$$

Cost analysis with the addition of workers on items on the critical path

The cost analysis of adding workers to items on the critical path aims to accelerate project completion without exceeding the planned time limit. In this method, focus is given to activities on the critical path because delays on this path will directly affect the project's total duration. Workers are usually added by considering the crashing cost and the resulting potential time reduction.

Worker Cost Slope Calculation

The acceleration of work duration is done by adding workers to the work on the critical path. The number of working hours remains 8 hours per day and 6 days per week. Based on worker productivity and the volume of work, it is calculated as follows:

A. Number of Workers in Existing Concrete Demolition Work

- (a) Work volume = 10,20 m³
- (b) Normal duration = 6 days
- (c) Number of normal workers = four people
- (d) Normal worker wage cost = IDR 47,823,000
- (e) Normal productivity = $\frac{(a)}{(b)}$
 $= \frac{10,20 \text{ m}^3}{6 \text{ hari}} = 1.7 \sim 2 \text{ m}^3/\text{day}$
- (f) Worker productivity = $\frac{(e)}{(c)}$
 $= \frac{2}{4} = 0.5 \text{ m}^3/\text{day}$
- (g) Number of additional workers = 6 people
- (h) Worker productivity = (f) x (g)
 $= 0.5 \times 6 = 3 \text{ m}^3$
- (i) Target duration = 4 days
- (j) Additional cost = (i) x (g-c) x worker's wage
 $= 4 (6-4) \times \text{IDR } 113,700$
 $= 4 \times (2) \times \text{IDR } 113,700$
 $= \text{IDR } 909,600$
- (k) Total cost = IDR 47,823,000 + IDR 909,600
 $= \text{IDR } 48,732,600$

From the above calculations, the cost slope is obtained as follows:

Cost slope of existing concrete demolition work

$$= \frac{(j)}{(b-i)} = \frac{Rp.909.600}{6-4} = \frac{Rp.909.600}{2} = \text{IDR } 454,800$$

B. Number of workers on masonry demolition work

1. Work volume = 3,55 m³
2. Normal duration = 6 days
3. Number of normal workers = three people
4. Normal worker wage cost = IDR 47,823,000
5. Normal productivity = $\frac{(a)}{(b)} = \frac{3,55 \text{ m}^3}{6 \text{ hari}} = 0.59 \sim 1 \text{ m}^3/\text{day}$
6. Worker productivity = $\frac{(e)}{(c)} = \frac{1}{3} = 0.33 \text{ m}^3/\text{day}$
7. Number of additional workers = 5 people
8. Worker productivity = (f) x (g) = 0.33 x 1 = 0.33 m³
9. Target duration = 4 days
10. Additional cost = (i) x (g-c) x worker's wage = 4 x (5-3) x IDR 113,700 = 4 x (2) x IDR 113,700 = IDR 909,600
11. Total cost = IDR 47,823,000 + IDR 909,600 = IDR 48,732,600

From the above calculations, the cost slope is obtained as follows:

Cost slope of masonry demolition work

$$= \frac{(j)}{(b-i)} = \frac{Rp.909.600}{6-4} = \frac{Rp.909.600}{2} = \text{IDR } 454,800$$

C. Number of Workers in Cycloop Concrete Demolition Work

1. Work volume = 37,50 m³
2. Normal duration = 10 days
3. Number of normal workers = four people
4. Normal worker wage cost = IDR 47,823,000
5. Normal productivity = $\frac{(a)}{(b)} = \frac{37,50 \text{ m}^3}{10 \text{ hari}} = 3.75 \sim 4 \text{ m}^3/\text{day}$
6. Worker productivity = $\frac{(e)}{(c)} = \frac{4}{4} = 1 \text{ m}^3/\text{day}$
7. Number of additional workers = 6 people
8. Worker productivity = (f) x (g)

9. Target duration = $1 \times 6 = 6 \text{ m}^3$
= 7 days
10. Additional cost = $(i) \times (g-c) \times \text{worker's wage}$
= $7 \times (6-4) \times \text{IDR } 113,700$
= $7 \times (2) \times \text{IDR } 113,700$
= IDR 1,591,800
11. Total cost = IDR 47,823,000 + IDR 1,591,800
= IDR 49,414,800

From the above calculations, the cost slope is obtained as follows:

Cost slope of cyclo-concrete demolition work

$$\begin{aligned}
 &= \frac{(j)}{(b-i)} \\
 &= \frac{\text{Rp.1.591.800}}{10-7} \\
 &= \frac{\text{Rp.1.591.800}}{3} \\
 &= \text{IDR } 530,600
 \end{aligned}$$

D. Number of Workers on Demolition Work of Existing Sluice Gates

1. Volume of work = 4 m^3
2. Normal duration = 5 days
3. Number of normal workers = three people
4. Normal worker wage cost = IDR 47,823,000
5. Normal productivity = $\frac{(a)}{(b)}$
= $\frac{37,50 \text{ m}^3}{10 \text{ hari}} = 3.75 \sim 4 \text{ m}^3/\text{day}$
6. Worker productivity = $\frac{(e)}{(c)}$
= $\frac{4}{4} = 1 \text{ m}^3/\text{day}$
7. Number of additional workers = 5 people
8. Worker productivity = $(f) \times (g)$
= $1 \times 5 = 5 \text{ m}^3$
9. Target duration = 3 days
10. Additional cost = $(i) \times (g-c) \times \text{worker's wage}$
= $3 \times (5-3) \times \text{IDR } 113,700$
= $7 \times (1) \times \text{IDR } 113,700$
= IDR 1,023,300
11. Total cost = IDR 47,823,000 + IDR 1,203,300
= IDR 49,026,300

From the above calculations, the cost slope is obtained as follows:

Cost slope of the sluice gate demolition work

$$\begin{aligned}
 &= \frac{(j)}{(b-i)} \\
 &= \frac{\text{Rp.1.023.300}}{5-3} \\
 &= \frac{\text{Rp.1.023.300}}{2} \\
 &= \text{IDR } 511,650
 \end{aligned}$$

E. Number of Workers on Cyclo Floor Concrete Work

1. Work volume = $81,37 \text{ m}^3$
2. Normal duration = 12 days
3. Number of normal workers = six people
4. Normal worker wage cost = IDR 47,823,000

5. Normal productivity $= \frac{(a)}{(b)}$
 $= \frac{81,37 \text{ m}^3}{12 \text{ hari}} = 6.78 \sim 7 \text{ m}^3/\text{day}$
6. Worker productivity $= \frac{(e)}{(c)}$
 $= \frac{7}{6} = 1.16 \text{ m}^3/\text{day}$
7. Number of additional workers = 8 people
8. Worker productivity = (f) x (g)
 $= 1.16 \times 8 = 9.8 \text{ m}^3$
9. Target duration = 9 days
10. Additional cost = (i) x (g-c) x worker's wage
 $= 9 \times (8-6) \times \text{IDR } 113,700$
 $= 9 \times (2) \times \text{IDR } 113,700$
 $= \text{IDR } 2,046,600$
11. Total cost = IDR 47,823,000 + IDR 2,046,600
 $= \text{IDR } 49,869,600$

From the above calculations, the cost slope is obtained as follows:

Cost slope of concrete cycloop floor demolition work

$$\begin{aligned}
 &= \frac{(j)}{(b-i)} \\
 &= \frac{\text{Rp.2.046.600}}{12-9} \\
 &= \frac{\text{Rp.2.046.600}}{3} \\
 &= \text{IDR } 682,200
 \end{aligned}$$

Tool Cost Slope Calculation

A. Number of tools in existing concrete demolition work

1. Work volume = 10,20 m³
2. Normal duration = 6 days
3. Number of normal tools = two pieces
4. Normal tool cost = Rp 1,153,125
5. Productivity $= \frac{(a)}{(b)}$
 $= \frac{10,20 \text{ m}^3}{6 \text{ hari}} = 1.7 \sim 2 \text{ m}^3/\text{day}$
6. Tool productivity $= \frac{(e)}{(c)}$
 $= \frac{2}{4} = 0.5 \text{ m}^3/\text{day}$
7. Number of tools = 4 pieces
8. Tool productivity = (f) x (g)
 $= 0.5 \times 4 = 2 \text{ m}^3$
9. Target duration = 4 days
10. Additional cost = (i) x (g-c) x tool rental fee
 $= 4 (4-2) \times \text{IDR } 450,000$
 $= 4 \times (2) \times \text{IDR } 450,000$
 $= \text{IDR } 3,600,000$
11. Total cost = IDR 1,153,125 + IDR 3,600,000
 $= \text{IDR } 4,753,125$

From the above calculations, the cost slope is obtained as follows:

Cost slope of existing concrete demolition work

$$\begin{aligned}
 &= \frac{(j)}{(b-i)} \\
 &= \frac{\text{Rp.3.600.000}}{6-4} \\
 &= \frac{\text{Rp.3.600.000}}{2}
 \end{aligned}$$

$$= \text{IDR } 1,800,000$$

B. Number of workers on masonry demolition work

1. Work volume $= 3,55 \text{ m}^3$
2. Normal duration $= 6 \text{ days}$
3. Number of normal tools $= \text{one piece}$
4. Normal tool cost $= \text{Rp } 1,153,125$
5. Normal productivity $= \frac{(a)}{(b)}$
 $= \frac{3,55 \text{ m}^3}{6 \text{ hari}} = 0.59 \sim 1 \text{ m}^3/\text{day}$
6. Productivity $= \frac{(e)}{(c)}$
 $= \frac{1}{3} = 0.33 \text{ m}^3/\text{day}$
7. Number of additional tools $= 2 \text{ tools}$
8. Worker productivity $= (f) \times (g)$
 $= 0.33 \times 2 = 0.66 \text{ m}^3$
9. Target duration $= 4 \text{ days}$
10. Additional cost $= (i) \times (g-c) \times \text{tool rental fee}$
 $= 4 \times (2-1) \times \text{IDR } 450,000$
 $= 4 \times (1) \times \text{IDR } 450,000$
 $= \text{IDR } 1,800,000$
11. Total cost $= \text{Rp } 1,153,125 + \text{Rp } 1,800,000$
 $= \text{IDR } 2,953,125$

From the above calculations, the cost slope is obtained as follows:

Cost slope of masonry demolition work

$$= \frac{(j)}{(b-i)}$$

$$= \frac{\text{Rp.1.800.000}}{6-4}$$

$$= \frac{\text{Rp.1.800.000}}{2}$$

$$= \text{IDR } 900,000$$

C. Number of workers on masonry demolition work

1. Work volume $= 37,50 \text{ m}^3$
2. Normal duration $= 10 \text{ days}$
3. Number of normal tools $= \text{two pieces}$
4. Normal tool cost $= \text{Rp } 1,153,125$
5. Normal productivity $= \frac{(a)}{(b)}$
 $= \frac{3,55 \text{ m}^3}{2 \text{ hari}} = 1.775 \text{ m}^3/\text{day}$
6. Productivity $= \frac{(e)}{(c)}$
 $= \frac{1,775}{2} = 0.88 \text{ m}^3/\text{day}$
7. Number of additional tools $= 4 \text{ tools}$
8. Worker productivity $= (f) \times (g)$
 $= 0.88 \times 4 = 3.52 \text{ m}^3$
9. Target duration $= 4 \text{ days}$
10. Additional cost $= (i) \times (g-c) \times \text{tool rental fee}$
 $= 4 \times (4-2) \times \text{IDR } 450,000$
 $= 4 \times (2) \times \text{IDR } 450,000$
 $= \text{IDR } 3,600,000$
11. Total cost $= \text{Rp } 1,153,125 + \text{Rp } 3,600,000$
 $= \text{IDR } 4,753,125$

From the above calculations, the cost slope is obtained as follows:

Cost slope of masonry demolition work

$$= \frac{(j)}{(b-i)} \\ = \frac{Rp.3.600.000}{10-4} \\ = \frac{Rp.1.800.000}{6} \\ = IDR 300,000$$

Table 9. Recapitulation of Worker Addition Cost Analysis

No.	Job Description	Normal		Additional Workers	
		Duration (Days)	Cost (Rp)	Duration (Days)	Cost (Rp)
II	DEMOLITION WORK				
2.1	Demolition of Existing Concrete	6	IDR 1,280,063	4	IDR 909,600
2.2	Demolition of Masonry	3	Rp. 495,966	4	IDR 909,600
2.3	Demolition of Existing Concrete Cyclops	4	Rp. 15,472,085	7	IDR 1,591,800
2.4	Demolition of Existing Sluice Gate	3	Rp. 7,846,968	3	IDR 1,023,300
IV	STRUCTURAL WORK				
4.1	Concrete Floor Stoops	12	Rp. 91,525,188	9	IDR 2,046,600

Source: Processed by Researcher, 2024

CONCLUSION

Based on the analysis that has been carried out on the Banjarsari Sluice Gate Construction project on the Pelayaran River, Sidoarjo Regency, using the Critical Path Method (CPM), several conclusions are obtained. First, based on the duration of all activities, the dependency logic relationship between activities, and calculations using the Microsoft Project 2021 application, the total duration required to complete this project is 66 working days. This shows that the Banjarsari Water Gate work was successfully accelerated to 66 working days, reduced from the original duration of 72 working days.

Future research on the Banjarsari Water Gate project could focus on several key areas. First, evaluating the environmental impact of the construction, particularly the effects of sedimentation, waste disposal, and other challenges on local ecosystems, would be valuable. A deeper exploration of risk management strategies could help mitigate delays and costs, especially when labor shortages or environmental factors disrupt projects. A comparative analysis of time management tools, such as CPM versus PERT, could offer insights into the most effective scheduling method for infrastructure projects. Furthermore, investigating how emerging technologies like AI and BIM can optimize project time and cost calculations through real-time monitoring and predictive analytics would be beneficial. Research could also focus on human resource optimization to balance labor productivity with cost-effectiveness and integrate sustainable construction practices in water infrastructure projects. Finally, a post-construction study on the long-term water gate maintenance, including IoT sensors for monitoring and cost-effective maintenance strategies, would provide a comprehensive view of the project's lifecycle.

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