Delays Analysis Of TRANSKO Tawes 11.3 DWT Mooring Boat Development Project Based On Risk Management

Imam Pujo Mulyatno[1], Samuel[2*], Feri Adi Mukhlisin[3], Syaiful Tambah Putra Ahmad[4]

Abstract— **In shipbuilding projects, it is often the case that the project completion time exceeds the planned target time. Risk is an important factor in estimating the project schedule. If risk occurs in a project, it is certain that the project duration will increase. Therefore, risk analysis and mitigation are needed in the risk management of shipbuilding projects. The case study in this research is the 11.3 DWT TRANSKO Tawes mooring boat construction project owned by PT Pertamina Trans Kontinental which is experiencing delays. With data in the form of the project main schedule, risk analysis uses Primavera Risk Analysis software integrated with the Monte Carlo method to analyze risks to the schedule and provide an estimate of the exact project completion time. By randomly decreasing the uncertainty variable for 201 iterations, the results show that the percentage value of project delays is 11.38% of the target project construction duration of 167 days so that the project is estimated to experience a maximum delay of 19 days from the planned target duration so that the project is completed in 186 days or 1 day longer than the actual duration of the project which is completed in 185 days. In the TRANSKO Tawes 11.3 DWT mooring boat construction project, 12 risks were obtained that affected the project with details of 3 high category risks, 2 medium category risks, and 7 low category risks. As for the actual duration of the project, there is an increase in productivity compared to the duration of the simulation results, which is 0.0001 DWT/mandays.**

Keywords—**Risk Assessment; Monte Carlo; Mooring Boat; Primavera Risk Analysis.**

I. INTRODUCTION

A project is a combination of temporary activities that mutually influence one another. It has a starting point (initial) and an ending point (terminal). The planning has a goal, the process is supported by various resources, and the implementation is limited by time [1].

However, in reality, we often encounter cases where the project completion time exceeds the targetted time. Research shows that almost 70% of projects have problems achieving the targetted time [2]. Failures certainly cause this both in terms of planning and execution. This is a form of project management failure that cannot be separated from the existence of several factors that influence each other, including time, cost, risk, quality, and resources. Risk is a very important factor in estimating or making a project schedule. Therefore the risk is a factor that must be considered in order to avoid possible project delays.

One of the methods used to solve these problems is the Monte Carlo method. The Monte Carlo method is useful in identifying risks (threats) or opportunities (opportunities). Besides, this method can determine how much influence an event or activity has on the project's duration. This method aims to model and analyze a system that contains risks and uncertainties [3]. In project management, Monte Carlo simulation is a reliable tool for project managers in analyzing risks and uncertainties that generally occur in a project [4]. For

software, there is Primavera Risk Analysis which has been systematically integrated with the Monte Carlo method so that the minimum and maximum duration of a project will be obtained by running the Monte Carlo simulation software.

Referring to the Type 1200 GT Pioneer Ship development project at PT. The 2015 JMI obtained 12 risks that affected projects with one extreme category, four high categories, four medium categories, and one low category with a project accuracy percentage of 12%. The risks that significantly influence the project are labor requirements, delays in material supply, and repairs or revisions due to recommendations after work [4]. Besides that, in constructing the 2000 GT Pioneer Ship at PT. JMI in 2016, 16 internal and external risks caused project delays, with details of 4 very high-risk categories, nine high-risk categories, and three medium-risk categories. Work equipment performance, labor requirements, and shipyard financial capabilities [5]. Whereas in the construction of Pertamina's 3500 LTDW White Product Oil Tanker Ship project, there were 12 risks, both internal and external, that caused the project to experience delays with details of 3 risk events from delays in design and planning, two risk events from delays in material/equipment supply, and seven risk events from delays in the production planning process. With a source of risk that requires primary treatment, namely repair/revision work due to adjustments to requests from the owner and classification parties [6]. As for the Lake Toba 300 GT Ro-Ro Ship construction project, 15 risk events were obtained, of which six risks were at the planning stage, three risks at the procurement stage, three

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risks at the quality control stage, and three risks at the financial stage [7].

Based on the elaboration above, analysis and evaluation will be carried out on the risks of the TRANSKO Tawes 11.3 DWT mooring boat development project owned by PT. Pertamina Trans Kontinental, which was delayed for 18 days in the process, resulted in additional production costs. The analysis uses the Monte Carlo method assisted by the Primavera Risk Analysis software so that the level of risk and the percentage of project decisions are obtained for further mitigation of risks that can lead to additional project duration so that the project is expected to be implemented on time.

II. METHOD

A. Object of Research

In this study, the object in the form of the main schedule was used from the TRANSKO Tawes 11.3 DWT mooring boat development project owned by PT. Pertamina Trans Continental at PT. Yasa Wahana Tirta Samudera. From the main schedule, an analysis will be carried out by linking the risks that have been identified and verified with the activities in the project. So, the shipbuilding project, which is planned to have a duration of 167 days, will be known to experience delays or be on time by analyzing the Monte Carlo method using Primavera Risk Analysis software. The main ship size data used in this study can be seen in table 1.

B. Monte Carlo Method

The Monte Carlo method is useful in identifying risks (threats) or opportunities (opportunities). Besides, this method can determine how much influence an event or activity has on the project's duration. The method uses input in the form of random numbers and can evaluate the deterministic or certainty of project duration [8].

This method has several advantages compared to other methods, including providing accurate measurement of results, using relatively simple and easy modeling, and evaluating the effect and impact of risk events. The Monte Carlo method has been used in a risk research study on the financial feasibility of MT tankers. Pagerungan 17,500 LTDW (Long Ton Deadweight) owned by PT. Pertamina (Persero) [9]. The steps in the Monte Carlo simulation method are as follows [8]:

1. Parametric modeling, $y = f(x_1, x_2, \dots x_n)$.
2. Generate a random input pool, $x_{i1}, x_{i2}, \dots x_{iq}$.
3. Evaluate the model and collect the results of the y calculations.
4. Repeat steps 2 and 3 for $i=0$ to n.

5. Analysis of the results using a histogram.

This research was assisted by the Primavera Risk Analysis software, which has been systematically integrated with the Monte Carlo method. So by running the Monte Carlo simulation software, the results are obtained in the form of a minimum and maximum duration of the project based on the risks that exist and occur during the course of the project [10]. Iteration of this method is used to assess risk due to uncertainty by referring to past data and involving random variables based on the characteristics of the input distribution. The following are the steps carried out in a Monte Carlo simulation using the Primavera Risk Analysis software in outline:

1) Determine the probability distribution of important variables, the important variables referred to in this study are the impact of adding days.
2) Associating variables with the main schedule in order to know the magnitude of the influence on the duration of the project.
3) Lowering variables randomly by means of iteration assisted by software so that the project's duration is obtained.

C. Risk Identification and Verification

Identification and verification are the initial stages in evaluating the project schedule. At this stage, the author collects both primary and secondary data [11]. Data collection techniques through observation, interviews, and questionnaires were distributed to the shipyard, especially with the project head and employees involved in the mooring boat development project. The output obtained in this stage is a list of risk events that affect project activities.

D. Risk Probability Value Index

The probability value often called the likelihood, is the probability that there will be a risk to the activity in a project. Following in table 2, there is a probability value based on the PT. Yasa Wahana Tirta Samudera.

E. Risk Result Impact Index

The impact index often called impact, is the amount of additional time that results in delays in the project due to a risk event. Table 3 shows the determination of the impact value based on PT. Yasa Wahana Tirta Samudera.

TABLE 1.
MAIN DIMENSION SHIP

No.	Name	Dimension
1.	Length Over All	7.22 m
2.	Length of Water Line	6.94 m
3	Breadth (Moulded)	2.70 m
4	Height (Moulded)	1.8 m
5	Draught (Hull)	1.2 m
6	Speed Max	7 knots
7	Main Engine	170 HP
8	Crews	2 Person

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TABLE 2.
RISK PROBABILITY VALUE INDEX

Indeks	Probability	Value (%)	
1	The possibility of this happening is very small	0%-20%	Rare
2	The potential for it to happen is small	21%-40%	Unlikely
3	Medium potential	41%-60%	Possible
4	The potential for it to happen is huge	61%-80%	Likely
5	The potential for occurrence is high in the short term	81%-100%	Almost Certain

TABLE 3.
INDEX DUE TO RISK IMPACT

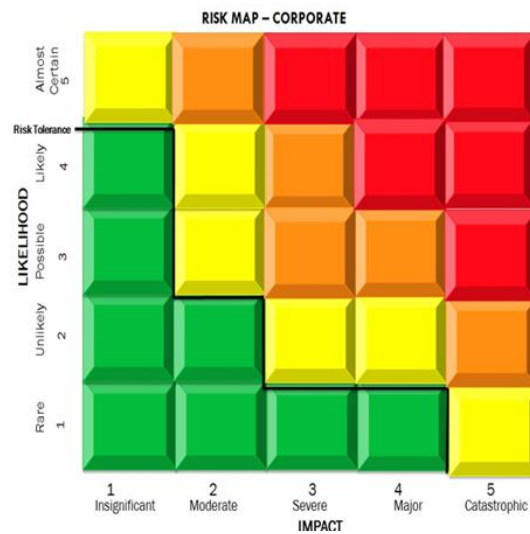| Indeks	Impact	Time Addition (%)
1	Insignificant	Does not affect employment days
2	Moderate	3% from employment days
3	Severe	> 3% s/d 6% from employment days
4	Major	> 6% s/d 10% from employment days
5	Catastrophic	> 10% from employment days

Figure 1. Risk Matrix Map

F. Risk Matrix Index

The risk matrix often called the level of risk, is a matrix used to determine the level of risk regarding the probability value index (likelihood) and the impact index so that the severity of risk can be identified. Based on the standard provisions of PT. Yasa Wahana Tirta Samudera, the risk matrix map is shown in Figure 1.

III. RESULTS AND DISCUSSION

A. Risk Analysis

In analyzing risk, there are several stages, including the following:

1) Risk Data

Before starting the simulation using the Monte Carlo method, it is necessary to prepare data in the form of risks that affect the course of the project. Through interviews and discussions with the head of the TRANSKO Tawes 11.3 DWT mooring boat development project, it was found that 12 risks affected the project, with details of the risks shown in table 4.

2) Probability Average Value

From the data on the probability value of risk events for work on the questionnaires that have been distributed to shipyards, then the average value of the probability of risk events for each job is calculated by adding up the probability values for each questionnaire and then dividing it by the amount of data.

$$RP_1 = \frac{Total\ Probability\ Value\ of\ Each\ Job}{Total\ Questionnaire\ Data} \qquad (1)$$

Where RP_1 = the average value of the probability of each job. After obtaining the average value of the probability of risk for each job, then we determine the average value of the probability of all jobs for each risk, by adding up the probability values of all the events of each risk and then dividing by the number of jobs affected.

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TABLE 4.
RISK DATA MOORING BOAT PROJECT

Risk Code	Risk Event
R01	Revision work due to inappropriate design
R02	Bad weather conditions during ship construction
R03	Low performance of work tools
R04	There is a revision of the work after the work
R05	Shipyard financial capability
R06	The problem of new types of work (transfer of technology)
R07	Approval from the owner and the classification bureau
R08	Slow response to job instructions
R09	Delay in design work
R10	Work delays due to delays in material supply
R11	Lack of communication between related parties
R12	Lack of manpower

TABLE 5.
PROBABILITY AVERAGE VALUE

No	Jobs	RP1 (%)	RP2 (%)
1	Design	20%	
2	Fabrication	27%	
3	Assembly Bottom Hull	27%	
4	Assembly Top Hull	27%	
5	Erection	27%	
6	Outfitting	27%	
7	Painting	27%	24%
8	Electrical	27%	
9	Interior	27%	
10	Launching	22%	
11	Navigasi	27%	
12	Sea Trial	20%	
13	Class Approval	10%	

$$RP_2 = \frac{Total\ Probability\ Value\ of\ All\ Jobs}{Number\ of\ Jobs} \quad (2)$$

Where RP_2 = the average value of the probability of all jobs. The following is the result of determining the average probability value for each job and all jobs in the highest-risk category. Table 5 shows that the average value of the probability of risk for each job has the highest percentage of 27%, with an average probability value of all jobs of 24%.

3) Impact of Adding Days

In calculating the impact of adding days, we first need to determine the distribution function for adding days. In the Monte Carlo simulation, there are three distribution types: normal, triangular, and beta. The value of the duration of adding days was obtained from a questionnaire distributed to PT employees. Yasa Wahana Tirta Samudera is involved in the mooring boat construction project from 5 divisions, including Production, Safety, Quality Control (QC), Production Planning & Controlling (PPC), and Facilities which are then averaged to obtain one value as data input. After that, we get the time estimation value using the following formula [12]:

$$Te = \frac{1\ Min\ +\ 4\ Most\ +\ 1\ Max}{6} \quad (3)$$

Where Te = estimated risk event for each activity. After we know the Te value of each job at each risk, then we get the total impact of additional days due to risk by adding up the Te value for each job. Table 6 shows the results of Te (time estimation) and the total impact of adding days in the highest-risk category. Table 6 shows that fabrication work has the greatest impact on additional days due to risk compared to other work, namely as many as nine days, with the total impact of adding days on all work at most as much as 74 days.

4) Percentage of Impact of Each Risk

After obtaining the total impact value of the additional days for each risk, we then determine the percentage value of the impact of each risk to make it easier for us to categorize the existing risks. The calculation of the percentage impact value is obtained from:

$$PD = \frac{Total\ Impact}{Total\ Duration\ of\ Jobs} \quad (4)$$

Where PD = percentage impact of each risk. The results of calculating the percentage impact of each risk are in table 7.

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TABLE 6.
CALCULATION OF TOTAL IMPACT

Jobs	Min (day)	Most (day)	Max (day)	Te	Total impact (day)
Design	1	2	3	2	
Fabrication	7	9	12	9	
Assembly Bottom Hull	5	8	10	8	
Assembly Top Hull	5	7	9	7	
Erection	4	6	7	6	
Outfitting	5	7	8	7	
Painting	4	6	7	6	74
Electrical	4	6	8	7	
Interior	4	6	7	6	
Launching	4	5	7	5	
Navigasi	4	6	8	6	
Sea Trial	4	5	7	5	
Class Approval	1	1	2	1	

TABLE 7.
CALCULATION IMPACT PERCENTAGE

Risk Code	Total impact (day)	Impact Percentage (%)
R01	29	9
R02	40	12
R03	40	12
R04	23	7
R05	23	7
R06	47	14
R07	22	6
R08	28	8
R09	32	9
R10	74	22
R11	20	6
R12	47	14

TABLE 8.
CALCULATION RISK INDEX VALUE

Risk Code	Probability Index (%)	Impact Index (%)	Risk Index
R01	13	9	0,0117
R02	18	12	0,0216
R03	22	12	0,0264
R04	11	7	0,0077
R05	18	7	0,0126
R06	13	14	0,0182
R07	12	6	0,0072
R08	19	8	0,0152
R09	12	9	0,0108
R10	24	22	0,0528
R11	19	6	0,0114
R12	23	14	0,0322

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Figure 2. Risk Matrix Map Mooring Boat Project

TABLE 9.
RISK RATING ON MOORING BOAT PROJECT

Risk Rating	Risk Code	Risk Index	Risk Category
1	R10	0,0528	High
2	R12	0,0322	High
3	R03	0,0264	High
4	R02	0,0216	Medium
5	R06	0,0182	Medium
6	R08	0,0152	Low
7	R05	0,0126	Low
8	R01	0,0117	Low
9	R11	0,0114	Low
10	R09	0,0108	Low
11	R04	0,0077	Low
12	R07	0,0072	Low

TABLE 10.
TRIANGULAR DISTRIBUTION IMPACT

Code	Jobs	Min (Day)	Most (Day)	Max (Day)
A01	Design	1	2	3
A02	Fabrication	7	9	12
A03	Assembly Bottom Hull	5	8	10
A04	Assembly Top Hull	5	7	9
A05	Erection	4	6	7
A06	Outfitting	5	7	8
A07	Painting	4	6	7
A08	Electrical	4	6	8
A09	Interior	4	6	7
A10	Launching	4	5	7
A11	Navigasi	4	6	8
A12	Sea Trial	4	5	7
A13	Class Approval	1	1	2

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5) Risk Index Determination

The risk index is a value used to assess the severity of a risk where the greater the risk index value, the more severe the impact caused by the risk. Calculating the value of the risk index can be done using the following formula:

$$IR = IP \ X \ ID \qquad (5)$$

Where IR = risk index, IP = probability index, and ID = impact index. The results of calculating the risk index for the mooring boat construction project can be seen in table 8. From the table above, we can see that the risk with code R10 has the greatest risk index, namely 0.0528. The lowest risk index value is found at risk with code R07, which is 0.0072.

6) Risk Category and Rating

Furthermore, each risk is grouped based on its category in the 5 x 5 risk matrix. The preparation of this risk matrix refers to the previously calculated probability index and impact index, which in the risk matrix map, the values are categorized into five levels. Where the level of the probability index category can be seen in table 2, and the impact index category is in table 3. Then these values are entered into the matrix column according to the value category so that the results of the risk level are obtained in Figure 2.

In Figure 2, there are 12 risks that affect work, with details of 3 risks in the high category (orange zone), two risks in the medium category (yellow zone), and seven risks in the low category (green zone). Based on PT. Yasa Wahana Tirta Samudera that risks in the red, orange, and yellow zones must be mitigated, while risks in the green zone are still at risk tolerance. In other words, they do not require mitigation efforts. If the severity is sorted based on the risk index value, the risk ranking results are obtained, as shown in Table 9. After compiling the risk ranking, three risks have the highest risk index values. The three risks fall into the high category, including lack of work delays due to delays in material supply, lack of labor, and low performance of work tools. While the approval from the owner and the classification bureau is the risk with the lowest index value.

B. Monte Carlo Simulation Evaluation

In the risk evaluation stage with the Monte Carlo method in outline, there are the following steps:

1) Event Probability Distribution

Before carrying out iterations on random variables, where what is meant by random variables in this study is the impact of adding days, it is necessary to determine in advance the type of probability distribution to be simulated. In the Monte Carlo simulation, there are three types of probability distributions, namely the normal distribution, the triangular distribution, and the beta distribution. This study uses the triangular distribution function so that there are three durations of adding days, namely the shortest duration (minimum day), the most likely duration (most likely day), and the slowest duration (maximum day). The duration of the additional days was obtained from a questionnaire distributed to PT employees. Yasa Wahana Tirta Samudera is involved in the mooring boat construction project originating from 5 divisions, including Production, Safety, Quality Control (QC), Production Planning & Controlling (PPC), and Facilities, which are then averaged to obtain one value as data input. The following is the distribution value of the impact of adding days for each job in the highest risk category as a result of a questionnaire with employees of PT. Yasa Wahana Tirta Samudera shown in table 10. Table 10 shows the number of additional days for each job, whether on a minimum day, most likely day, or maximum day.

2) Risk Impacted Builds

After the variables are distributed according to the type of function, we then integrate them into the main project schedule that has been modeled in the Primavera Risk Analysis software. So that the value of the impact of the additional days that have been distributed will affect the main project schedule for the following process of running the software using the iteration principle.

3) Determining the Accuracy Percentage of the Project

In accordance with the principle of the Monte Carlo method, which is to randomly derive uncertain variables from obtaining the appropriate duration of project completion, an iterative technique is used to obtain the duration of the project due to risk. The iteration is carried out repeatedly until the convergence limit with the Convergence Iteration Frequency is 100, and the Convergence Threshold result is $\leq 1\%$. From the calculation of these provisions, the following results are obtained:

$$CT = \frac{(Mean\ 201) - (Mean\ 100)}{Mean\ ke - 100} \ X \ 100\% \qquad (6)$$

$$CT = \frac{166 - 165}{165} \ X \ 100\%$$

$$CT = 0{,}6\%$$

From the CT (Convergence Threshold) calculation above, the result is that the CT value in the 201st iteration is 0.6%, meaning that in the number of iterations, the distribution graph is declared to have converged and does not require any more iterations afterward. Furthermore, 201 iterations of running software were carried out with the help of Primavera Risk Analysis software. The excel formula used in this software to calculate random numbers is:

$$RAND = r\_triangular(min, max, most\ likely) \qquad (7)$$

The formula for calculating random number variations using the Linear Congruential method with the following formula:

$$RAND = \frac{a^2 + b^2 + c^2 - ab - ac - bc}{18} \qquad (8)$$

With information a = minimum day, b = maximum day, c = most likely day. This formula is used to calculate

variations of random numbers in the Primavera Risk Analysis software to then obtain the results of calculating random numbers, as shown in Table 11.

Table 11 shows the random numbers from each iteration, where these random numbers are the impact of adding days to each activity due to risk. From these figures, project completion scenarios are compiled starting from the fastest completion (minimum duration) and the longest completion (maximum duration), along with the duration determined based on the frequency of each scenario so that the project duration scenario obtained from the simulation results are shown in Table 12.

TABLE 11.
RANDOM NUMBERS IN EACH ITERATION

Code	Iteration								
	1	2	3	4	5	.	.	.	201
A01	2	2	2	0	2				2
A02	10	8	10	9	7				9
A03	8	6	8	8	7				8
A04	6	6	7	7	7				7
A05	5	5	6	6	4				6
A06	7	6	7	7	6				6
A07	5	4	6	3	2	.	.	.	6
A08	5	5	7	4	3				6
A09	6	4	5	3	3				6
A10	5	4	5	3	2				4
A11	5	4	7	6	3				5
A12	5	4	5	4	2				5
A13	2	2	1	0	2				1

TABLE 12.
MONTE CARLO SIMULATION PROJECT DURATION

Duration (Day)	Project Decisions (%)
154	5
160	15
161	20
162	25
163	30
164	40
165	45
166	53
167	61
168	65
169	70
171	75
174	80
175	85
178	90
181	95
186	100

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Table 12 shows that after running 201 iterations, the duration of the project decision was completed in 186 days with a project decision percentage of 100%. The graph of the distribution of opportunities for mooring boat development projects can be seen in Figure 3.

Figure 3 shows that the project, which is targeted to run for 167 days, has an on-target chance of success of 61%. In other words, the project may experience delays, where the maximum delay will be completed within 186 days. Let us compare it with the actual duration of projects that experience delays of up to 185 days. We can conclude that if the project is completed one day before the maximum duration, that has been integrated with risk.

C. Project Activity due to Risk

Sensitive activities are activities or work on projects that have a considerable risk influence so that they tend to be critical or prone to delays or delays that affect the schedule of the shipbuilding project. After analysis, table 13 shows the results of project-sensitive activities.
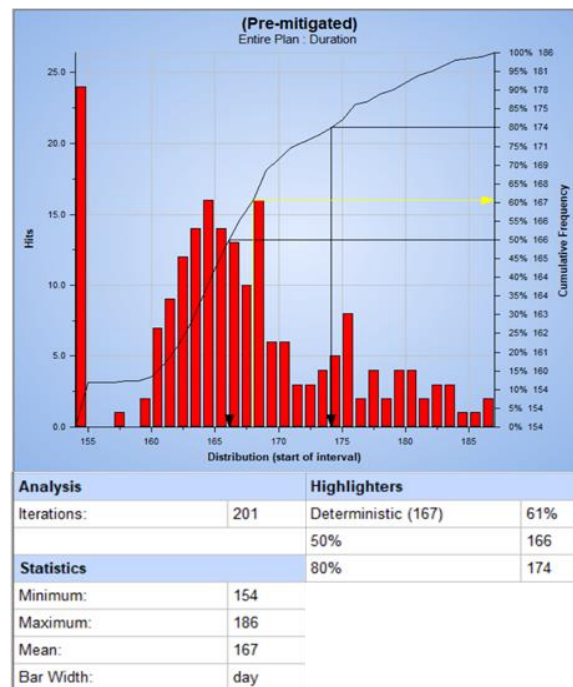

Figure 3. Project Persistence Opportunity Histogram Before Mitigation

TABLE 13.
PROJECT SENSITIVE ACTIVITY DUE TO RISK

No.	Jobs	Risk
1	Electrical	93%
2	Sea trial	92%
3	Interior	92%
4	Navigasi	91%
5	Launching	91%
6	Painting	90%
7	Erection	88%
8	Fabrikasi	88%
9	Assembly Bottom Hull	86%
10	Assembly Top Hull	86%

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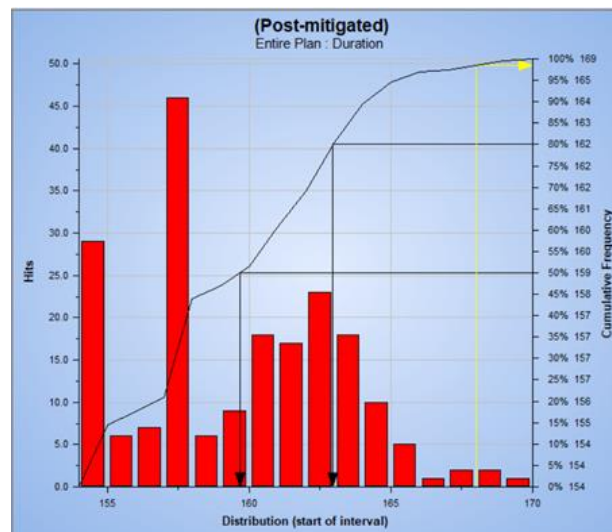*(pISSN: 2541-5972, eISSN: 2548-1479)*

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Figure 4. Histogram of Project Persustence Opportunities After Mitigation

TABLE 14.
RISK MITIGATION

No	Risk Event	Risk Category	Risk Mitigation
1	Work delays due to delays in material supply	High	High Choose vendors who have a good track record and follow up and monitor during the purchase order process
2	Lack of manpower	High	High Plan the needs of workers for each job carefully
3	ow performance of work tools	High	High Provide periodic maintenance and checks on work to
4	Bad weather conditions during ship construction	Medium	Preparing work shelters from the rain
5	The problem of new types of work (transfer of technology)	Medium	Moderate Providing training related to understanding class rules and the latest technology related to the types of projects being built

TABLE 15.
RESULT OF PROJECT PRODUCTIVITY CALCULATION

Description	Duration (days)	Productivity (DWT/man-days)
Target duration	167	0,0169
Simulation duration	186	0,0152
Actual duration	185	0,0153
Duration after mitigation	169	0,0167

The table above shows that electrical work has the highest level of sensitivity to risk compared to other jobs. As for design and class approval work, it has the lowest level of sensitivity compared to other jobs.

D. Risk Mitigation

After the risk assessment process has been completed, in which each risk has been categorized based on its level, the next step that must be taken is risk mitigation or risk response. Based on PT. Yasa Wahana Tirta Samudera that risks in the low category do not require mitigation efforts to obtain risk mitigation results, which can be seen in table 14.

If the mitigation efforts are carried out optimally, and these risks do not occur, then based on the simulation results by eliminating the five risks above, the results for the duration of project completion are obtained, as shown in Figure 4.

From figure 4, it can be concluded that mitigation efforts can be maximized to reduce the five risks. The risks include delays in work due to delays in material supply, lack of manpower, the low performance of work tools, bad weather conditions during ship construction, and problems with new types of work (transfer of technology). Then the project's duration is estimated to be completed in 169 days. Compared to the duration of the simulation results before mitigation is carried out, namely 186 days, the project will be completed 17 days faster than the previous duration.

E. Project Success Measures Validation

The validation of the simulation results uses empirical equations to determine the value of the Average Absolute Percentage Error (MAPE). If MAPE <25%, then the simulation results can be accepted satisfactorily. On the other hand, if MAPE > 25%, then the simulation results are considered unsatisfactory. The following is the result of the MAPE simulation results.

$$MAPE = \frac{Time\ Delay}{Time\ Project}\ X\ 100\% \qquad (8)$$

$$MAPE = \frac{(186 - 167)\ days}{167\ days}\ X\ 100\%$$

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$$MAPE = \frac{19 \ days}{167 \ days} \ x \ 100\%$$

$$MAPE = 11,38\%$$

From the results of the analysis using the software, it is deterministic that the project is likely to be delayed, where the maximum project will be completed on the 186th day. The results obtained are an absolute error of average project duration of 11.38%. In other words, MAPE <25%, so the simulation can be accepted as universally satisfying.

F. Project Productivity Calculation

Productivity can be interpreted as the ability of workers to produce work. Project productivity can be calculated by dividing the total work volume by the project's duration, which has previously been multiplied by the average number of workers per day. The magnitude of the value of project productivity can be known from :

$$Productivity = \frac{Job \ Volume}{Duration \ x \ Number \ of \ Worker} \quad (9)$$

From the data obtained, a working volume of 11.3 DWT with an average number of workers of 4 people/day with a project target of completion in 167 days, but after conducting a simulation by linking the risk, the maximum duration of the project is obtained for 186 days and in implementation. The project was completed 185. It is obtained the results of calculating project productivity can be seen in table 15.

Table 15 shows that the actual duration of the project productivity is 0.0016 DWT/man-days less than the project productivity at the target duration but 0.0001 DWT/man-days greater than the project productivity at the duration of the simulation results. As for the duration of the mitigation planning results, an increase in productivity values was obtained by 0.0015 DWT/man-days from the duration of the simulation results, but it was still 0.0002 DWT/man-days smaller than the target duration.

IV. CONCLUSION

This research shows 12 risks that affect the TRANSKO Tawes 11.3 DWT mooring boat construction project with details of 3 high-category risks, two medium-risk categories, and seven low-category risks. After the Monte Carlo simulation was carried out by linking the existing risks, the deterministic for the success of the project was completed in 167 days by 61%, and the duration of the project was completed in 186 days or 19 days longer than the planning duration. Electrical work, sea trial, interior, and navigation are the most sensitive activities to the project when risks occur, so they need special attention. There are three high-risk categories and two medium-risk categories that require a response. The mitigation efforts that can be made for the three high-risk categories include choosing vendors who have a good track record as well as following up and monitoring during the purchase order process, carefully planning the needs of workers for each job, and providing maintenance and periodic checks on work tools. Whereas for the two moderate risk categories, this can be done by preparing permanent and semi-permanent rain protection buildings and providing training related to understanding class rules and the latest technology related to the type of project being built. If mitigation efforts can be carried out optimally, the duration of project completion, which was previously 186 days, can be completed faster in 169 days. The project productivity for the simulation duration is 0.0152 DWT/man-days, and for the actual duration, it is 0.0153 DWT/man-days, or in other words, the project productivity for the actual duration is 0.0001 DWT/man-days greater than the productivity for the simulation duration. Meanwhile, if mitigation efforts can be carried out optimally, a project productivity value of 0.0167 DWT/man-days will be obtained.

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