Acceleration Strategy of Ship Reparation Project Using the Ranked Positions Weight Method: Comparative Evaluation Between Adding Manpower and Work Time

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Delays in settlement of a ship repair project in an Indonesian shipyard are still common, resulting in a schedule that cannot be carried out according to the contract schedule. This study investigates the acceleration duration by calculating the track balance using the Ranked Positions Weight Method (RPWM), used within the scheduling system to obtain a balanced schedule arrangement with an even distribution of labor resources or manpower. This method is used to solve the MT Poka Jo (IMO: 9918119) ship repair's acceleration of duration analysis at the Tegal shipyard in Indonesia. The study aims to achieve efficient project scheduling by reducing project completion time and cost-effectiveness. The analysis was performed to assess the amount of labor produced, network diagram, critical track, balance of the critical track, acceleration of the project's duration, increase in labor, and additional working hours (overtime). The network diagram, which comprises 18 tasks on the important track, has a tracking efficiency of 98% after one day, according to the findings. The addition of labor of 10% could reduce the duration of the project up to 16.92% from 65 days to 54 days, with an increase of cost of 3.83% from the initial condition total cost (from US$ 706.62 to US$ 733.7). On the other hand, with the addition of 3 working hours, a duration acceleration of 10.77% from 65 days to 58 days, with an increasing cost of 59.35% (from US$ 706.62 to US$ 1,126.02) can be obtained. As a result, the increase in labor could be a valuable reference for shipyard personnel to anticipate project completion delays.

KEY WORDS

~ Float time
~ Ranked positions weight method
~ Network diagram
~ Repair project acceleration

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1. INTRODUCTION

In order to fulfill the ship owner's request, it is crucial that the ongoing project is completed within the set timeframe as this can significantly impact the cost. To achieve this, effective project management is necessary to expedite the project, decrease fabrication cycle times, maintain product quality, and anticipate any unexpected issues (Chiu et al., 2021). Ship repair is a lucrative business for shipyards in developing countries. According to

Ahluwalia and Pinha (2014) and Research and Markets (2022), the global ship repairing market was projected to reach US$ 32.29 billion in 2021 and is expected to increase to US$ 39.04 billion in 2022. Major shipyards worldwide are also striving to incorporate advanced technology into their processes although this usage remains limited in developing countries such as Indonesia. Traditional ship repair in developing countries can take up to 14 to 21 days for non-complicated cases, such as barges (Amenan, 2022). Given the financial constraints of shipyards in these regions and their continued reliance on traditional techniques, increasing the efficiency of the ship repair process is a practical and viable solution. Completing ship repair projects within the set timeframe is crucial to managing costs effectively. The ship repair industry is a lucrative business for developing countries, and the global market is expected to continue growing. Incorporating advanced technology into shipyard processes is a trend worldwide although this usage remains limited in certain regions. Increasing the efficiency of ship repair processes is a practical solution for shipyards in developing countries that face financial constraints and rely on traditional techniques.

Time acceleration can be calculated using efficient project scheduling management, one of which is the use of the Ranked Positions Weight Method (RPWM). This method was first introduced by Helgeson and Birnie (1961) by calculating the positional weight of each work unit on the assembly production line (Helgeson and Birnie, 1961). This method can determine the lateness efficiency, production rate, line efficiency, balance delay and smoothness index to determine a more efficient worker allocation (Deshpande and Joshi, 2007a), (Ginting and William, 2020), (Hariyanto and Azwir, 2021). This method has been widely applied in manufacturing and fabrication factory with high production rates. The use of this method in the shipyard is still very rare because the production line in the shipyard is different from the production line in manufacturing. According to its characteristics, the production process in the shipyard is one of many very complex business and production processes (Hadjina et al., 2015).

Based on research by Hamzas et al. (2017), the use of the ranked positions weight method for the double-sided assembly line in the automotive industry can increase efficiency from 86% to 92% and minimize workstations from 17 to 16 workstations. Meanwhile, for the construction project, Handa et al. (1992) implemented this method for bridge construction. They used the ranked positions weight method in an algorithm that could be used as an alternative to the Critical Path Method (CPM). The execution scheduling of the mixed use of the Tanjung Barat Southgate project conducted by Wacono and Ginartra (2019) by analyzing positional weight using the RPWM resulted in a 5 day acceleration of the project, which was initially performed with a duration of 396 days that changed to 391 days.

From the several studies listed, it is reasonable to conclude that the RPWM is a method that can be used as a project acceleration method by analyzing the schedule to reduce the duration of work while remaining cost-effective. The RPWM is not widely used in shipping. As a result of this research, the RPWM is expected to be one of the methods that could be used in optimizing the schedules of repair projects to add more references in the field of project management in the shipping industry. It is anticipated in this study that by utilizing the RPWM in rescheduling the MT Poka Jo (IMO: 9918119) reparation project at the Tegal shipyard, time and labor could be optimized, resulting in a reduction in the production cost and increased profit for shipyard personnel. With the alternative of increasing labor and working hours, the acceleration of duration would be considered to anticipate work problems that might result in project completion delays. The goal of analysis using such a method is to find the comparison results from labor increase or worktime increase strategy in the acceleration of project completion with the parameter of duration changes and production cost increase.

2. LITERATURE REVIEW

Ship repair acceleration projects can have various benefits. Dlugokecki (2010) found that the project management approach to shipbuilding and ship repair project environments can enable shipyards to achieve reduction in project costs and cycle time. One of the methods used to ship repair acceleration projects is the RPWM. The RPWM is a multi-criteria decision-making (MCDM) method that is used to prioritize and rank alternatives in a decision-making process. It has been widely used in various domains such as project management, engineering, and transportation. The RPWM is a heuristic method commonly utilized to arrange and distribute the description element time along the workstations in the system (Hakim et al., 2018). It was introduced by Helgeson and Birnie in 1961. The RPWM was first introduced as a method to prioritize alternatives based on their relative importance. The method uses a weighting scheme that assigns a higher weight to alternatives that are more important, and a lower weight to alternatives that are less important (Ginting & William, 2020) . The RPWM has several advantages compared to other MCDM methods. It is simple, easy to implement, and does not require complex mathematical calculations. Additionally, it is able to incorporate both quantitative and qualitative information in the decision-making process.

Several applications of the RPWM can be found in the line balancing problem. Line balancing is usually performed to minimize the imbalance between machines or personnel in order to meet the desired output of the assembly line. Assembly line balancing problem by using the RPWM was conducted by Hamzas et al. (2017), Siregar (2020), and Edokpia & Owu (2013). The performance with the RPWM proved to be better than the actual method of the company, which can be seen from the reduction in the number of work centers, the number of idle, and the value of line efficiency, balance delay and smoothing index better. Islam et al. (2019) used the combination of the RPWM for production efficiency improvement for sewing line problem. Through the study, they produced the product at a high production rate through the minimum cost and meet the daily production target.

The method can be used for project scheduling, specifically for building operations in ship repair projects, in addition to being utilized for line assembly. It should be mentioned that construction work is extremely similar to assembly line manufacturing. The most effective sequence for completing tasks is determined using the ranked positional weight (RPW) method, a scheduling tool that has been employed in shipbuilding projects. The RPW approach entails weighting activities according to their importance before ranking them based on their combined weighted scores. The RPW has also been used to enhance ship project schedules when combined with other scheduling methods. A genetic algorithm and the RPW were combined to optimize the schedule of a shipbuilding project, and it was discovered that the hybrid approach might shorten project time and increase resource utilization. According to the literature, the RPW can be a useful technique for scheduling ship projects, especially for prioritizing tasks and enhancing project efficiency. However, the use of the RPW might necessitate a lot of work in terms of weighting and ranking activities, and it might not take all project-related sources of uncertainty into consideration. While the RPWM has many advantages, it also has some limitations. One of the main limitations is that it assumes that all alternatives can be ranked in a single dimension, which may not be the case in all situations. In addition, the method relies on the subjective opinions of decision-makers, which may lead to bias in the ranking process.

3. RESEARCH METHOD

3.1. Ship Data

The docking repair operation on MT Poka Jo (IMO: 9918119), owned by PT Pelayaran Berkat Robohot, at the Tegal shipyard, which began on May 25, 2020 and ended on August 11, 2020, served as the the object of study. Due to difficulties encountered during the undocking phase, the ship repair project experienced a setback of 7 days, highlighting the critical importance of accelerating the project analysis to prevent further delays. The acceleration project involves a comprehensive review of the repair project plan, identifying any bottlenecks or inefficiencies that may be causing delays. By addressing these issues, the acceleration project aims to streamline the project process and ensure that all critical activities are completed in a timely and efficient manner. The importance of the acceleration project cannot be overstated as any further delays could have significant consequences for the project's timeline and overall success. Delays in the project could result in increased costs, reduced productivity, and damage to the company's reputation. To avoid these negative outcomes, it is crucial to implement the acceleration project strategy.

The main schedule and repair list are the data types used, and their duration's acceleration will be examined to shorten the estimated project completion time while maintaining an ideal cost. Vessel’s primary measurement data are explained in Table 1, and its overall organization is shown in Figure 1. To develop a description of the work process for the ship repair project, the calculation analysis in this study employs primary data collected through a live observation process using field observation and interviews with the company personnel and day workers at the shipyard (Tam and Palaneeswaran, 1999). All shipbuilding data required will be complemented by field observation. The vessel’s repair project schedule, repair list, general design, and the principal measurement are the data that were gathered. The structure, amenities, and worker information for the shipyard include the number of employees, daily wages, and the number of working hours. Secondary sources such as journals, papers, comparable study findings from earlier studies, and project management instruction books are utilized when supporting data is needed. Such data is used as data confirmation and source of references for the assessment process in this study.

Table 1.
Primary measurements of MT Poka Jo (IMO: 9918119).

Parameter	Value
Length Overall (LOA)	66.10 m
Length Between Perpendiculars (LPP)	64.15 m
Breadth (B)	10.00 m
Height (H)	4.50 m
Gross Tonnage (GT)	731 ton
Deadweight (DWT)	1,281 ton

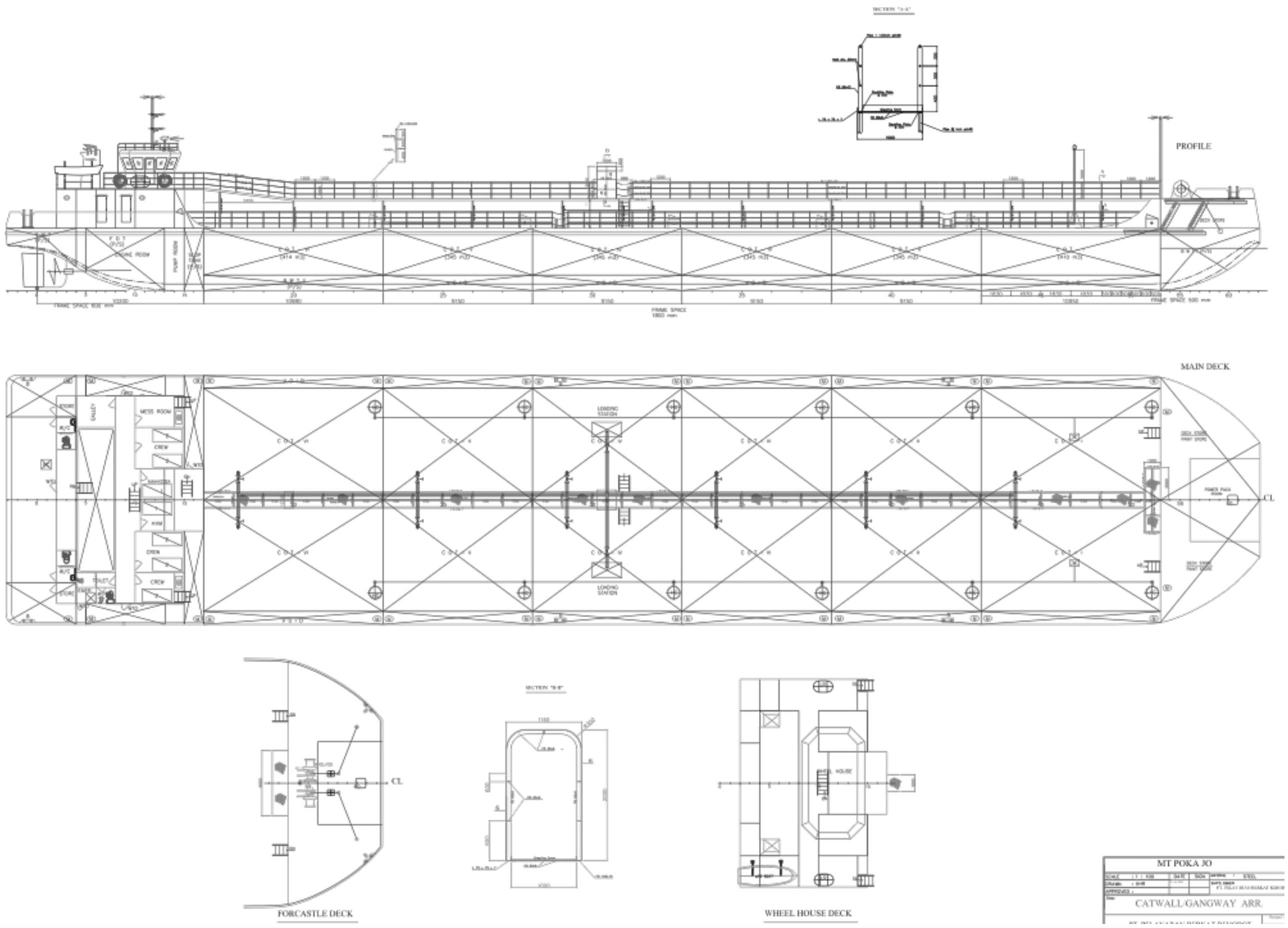

Figure 1.
General arrangement of MT Poka Jo (IMO: 9918119).

3.2. Project Scheduling

The proper organization and sequencing of activities in a project's workflow is essential to ensure that the project stays on track with the predetermined plan. This research aims to arrange the work schedule of a project systematically and in detail using Microsoft Project software. The first step involves dividing the work items according to the work breakdown structure (WBS), followed by identifying the predecessor and successor of each work item. As Hamilton (1997) suggests, the predecessor refers to the work that must be completed before the following work can start, while the successor represents the subsequent work that follows the completion of the previous work, as noted by Sadewo et al. (2017). The connection between each work item is established using one of three relationships: start to start (SS), finish to start (FS), or finish to finish (FF). The software will provide the output in the form of the critical track, which identifies the sequence of work items that are crucial to the project's success. Efficient scheduling is crucial in project management as it helps to optimize the use of resources and time, and minimize delays and costs. The use of software like Microsoft Project enables project managers to develop and monitor project schedules effectively. With the help of predecessor and successor relationships, project managers can determine the logical sequence of tasks, identify the critical path, and allocate resources efficiently. Overall, proper scheduling is an essential aspect of project management that can significantly impact project success.

3.3. Float Time Calculation Using RPWM

The RPWM is a method to count the positional weight of each work to achieve average time efficiency (Tam and Dissanayake, 1998). With schedule analysis using the RPWM, its final result would be generated as a track balance of each work so that the labor could be equally allocated to press float time. The data processing steps in this study are analyzing the schedule and repair list using Microsoft Project software to be grouped into several workstations according to work breakdown structure (WBS). The following step is determining the predecessor of each work to arrange a network diagram. From the arranged network diagram, the calculation of earliest start (ES), earliest finish (EF), latest start (LS), latest finish (LF), and total float (TF) could be analyzed, henceforth arranging the precedence diagram according to the float time value of 0. The float value could be determined using Eq. 1 (Suputra, 2011).

$$T = LF - EF \tag{1}$$

TF (total activity slack/ float) is the amount of float time between each work, while LF is the latest allowable activity finish time, and EF is earliest activity finish time. Calculating the positional weight of each critical work according to the precedence diagram track is using the RPWM matrix method. The longest operation time is 11 days. Later, performing work leveling according to its positional weight ranking where work with major weight has a minor value of float time, the work track balance efficiency according to the RPWM could be understood. To analyze the track balance, it is necessary to determine the number of stations with Eq. 2 to 4 (Purnamasari and Cahyana, 2015).

$$Number\ of\ stations = \frac{Total\ project\ time}{CT} \tag{2}$$

$$LE = \frac{Number\ of\ time\ elements}{Number\ of\ working\ stations \cdot Cycle\ time} \cdot 100\% \tag{3}$$

$$SI = \sqrt{\Sigma\,(CT - ST)^2} \tag{4}$$

The total project time is the entire duration elapsed to complete a project, and CT (cycle time) is the cycle time that could be determined using a technical approach. Hence, the amount of cycle time is determined using the longest operation time. LE (line efficiency) is the percentage of track efficiency. SI (smoothness index) is the float-time average index, while ST (station time) refers to the amount of time left on each station. After the track balance is arranged efficiently, the next step is to analyze the influence of labor increase alternative and overtime increase upon duration changes and cost optimization after the acceleration. To count the productivity of labor change, duration change, cost change, and percentage change, Eq. 5 to 12 can be used.

$$Productivity = \frac{Work\ volume}{Work\ duration} \tag{5}$$

$$Labor\ productivity = Initial\ prod. + \frac{Initial\ prod. \cdot Number\ of\ labour\ increas}{Normal\ number\ of\ workers} \tag{6}$$

$$Hourly\ productivity = \frac{Initial\ prod.}{Working\ hours\ daily} \tag{7}$$

$$Overtime\ productivity = Initial\ prod. + (Hourly\ prod. \cdot Time\ increases \cdot Efficiency) \tag{8}$$

$$New\ duration = \frac{Work\ volume}{New\ productivity} \tag{9}$$

$$Overtime\ cost = Daily\ wage + Overtime\ wage \tag{10}$$

$$Total\ cost = Workers\ x\ Wage \cdot Duration \tag{11}$$

$$Percetange\ change = \frac{(New\ data - Initial\ data)}{Initial\ data} \cdot 100\% \tag{12}$$

3.4. Analysis of Line Balancing with RPWM

The RPWM is applied to calculate the positional weight of each work item to be grouped into several new stations to reach the line balancing value. The RPWM is an optimal method to elevate the value of track efficiency (Ghutukade and Sawant, 2013); hence its work productivity would increase and reduce the work duration to be faster. In the calculation of the RPWM, a precedence diagram was used in composing the work order. The system in the precedence diagram is composed of rectangular nodes and completed with another attribute such as arrows that function as an indicator for the relationship between the related activities (Laksito, 2005). With these relationships between nodes, it would be easier to track control in the execution process (Isaac and Hajdu, 2016).

The steps involved in the RPWM are as follows. Firstly, the critical path of work is determined using a precedence diagram. Secondly, the matrix calculation is analyzed based on the critical path of work. Thirdly, the positional weight of work is calculated by arranging the matrix. The positional weight indicates the order of work that has top priority in completion. The order remains unchanged because the critical path of work has been determined. Therefore, this arrangement of positional weight allows us to analyze work that may be delayed or has low productivity. Fourthly, the balance of the line is calculated by determining the number of workstations using Equation 2. Each workstation is then grouped into a pre-existing workstation with a maximum capacity equal to the cycle time, which is 11 days. The result is the idle time (total idle time). Fifthly, line efficiency and smooth index are calculated using formulas 3 and 4. Based on the balance of the line data obtained, it can be concluded that the line efficiency is 98% with a possible idle time of one day. Based on the data obtained from the balance of the assembly line, project managers can conclude important information about the project's progress and status. This data can be used to identify potential areas for improvement, allocate resources more effectively, and ensure the project's success. Figure 2 depicts the making of the critical reparation project of the vessel using the precedence diagram. Matrix composing according to the work order shown in the precedence diagram is used to calculate positional weight from each work activity. Table 2 shows the RPWM matrix calculations from the order of work reparation project to calculate the positional weight of each work item.

Table 2.
RPWM matrix calculations.

Preceding Operations	Following Operations																	
	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
A	-	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
B	0	-	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
C	0	0	-	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
D	0	0	0	-	1	1	1	1	1	1	1	1	1	1	1	1	1	1
E	0	0	0	0	-	1	1	1	1	1	1	1	1	1	1	1	1	1
F	0	0	0	0	0	-	1	1	1	1	1	1	1	1	1	1	1	1
G	0	0	0	0	0	0	-	1	1	1	1	1	1	1	1	1	1	1
H	0	0	0	0	0	0	0	-	1	1	1	1	1	1	1	1	1	1
I	0	0	0	0	0	0	0	0	-	1	1	1	1	1	1	1	1	1
J	0	0	0	0	0	0	0	0	0	-	1	1	1	1	1	1	1	1
K	0	0	0	0	0	0	0	0	0	0	-	1	1	1	1	1	1	1
L	0	0	0	0	0	0	0	0	0	0	0	-	1	1	1	1	1	1
M	0	0	0	0	0	0	0	0	0	0	0	0	-	1	1	1	1	1
N	0	0	0	0	0	0	0	0	0	0	0	0	0	-	1	1	1	1
O	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	1	1	1
P	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	1	1
Q	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	1
R	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-

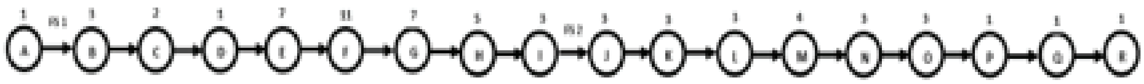

Figure 2.
Critical work reparation project of MT Poka Jo (IMO: 9918119) using precedence diagram.

3.5. Leveling Analysis

The process of leveling or arranging work based on positional weight ranking is an effective way to identify the most important tasks and prioritize them accordingly. By creating a priority sequence based on the positional weight of each task, it becomes easier to schedule and complete the most critical activities first. This leveling process is essential for ensuring that work resources are distributed equally every day. By prioritizing tasks based on their importance, employees can focus their efforts on the most significant activities, making sure that important projects are completed on time. Positional weight analysis refers to the sequence of work series, where the sequence does not change because it has been arranged as a critical path work series.

Moreover, this approach helps to avoid overburdening employees with tasks that are not as important, leading to a more balanced workload distribution. It also provides a clear roadmap for completing tasks in an efficient and effective manner. The process of leveling or arranging work based on positional weight ranking is a valuable tool for organizations to prioritize tasks and ensure that work resources are distributed fairly, leading to improved productivity, better time management, and higher job satisfaction among employees.

4. RESULT AND DISCUSSION

4.1. Float Time Calculation

Float time is the possible total time for a work to run into delay or postponement (Ammar and Mohieldin, 2002). The value of Total Float (TF) is obtained from the reduction of the latest finish (LF) along with the earliest finish (EF). A network diagram is a dependency connection between work parts described in the form of a network diagram (Siregar, 2020). The work order is arranged based on the sequence of project activities with work connection and duration time. The order of activities arranged on the network diagram could determine its float time or total float. Table 3 shows the node structure on the network diagram arrangement to calculate the sequential value of the ES, LS, EF, LF, and TF.

Table 3.
Table structure on a series of diagrams.

ES	Duration	LS
	Working Name	
EF	TF	LF

Such arrangement counts the value amount of the ES, LS, TF, LF, and EF. Figure 3 presents the arrangement of the network diagram according to the work order to calculate the value of the ES, LS, EF, LF, and TF. From the work order in Figure 3, it could be known that work A is the predecessor of work B, while work C and work D are the successors of work B. The float time value could be calculated using Eq. 1 according to the duration order of each work item that interconnects. The amount of float value obtained shows how long such work could run into a delay or postponement without influencing the final duration of project completion.

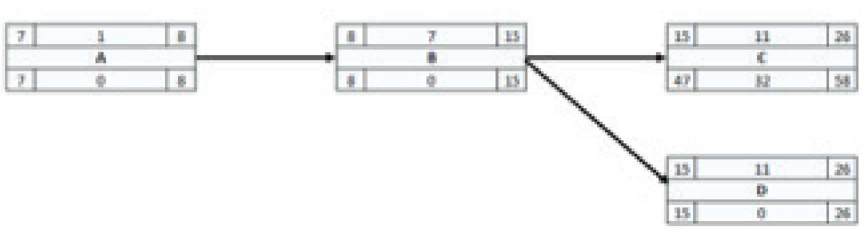

Figure 3.
Cross-activities connection within the network diagram.

4.2. Critical Track Analysis

The critical track refers to a work sequence from the beginning to the end that depends on each other and should be finished at the planned time to prevent any delay (Deshpande and Joshi, 2007b). If one of the works included in the critical track experiences a delay, it may delay the whole project's completion. Analyzing the amount of float value is a way to assign which works should be included in the critical track, wherein critical work is marked by the amount of float value of 0, which indicates such work item does not have any deadlines to experience any delay or postponement. Table 4 presents the work summary included in the critical track according to the analysis of float time value. In Table 4, the completion of the vessel's reparation project indicates 18 essential works with a float time of 0.

Table 4.
Ship repair project critical track works MT Poka Jo.

Code	Working Name	EF	LF	TF
A	Going to the dock	1	1	0
B	Scraping	5	5	0
C	Sandblasting	7	7	0
D	Measuring plate thickness with ultrasonic test	8	8	0
E	Replating double bottom partition	15	15	0
F	Replating right and left side plate	26	26	0
G	Changing ship's name and sling	33	33	0
H	Replating winch foundation in the right and left course	38	38	0
I	Right and left winch brake lining replacement	41	41	0
J	Reconstruction of the left front deck on the poop deck	46	46	0
K	Reconstruction of the left front deck on the poop deck	49	49	0
L	Stay bulwark forecastle right and left	52	52	0
M	Emergency door repair	56	56	0
N	Relling repairment	59	59	0
O	Superstructure painting	62	62	0
P	Docking report writing	63	63	0
Q	Getting off the dock	64	64	0
R	Sea Trial	65	65	0

4.3. Calculation of Weight Position

The positional weight of each activity can be calculated by adding the activity's duration to the total number of activities, as determined by the matrix calculations (Suputra, 2011). Table 5 displays the positional weight composition of each work item. The results indicate that the work item with the highest duration is the replating of the right and left side plate, which requires 11 days to complete. Moreover, the going-to-dock working activity has the highest workload. Determining the positional weight of each activity is crucial to effective project management. This information helps to allocate resources and time effectively and prioritize activities based on their importance and impact on the project's success. By identifying the work items with the highest positional weight, project managers can focus their efforts on these critical tasks and ensure that they receive adequate resources and attention. In addition, the analysis of the positional weights can help to identify potential areas for optimization and improvement. For example, if a work item has a high positional weight but a relatively short duration, it may indicate that the activity is inefficient or could be completed more quickly with better resource allocation or process optimization.

Table 5.
The calculations of the positional weight of each work item.

	Working Name	Duration (Day)	Workload
A	Going to the dock	1	64
B	Scraping	4	60
C	Sandblasting	2	58
D	Measuring plate thickness with ultrasonic test	1	57
E	Replating double bottom partition	7	50
F	Replating right and left side plate	11	39
G	Changing ship's name and sling	7	32
H	Replating winch foundation in the right and left course	5	27
I	Right and left winch brake lining replacement	3	24
J	Reconstruction of the left front deck on the poop deck	5	19
K	Mest top deck pole rope replacement	3	16
L	Stay bulwark forecastle right and left	3	13
M	Emergency door repairment	4	9
N	Relling repairment	3	6
O	Superstructure painting	3	3
P	Docking report writing	1	2
Q	Getting off the dock	1	1
R	Sea Trial	1	0

4.4. Calculation of Track Balance

From the existing positional order rank, equal distribution of labor could be conducted by grouping work items into several new stations. Wherein each station has its maximum work time capacity so that from each station the maximum distribution of labor sources can be carried out evenly. To analyze the track balance using the RPWM, the first step that must be conducted is to determine the number of the new station using the comparison between the project's total time with the cycle time of each work item. On the scale of a huge project, the cycle time is set using the technical approach method so that the analysis track balance in this research, the cycle time is set using the longest work duration (Baroto, 2002). Every new work station has a maximum duration capacity with the number of the cycle time that is set in advance. After that, work items are grouped into each station with the estimated time by the cycle time. Table 6 shows the data of the grouped work items in each station according to the calculations using the RPWM method.

Table 6.
Grouped work stations.

Work Station	Work Item	Station Time	Idle Time
I	B, E	4+7=11	0
II	F	11	0
III	A, C, D, G	1+2+1+7=11	0
IV	J, K, L	5+3+3=11	0
V	H, I, N	5+3+3=11	0
VI	M, O, P, Q, R	4+3+1+1+1=10	1
Idle Time Total			1

From the grouping of each station, it could be discerned that the total idle time is 1 day. Next, the line balance is analyzed using line efficiency and Smoothness Index to determine the line's efficiency level. Line efficiency is defined as the average efficiency of workstations in line production (Mundel and Danner, 1994). Therefore, analysis of line efficiency is used to determine the efficiency level of the work trajectory that has been composed. Line efficiency is analyzed by comparing the number of time elements to the number of work stations with the amount of time available in percent. From the analysis conducted, a line efficiency of 98% is obtained. Line efficiency is calculated using a comparison of the total element time to the number of work stations with the cycle time available in percentage according to Eq. 3. The total element time of 65 days were compared with 6 total stations and the 11 days of cycle time based on the longest time of operation time. The Smoothness Index is an index that shows the relative smoothness of the balancing assembly process of a work trajectory (Purnamasari and Cahyana, 2015). A trajectory with high optimization would have a small delay time value in which the delay time could be analyzed through the amount of smoothness index, and it is also obtained that the delay time is 1 day. Table 7 shows the calculations and results from the analysis of the balance from critical path work using the RPWM method. The analysis of the track balance, the value of line efficiency, and smoothness index will show the efficiency and trajectory optimization in a work order. From the aforementioned calculations, it could be concluded that the trajectory has a balanced cycle time, so the track balance is already well. The trajectory balance calculation shows that the trajectory efficiency value is 98% with idle time and smoothness index value is 1.

Table 7.
Analysis of trajectory balance using line efficiency and smoothness index.

Work Stations	Work Items	ST (Stations Time)	CT (Cycle Time)	(CT-ST)	($\sqrt{(CT-ST)^2}$)
I	A, B, C, E	11	11	0	0
II	F	11	11	0	0
III	D, T, U, V	11	11	0	0
IV	G	11	11	0	0
V	H, Y, Z	11	11	0	0
VI	I, J, AA, BB	10	11	1	1
Total		65			1

4.5. Calculation of Project Acceleration

4.5.1. Initial Condition of the Project

The acceleration of a project is conducted to lessen the duration of a project as a whole after analyzing an alternative in an existing working network (Saputra, 2014). An acceleration alternative is a way that is mostly conducted to fasten the duration of activities in a project so it would be completed in a much faster target time from the normal duration that has been set. In this research, the acceleration duration in completing the project offered an alternative: additional labor and working hours (overtime).

From the data that has been compiled on the reparation of the vessel, the project was conducted on the labor of 36 people in a total of 65 effective working days, 6 days a week and 8 working hours a day. The work lasted from 8.00 AM until 5.00 PM WIB with a break for an hour from 12.00 PM until 01.00 PM WIB. For overtime hours, the work would begin at 06.30 PM WIB. In doing the acceleration of the project, the first phase that must be conducted is to calculate the value of productivity. Productivity is a ratio between output and input (Laksono, 2007). In this case, production output is in the form of the volume of work that will be completed, and the production input is in the form of how long the duration is needed to finish the work. The change in production value will affect the duration of the project work, which will result in a change in total production cost. The total labor cost is calculated by multiplying the number of workers by the cost of daily wages and the duration of the work. For the initial condition from these cases, the project cost calculation reached US$ 706.62.

4.5.2. Project Acceleration by Adding Manpower

Adding labor is one of the alternatives for accelerating the duration to anticipate delays in completing the project. To compare the percentage of the most efficient additional labors, the calculations were conducted in several additions, and that was 5%, 10%, 20%, or 30%. To determine the number of additional labors, the percentages of additional labor are calculated from the total number of early labors. Next, the total additional labor would be allocated to the work items with a load value that is dense with a long work duration. The workstation that needed additional workers is replating of left and right side plate because it has the highest work duration; therefore, adding more workers to increase the productivity was needed. With the change in the number of labors, there will also be an effect in which the project's productivity is affected. The amount of the new productivity is obtained by adding normal productivity with additional labor productivity. The addition of labor increased the work productivity, creating a possibility of duration accelerations. The new duration after the acceleration is obtained by comparing the existing work volume to new productivity after the additional labor. The total cost that is needed to complete the project with acceleration alternative additional labor is estimated through the total number of workers, the daily wages of each worker, and the duration of work. As the result of the analysis, to compare the efficiency level between each variation of the percentage, the percentage is determined by comparing the difference between the initial data and the new data to the initial data in percentage. Table 8 compares the end calculations result with additional variations of labor for 5%, 10%, 20%, and 30%.

Table 8.
Effect of additional manpower to the initial project.

Additional Labours (%)	Total Labours	Project Duration	Total Cost (US$)	Reduction Percentage of Project Duration (-)	Increasing Percentage of Total Cost (+)
0	36	65	706.62	Initial Condition	
5	38	59	720.80	9.23%	2.01%
10	40	54	733.70	16.92%	3.83%
20	44	49	760.78	24.62%	7.66%
30	47	45	773.67	30.77%	9.49%

4.5.3. Project Acceleration by Adding Working Hours (Overtime)

Adding working hours outside the initial working hours (overtime) could be an alternative to increasing productivity in a job. An analysis of several working hours' variations is conducted to indicate the number of the most efficient working hours, which are 1 hour, 2 hours, 3 hours, 4 hours, and 5 hours. In determining the number of additional working hours, a calculation of the amount of productivity every hour is conducted using comparisons from normal productivity to initial working hours per day. After that, the new work productivity could be determined by adding productivity per hour adapted to the number of additional working hours and its efficiency with normal productivity. So, the longer the working time is carried out, the greater the daily productivity will increase. With the increasing daily productivity, the duration of the work on an item would be less. The new duration is analyzed using comparisons between work volume with new productivity after the addition of working hours. For cost analysis, the daily overtime wage must be calculated by calculating daily wage with overtime wage per hour and then is customized with how many the workers are and how long the duration is. Comparisons from each variation calculation that is obtained could be analyzed through the change in percentage by comparing the difference between the initial data with the final data calculated from the initial data in percentage. Table 9 shows the data comparisons from the resulting calculations with variations of additional working hours for 1 hour, 2 hours, 3 hours, 4 hours, and 5 hours.

Table 9.
Effect of additional working hour to the initial project.

Additional Working Hours	New Duration	Total Cost (US$)	Reduction Percentage of Project Duration (-)	Increasing Percentage of Total Cost (+)
0 hour	65	706.62	Initial Condition	
1 hour	64	884.89	1.54%	25.23%
2 hours	61	1,013.51	6.15%	43.43%
3 hours	58	1,126.02	10.77%	59.35%
4 hours	55	1,222.40	15.38%	72.99%
5 hours	48	1,235.94	26.15%	74.91%

4.5.4. Comparison Result Between Adding Working Hours and Manpower

The impact of manpower and working hours on project duration is significant and has been analyzed in this study. In Figure 4, the diagram shows the effect of adding labour to the total duration of the project. The results indicate that adding labor will accelerate the duration of the project with an increase in total cost. The more labor added, the faster the project will be completed, but the total cost of the project will increase. For example, adding 30% more labor increases the total cost by 9.49% of the initial total cost, from US$ 706.62 to US$ 773.67, and reduces project duration from 65 days to 45 days.

Figure 5 displays the impact of additional working hours (overtime) on project duration and total cost. It shows that increasing working hours will reduce the project duration. For instance, adding 5 hours in working hours can reduce the project duration from 65 days to 48 days, but at the same time, there is a drastic increase in the total cost by 74.91% of the initial total cost, from US$ 706.62 to US$ 1,235.94. Figure 6 provides a comparison between the impact of adding labor and adding working hours to the total cost and project duration.

Based on Figure 6, the trendline on additional manpower has a linear result with a coefficient of derivation (R2) of 0.9733; the coefficient of determination is the proportion of the variation of the dependent variable that can be predicted from the independent variable on the linear result (Zhang, 2017), while the linear trendline is expressed by the Equation 13.

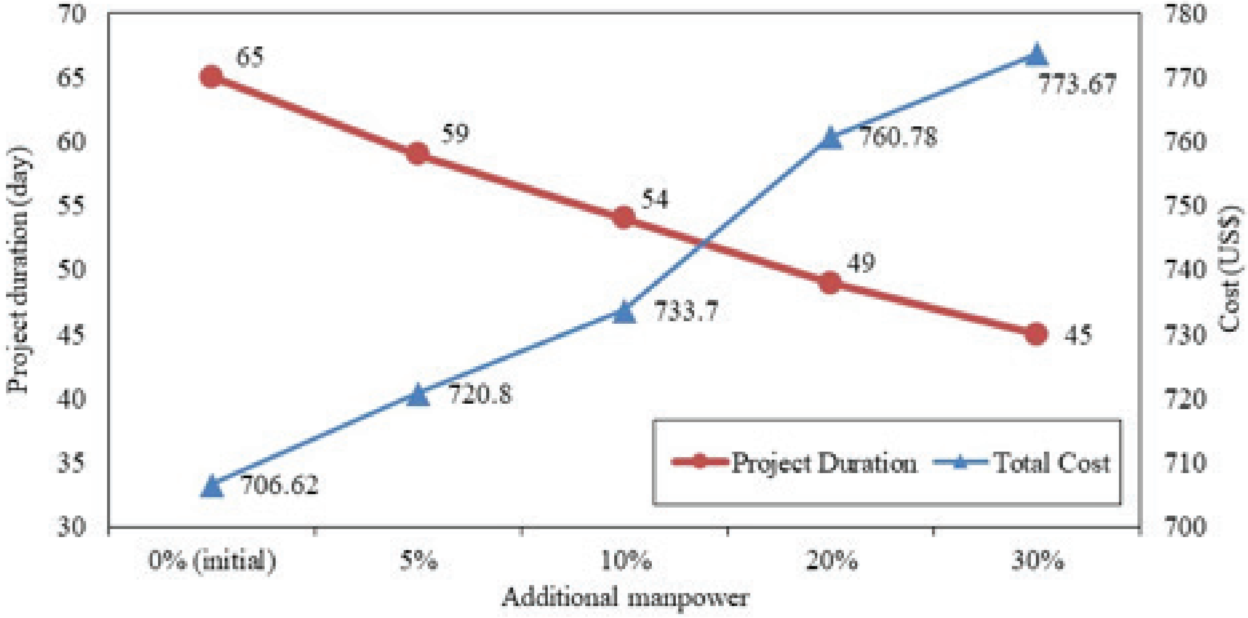

Figure 4.
Influence of additional labors on duration and cost.

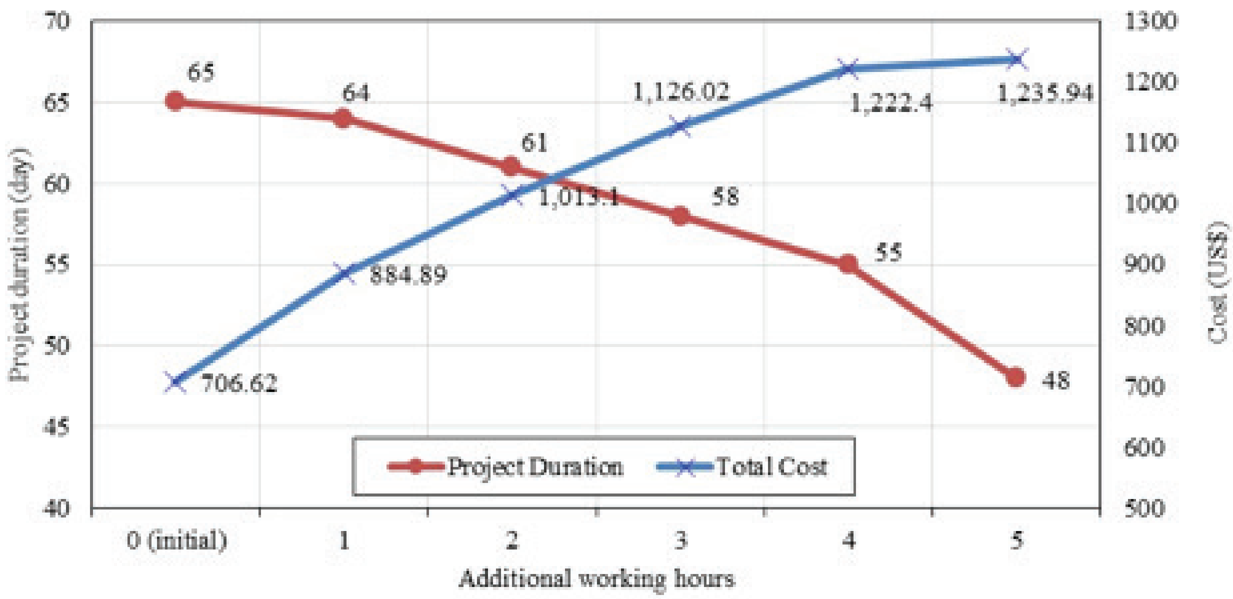

Figure 5.
Influence of additional working hours on duration and cost.

$$y_1 = 3.4568x + 699.02 \quad (13)$$

In contrast to the additional manpower, the additional working hour shows a logarithmic trendline result with the approximate formula expressed by Equation 14.

$$y_2 = 738.88x^{0.1955} \quad (14)$$

Using the result in Figure 6, an additional 5% of employees will reduce project duration by 9.23% from 65 days to 59 days, with a 2.01% increase in total costs from US$ 706.62 to US$ 720.8. With the same target duration (59 days) when using the additional working hours' method and with the same total labor, it will increase total costs from around US$ 1,013.51 to US$ 1,126.02. It can be concluded that the addition of labor is financially more profitable than the addition of working hours. The most efficient acceleration of duration is chosen by the alternative of adding labor of 10% or adding 3 working hours. The addition of labor of 10% could reduce the duration of the project up to 16.92% from 65 days to 54 days, with an increase of cost of 3.83% from the initial condition total cost (from US$ 706.62 to US$ 733.7). On the other hand, with the addition of 3 working hours, a duration acceleration of 10.77% from 65 days to 58 days, with an increasing cost of 59.35% (from US$ 706.62 to US$ 1126.02) can be achieved.

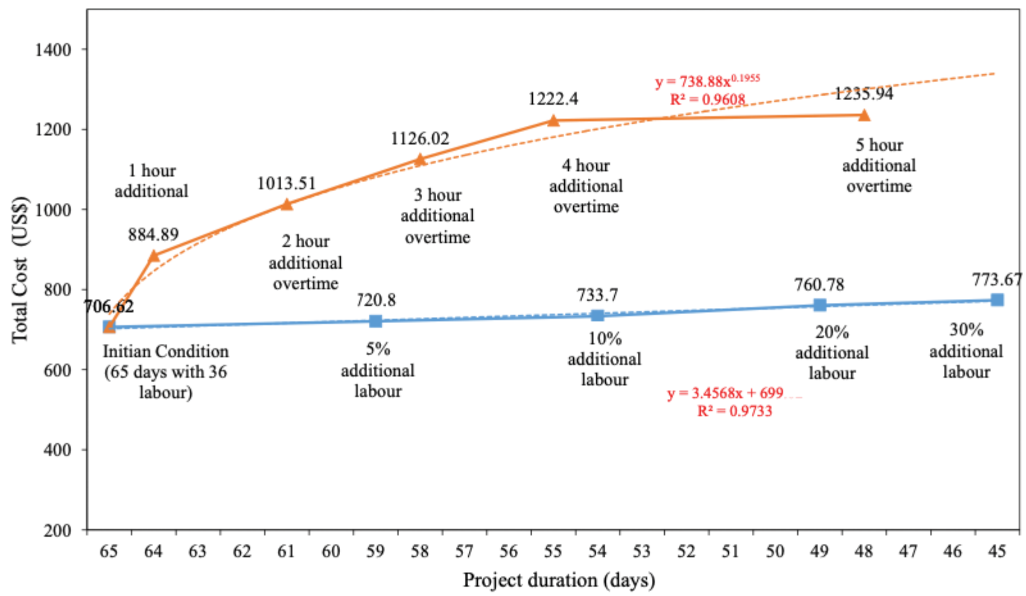

Figure 6.
Comparison of additional manpower and additional working hour to project duration and total cost increasing.

5. CONCLUSIONS

The result of data processing in this research of MT Poka Jo (IMO: 9918119) ship reparation project using the Ranked Positions Weight Method (RPWM) and acceleration shows the network value diagram progressing with the track balance of 98% and smoothness index value of 1% with an idle time of 1 day. Duration acceleration is conducted in 2 ways: the addition of labor and the addition of working hours (overtime). Every alternative is calculated with several variations. The addition of labor is calculated with additional variations with the number of 5%, 10%, 20%, or 30%. In addition, the alternative of adding working hours (overtime) is calculated with the additional variation length of 1 hour, 2 hours, 3 hours, 4 hours, or 5 hours. The most efficient acceleration of duration is chosen on the alternative of adding labor of 10% or adding 3 working hours. The addition of labor of 10% could reduce the duration of the project up to 16.92% from 65 days to 54 days, with an increase of cost of 3.83% from the initial condition total cost (from US$ 706.62 to US$ 733.7). On the other hand, with the addition of 3 working hours, a duration acceleration of 10.77% from 65 days to 58 days, with an increasing cost of 59.35% (from US$ 706.62 to US$ 1,126.02) can be obtained. From the aforementioned data comparison, adding labor is more effective and efficient in terms of duration acceleration and increasing cost. Therefore, the addition of labor could be used as a reference by the shipyard to anticipate delays in project completion.

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CONFLICT OF INTEREST:

Authors declare no conflict of interest.

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