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Comparative Analysis of CPM and PERT Methods for Scheduling the Repair Process of KMP. Kormomolin

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Abstrak

In the maritime industry, scheduling ship repair projects is an important aspect that determines operational efficiency and navigational safety. An appropriate scheduling method can help optimize project duration and manage uncertainties that may arise during project implementation. Two commonly used methods are the Critical Path Method (CPM) and the Program Evaluation and Review Technique (PERT), which apply deterministic and probabilistic approaches, respectively. This study was conducted on the repair project of KMP. Kormomolin, which had an initial planned duration of 52 days and involved 58 technical activities. The CPM method was used to identify the critical path based on fixed activity durations obtained from the repair list, while the PERT method was applied to estimate project duration using three-time estimates: optimistic, most likely, and pessimistic. The analysis was carried out using Microsoft Project and manual calculations to determine Early Finish (EF), Late Finish (LF), Total Float, and the probability of project completion. The CPM analysis showed that the project could be completed within 48 days, with a critical path consisting of activities with no slack. Meanwhile, the PERT method produced an estimated project duration of 50 days, with a completion probability of 95.82%. The CPM method provides stricter time control, whereas PERT offers greater flexibility in dealing with uncertainty. CPM is more suitable for projects with a stable work structure and clear activity sequences, while PERT is more appropriate for projects involving many variables and risks. The integration of both methods is recommended to produce more adaptive and comprehensive project planning in the ship repair industry.

Keywords: CPM, critical path, KMP. Kormomolin, PERT, probability, ship repair.

1. INTRODUCTION

Project scheduling is one of the main elements of project planning that provides information on the planned schedule and project progress in terms of resource performance, including cost, labor, equipment, materials, project duration, and time progress. In the scheduling process, activities and the relationships between activities must be arranged in a detailed and systematic manner. This is intended to assist project implementers in monitoring, controlling, and evaluating project performance. Management is the process of planning, organizing, coordinating, and controlling resources to achieve objectives efficiently and effectively. In construction activities, several aspects require proper management, including performance, accuracy, precision, carefulness, and safety to achieve the expected results [1].

A project generally consists of complex activities that require strict and structured planning, supervision, and control. Project management activities begin with careful planning, including project planning, scheduling, control, and execution planning, so that serious problems can be minimized during implementation. If a project is not properly planned, many interrelated activities may affect one another and cause delays. In practice, the completion time of a project may vary, making it difficult to ensure that the estimated project duration can always be achieved. The accuracy of project completion time estimation depends on the accuracy of duration estimates for each project activity. In addition to time estimation, the relationship among project activities must also be clearly defined. Estimating project time and cost is necessary to optimize available resources and minimize risks while still achieving optimal results [2].

In the maritime industry, ship repair is an important activity that affects operational continuity and navigational safety. A vessel that is not in proper condition can cause financial losses and increase safety risks. Ship repair is therefore an unavoidable requirement in the vessel life cycle. Ships may experience damage due to several factors, such as abrasion, corrosion, material wear, and accidents. For this reason, repair activities are essential to extend the service life of vessels and maintain their safety and reliability. Timely and high-quality repair work can prevent accidents and losses caused by structural or operational failure [3]. In this context, careful planning of material resources and project duration is a key factor in ensuring the efficiency and effectiveness of ship repair activities [4].

In Indonesia, the ship repair industry still faces several challenges, including limited resources and the low adoption of effective project management technologies. Therefore, this study aims to analyze and compare the effectiveness of the Critical Path Method (CPM) and the Program Evaluation and Review Technique (PERT) in the context of ship repair in Indonesia. Through a better understanding of these two methods, the ship repair industry is expected to improve its project performance, operational efficiency, and competitiveness.

2. METHODS

This study used a quantitative approach based on data collected from the repair project of KMP. Kormomolin at PT. Industri Kapal Indonesia (Persero). The analysis was conducted using Microsoft Project and manual calculations to determine the values of Earliest Start (ES), Earliest Finish (EF), Latest Start (LS), Latest Finish (LF), and Total Float. The data used in this study were obtained from the repair schedule of KMP. Kormomolin, which was carried out at PT. Industri Kapal Indonesia shipyard over a planned duration of 52 days. The general specifications of the vessel are presented in Table 1.

Table 1. General data of KMP. Kormomolin

Description	Information
Name	KMP. Kormomolin
Type of vessel	Ferry
Owner	PT. ASDP Indonesia (Persero)
LOA	46.60 m
LBP	41.44 m
Breadth	12 m
Height	3.90 m
Draft	2.40 m
DWT	884 tons

The object of this study was the repair project of KMP. Kormomolin, analyzed by comparing the repair duration using the Critical Path Method (CPM) and Program Evaluation and Review Technique (PERT). The analysis was carried out by identifying project activities involved in the ship repair process. These identified activities served as the basis for the CPM and PERT analysis. The activity duration data used in Table 2 was based on the planned duration stated in the repair list of KMP. Kormomolin.

Table 2. Work items and duration

No	Repair stage	ID	Duration days
1	General service	1, 2, 3	16
2	Docking and undocking	4, 5, 6	17
3	Hull maintenance	7, 8, 9, 10	11
4	Anchor and chain	11, 12, 13	3
5	Sea chest and valve	14, 15	2
6	Propeller and shaft	16–22	12
7	Structural replating	24–30	25
8	Interior and deck	31–37	17
9	Winch and ramp door	38–42	15
10	Car deck and tank	43–46	15
11	Piping and electrical work	48–51, 52–53	10
12	Others	54–57	3

2.1 CPM and PERT Methods

2.1.1 Critical Path Method

The Critical Path Method (CPM) is a project scheduling technique used to analyze a network of activities to estimate the total project duration. The critical path of a project is a sequence of activities that determines the shortest possible time for project completion. It is the longest path in the project network diagram and has the least scheduling flexibility [5]. The CPM method consists of two main calculation stages, namely forward pass and backward pass. The forward pass is carried out from the initial node to the final node to determine the earliest possible time for each activity. The backward pass is carried out from the final node back to the initial node to determine the latest possible time for each activity without delaying the project completion time [6].

2.1.2 Forward Pass Calculation

The purpose of the forward pass calculation is to determine the earliest start and earliest finish times of each project activity [7]. The earliest finish time can be calculated using Equation (1).

$$EF = ES + t \qquad (1)$$

Where EF is earliest finish time of an activity, ES is earliest start time of an activity and t is activity duration.

2.1.3 Backward Pass Calculation

The purpose of the backward pass calculation is to determine the latest start and latest finish times of each project activity. The latest start time can be calculated using Equation (2).

$$LS = LF - t \qquad (2)$$

where LS is latest start time of an activity, LF is latest finish time of an activity and t is activity duration. Based on the results of the forward and backward pass calculations, an activity is classified as critical if it satisfies the following conditions:

$$ES = LS$$
$$EF = LF$$
$$LF - ES = \text{Activity Duration}$$

2.1.4 Total Float

Total Float is the amount of time by which an activity can be delayed without affecting the overall project completion time. Total Float can be calculated using Equation (3).

$$Total\ Float = EF - LF \qquad (3)$$

Where EF is earliest finish, LF is latest finish. Based on Equation (3), an activity is on the critical path when the Total Float value is equal to zero.

2.1.5 Program Evaluation and Review Technique

The Program Evaluation and Review Technique (PERT) is a network-based project scheduling method that uses three time estimates for each activity [9]. These three estimates are used to calculate the expected completion time and the probability of completing the project within a specified target duration. The three time estimates in the PERT method are as follows:

- The optimistic time (a) is the shortest possible activity duration, assuming that the activity is carried out under ideal conditions without obstacles or delays.
- The most likely time (m) is the activity duration that is most likely to occur under normal working conditions, including acceptable delays.
- The pessimistic time (b) is the longest possible activity duration, assuming that the activity experiences significant obstacles or delays.

2.1.6 Expected Time Calculation

The expected time in PERT is calculated by assuming that the probability of optimistic and pessimistic conditions is equal, while the most likely condition has four times greater weight. The expected time can be calculated using Equation (4).

$$Te = \frac{a + 4m + b}{6} \qquad (4)$$

Where *Te* is expected activity time *a* is optimistic time *m* is most likely time and *b* is pessimistic time.

2.1.7 Standard Deviation

To determine the level of uncertainty in the activity duration estimate, the PERT method calculates the standard deviation (S). The standard deviation is calculated as one-sixth of the range between the pessimistic and optimistic time estimates, as shown in Equation (5).

$$S = \frac{1}{6}(b - a) \qquad (5)$$

Where *S* is standard deviation of the activity *a* is optimistic time *b* is pessimistic time.

2.1.8 Variance of Activity Duration

In the PERT method, in addition to calculating the expected activity time (Te), it is also important to measure the uncertainty of the estimate. This can be done by calculating the variance (V) of each activity. Variance shows the degree of dispersion or deviation of activity duration from the expected average value. The variance is calculated based on the difference between pessimistic time (b) and optimistic time (a), as shown in Equation (6).

$$V(Te) = S^2 = \left[\frac{b - a}{6}\right]^2 \qquad (6)$$

or:

$$V(Te) = S^2 \qquad (7)$$

Where *V(Te)* is variance of expected activity time and *S* is standard deviation. After the expected duration and variance of the critical path are obtained, the probability of project completion can be determined using the Z value. The Z value is calculated using the target schedule, the expected duration of the critical path, and the standard deviation. The probability of completing the project within the target duration is then obtained from the normal distribution table.

3. RESULTS AND DISCUSSION

3.1 Analysis Using the Critical Path Method

The arrangement of work sequences is essential for operational efficiency and project completion in the shipbuilding and ship repair industry, which involves complex and highly interrelated activities. Shipyards commonly use project management software, such as Microsoft Project, to plan, schedule, and control various stages of a project. In this study, the work sequence was presented in the form of a Gantt chart. The Gantt chart displays the list of activities on the left side and horizontal bars on the right side, indicating the duration, sequence, and relationships among tasks. Figure 1 shows the Gantt chart of the KMP. Kormomolin repair project and the dependency relationships among repair activities.

After arranging the work sequence using Microsoft Project, the analysis was continued using the Critical Path Method (CPM). The CPM analysis was carried out through forward pass calculation, backward pass calculation, and Total Float calculation in the repair process of KMP. Kormomolin. The results of the calculation are presented in Table 2.

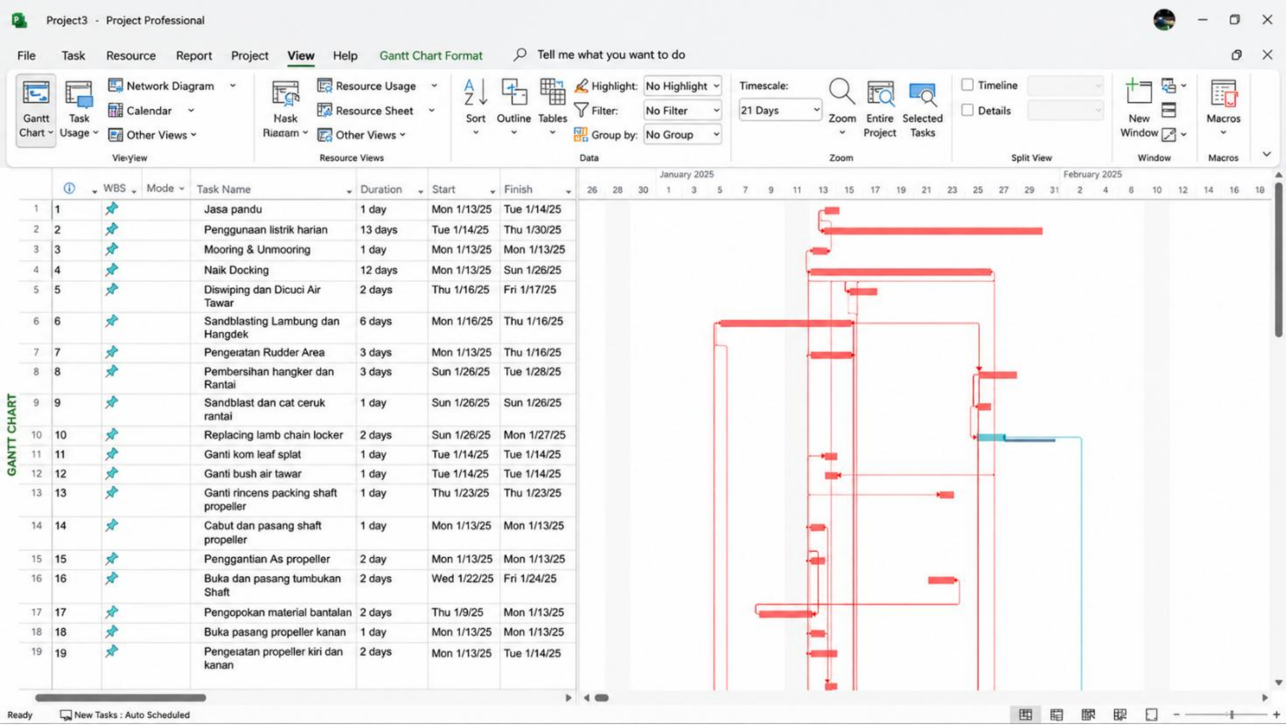

Figure 1. Work sequence presented in the form of a Gantt chart

Table 2. Results of forward pass, backward pass, and Total Float calculation for the KMP. Kormomolin repair project

No	Repair Stage	ID	Duration (days)	ES	EF	LS	LF	Float
1	General Service	1, 3	16	0	1	0	1	0
2	Docking and Undocking	4, 5, 6	17	1	3	1	3	0
3	Hull Maintenance	7, 8, 9, 10	11	5	14	8	17	3
4	Anchor and Chain	11, 12, 13	3	3	4	18	19	15
5	Sea Chest and Valve	14, 15	2	11	12	34	36	23
6	Propeller and Shaft	16–22	12	12	14	25	27	13
7	Structural Replating	24–30	25	11	15	11	15	0
8	Interior and Deck	31–37	17	11	13	11	13	0
9	Winch and Ramp Door	38–42	15	27	30	27	30	0
10	Car Deck and Tank	43–46	15	21	23	21	23	0
11	Piping and Electrical Work	48–51, 52–53	10	21	28	21	28	0
12	Others	54–57	3	3	5	18	20	15

Based on the calculation in Table 2, the critical path can be determined from activities with a Total Float value of zero. Most activities have Total Float = 0, which means that these activities are located on the critical path. Any delay in these activities will directly affect the overall project completion time.

Several activities have positive Total Float values, indicating that they have scheduling flexibility and can be delayed within a certain period without affecting the overall project duration. These activities include hull maintenance with a float of 3 days, anchor and chain work with a float of 15 days, sea chest and valve work with a float of 23 days, propeller and shaft work with a float of 13 days, and other activities with a float of 15 days. Based on the CPM analysis, the total completion time of the KMP. Kormomolin repair project was 48 days.

Figure 2. Critical path of the KMP. Kormomolin repair project

3.2 Analysis Using Program Evaluation and Review Technique

The Program Evaluation and Review Technique (PERT) was used to calculate the probability that the project could be completed on time. Unlike CPM, which uses planned activity durations based on the repair list, PERT uses three time estimates for each activity, namely optimistic duration (a), most likely duration (m), and pessimistic duration (b). The pessimistic duration is estimated by considering possible constraints based on the experience of project implementers. Several factors considered in the estimation include weather conditions, working environment, labor availability, equipment, and materials.

Table 3. Results of a, m, b, expected time, standard deviation, and variance calculations

No	Repair Stage	ID	a	m	b	Expected Time (Te)	Standard Deviation	Variance
1	General Service	1, 2, 3	0.1	0.2	0.4	2.0	0.05	0.0025
2	Docking and Undocking	4, 5, 6	0.4	0.8	0.4	7.0	0.00	0.0000
3	Hull Maintenance	7, 8, 9, 10	1.5	2.8	4.0	3.6	0.00	0.0000
4	Anchor and Chain	11, 12, 13	1.0	2.0	1.0	1.7	0.00	0.0000
5	Sea Chest and Valve	14, 15	0.3	1.0	0.5	0.8	0.04	0.0016
6	Propeller and Shaft	16–22	0.5	1.0	3.0	2.1	0.00	0.0000
7	Structural Replating	24–30	4.8	8.0	6.4	7.2	0.27	0.0729
8	Interior and Deck	31–37	0.5	1.0	2.0	1.7	0.00	0.0000
9	Winch and Ramp Door	38–42	0.5	1.0	2.0	1.6	0.08	0.0064
10	Car Deck and Tank	43–46	0.1	1.0	2.0	1.5	0.15	0.0225
11	Piping and Electrical Work	48–51, 52–53	0.1	1.0	2.0	1.5	0.07	0.0049
12	Others	54–57	0.1	1.0	2.0	1.5	0.07	0.0049
	Total V(Te)							2.3
	Standard Deviation							1.15

3.3 Estimation of Project Completion Probability

To determine the probability of project completion using the PERT method, the standard normal variation formula was applied. The calculation was conducted using Equation (8).

$$Z = \frac{T(d) - Te}{S}$$
$$Z = \frac{52 - 50}{1.15} = 1.73$$

Based on the Z value of 1.73, the probability value obtained from the standard normal distribution table is 0.9582. Therefore, there is the probability of completing the KMP. Kormomolin repair project within 52 days is 0.9582, or 95.82%. This result indicates that, based on the PERT analysis, the project has a high probability of being completed within the planned duration.

Table 4. Comparison of CPM and PERT methods in the KMP. Kormomolin repair project

No	Description	Result
1	The CPM method uses a deterministic time estimate analyzed from the project repair list. This method applies the Activity on Arrow concept or Finish-to-Start logical relationship.	Based on the critical path analysis, the project duration obtained using CPM was 48 days. The critical activities consisted of activity IDs 1–9, 15, 20–22, 28–42, and 44–52.
2	The PERT method uses three time estimates, namely optimistic time (a), most likely time (m), and pessimistic time (b).	PERT used the same critical path as CPM, but produced a different estimated duration. Based on the normal distribution table with a Z value of 1.73, the probability of completing the repair project within the planned duration was 95.82%.
3	Field planning	Based on the planned duration stated in the repair list of KMP. Kormomolin, the project duration was 52 days.

The comparison shows that CPM provides a minimum project duration of 48 days by identifying the critical path based on fixed activity durations. This method is useful for controlling project time and identifying activities that cannot be delayed. Meanwhile, PERT provides a probabilistic estimate by considering uncertainty in activity durations. The PERT analysis showed that the project could be completed within 50 days, with a 95.82% probability of completion within the planned duration of 52 days. Thus, CPM is more suitable for projects with stable and predictable activity structures, while PERT is more appropriate for projects that involve uncertainty and variable working conditions.

4. CONCLUSION

Based on the comparative analysis of the CPM and PERT methods in the repair process of KMP. Kormomolin, several conclusions can be drawn. The CPM analysis showed that the minimum duration of the KMP. Kormomolin repair project was 48 days. This result was obtained by identifying the critical path, which consists of activities with zero Total Float. Activities on the critical path must be carefully controlled because any delay in these activities will directly affect the overall project completion time.

The PERT analysis, which considers uncertainty in activity duration, produced an estimated project duration of 50 days. Based on the calculation of the Z value, the probability of completing the repair project within the planned duration of 52 days was 95.82%. This indicates that the project has a high probability of being completed within the planned schedule when uncertainty factors are considered.

The fundamental difference between CPM and PERT lies in the approach used to estimate activity duration. CPM applies a deterministic approach with fixed activity durations, making it suitable for projects with stable work structures and predictable activity sequences. In contrast, PERT applies a probabilistic approach by using three-time estimates, allowing it to accommodate uncertainty and produce a more realistic estimation of project completion probability. In the KMP. Kormomolin repair project, CPM was more effective for time control and critical path identification, while PERT was more useful for anticipating risks and uncertainties. Therefore, the integration of CPM and PERT is recommended to produce a more adaptive, measurable, and comprehensive project scheduling plan in ship repair activities.

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