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Risk Analysis of Delay in Ship Repair KM Binaiya with Bayesian Network Method

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***Abstract*— Ship repair is a project that is short in process so that time is an important element in its completion parameters. Delay is something that can happen to a job. A job experiencing delays must have a cause that affects the work. Causes of delay in the case of ship repair are poor time management, less skilled human resources, the addition or development of work. But whatever the obstacles, shipyards are still required to complete the ship repair process in a timely manner. Seeing this problem, this research was conducted to provide input in connection with the strategies used by PT XYZ in overcoming the delay factor in the repair of the KM Binaiya ship. In the research to support this thesis, the Bayesian Networks Method is used to analyze the factors that cause delays in ship repairs. After risk identification using the Bayesian networks method. The highest risk is replete activities as minor categorized, where the caused tank cleaning work related to hazardous waste, which must be cleaned to be safe for hot work with a risk score of 0.108. The second cause is installation of scaffolding for replete work facilities at height with a risk score of 0.054.**

Keywords— *Bayesian Networks, Replete , Delay Ship Repair*

I. Introduction

Ship repair is an activity that is carried out regularly and periodically and is carried out when parts of the ship are no longer functioning properly to be operated [6]. Reparation means making repairs to parts of the ship that no longer meet classification standards or are no longer suitable for operation. The parts of the ship that are often repaired are the construction, hull and outfitting parts [2].

In the process of ship repair activities, there is always the potential for things that cause delays in completing the ship repair process, such as delays in implementation, changes in ship repair lists, delays in material presentation, weather influences, and the influence of human resources [10]. Delays like this will certainly cause losses for the owner of the ship to be repaired and the shipyard that will repair the ship. As a result of these delays, the shipyard also cannot work on other ships because the land to be used still has ships that experience these delays. The shipyard will also be penalized if the ship repair process does not run according to the schedule agreed upon by both parties. One of the biggest causes of delays in the ship repair process is the procurement of materials to be used and also the addition of ship repair activities. PT XYZ itself has many examples of repair cases that have changed the schedule from the initial schedule that has been set. The latest exampl in 2020 was the KRI Usman Harun-359. The ship originally had a repair schedule for 14 days, but after there was work development, the repair schedule changed to 35 days. In 2022 there is also the KM AWU ship, this ship from PT PELNI. The initial plan will schedule a 14-day ship repair, and after the development of ship repair work, the repair schedule will be 16 days. The delays in the ship repair process do not only occur at PT XYZ in 2017 at PT DOK Lamongan beach. There was also a delay in the ship repair process. The ship that experienced the delay was the barge BG. RIMAU 3318. The ship repair process was delayed for 6 days.

In cases that often occur at PT XYZ, there are several common factors that cause delays in the ship repair process [7]. These factors are the lack of human resources available at the shipyard, delays in supplying materials, inconsistent with the schedule that has been made (there are many revisions to the work submitted by the ship owner), human resources are less competent in their fields so as to cause work to be delayed and delayed, and the last one at PT XYZ there are work time limits, this work time limit can be found in the case of work on KRI [9]. These problems must be quickly resolved by the shipyard industry as a reparation implementer to get a solution to the delay. In determining or measuring the factors of delay factors in ship reparations can be measured by the Bayesian Network approach. Bayesian Networks (BN) itself is a strong Probability approach that is often used for reasoning, diagnosis, prediction and decision making under uncertainty [3]. The ability of BN to exploit quantitative and qualitative data to generate posterior probabilities is very helpful in the field of risk assessment [8]. The measurement of the risk of the shipbuilding industry with the Bayesian network with a questionnaire approach has been carried out by Lee [13]. The model developed for each network at its node has not been analyzed until the risk value (VaR/Value at Risk) is obtained. The risk analysis is carried out on material components [14].

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TABLE 1.
SHIP DATA OF KM. BINAIYA

Information	Amount
Overall length of the ship (LOA)	99.8 M
Dead Weight Tonnage (DWT)	1400 Ton
Ship Height (D)	4,2 M
Ship Width (B)	18 M
Speed	14,8 Knot

In this research, the case study taken is the KM ship repair project. Binaiya. KM Ship. Biania is one of the national shipping vessels owned by PT Pelni which has a fairly long route. This passenger ship has an overall length (LOA) of 99.8 meters, ship height 4.2 M, ship width (B) 18 meters.

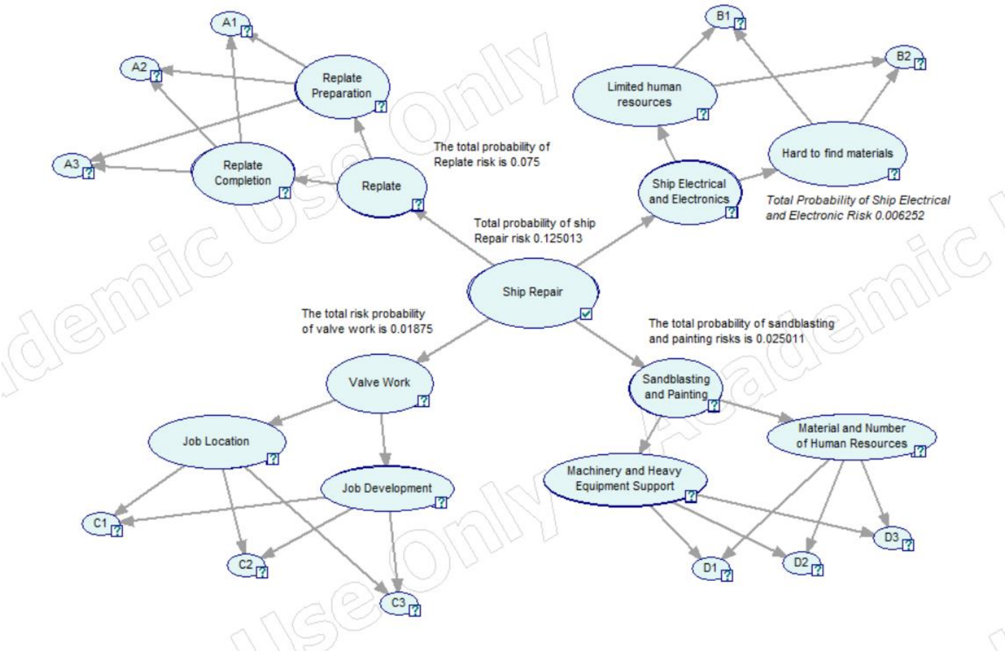

Figure 1. Network model in Genie software

II. METHOD

A. Description

Risk identification is the most important step for risk assessment. Identifying relevant potential risks at the production process level forms a solid foundation for continuing the risk analysis and risk evaluation stages. One of the most important tasks is to define the boundaries within which risks will be assessed, as it is very easy to deviate from production process-level risks to organization/industry-level risks. The best way to define these boundaries is by discussing with the team to assess the risk and scope of the risk assessment. Bayesian Network is robust for reasoning, diagnosis, forecasting, and making decisions when faced with uncertainty, a probabilistic method is frequently utilized. [5]. In the field of risk assessment, Bayesian Networks' capacity to use both quantitative and qualitative data to produce posterior probabilities is particularly helpful. The probability of a child node C given that the parent node is true is known as the conditional probability and is represented by the symbol P (Pt | C) [11]. Bayes' theorem serves as the foundation for the relationship between nodes in Bayesian networks, which can be expressed as follows:

$$P(\mathrm{Pt}|\mathrm{C}) = \frac{p\,(C|Pt)*p\,(Pt)}{P\,(C)} \quad (1)$$

Where, P (Pt | C) is the conditional probability that the parent node (Pt) occurs if the child node (C) occurs. Similarly, P(Pt) and P(C) occur [2].

For risk assessment using BN, each risk event is considered as a node and the complex relationships between these risk events are captured through conditional probabilities [4]. This Bayesian Network method has several advantages over other methods, namely: Relatively easy to implement because it does not use numerical optimization, matrix calculations and others, Efficient in training and use, can use binary or polynomial data [1].

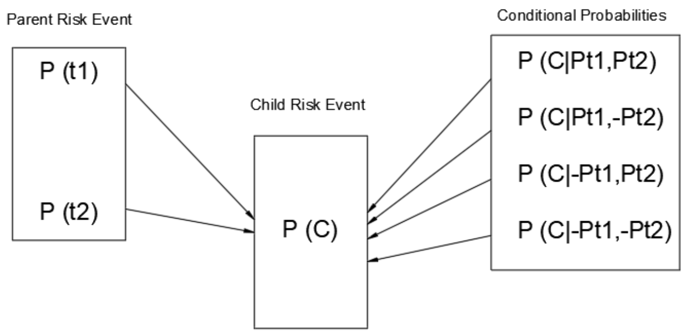

Figure 2. Bayesian Networks

Because it is assumed to be independent, it allows this method to be implemented with a variety of data sets. The resulting accuracy is relatively high. In addition, Bayesian Networks (BN) enable back-propagation which helps trace the source of problems. When the probability of occurrence (Posterior Probability) of a child node is known, the probability of the parent node can be updated using the inverse application of Bayes' theorem. This helps users to identify the root causes of risk events [8].

From each grouping of risk events, risk agents, risk sources both internal and external in several repair activities carried out on the KM Binaiya ship at PT XYZ, including replete repair activities, ship electronics and electrical repair activities, valve repair activities, sandblasting and painting repair activities.

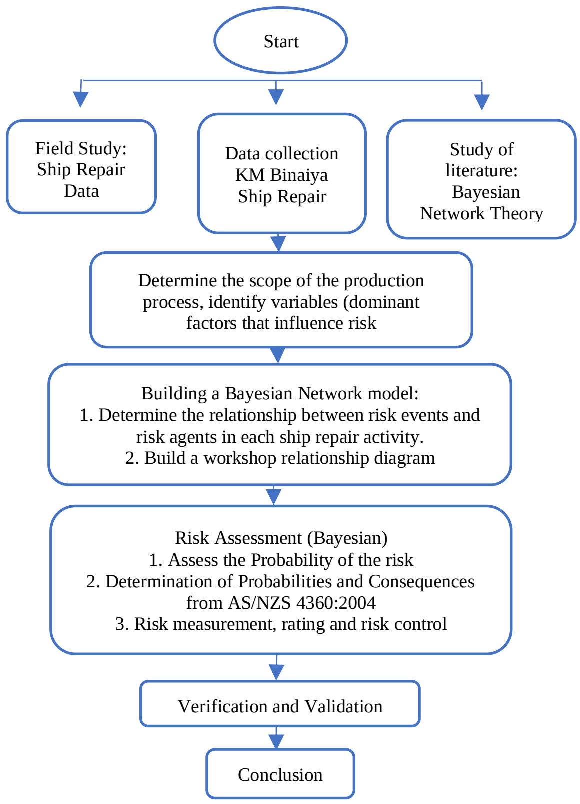

Figure 3. Flow Chart of Research Methodology

This data collection process is used as information or supporting data that will be done in this study. Starting from primary data taken in the field, namely surveys, interviews and filling out questionnaires by the shipyard consisting of the head of the work coordinator and some of his staff. After the data has been obtained, it will be analyzed using the Bayesian Networks Method. Identification of the causes of this delay is carried out based on several causes of ship repair delays obtained from the results of interviews. The results of the questionnaire as the basis for calculating the risks that affect each activity related to the ship repair process.

Research Model

The research model used in this research is a primary data research model, namely survey-based research to research subjects in the data collection process.

Research Design

- Bayesian model on ship repair activities.
- Determine the weighting factor of each ship repair activity. The basis for the preparation of weighting factors in work activities based on "Proportional *progress* Reparations" means that the balance in carrying out production is divided into several stages of work with the term Approach proportional *progress* reparations distributed in each ship repair activity.
- Develop a questionnaire related to the factors of repair delays in each activity.
- Measuring delay factors with Bayesian theory.

Data Acquisition and Data Analysis Techniques

The data acquisition technique used in this research is using field surveys. After the data has been obtained, then the data will be analyzed using the Bayesian Networks Method.

Conclusion

After the analysis is carried out by measuring, ranking risks and controlling the latest risks, conclusions are obtained from the results of risk analysis on ship repair using the *Bayesian Networks* method.

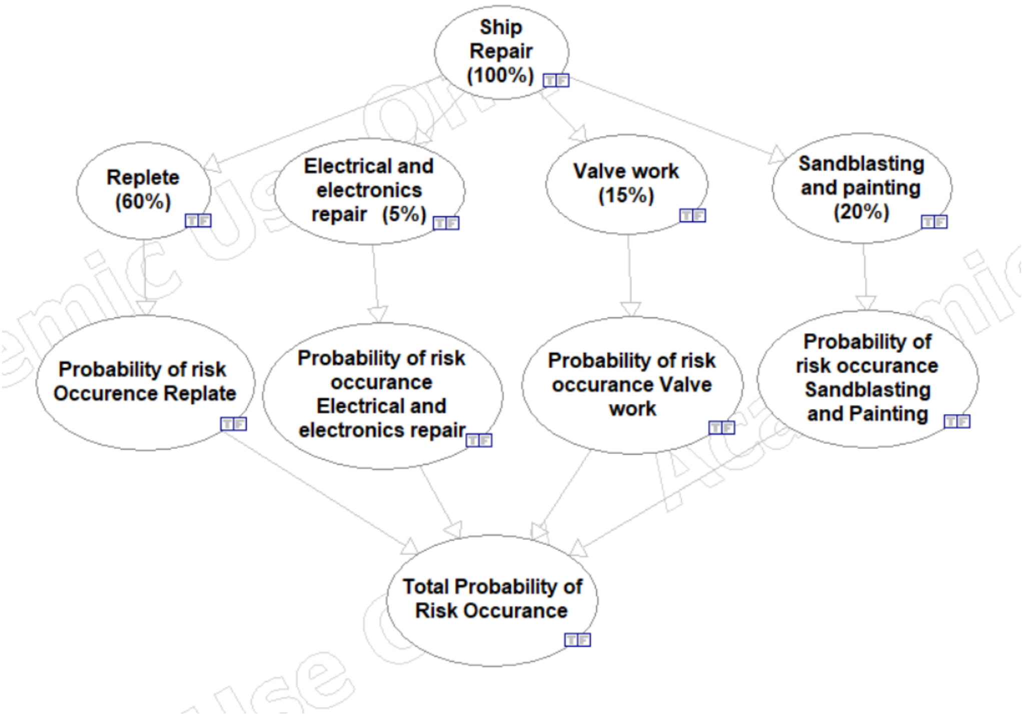

Figure 4. Ship Repair Bayesian Networks

The Bayesian Network model based on the data above will be described in more detail in accordance with the identification of risks in replete work, electrical and electronic repair work, valve work, and painting and sandblasting work. Bayesian network model on KM ship repair. KM Binaiya can be seen in the figure above. This model has synergy and close interrelationships in it. This model cannot work well if it does not support each other between models in the repair work. Ship repair requires full support from the cooperation of these models.

B. Numerals

Assessment of the probability value of risk occurrence is carried out using the probability theorem approach in statistical science [12]. The probability value in question is analyzed using the Bayes theorem formula, where there is a partition relationship between the parts that make up the entire sample space shown in the figure The sample space in question is the KM Binaiya ship repair process, the partitions are shown in Figure 5.

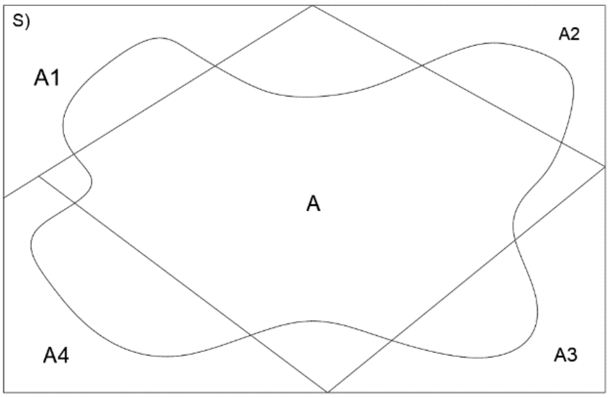

Figure 5. Partition Concept Ship Repair

Where: A is the ship repair process.
A1: Replete work, A2: Shipboard electronics and electrical work, A3: Valve work, A4: Sandblasting and painting work. The division of the sample space above can be formulated in the Bayesian solution as follows: If {A1, A2............, An}, is a partition space of the sample space S and if the partition A1, A2,.....................An, has a probability not equal to zero, then the probability:

p(A) = p(A1). p(A|A1) + p(A2). p(A|A2) + ... + p(An). p(A | An) (1)

or can be written as follows:

$$p(A) = \sum_{j=1}^{n} p(A1).p(A|A1) \quad (2)$$

By using the conditional probability:

$$p(Ak|A) = \frac{p(AnAk)}{p(A)} = \frac{p(Ak).p(A|A1)}{p(A)} \quad (3)$$

So

$$p(Ak|A) = \frac{p(Ak).p(A\backslash Ak)}{p(A1).p(A|A1) + p(A2).p(A|A2) + \cdots .... + p(An).p(A|An)} \quad (4)$$

Or

$$p(Ak|A) = \frac{p(Ak).p(A|Ak)}{P(A1)p(A|A1)} \quad (5)$$

The Bayesian network model developed for formula (5) the ship repair process is as follows:

$$\frac{Probability\ of\ risk\ occurance\ ship\ repair\ network\ process}{\sum \frac{1}{Number\ of\ ship\ repair\ network\ processes} x\ the\ weight\ of\ each\ ship\ repair\ network} \quad (6)$$

The impact of risk is based on three factors, namely scheduling factors, cost factors as a manifestation of costs that must be incurred by shipyards due to schedule delays. And factors that reflect a decrease in performance will determine the accuracy of reparations and the ability of shipyard companies.

III. Results and Discussion

Each activity has the influence of the size of the constraint. Bayesian method using the formulation of the results of the opportunity for each activity is transformed with assumptions in accordance with the situation of the shipyard depending on the risk chance value of each activity this will have an impact on the loss of productivity of each activity and extend the repair process time of each activity.

The impact of constraints on each activity can be seen as the resilience index multiplied by the productivity index of the activity. The value of the repair resilience index is measured by the probability value in each activity. Identification of the causes of this delay is carried out based on several causes. From some of these causes a table is made. The following are the results of identifying the causes of ship repair delays obtained from the interview results in Table 2.

TABLE 2.
INFLUENTIAL RISK FACTORS

Activities	Risks That Matter
Replete	Tank cleaning work related to hazardous waste must be cleaned to make it safe for hot works.
	Installation of scaffolding for replete work facilities at heights.
	Replacement of other components after dismantling the hull plate, e.g., replacement of frames, brackets, collars etc.
Shipboard electronics and electrical	No sub con capable of carrying out Electrical - electro works due to the need for specialized skills
	Sourcing materials is difficult due to scarcity in the market.
Valve work	Carried out cleaning at the site before dismantling the valve.
	Supporting work is not controlled by the completion time and number of human resources.
	Work tools used in the field are limited .
Sandblasting and painting	Limited compressor set.
	Equipment accessories break down quickly.
	High electrical power consumption.

TABLE 3.
RISK DATA SHIP REPAIR

Risk Code	Risk Event
A1	Tank cleaning work related to hazardous waste must be cleaned to make it safe for hot works.
A2	Installation of scaffolding for replete work facilities at height.
A3	Replacement of other components after dismantling the hull plate, e.g., replacement of frames, brackets, collars etc.
B1	No sub con capable of carrying out Electrical - electro works due to the need for specialized skills.
B2	Sourcing materials is difficult due to scarcity in the market.
C1	Carried out cleaning at the site before dismantling the valve.
C2	Supporting work is not controlled by the completion time and number of human resources.
C3	Work tools used in the field are limited.
D1	Limited compressor set.
D2	Equipment accessories break down quickly
D3	High electrical power consumption.

There are four divisions of work in the KM Binaiya ship repair process, namely the replete work process, the electrical and electronic repair work process, the valve work process, and the painting and sandblasting work process. So that the probability of each process is formulated with an approach of ¼ x the weight of each activity process. In the replete work activity there are two activities, so the probability of each sub-process activity is formulated with a 1/2 x weight approach to each sub-process.

There are a number of hazards that have an effect. So that the probabilities of each hazard are 1/4 x the weight of the replete work process x 1/2 x the weight of the replete work sub-process x 1/6 the weight of each hazard (there are 6 hazards). Mathematically from the formula (5), the general formulation of the probability value of the risk occurrence of the replete work network model is as follows:

$$\frac{1}{Number\ of\ main\ network\ Processes}\ x\ the\ weight\ of\ the\ Replating\ work\ process\ x\ \frac{1}{Number\ of\ Replating\ Sub\ Processes}\ x \text{ the weight of each Replete sub-process } x\ \frac{1}{hazard\ load} \quad (7)$$

From this formula (7), an assessment of the probability of delay risk is carried out and finally the probability value is obtained as shown in Table 4. Probability of network model on replete work.

TABEL 4.
PROBABILITY OF REPLATE NETWORK MODEL

Activity	Hazard	Probability
Replete Preparation (Weight Factor 60%)	Tank cleaning work related to hazardous waste must be cleaned to be safe for hot work	0.015
	Scaffolding installation for replete work facilities at height	0.015
	Replacement of other components after the hull plate has been dismantled, for example changing frames, brackets, collars.	0.015
Replete completion (Weight Factor 40%)	Tank cleaning work related to hazardous waste must be cleaned to be safe for hot work	0.01
	Scaffolding installation for replete work facilities at height	0.01
	Replacement of other components after the hull plate has been dismantled, for example changing frames, brackets, collars.	0.01

In the activity of electrical and electronic ship repair work there are 2 activities, so the probability of each sub-process activity is formulated with an approach of 1/2 x the weight of each sub-process. There are several numbers of hazards that affect. So that the probabilities of each hazard are 1/4 x the weight of the electrical and electronic ship repair work process x 1/2 x the weight of the electrical and electronic ship repair work sub-process x 1/4 the weight of each hazard (there are four hazards). Mathematically, the general formulation of the probability value of the risk occurrence of the replete work network model is as follows:

$$\frac{1}{Number\ of\ main\ network\ Processes}\ x\ The\ weight\ of\ the\ ship's\ electrical\ x\ \frac{1}{Number\ of\ ship\ electrical\ and\ electronic\ work\ sub\ processes}\ x\ the\ weight\ of\ each\ sub\ electrical\ and\ electronic\ work\ x\ \frac{1}{hazard\ load} \quad (8)$$

From formula (8), an assessment of the probability of delay risk is carried out and finally a probability value is obtained as shown in Table 5. Probability network model on ship electrical and electronic repair works.

TABEL 5.
NETWORK MODEL PROBABILITY OF SHIP ELECTRICAL AND ELECTRONIC REPAIRS

Activity	Hazard	Probability
Limited human resources in the fields of electricity, electronics, and navigation (Weight Factor 70%)	There is no sub-contractor who is able to carry out electrical work - electro because it requires special expertise	0.002188
	Sourcing materials is difficult because they are scarce in the market	0.002188
Hard to come by repair materials (Weight Factor 30%)	There is no sub-contractor who is able to carry out electrical work - electro because it requires special expertise	0.000938
	Sourcing materials is difficult because they are scarce in the market	0.000938

In the valve repair work activity there are two activities, so the probability of each sub-process activity is formulated with a 1/2 x weight approach respectively. There are several sub-processes that affect the number of hazards. So, the probability of each hazard is 1/4 x the weight of the valve repair work process x 1/2 x the weight of the valve repair work sub-process x 1/6 the weight of each hazard (there are six hazards). Mathematically, the general formulation of the probability value of the risk occurrence of the replete work network model is as follows:

$$\frac{1}{Number\ of\ main\ network\ Processes}\ x\ Valve\ repair\ x\ \frac{1}{Number\ of\ Valve\ Repair\ Sub\ Processes}\ x\ the\ weight\ of\ each\ valve\ x\ \frac{1}{hazard\ load} \quad (9)$$

From formula (9), an assessment of the probability of delay risk is carried out and finally the probability value is obtained as shown in Table 6. Probability of network model on valve repair work.

TABLE 6.
NETWORK MODEL PROBABILITY OF VALVE REPAIR

Activity	Hazard	Probability
Job Location (Weight Factor 40%)	Cleaning is carried out at the location before dismantling the valves	0.0025
	Support work is not controlled by the completion time and number of human resources	0.0025
	The number of available human resources is less	0.0025
There is job development (Weight Factor 60%)	Cleaning is carried out at the location before dismantling the valves	0.00375
	Support work is not controlled by the completion time and number of human resources	0.00375
	The number of available human resources is less	0.00375

In painting and sandblasting work activities there are 2 activities, so the probability of each sub-process of painting and sandblasting activities is formulated with an approach of 1/2 x the weight of each sub-process there are several numbers of hazards that affect. So that the probability of each hazard is 1/4 x the weight of the painting and sandblasting work process x 1/2 x the weight of the painting and sandblasting work sub-process x 1/6 the weight of each hazard (there are six hazards). Mathematically, the general formulation of the probability value of the risk occurrence of the replete work network model is as follows:

$$\frac{1}{Number\ of\ main\ network\ Processes}\ x the\ weight\ of\ the\ painting\ and\ sandblasting\ x\ \frac{1}{Number\ of\ sub-processes\ of\ painting\ and\ sandblasting}\ \text{x}\ the\ weight\ of\ each\ painting\ and\ sandblasting\ process\ x\ \frac{1}{hazard\ load} \quad (10)$$

From formula (10), an assessment of the probability of delay risk is carried out and finally the probability value is obtained as shown in Table 7. Probability of the network model on sandblasting and painting work. This network model is a protection repair and painting work on the ship's body. The completeness of the work in it is the machine and supporting heavy equipment and materials and the number of human resources. The weight value of each sub model is obtained from data taken from PT XYZ.

TABLE 7.
PROBABILITY MODEL OF SANDBLASTING AND PAINTING

Activity	Hazard	Probability
Engines and Supports (Weight Factor 80%)	Limited compressor set.	0.006667
	Accessories equipment quickly damaged	0.006667
	High power consumption	0.006667
Material and Number of Human Resources. (Weight Factor 20%)	Limited compressor set.	0.001667
	Accessories equipment quickly damaged	0.001667
	High power consumption	0.001667

In the replete working process, the electrical and electronic ship repair work process, the valve work process, and the painting and sandblasting work process. The probability results obtained are compared with Table 8, which refers to the criteria for probability and potential consequences used for comparison of standards used to obtain the level of risk consequences for delays in the ship repair process.

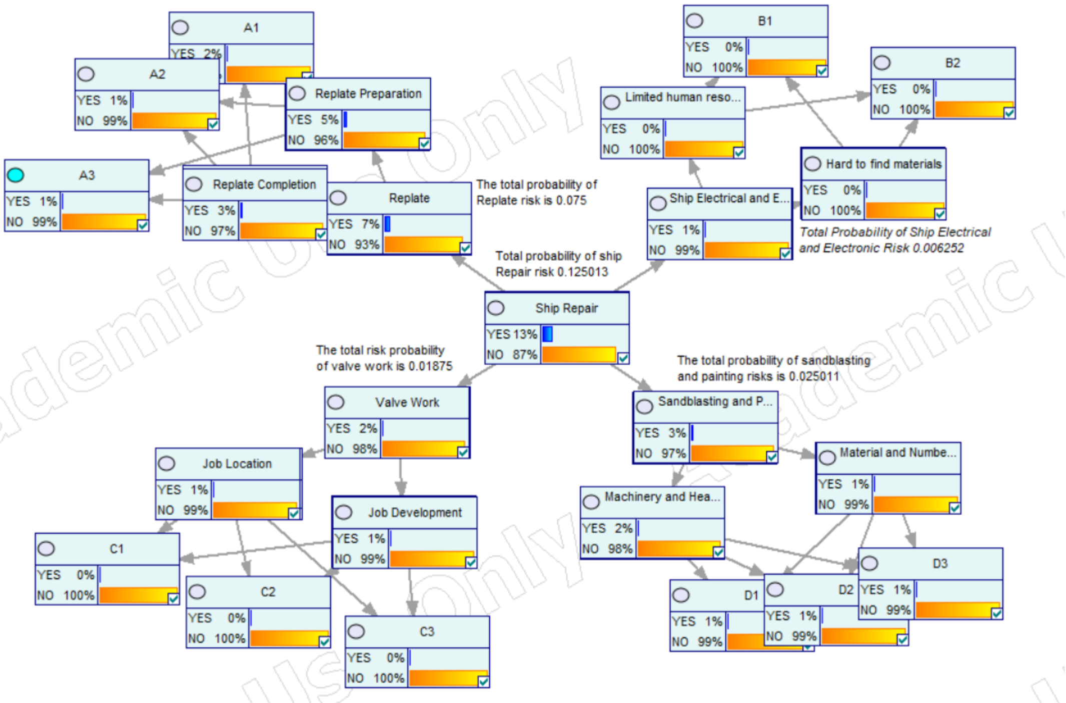

Figure 6. Network model in Genie software

TABLE 8.
DEFIINITION OF PROBABILITY CRITERIA (LIKELIHOOD)

Likelihood	Description of Likelihood
Rare	< 1%
Unlikely	1% - 5%
Possible	5% - 25%
Likely	25% - 60%
Almost Certain	> 60%

In the risk evaluation, there are probability and impact functions, where the probability function is measured using the Bayesian Network. In the total number of opportunities for each workshop, the total opportunity value will be compared with the standard opportunities in the provisions of The Australian New Zealand Risk Management Standard (AS/NZS 4360:2004). In consideration of the ALARP (As Low As Reasonably Practicable) determination, which is the minimum acceptable risk at which the work can be performed (usually expressed in units of 1 to 100 accident /failure events in 1 million years), the Australian and New Zealand Standard: AS/NZA 4360:2004 standard is widely accepted and developed and adopted throughout the industry. The standard chance according to the provisions can be shown in Table 8.

TABLE 9.
CONSEQUENCES CRITERIA

Consequences	Consequences Criteria
Insignificant	Time wasted < 10 days
Minor	Time wasted 10 s/d 20 days
Moderate	Time wasted 20 s/d 50 days
Major	Time wasted 50 s/d 100 days
Catastrophic	Time wasted > 100 days

The impact function is measured using the consequence criteria in Table 9. The-each node has a different chance value rating. The ratings on the nodes have the number of states and interval width associated with the workshop performance rating. Consider the node ranked time wasted as a risk opportunity with five interval widths as shown in Table 9. The value of ship replete work network criteria compared to probability standards (Likelihood) can be compiled in Table 10. The value of ship electrical and electronics work network criteria compared to probability standards (Likelihood) can be compiled in Table 11.

TABLE 10.
THE LIKELIHOOD CRITERIA FOR THE REPLATE NETWORK MODEL

Activity	Hazard	Probability	Likelihood Criteria
Replete preparation	Tank cleaning work related to hazardous waste must be cleaned to be safe for hot work	0.015	Rare
	Scaffolding installation for replete work facilities at height	0.015	Rare
	Replacement of other components after the hull plate has been dismantled, for example changing frames, brackets, collars.	0.015	Rare
Replete completion	Tank cleaning work related to hazardous waste must be cleaned to be safe for hot work	0.01	Rare
	Scaffolding installation for replete work facilities at height	0.01	Rare
	Replacement of other components after the hull plate has been dismantled, for example changing frames, brackets, collars.	0.01	Rare

TABLE 11.
THE LIKELIHOOD CRITERIA FOR THE ELECTRICAL AND ELECTRONICS WORK MODEL

Activity	Hazard	Probability	Likelihood criteria
Limited human resources in the fields of electricity, electronics, and navigation	There is no sub-contractor who is able to carry out electrical work - electro and because it requires special expertise	0.002188	Rare
	Sourcing materials is difficult because they are scarce in the market	0.002188	Rare
Hard to come by repair materials	There is no sub-contractor who is able to carry out electrical work - electro and because it requires special expertise	0.000938	Rare
	Sourcing materials is difficult because they are scarce in the market	0.000938	Rare

The value of ship valve repair criteria compared to probability standards compared to probability standards (Likelihood) can be compiled in Table 12. The value of the sandblasting and painting job network criteria compared to the standard probability (likelihood) can be arranged in the Table 13.

TABLE 12.
THE LIKELIHOOD CRITERIA FOR SHIP VALVE REPAIR WORK NETWORK MODEL

Activity	Hazard	Probability	Likelihood Criteria
Job location	Cleaning is carried out at the location before dismantling the valves	0.0025	Rare
	Support work is not controlled by the completion time and number of human resources	0.0025	Rare
	The number of available human resources is less	0.0025	Rare
There is job development	Cleaning is carried out at the location before dismantling the valves	0.00375	Rare
	Support work is not controlled by the completion time and number of human resources	0.00375	Rare
	The number of available human resources is less	0.00375	Rare

TABLE 13.
CRITERIA FOR LIKELIHOOD NETWORK MODEL OF SANDBLASTING AND PAINTING

Activity	Hazard	Probability	Likelihood criteria
Engines and supports	Limited compressor set.	0.006667	Rare
	Accessories equipment quickly damaged	0.006667	Rare
	High power consumption	0.006667	Rare
Material and number of human resources	Limited compressor set.	0.001667	Rare
	Accessories equipment quickly damaged	0.001667	Rare
	High power consumption	0.001667	Rare

The results of the delay of each activity in ship repair can be shown in table 14, which is a summary of the delay in work realization time against the planning time. This is after entering the inhibitor variable or inhibiting variable from the Bayesian method risk opportunity. The level of delay in the Production time of each workshop between Realization and Planning simulation results can be shown in Table 14.

TABLE 14.
CONSEQUENCES CRITERIA

No	Process	Probability	Consequences (Days)	Consequences Criteria
1	Replete Job			
	Replete Preparation	0.045	5	Insignificant
	Replete Completion	0.03	5	Insignificant
	Total	0.075	10	Minor
2	ship's Electrical and Electronics Work			
	Limited human resources in the fields of electricity, electronics, and navigation	0.004376	5	Insignificant
	Hard to come by repair materials	0.001876	3	Insignificant
	Total	0.006252	8	Insignificant
3	Ship Valve Repair Work			
	Job Location	0.0075	5	Insignificant
	There is job development	0.01125	3	Insignificant
	Total	0.01875	8	Insignificant
4	Sandblasting and Painting Work			
	Engines and Supports	0.02001	5	Insignificant
	Material and Number of Human Resources	0.005001	5	Insignificant
	Total	0.025011	10	Minor

From the results of the risk analysis of the ship repair process carried out on several ship repair process jobs, namely the replete work process, the ship's electronics and electrical work process has the results of the probability level in the Replete work, the highest potential delay is in the tank cleaning work related to hazardous waste that must be cleaned to be safe for hot work reaching a probability of delay of 0.015. This happens because the cleaning process that takes a long time causes the risk level of delay to be high. Then based on the probability level on the ship's electronics and electrical work, the highest potential delay is due to the absence of a sub con capable of carrying out electrical work – electro, because it requires special expertise. This is because Sub con workers or daily freelancers do not understand work that must have special abilities, therefore it has the highest probability level of risk in the repair work of ship electronics and electricity.

Furthermore, based on the level of probability in the valve work, the highest potential delay is in the work of waiting for cleaning to be carried out at the location before dismantling the valve reaching a probability level of 0.00375. This is the highest level of risk because you have to wait for the work to be completed before you can carry out the next work. Finally based on the level of probability in sandblasting and painting work, the highest potential delay is in the lack of work tools reaching a probability of delay of 0.006667. This is due to the lack of a compressor set which causes the speed of work to decrease. Based on the level of probability analyzed in this study, ship's electrical & electronics work and ship valve repair work activities fall into the Insignificant risk category. The replete job and sandblasting & painting work activities fall into the minor risk category.

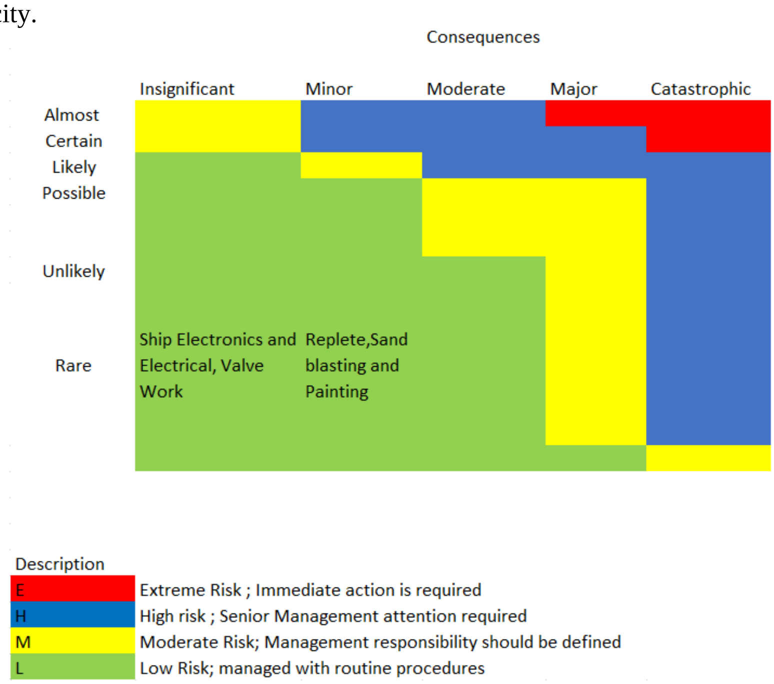

Figure 7. Risk Mapping of Ship Reparation

Based on the risk mapping in the figure. In some of the activities that make up the ship repair process have their respective risks and the risk impact of delays caused by factors that cause delays in each activity. Based on risk analysis mapping on each ship repair activity includes:

- Replete activities categorized as low risk.
- Electronics and Electrical Ship activities fall into the low risk category.
- Valve work falls into low risk.
- Sandblasting painting work falls into low risk.

Based on the risk mapping in each activity, it will affect the strategy carried out in overcoming delays in the ship repair process in each activity.

IV. CONCLUSION

The results of the analysis of risk identification research causing delays in KM Binaiya ship repair using the *Bayesian Networks* method are obtained as follows. Risk analysis using the Bayesian networks method found that ship repair has 4 risks with the highest risk in the replete process. The results of the risk score analysis of KM Binaiya ship repair delays using Bayesian Networks:

- The highest level of risk in the replete work process is tank cleaning work related to hazardous waste must be cleaned to make it safe for hot work with a risk score of 0.075.
- The level of risk in electrical and electronic ship repair work is that there is no sub con capable of carrying out electrical work - electro because it requires special expertise with a risk score of 0.006252.
- The level of risk in the Valve Repair work is that the supporting work is not controlled by the completion time and the number of human resources with a risk score of 0.01875.
- The level of risk in sandblasting and painting work is limited compressor set with a risk score of 0.025011.

Risk mitigation in the process that has the most influence on ship repair is speeding up barrier work with 24-hour overtime and additional human resources. The addition of scaffolding pipe material and human resources.

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