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A Review Article: Impact of Using Critical Path Method (CPM) For Ship Repair Process

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ABSTRACT

Every ship that sails must be repaired to maintain seaworthiness and the safety of its users. Ship repairs that are carried out will take a considerable amount of time, so planning and scheduling must be completed before the repair process begins. The scheduling process at the shipyard is generally still done manually, involving the creation of a list of repairs. It has the potential to cause delays and increase the costs incurred. The use of the Critical Path Method (CPM) is an option to improve the effectiveness and efficiency of the repair process in terms of time and labor, and of course, minimize costs. This study aims to determine the effect of using the critical path method in the ship repair process, utilizing a literature review of several scientific articles. Of the 15 articles used in this study, 14 reported that the use of the critical path method enhances the effectiveness and efficiency of the ship repair process.

KEYWORDS: *Critical Path Method, Effectiveness, Efficiency, Ship repair.*

1. INTRODUCTION

Ship repairs are an unavoidable necessity, as neglecting them can have serious consequences that could potentially disrupt smooth operations. Therefore, optimizing the annual ship repair time is essential. In supporting the development of the maritime sector, the shipbuilding industry plays a key role in marine transportation. This industry is responsible for providing ships for transportation as well as the maintenance and repairs necessary for maritime development [1].

Utilizing project management, a project plan, schedule, and resource allocation are created for a given project. Effective project planning is crucial for guiding the implementation of agreed-upon work activities within the designated timeframe. The work activities are outlined in a repair list and then formulated into a main schedule for ship repair work. Scheduling a project is prepared carefully and with full consideration to ensure that work activities are carried out according to the schedule and do not exceed the predetermined duration [2].

Delays are considered an aspect that project implementers and shipyards must anticipate, as they can affect the reputation of all parties involved. Delays in completing a project also result in fines that project implementers and shipyards must bear. The profit potential that can be obtained is reduced, so delays in project completion must be avoided through systematic scheduling, such as a schedule [3]. Poorly planned main schedules can prevent repair projects from experiencing delays. In addition, inefficient activity scheduling in each workshop can result in inefficiencies in time and labor. Therefore, risk analysis of delays is a need for each project activity [2].

Scheduling is conducted to ensure that the work carried out during the ship repair process is more organized and to determine the time required for each activity in the ship repair process, as well as the overall time required to complete the ship repair project, thereby avoiding costly delays [4]. The faster a project is completed, the better the company's (or industry's) performance, as indicated by increased income, increased public trust, and consistent project timelines. Consequently, the dock and shipping industry will continue to grow, supporting the development and advancement of Indonesia's maritime sector [5].

The process of speeding up this time is called a program crash, where the duration of activities located on the critical path and having the lowest cost slope is accelerated. It involves calculating the changes in project costs that occur due to acceleration. This method is carried out continuously until the network with a critical path reaches a saturated condition, which means that it is no longer possible to reduce the implementation time (optimal point) on the critical path.

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Construction projects must be carried out with proper planning and control to accelerate project implementation with the least additional cost [6].

The CPM is a popular scheduling technique for projects in the construction industry, used to estimate project duration. The method assumes that only the longest path (critical path) through a network structure affects the duration of the project. It implies that only the critical path needs to be considered for estimating project duration. Any task on a critical path is crucial because a change in these activities can significantly impact the project's duration. Thus, there is no slack in the activities, and the project delay corresponds to the delays of a critical task. The method is efficient for schedules with few parallel paths and when there is good knowledge about activity durations, meaning that the standard deviation is slight [7].

The total duration of the project can be used to calculate the critical path using the CPM method. A critical path is a sequence of essential activities that determines the timeframe for project completion [8]. The critical path concentrates on time and cost tradeoffs. This activity is a project activity model described in the form of a network used for planning, scheduling, and controlling the project. Optimal duration in project implementation can be obtained by using a supporting application that can be used in planning and scheduling the activities of a project, all of which aim to optimize the work of a project so that there will be efficiency in terms of cost and execution time of the ship being built [6].

To determine the critical path of a project, it is necessary to decide on the ES (earliest start), LS (latest start), EF (earliest finish), and LF (latest finish) values, which are connected in an AOA (activity on arrow) diagram, as shown in Figure 1. A forward calculation is performed to determine the end time of the repair activity sequence, starting with the initial activity, which has a value of 0, and proceeding in sequence until the repair work item is completed [9].

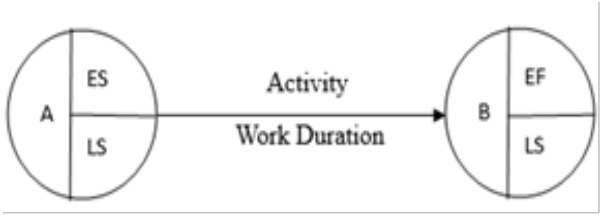

Figure 1: Activity on arrow (AOA) diagram

The total float is calculated by finding the difference between the slowest start of the activity and the earliest start of the activity. If going to use the equation (S = LS – ES), or it can be calculated by finding the difference between the time the activity is completed at the latest and the time the activity is completed the fastest (S = LF – EF) [6]. The formula shown below:

$$S = LS - ES \quad (1)$$

Where,
S : total float
LS : when the activity starts at the latest
ES : the fastest time the activity starts

Based on the background, this study aims to determine the impact of using the critical path method (CPM) in the ship repair process, utilizing a literature review method that incorporates several scientific articles.

2. METHODS

The method employed is a literature review, which provides various articles related to the use of CPM, with the limitation of excluding its application in the shipbuilding process. The articles are obtained from many electronic databases, including Google Scholar, Scopus, and the Journal of Marine Engineering from Diponegoro University.

The search term used for this research was "CPM in shipyard"; however, because the data that appeared also included building new ships, the search term was changed to "CPM in repair process". The search results yielded a more specific search for articles regarding the use of CPM in the repair process, in line with the predetermined problem limitations. There are no language restrictions when searching for articles. The results are predominantly in Indonesian, but there are a few articles in English.

This study is strengthened by 14 national journals and one international journal published between 2014 and 2024. The keywords used are "Critical Path Method", "effectiveness", "efficiency", and "ship repair".

3. RESULT AND DISCUSSION

The impact of this research will be the impact of using CPM when scheduling ship repair processes. Time, cost, and labor are taken into consideration. In terms of time, the speed of completion of the repair project is evaluated by comparing the project completion time when using the CPM method, when not using the CPM method, or when using other methods.

From a cost perspective, the costs incurred during the repair project are calculated. Some articles also calculate a penalty for late completion. It is also a factor in considering the feasibility of using the CPM method. It will have a good impact on saving the company money. The labor aspect is a significant factor that significantly influences the two previous elements, considering the number of laborers and their impact on completion time and additional costs incurred due to overtime. Table 1 summarizes the 15 articles reviewed. To maximize comparison results, the authors compared the use of CPM with other methods. Twelve articles compared CPM with conventional scheduling methods. Additionally, three articles compared CPM with other methods, including PERT, CCPM, and PDM.

PERT is a probabilistic method based on the assumption that a probability density function can describe the duration of a single activity. The project duration can be calculated by summing the "expected" durations of each activity in the critical path. PERT considers uncertainties during the construction process to plan, schedule, and control complex projects with multiple uncertainties [10].

The aim of Article 10 is to plan an effective schedule for repairing the ship. The result is that using CPM can be the best option, as it will be more profitable both in terms of time, as the work will be completed faster than the estimated time. It will also be more cost-effective, as there will be no penalty for late work.

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Table 1: List of articles

Article Number	Purpose Using Method	Method	Result Research
1	Minimizing delays for the repair of 4 ships	CPM	CPM made ship repair faster
2	Optimizing repair schedule	CPM	CPM optimizes repair schedule
3	Obtain the most efficient duration and cost	CPM	Time and cost efficiency
4	Obtain an efficient work schedule	CPM	Optimize the work process
5	Minimize delays in the ship repair process	CPM	Effective and efficient for scheduling
6	Knowing the critical chain, crashing duration, and workshop-level productivity value	CPM	Speed up the work process without increasing the cost
7	Get a more useful production process	CPM	Positive impact on workflow and company image
8	Optimizing repair time and rescheduling using CPM	CPM	Repair time was successfully optimized
9	Optimizing the schedule for the project	CPM	The project completion time was reduced by 2 days
10	Planning an effective schedule	CPM & PERT	CPM made work effective and efficient
11	Identifying the critical path and time efficiency	CPM	Minor and major repairs can be completed faster
12	Analyze scheduling productivity	CPM & CCPM	CCPM is better than CPM
13	Optimizing productivity and schedule efficiency	CPM	The project completion duration is faster
14	Obtain repair time	CPM	The estimated work time can be more determinate.
15	Preparing an efficient ship repair schedule	CPM, PDM & PERT	CPM is better than PDM & PERT

The second article, article number 12, compares Critical Chain Project Management (CCPM) with CPM. In 1997, Dr. Eliyahu Goldratt introduced a new approach to project management after 40 years with the publication of his best work, "Critical Chain." The ingenuity of Goldratt's method was creating a new shift, which, for the first time, collected both aspects (human and methodological) of a project management algorithm into a single framework. Critical chain methodology is based on a deep understanding of human nature and its impact on the project management framework. Based on this method, critical chain management enables projects to be completed in a significantly shorter time than the critical path method. Furthermore, the critical chain method is more straightforward, and the project team faces less workload in the planning and execution stages [11].

The aim of Article 12 is to analyze scheduling productivity, and Article 12 shows that CCPM can be a more efficient option than CPM. Based on the results obtained, both the time aspect and the cost aspect have a significant impact. The duration of the schedule using CPM is 98 days and costs 1,369,520,000.00 rupiahs. The CCPM method has a duration of 71 days and a cost of approximately Rp. 1.027.140.000,00. From these results, the CCPM method is 27 days faster than CPM and saves costs of Rp. 342.380.000,00 [13].

The last article compared with other methods is article number 15. The article compares CPM with two different approaches: the first is PERT, and the second is the Precedence Diagram Method (PDM). PDM is a scheduling method used to determine which activities will be carried out during the project and to determine when the project will be completed [4].

The advantage of the PDM is that it does not require dummy or additional activities, simplifies the project network creation, and the interdependence between activities can be arranged without adding new tasks [12]. The aim of Article 15 is to prepare an efficient ship repair schedule, and the result is that the best method to implement in the field is CPM because it has total float, whereas the PDM method does not. The total duration results for the CPM and PDM methods do not differ because the CPM method relies on dependencies for each activity, and neither requires dummy time. The PERT method is not significantly different from the CPM method, except that the PERT method uses three-time estimates, allowing it to determine the probability of a project being completed on time [4].

4. CONCLUSION

This review has discussed 15 articles that utilize the CPM method, considering three key aspects: time, work, and labor. Of the 15 articles, 14 reported that the use of the CPM increases the effectiveness and efficiency of the ship repair process. From a time aspect, using CPM is faster to complete the repair process. The cost aspect allows CPM to save costs more, and from a labor aspect, it can save time and costs as

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well. One of the articles is surely recommended in conjunction with another option, namely Critical Chain Project Management (CCPM). CCPM is more efficient than CPM because the working time can be faster by up to 27 days. CPM can be compared with other methods to see which is more effective and efficient for scheduling the repair process.

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