

Analysis of Work Network and Critical Trajectory on Penganten - Ngampal Road Reconstruction Project Using Critical Path Method (CPM)

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Abstract

The Reconstruction Project of Penganten-Ngampal Road in Bojonegoro Regency faces challenges in time and resource management, leading to project delays. These delays affect time and cost efficiency, which are key issues in achieving the project's objectives. To address this problem, this study aims to analyze the project's work schedule and critical path using the Critical Path Method (CPM). The research employs a quantitative method, with data collected through primary and secondary data sources. Primary data was obtained through field observations and questionnaires, while secondary data was gathered from project documents and relevant literature. Using CPM, the first step was to construct the project's work schedule based on the work breakdown structure (WBS) and the relationships between activities. An analysis was then performed utilizing forward pass and backward pass methods to identify the critical path. This path comprises tasks that require timely completion to avoid causing additional project delays. The results show that the critical path for the Penganten-Ngampal Road Reconstruction Project is identified in activities with codes A, C, D, E, and F. The total project completion duration based on the analysis is 47 days. Activities on this critical path must be completed on time, as delays in any of these activities will affect the overall completion of the project. Therefore, better time management and proper resource allocation for critical activities are essential to complete the project according to the planned timeline.

Keywords: Time Management, Critical Path Method (CPM), Critical Path, Forward Pass, Backward Pass.

1. Introduction

Infrastructure development is a crucial component in supporting economic growth and improving people's welfare. Good infrastructure not only serves as a foundation for economic activity, but also as a link that strengthens social and cultural interactions between regions. One important element of infrastructure is the road network, which serves as the main means of transportation and link between regions. Good quality roads not only facilitate community mobility, but also contribute to economic growth, improved social welfare and strengthened cultural relations. Good roads enable more efficient distribution of goods and services, reduce transportation costs, and improve accessibility to public services such as education and health. However, road construction projects often face various challenges, ranging from limited resources, unfavorable weather conditions, to complexities in management that require planned solutions (Astari et al., 2022)

Construction project management requires a systematic approach so that project implementation can run according to plan. One technique that is widely used for project



scheduling is the Critical Path Method (CPM). This approach is used to pinpoint the critical path, consisting of a sequence of tasks that dictate the overall project duration.

Grasping the critical path allows the project manager to focus on the tasks that have a major impact on the overall timeline for project completion. The critical path delivers essential insights to project managers about tasks that require priority attention to ensure timely completion and avoid delays. Moreover, implementing CPM facilitates better risk assessment and resource allocation, enabling projects to be executed more efficiently.

The Penganten-Ngampal Road Reconstruction Project is one of the strategic projects designed to improve connectivity in Bojonegoro Regency, East Java. The project has a target completion time of 120 calendar days with a budget of Rp10,656,000,000.00. However, in its implementation, the project took up to 170 calendar days due to significant technical and operational obstacles. This delay indicates weaknesses in the project's time planning and resource management. Therefore, a thorough evaluation of the scheduling system used is required to ensure conformity between plans and realization in the field.

Weaknesses in project scheduling often have significant consequences for implementation efficiency and final results. Inaccuracies in scheduling not only extend project time, but also increase the risk of cost overruns and waste of resources. In the context of road projects, ineffective scheduling can affect the quality of work that does not meet standards, disrupt community mobility, and impact local economic growth (Hasnah & Herwanto, 2023). For example, if scheduling does not consider weather factors or material availability, the project may experience prolonged delays, which in turn can lead to community dissatisfaction and economic losses for the area.

The Critical Path Method (CPM) was introduced in the 1950s as a deterministic tool designed to support the planning and control of complex projects. CPM enables in-depth analysis of project networks, including the identification of activities, durations, and dependency relationships between activities. This technique is particularly relevant in road reconstruction projects, where many activities are interconnected and have different priorities (Uktolseja et al., 2023). By using CPM, project managers can visualize the entire process and identify critical points that require more attention, so as to optimize the allocation of resources and time.

The advantage of the CPM method lies in its ability to identify the critical path and offer practical solutions to minimize delays. By doing this identification, projects can be prioritized according to needs, so that obstacles in implementation can be minimized, and potential waste of time and money can be avoided (Husna et al., 2022). In road projects, the critical path usually includes preparatory work, the main structure, and the final completion stage, all of which require special attention in order to run smoothly. For example, if preparatory works such as measurement and mapping are not carried out in a timely manner, then the entire set of subsequent activities will be affected, causing potentially costly delays.

CPM not only serves as a guide in prioritizing work, but also offers flexibility in project planning and control. The representation of the work network in diagrammatic form facilitates the visualization of relationships between activities, which allows project managers to identify activities that can be performed simultaneously or activities that have slack. This aspect is particularly crucial in road projects, which often involve multiple disciplines (Ismail, 2021).

The delays experienced in the Penganten-Ngampal Road Reconstruction project provide important insights into the need to develop a schedule that is adaptive to changing conditions in the field. Various factors such as weather, material limitations, and labor coordination are challenges that must be considered from the planning stage. CPM allows for more measurable

risk analysis related to delays, as well as providing data-driven solutions to mitigate these risks (Rahman, 2021).

The application of the CPM method in this project is expected to provide a comprehensive understanding of the project work network and solutions to accelerate completion time through approaches such as crashing. This strategy can be applied to accelerate the completion of activities on the critical path with the addition of certain resources, without sacrificing the quality of the final project result (Adrianti et al., 2024). Thus, the CPM method serves not only as a planning tool, but also as an effective evaluation tool to ensure the project stays within the set budget and time.

The growing complexity of construction project challenges necessitates the implementation of the Critical Path Method (CPM) as a strategic approach to enhance both the efficiency and effectiveness of project management. By identifying important activities on the critical path, project managers can ensure proper resource allocation and prevent further delays. This makes CPM a relevant and applicable method for road infrastructure projects in Indonesia (Manurung & Susanty, 2022).

2. Methods

This research uses a quantitative approach to analyze the work network and critical path on the Penganten-Ngampal Road Reconstruction project by applying the Critical Path Method (CPM). This approach was chosen because it allows systematic analysis of data, provides an in-depth understanding of project dynamics, and identifies the most important activities in the management of time and resources. The CPM was used to determine the project's critical path, which is defined as a series of activities that have no time buffer. As a result, any delays in these activities will directly impact the overall duration of the project.

2.1. Data Collection

1. Primary Data

Looking for information that is not written or data that has a high level of accuracy. The survey included the following:

a. Field Observation

The purpose of this observation is to collect data that cannot be written down, which can only be obtained through direct observation of the condition of the Penganten - Ngampal road reconstruction. Activities carried out include measurement, continuity assessment, and observation of the physical condition of the road being worked on.

b. Questionnaire

The questionnaire was used to measure the level of community satisfaction with the Penganten - Ngampal road reconstruction program implemented by the Bojonegoro PUPR Office, as well as to find out the preferences of the parties directly involved in the road project.

2. Secondary Data

Secondary data was obtained through literature review, previous research, relevant maps, and information on the condition of the research area obtained from relevant agencies. The purpose of this survey is to collect data that will be processed using available analytical tools.

2.2. Data Analysis Using Critical Path Method (CPM)

Data analysis was conducted using the Critical Path Method (CPM) approach to determine the critical path in the project. CPM is a project management technique used to plan, schedule, and manage projects more effectively. CPM is essential for identifying the

critical path, which includes the activities that determine the total duration of a project. By understanding the critical path, project managers can focus on the activities that have the greatest impact on the project's completion timeline. The following steps detail how to apply the CPM technique:

1. Identification of Project Activities

The initial stage of CPM analysis involves determining all the tasks necessary to finalize the project. These tasks are derived from the work breakdown structure (WBS), which provides a detailed, hierarchical outline of all the work to be accomplished.

2. Preparation of Work Network Diagram

A network diagram is an important tool in project management that is used to represent the relationship between the various activities involved in a project. By drawing up this diagram, the project manager can get a clear picture of how each task interacts with each other and contributes to the achievement of the overall project goals.

3. Critical Path Calculation

The project critical path is calculated by performing the following steps:

- a. **Forward Pass:** Forward calculation is done to determine the earliest time an activity starts and finishes. The formula used:

$$\mathbf{EF \text{ (Earliest Finish)} = ES \text{ (Earliest Start)} + D \text{ (Duration)}}$$

Where:

ES is the earliest time an activity can start.

D is the duration of time for the activity.

Backward Pass: Backward calculation is used to determine the latest time an activity can start and finish without delaying the project. The formula used:

$$\mathbf{LS \text{ (Latest Start)} = LF \text{ (Latest Finish)} - D \text{ (Duration)}}$$

Where:

LF is the latest finish time of an activity.

D is the duration of the activity.

4. Determining Critical and Non-Critical Paths

The critical path is the path of activities that determine the total duration of the project. If activities on this path are delayed, then the entire project will be affected. Critical path identification is done by calculating Float, which is the free time available for each activity:

$$\mathbf{Float = LS - ES \text{ or } Float = LF - EF}$$

If Float = 0, then the activity is on the critical path. In contrast, activities on the non-critical path have more than 0 float, so they have time flexibility without affecting the overall project completion.

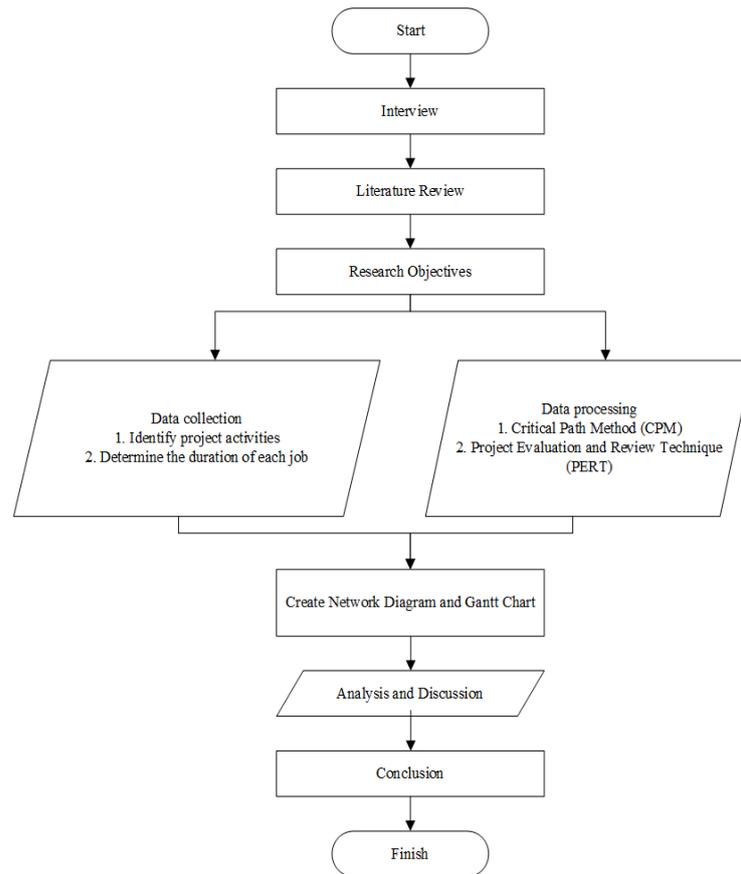


Figure 1. Research Flowchart

3. Results and Discussion

3.1. Critical Path Method (CPM) Analysis

In the Penganten-Ngampal Road Reconstruction project, the application of the CPM method serves to analyze the work network and identify critical paths that form the basis for project planning. This project involves various activities that are interrelated and have a predetermined duration. Through this analysis, it is expected to obtain a clear picture of the relationship between activities, calculation of allowance time, and determination of critical paths that affect the project completion time.

The CPM method in the context of the Penganten-Ngampal Road Reconstruction project is used to evaluate the work network and determine the critical path that is essential for project planning. The project consists of a number of interdependent activities and has a specific execution time. The purpose of this analysis is to map the interactions between activities, calculate time allowances, and identify critical paths that impact the overall project completion duration.

3.1.1. Relationships between Activities

Analysis of the relationship between activities in the Penganten-Ngampal Road Reconstruction project was carried out by utilizing a work breakdown structure (WBS). WBS is a project management tool that divides the project into smaller and more manageable parts. The following is a sequence of activities in accordance with the dependency relationship on the Penganten - Ngampal Bojonegoro Road Reconstruction Project in detail can be seen in Table 1.

Table 1. Relationships between Activities

Activity Code	Type of Work	Duration	Previous Activities
A	General	4	-
B	Construction Safety Management System (CSMS)	10	A
C	Earthwork and Geosynthetic	15	A
D	Graded Pavement and Cement Concrete Pavement	9	C
E	Asphalt Pavement Work	1	F, G
F	Structural Works	18	D, G
G	Graded Pavement and Cement Concrete Pavement	4	B

3.1.2. Analysis of Forward Calculation (Forward Pass)

Forward calculation, also known as forward pass, is a method used to determine the start and finish time of each activity by calculating from the starting point of the project. The first process in forward calculation is from start to finish, which is used to calculate EF (early finish) by summing the ES and duration of the activity in question.

Table 2. Forward Calculations

No.	Type of Work	Duration (day)	Activity Code	ES	EF
1.	General	4	A	0	4
2.	Construction Safety Management System (CSMS)	10	B	4	14
3.	Earthwork and Geosynthetic	15	C	4	19
4.	Graded Pavement and Cement Concrete Pavement	9	D	19	28
5.	Asphalt Pavement Work	1	E	46	47
6.	Structural Works	18	F	28	46
7.	Graded Pavement and Cement Concrete Pavement	4	G	14	18

3.2. Analysis of Backward Calculation (Backward Pass)

After completing the forward calculation, the next step is to perform a backward pass. This process starts from finish to start, which aims to calculate LS (the latest time to start the activity). The LS value is obtained by reducing the LF (slowest time to complete the activity) by the duration of the activity.

Table 3. Backward Calculations

No.	Type of Work	Duration (day)	Activity Code	LS	LF
1.	General	4	A	0	4
2.	Construction Safety Management System (CSMS)	10	B	14	24

No.	Type of Work	Duration (day)	Activity Code	LS	LF
3.	Earthwork and Geosynthetic	15	C	4	19
4.	Graded Pavement and Cement Concrete Pavement	9	D	19	28
5.	Asphalt Pavement Work	1	E	46	47
6.	Structural Works	18	F	28	46
7.	Graded Pavement and Cement Concrete Pavement	4	G	24	28

3.3. Calculating Project Total Float

After completing the forward and backward calculations, the next step is to determine the total project float. Total float, or what is often referred to as slack time, is the leeway time available for each activity in the project without affecting the project's final completion date. In other words, total float gives an idea of how much time an activity can take before affecting the overall project schedule.

Activities that have float equal to zero (float = 0) are considered to be on the critical path. The critical path is the set of activities that determine the total duration of the project. Delays in any of the activities on the critical path will directly affect the overall project completion time. Therefore, strict management and special attention are required to ensure that all activities on the critical path are completed on time.

Table 4. Calculation of Total Float and Free Float.

Activity Code	Duration (day)	Free Float (FF)	Total Float (TF)
A	4	0	0
B	10	10	10
C	15	0	0
D	9	0	0
E	1	0	0
F	18	0	0
G	4	10	10

3.4. Determining Activities on the Work Network and Critical Trajectory

After determining the Total Float in the project, activities located on the critical path can be identified by observing activities that have a float value of 0.

Table 5. Activities on the Critical Path

Activity Code	Type of Work	Duration	Free Float (FF)	Total Float (TF)
A	General	4	0	0
B	Construction Safety Management System (CSMS)	10	10	10
C	Earthwork and Geosynthetic	15	0	0

Activity Code	Type of Work	Duration	Free Float (FF)	Total Float (TF)
D	Graded Pavement and Cement Concrete Pavement	9	0	0
E	Asphalt Pavement Work	1	0	0
F	Structural Works	18	0	0
G	Graded Pavement and Cement Concrete Pavement	4	10	10
Total Duration		47		

From the table above, it can be seen that activities with codes A, C, D, E, and F are on the critical path. The total project completion duration obtained using the Critical Path Method (CPM) is 47 days.

4. Conclusion

Based on the results of the analysis conducted with the Critical Path Method (CPM) on the Penganten-Ngampal Road Reconstruction project, it was identified that the critical path includes activities with codes A, C, D, E, and F. The critical path consists of a series of activities that have no time flexibility (total float = 0) and must be carried out according to a defined schedule to guarantee the project's on-time completion. The total duration of project completion, based on the analysis, is 47 days, which includes all activities on the critical trajectory from the beginning to the end of the project.

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