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Original Article

Analysis of the Probability of Successful Completion Time of the Penganten-Ngampal Road Reconstruction Project Using the PERT Method

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Abstract

Infrastructure project delays are often a major challenge in the construction industry, including the Penganten - Ngampal Road Reconstruction project which experienced a 50-day delay from the initial target. This problem is caused by the uncertainty of external factors such as weather and limited resources. This research aims to calculate the probability of success of project completion time using quantitative descriptive method with Program Evaluation and Review Technique (PERT) approach. This method involves three estimates, namely optimistic, most likely, and pessimistic times to evaluate the average duration and critical path of the project. The data used consisted of project reports, field observations, and calculations using POM-QM software. The analysis shows that the project critical path consists of activities A, C, D, E, and F with a total duration of 60 days. The probability of completing the project within 60 days reached 98.21%, showing the effectiveness of the PERT method in managing time uncertainty.

Keywords: Project Management, Road Reconstruction, Probability of Completion, Critical Path, Quantitative Descriptive.

1. Introduction

Construction projects are a crucial indicator of infrastructure development, playing a significant role in driving economic growth and improving the quality of life. Their success largely depends on precise time management, particularly during the planning and execution phases. Effective scheduling is key to maximizing the use of resources such as labor, materials, and heavy equipment, optimizing costs, and minimizing delays that can lead to cost overruns and damage the reputation of construction companies. According to Dimyati & Nurjaman (2014), systematic project management involves planning, organizing, execution, and control, where project needs analysis, clear task allocation, disciplined implementation, and routine monitoring are essential aspects for achieving goals (Dimyati & Nurjaman, 2014). With a well-planned approach, construction projects can run smoothly, on schedule, and provide long-term benefits, such as sustainable infrastructure development and improved public welfare, making investment in efficient project management crucial for future project success.

Project delays are often a critical issue in the construction industry, caused by factors such as resource limitations (Agrawal & Halder, 2020), weather changes, or technical

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challenges in the field (Astari et al., 2022). These factors not only affect project timelines but also increase costs, impacting overall project efficiency and effectiveness. Rani (2016) suggests that one effective approach to minimizing these risks is using scheduling techniques that allow for more accurate predictions of project duration (Rani, 2016).

PERT (Program Evaluation and Review Technique) method has been a cornerstone of planning and evaluating complex projects since its introduction in the 1950's (Astari et al., 2022). This method is highly useful in managing uncertainty in large projects by considering three time estimates: optimistic, most likely, and pessimistic, which are combined to produce a more accurate average time estimate. PERT not only assists in time planning but also enables probability analysis, providing valuable insights for strategic decision-making, such as resource allocation and risk management. Additionally, the method facilitates better communication among team members and stakeholders and helps understand dependencies between activities (Hasnah & Herwanto, 2023). Hence, PERT is particularly relevant for projects with high uncertainty, such as infrastructure projects, which involve numerous external variables that can affect schedules and costs.

Roads are vital infrastructure serving as connectors between regions, supporting mobility, and boosting economic activities by facilitating the transport of goods and people, improving accessibility, and accelerating social development (Srinivasu et al., 2013). The Reconstruction of Penganten - Ngampal Road Project is a notable example of improving road quality to reduce congestion, enhance safety, and shorten travel time. However, this project experienced a delay of up to 50 days from the initial target of 120 calendar days. The delays were caused by unpredictable weather, suboptimal resource management, and ineffective coordination among involved parties, impacting community accessibility and local economic activities. Thus, evaluations and improvements in project management are needed to ensure future infrastructure projects are completed on time and deliver maximum benefits to society (Puspitasari et al., 2023).

Such delays not only result in wasted time but also have the potential to increase overall project operational costs. Hence, applying the PERT method to analyze the probability of successful project completion is crucial. With PERT, every critical step in the project can be thoroughly evaluated, and decisions can be made based on measurable probability data. Additionally, this analysis allows for an evaluation of the project's network to understand the critical path that influences the overall project duration.

Moreover, successful project time management relies not only on the techniques used but also on the utilization of supporting technology. For example, software like POM-QM can simplify calculations and visualize the project's critical path. This technology provides project managers with a clearer picture of the project's completion possibilities, making it easier to plan necessary corrective actions.

This study aims to calculate the probability of successful completion of the Penganten - Ngampal Road Reconstruction Project using the PERT method. Through this approach, it is expected to obtain more accurate information about project performance and the factors contributing to delays. The findings of this study are anticipated to serve as a reference for similar future projects in managing completion times more effectively and efficiently.

2. Literature Review

The PERT (Program Evaluation and Review Technique) method is a project planning technique that accounts for uncertainties in activity completion times by using three time estimates: optimistic, most likely, and pessimistic. The application of PERT is particularly

beneficial for complex projects, such as the Penganten-Ngampal Road Reconstruction, which faces challenges like adverse weather, labor shortages, and unstable material supplies. Through PERT, project teams can identify critical activities and plan mitigation steps to overcome obstacles, such as rescheduling or procuring backup materials. Initially planned for completion within 120 days, this project experienced a 50-day delay due to factors like weather conditions and suboptimal resource management. These delays have impacted travel times and economic activities in the surrounding areas. Therefore, evaluation and improvement of project management are essential to ensure timely completion of infrastructure projects, maximizing their benefits to the community.

Previous studies indicate that the PERT method yields results closer to actual conditions compared to deterministic methods like the Critical Path Method (CPM). For example, in the XYZ Museum construction project, PERT demonstrated a 99.8% success probability, completing the project 25 days ahead of the initial schedule (Astari et al., 2022). This study highlights that by addressing time uncertainties through three estimation approaches, PERT can provide more reliable outcomes to ensure projects are completed on schedule. A similar approach can be applied to the Penganten-Ngampal Road project to manage variables affecting project progress.

In another study by Uktolseja (2023), PERT was applied to a road preservation project, resulting in an optimal project duration of 270 days—shorter than the actual duration of 301 days (Uktolseja et al., 2023). The success probability for this duration was 54.38%, increasing to 99.98% if the project was completed in 275 days. This research demonstrates that PERT can be used to establish various duration scenarios with different success probabilities, aiding in more strategic decision-making for project scheduling, including for the Penganten-Ngampal Road Reconstruction project.

In the context of project planning, Nanda et al., (2023) emphasized that PERT offers the additional benefit of identifying critical activities that affect the overall project duration (Nanda et al., 2023). By calculating the standard deviation of project completion times, PERT helps anticipate potential delays. In the River Tourism project, PERT resulted in an optimal project duration of 146 days with a standard deviation of 18 days. These findings show that PERT not only aids in predicting project completion times but also provides critical information about risks that must be managed during project execution.

Similar results were found in a study by Husna (2022) on the Al-Ikhlas Prayer Room construction project (Husna et al., 2022). Using PERT, the project duration was estimated at 155 days with a 92.07% success probability. Additionally, the study showed that PERT facilitates more measurable planning for resource allocation and scheduling of each project activity. Implementing the PERT method in the Penganten-Ngampal Road project can help ensure the project stays on track despite unavoidable uncertainties.

3. Methods

3.1. Type of Research

The type of research used is quantitative descriptive research. This study aims to analyze the data of the Penganten-Ngampal Road Reconstruction project numerically, particularly in evaluating the project's duration and completion probability using the PERT (Program Evaluation and Review Technique) method.

3.2. Data Collection

1. Primary Data

Primary data was obtained directly from the field through surveys, including field observations to assess the physical condition of the Penganten-Ngampal Road Reconstruction project, progress measurements, work continuity, and evaluations of the road's physical condition. Additionally, questionnaires were distributed to the local community and parties directly involved in the project to assess public satisfaction and the preferences of those engaged in the project.

2. Secondary Data

Secondary data was obtained through literature reviews, project documents such as S-curves (time schedules), daily, weekly, and monthly progress reports, and estimated activity duration data, which includes optimistic, most likely, and pessimistic time estimates. Furthermore, geographical data and information on the research area were obtained from relevant institutions to understand environmental conditions that could affect project execution.

The data analysis stages using the PERT (Program Evaluation and Review Technique) method for the Penganten-Ngampal Road Reconstruction project are as follows:

1) Identifying tasks and three time estimates for each task: optimistic time, most likely time, and pessimistic time.
2) Calculating the duration based on the three time estimates to determine the average value.
3) Creating a network diagram using the average duration value (Te).
4) Calculating the standard deviation and variance for each task.
5) Determining the likelihood of meeting the project completion target by using the expected time (Te) and the scheduled target time (Td).

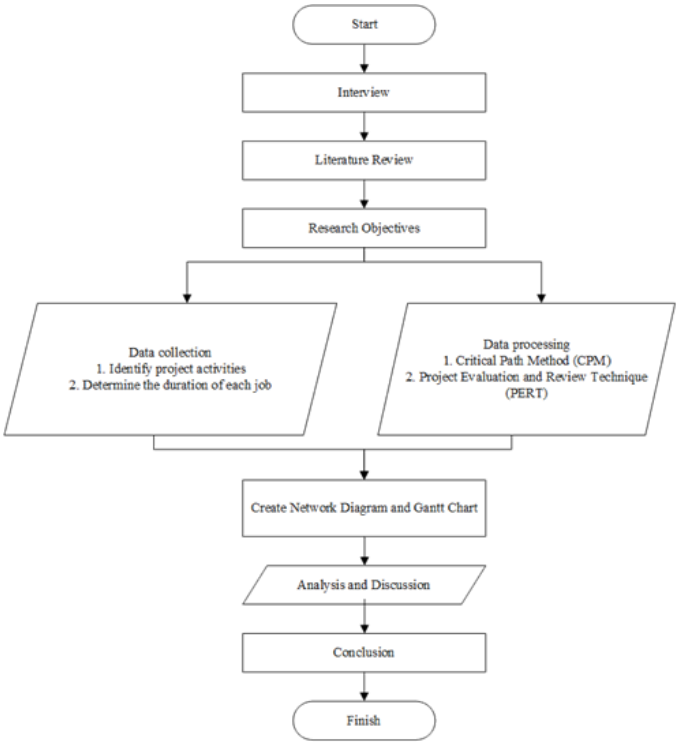


Figure 1. Research Flowchart

4. Results and Discussion

The PERT (Program Evaluation and Review Technique) method is one of the techniques in project management used to plan, manage, and control projects more effectively. This method is particularly useful in situations that involve uncertainty in the estimated completion time of an activity. PERT allows project managers to identify and analyze the various paths that exist in the project, as well as determine the time required to complete the project as a whole more accurately.

The first stage in applying the PERT method is to estimate the time to complete each activity in the project. This time estimation is divided into three categories, namely:

1) Optimistic Time (a): This is an estimate of the shortest time that may be required to complete an activity if all supporting factors are running very well. In this context, any obstacles or delays that could potentially occur are ignored, so the time estimate given is the most ideal and optimal.
2) Most Likely Time (m): This is the most realistic estimate of time to complete an activity, which is based on experience and available information. This time reflects normal conditions where some external or internal factors may affect the smooth running of the activity, but no factor is too extreme or hinders the project significantly.
3) Pessimistic Time (b): This is an estimate of the longest time it might take to complete the activity if things do not go according to plan. In this case, all factors that could cause major delays or obstacles in the execution of the activity are considered, so the time estimate given is the worst or slowest.

Table 1. Time Estimation

Activity Code	Activity	Optimistic Time (a)	Most Likely Time (m)	Pessimistic Time (b)
A	General	4	6	8
B	Construction Safety Management System (CSMS)	10	14	18
C	Earthwork and Geonsynthetic	15	17	20
D	Graded Pavement and Cement Concrete Pavement	9	13	15
E	Asphalt Pavement Work	1	3	6
F	Structural Works	18	20	23
G	Graded Pavement and Cement Concrete Pavement	4	6	9

4.1. Determining te Value

After estimating the time for each activity in a project, the next step is to calculate the value of te (expected time), standard deviation, and variance for each of these activities. This calculation is very important to provide an overview of the time required to complete the activity as well as the level of uncertainty or variation that may occur during the implementation of the activity.

1) Expected Time (te)

The expected time value, or te, is an average estimate of the time required to complete an activity, considering three different time possibilities: optimistic time (a), most likely time (m), and pessimistic time (b).

The formula for calculating the expected time is:

$$\text{te} = \frac{a + 4m + b}{6}$$

Here, a is the estimated time if things go very smoothly (optimistic), m is the most realistic or most frequent time (most likely), and b is the time needed if things go slower or hit a snag (pessimistic). Using these three values, the above formula calculates a weighted average, where the most likely time is given a greater weight.

4.2. Standard Deviation (S)

Standard deviation measures the extent to which the execution time of an activity may vary from the expected time. This variation is very important to know because it shows the uncertainty that may exist in the implementation of activities. The greater the standard deviation, the greater the likelihood of significant time changes.

The formula for calculating standard deviation is:

$$\text{S} = \frac{(b - a)}{6}$$

Here, the difference between the pessimistic time (b) is divided by 6, which is a factor to measure the spread of time in the Beta distribution used in this calculation. The greater the difference between the optimistic and pessimistic times, the greater the standard deviation, which means the greater the uncertainty in the time estimation.

4.3. Activity Variance

Variance is the square of the standard deviation and gives an idea of how much the activity time varies in the form of numerical values. This variance is important for calculating the level of uncertainty in more detail and provides additional information about potential time fluctuations that occur.

The formula for calculating activity variance is:

$$\text{V(te)} = S^2$$

Where S is the pre-calculated standard deviation. This variance provides further information regarding potential time changes in an activity based on the calculated standard deviation. After calculating the values of te, standard deviation, and variance for each activity, the results of these calculations are presented in Table 2.

Table 2. Te value, standard deviation and variance of activities

Activity Code	Activity	(a)	(m)	(b)	te	S	V(te)
A	General	4	6	8	6	0,67	0,44
B	Construction Safety Management System (CSMS)	10	14	18	14	1,33	1,78
C	Earthwork and Geonsynthetic	15	17	20	17,17	0,83	0,69
D	Graded Pavement and Cement Concrete Pavement	9	13	15	12.67	1	1
E	Asphalt Pavement Work	1	3	6	3,17	0,83	0,69
F	Structural Works	18	20	23	20,17	0,83	0,69
G	Graded Pavement and Cement Concrete Pavement	4	6	9	6,17	0,83	0,69

1. Determining the Variance and Standard Deviation of the Project on the Critical Path, presented in Table 3.

Table 3. Variance and standard deviation of project deviation on critical trajectory

Activity Code	Activities on critical path	te	V(te)
A	General	6	0,44
C	Construction Safety Management System (CSMS)	17,17	0,69
D	Graded Pavement and Cement Concrete Pavement	12,67	1
E	Asphalt Pavement Work	3,17	0,69
F	Structure Work	20,17	0,69
Project Variance ∑ V(te) and total time on the critical path		3,53	
Project Standard Deviation		1,88	

2. PERT calculation with POM-QM application The results of PERT calculation with the application are presented in Fig. 2.

PERT PENGANTEN 1 Solution

Activity	Activity time	Early Start	Early Finish	Late Start	Late Finish	Slack	Standarc Deviatior	Variance
Project	59.17						1.88	3.53
A	6	0	6	0	6	0	.67	.44
B	14	6	20	15.67	29.67	9.67	1.33	1.78
C	17.17	6	23.17	6	23.17	0	.83	.69
D	12.67	23.17	35.83	23.17	35.83	0	1	1
E	3.17	56	59.17	56	59.17	0	.83	.69
F	20.17	35.83	56	35.83	56	0	.83	.69
G	6.17	20	26.17	29.67	35.83	9.67	.83	.69

Figure 2. PERT calculation with POM-QM application

From the results of the analysis that has been carried out, it can be concluded that the critical path in the Program Evaluation and Review Technique (PERT) method consists of a series of activities, namely A, C, D, E, and F, with a total project duration of 60 days. This critical path is the set of activities that has the longest total duration and, therefore, determines the overall project completion time. Each activity in this critical path has a very high dependency, so a delay in the implementation of one of the activities will directly affect the overall project completion time.

The PERT method also considers the uncertainty in achieving the target project completion schedule. This uncertainty is measured using the z value, which serves to determine the likelihood that the project can be completed in accordance with the predetermined target time. The calculation of the z value is done with the following formula:

$$\text{Z Value} = \frac{(T - \mu)}{\sigma}$$

Where:

T is the target time for project completion (in this case 60 days),

μ is the estimated average time to complete the project,

σ is the standard deviation which describes how much variation or uncertainty there is in the project completion time.

For the calculation in z value, it is calculated as follows:

$$\text{Z Value} = \frac{(6.0 - 2.0)}{1.88} = 2.12$$

Once the z value is calculated, we refer to the normal z distribution table to find the probability associated with the z value. Based on the attached normal z distribution table, the z value = 2.12 has a result of 0.9821. This indicates that the probability of the project being completed on time within 60 days is 98.21%. In other words, there is a 98.21% probability that the project will be completed on time, which indicates a high level of confidence in the time estimate that has been made, and can be used as a basis for managing and anticipating potential delays.

To get a more complete picture of the details of each activity on the critical path, time estimates, and standard deviations, see Table 4.

Table 4. Project completion probability target

No	Completion Target (Days)	Deviation Z	Normal Distribution Table	Probability of Project Completion (%)
1	20	0.00	0,5	50%
2	47	1,43	0,9236	92%
3	60	2,12	0,983	99%

Based on the analysis that has been carried out above, we can conclude some important things about the probability of project completion in various time durations as follows:

1. The probability of project completion within 20 days is 50%. This shows that there is a considerable possibility, but still uncertainty, that the project can be completed in a shorter time than the initial estimate.
2. The probability of project completion with an additional 47 days is 92%. This indicates that by extending the project duration by 47 days, the chances of successfully completing the project are very high, although there is still some uncertainty regarding achieving the goal within that timeframe.
3. The probability of project completion with an additional 60 days is 99%. With an additional 60 days, it is almost certain that the project will be completed as planned, indicating that the longer the time provided, the greater the probability of successful completion.

5. Conclusion

Based on the results of the study, it can be concluded that the use of the PERT method in evaluating the completion time of the Penganten - Ngampal Road Reconstruction project provides a clearer picture of the duration required and the probability of success. Using the PERT method, the critical path of the project was identified in activities A, C, D, E, and F. The total time to complete the activities on this critical path is 60 days. In addition, based on the probability calculation, the project has a 97% chance of being completed within 60 days according to the calculated time estimate.

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