Annals of R.S.C.B., ISSN:1583-6258, Vol. 25, Issue 2, 2021, Pages. 3341 - 3356
Received 20 January 2021; Accepted 08 February 2021.

# Analysis the Risk of the Ship Accident in Indonesia with Bayesian Network Model Approach

**Sereati Hasugian[1*], Maulidiah Rahmawati[1], A.A. Istri Sri Wahyuni[1], Iie Suwondo[1], Imam Sutrisno[2]**
[1]Politeknik Pelayaran Surabaya, Surabaya, Indonesia
[2]Politeknik PerkapalanNegeri Surabaya, Surabaya, Indonesia
Corresponding E-mail: sereati.hasugian@poltekpel-sby.ac.id

**Abstract.**The fluctuation of ship accidents by type of accident like aground, fire, collision, sinking, capsized and other cases indicate that efforts to reduce vessel accidents towards zero accident has not been reached. It was realized that the shipping industry is a potential that has a high risk level. Ship accident scene is complex and requires a multidisciplinary several approaches. This research was conducted with the aim of identifying and measuring patterns of relationships ship accident causal factors using Bayesian Network and make recommendation the efforts made to minimize the chances of a ship accident or structure based prediction pattern of Bayesian Network. The approach taken in this research through quantitative descriptive. Data collected through the survey respondents who had long been in the field of shipping as the primary data and the investigation report NTSC as secondary data. Based on Bayesian models Network found that the accident ship directly affected by natural factors and human factors. While technical factors, safety culture, safety and regulatory perception is directly related to the human factor. Technical factors, safety culture, the perception of safety and regulation did not give a significant influence, but when maximized the chances of a boat accident at 46.42%. Efforts are underway to decrease opportunity ship accidents is on these factors is done through continuous improvement committed both at the organizational level as well as personal.

**Keywords:** ship accident, risk, bayesian network

## 1.Introduction

***Background.***

Safety of shipping is one of the strategic issues are always a concern every time. Ships are modes of transport which plays a strategic role in the economy of a nation. However, based on the data of the NTSC since 2007 up to April 2019 showed that the ship had an accident in the form aground, fire, collision, sinking, capsized and other accidents that occur both in the territorial waters, rivers, the sea, the port can be divided into area of the pier, jetty fuel terminal, and other areas. The ship accidents can be caused by several factors, human factors (human error) and technical factors. The number of accidents that fluctuates vessel showed that the decline in accidents towards zero-accident has not been achieved.

Ship accident scene is seen as a complex problem involving multiple factors, including human factors, technical, natural or other factors that cannot be identified. Accidents ship as part of the safety of navigation is a system that involves various aspects, ranging from regulatory, organizational, psychological and technical and other aspects. Recognizing the complexity of the accident as part of the shipping safety system then the approach taken in identifying the risk factors of ship accidents can be one of them through modelling. Achievement of zero-accident which has always been the goal of salvation can be created with the support of a safety management model to minimize the risk of accidents in passenger / person, the environment and goods.

Annals of R.S.C.B., ISSN:1583-6258, Vol. 25, Issue 2, 2021, Pages. 3341 - 3356
Received 20 January 2021; Accepted 08 February 2021.

Variable modelling as a representation of the factors can be simulated to identify the extent of the influence a factor against shipwrecks. One variable modelling is done through Bayesian Network approach aimed at finding and representing the relationship between variables as causal factors influence the occurrence of shipwrecks. The use of this approach because of factors that influence the boat accident had a causal relationship that need to be identified pattern or structure, so that predictable preventive or mitigation measures to address them.

*1.1.Formulation of the problem*

Based on this background, the formulation of research problems, among others:

What is the structure / pattern of the relationship between cause of the accident the ship using Bayesian Network?

How to influence the causal factors of the accident scene ship opportunities based Bayesian Network models?

How to efforts made to reduce the risk of ship accidents based on the structure / pattern probability predictions generated by Bayesian Network?

*1.2.Research purposes*

Based on the formulation of the problem, the research objectives are:

Identify structure / pattern of the relationship between cause of the accident the ship using Bayesian Network

Develop recommendations related to the efforts made to reduce the risk of ship accidents based on the structure / pattern probability predictions generated by Bayesian Network

*1.3.Benefits of Research*

This research is expected to provide benefits such as:

For theoretical benefits, this research may contribute insight and knowledge pertaining to risk and efforts to avoid a ship accident by the crew and parties related to the identification of factors and patterns of relationships probabilities factors causing shipwrecks.

For practical benefits, this study is expected to provide recommendations to all parties / sectors in the field of shipping on the efforts made to improve the safety of cruise ships in Indonesia.

## 2.Literature

*2.1.Risk Analysis in the Maritime Safety*

The cruise industry is known as a high-risk level which can have catastrophic consequences that the chances of having an impact on society (Oltedal and Lützhöft, 2018), Recognizing the magnitude of the impact and consequences of the cruise is related to safety. On the basis of the consideration in which safety is a system, the safety can be implemented through a management or management. According to Pillay (2015), Safety management experience three developmental era, where every era has a different focus. The first era of safety management focused on technology and human, to the era of two focuses on the technical and socio-culture and era into three focused on endurance. in view Pillay (2015) various studies related to the safety management of multidisciplinary and has a wide scope must be integrated within a theoretical framework. Based on identification Pillay (2015), Found that exploration is needed related to the usefulness of understanding of safety management within a specific industry, the type of hazard or risk, or the progress of cross-regional development in developed and developing countries, which are also useful in education and training for professional actors in the future.

Safety has implications related to understanding the role of the actor / actors to the concept, possibilities and consequences of events / events that can threaten a system, which in turn

required a decision to perform an oversight or control to deal (Haapasaari, Helle, Lehikoinen, Lappalainen, &Kuikka, 2015), Safety is generally defined as free from unacceptable impacts and serious or can be declared as free from unacceptable risk or potential outcomes (Oltedal&Lützhöft, 2018),

Shipwreck is a complex issue, so some studies suggest shipping safety-related concern involving various aspects. Faturachman& Mustafa (2012) states that the causes of the accident the ship that is the human factor, technical and nature. The human factor is considered as a factor that has the greatest contribution in a boating accident that caused by a lack of vigilance, the ability of the crew to master and overcome the various conditions that may occur in the operation of the vessel (Faturachman& Mustafa, 2012), Technical factors are usually related to the accuracy of ship design, ship maintenance which in turn related to the presence of damage in some parts of the ship, while natural factors caused by bad weather, storms, high waves, strong currents and fog that have the potential to lack of visibility (Faturachman&Mustafa, 2012), Some studies show a lack of focus or attention to the safety of shipping to different aspects, which were related to the regulation or policy, which on a global scale, the provisions related to safety of navigation is regulated by the International Maritime Organization (IMO), which is adapted to regional conditions of each country (Haapasaari et al., 2015), The focus on shipping safety cannot be separated from the safety culture(Arslan, Kurt, Turan, and De Wolff, 2016; Nævestad, Phillips, Størkersen, Laiou, and Yannis, 2019), Actor covering regulator / authority (Almklov&Lamvik, 2018), Related psychological perception of safety (Bergheim, Nielsen, Mearns, and Eid, 2015), Arslan, Kurt, Turan, and De Wolff (2016) propose a strategic step improvement and action plans yan include the dimension of communication, trust between employers and employees, feedback (feedback), involvement, lack of mutual trust, problem identification, promotion of safety, responsiveness, safety awareness (safety awareness), as well as training and competence. On the side of safety related psychology, Oltedal&Lützhöft (2018) stating that the safety climate can affect risk perception and safety behaviors associated with while doing work. Therefore, consideration of the safety climate is very important in the work environment on the ship, where there is the challenge of working to realize a significant(Oltedal&Lützhöft, 2018), In addition, the intensity of maritime traffic certain areas could have serious negative consequences in the form of a ship accident that is potentially the loss of life, damage to the environment(Mullai&Paulsson, 2011; Haapasaari et al., 2015; Zhang, Teixeira, Guedes Soares, Yan, and Liu, 2016), The property / wealth and activities (Mullai&Paulsson, 2011), Therefore Haapasaari et al., (2015) stated the necessary action to implement the preventive and mitigation measures in tackling the dangerous consequences. Realizing that the maritime industry has experienced and bears witness to the occurrence of several marine transportation accidents in the world, it raises awareness of experts and policy makers about the importance of risk assessment and safety in maritime transport and port operations(Cho, Lee, & Moon, 2018), This is also consistent with the understanding of the concept of formal and informal safety is necessary regarding the identification, assessment and risk evaluation(Haapasaari et al., 2015), Assessment of the risk of the safety system is ultimately measured by the free of injuries, accidents, security breaches or incidents that cause potential harm(Oltedal&Lützhöft, 2018), Therefore, the risk is seen as an important issue in the maritime industry, due to the public's attention due to some accidents are catastrophic(Cho et al., 2018), However, according to Cho et al. (2018) There are several obstacles in maritime risk management, including related hardware and software, such as safety facilities, public traffic system, operations management and languages.

According to Zhang, Teixeira, Guedes Soares, Yan, and Liu (2016) and Zhang (2018), accidents (accident) or incident at sea is still going on and cannot be avoided altogether, although there have been several safety measures, so that the risk assessment (risk

assessment) is seen as one of the effective measures to identify, mitigate and manage the risk of maritime transport. In line with this, risk management aims to overcome the negative effects of risk through the identification, analysis and assessment (Cho et al., 2018), Through the Resource-Based View, (Cho et al., 2018) can identify that infrastructure as tangible resources and operational efficiency as intangible resources, can reduce the risk of maritime traffic and increase the volume of the vessel.

*2.2.Bayesian Modeling Risk Analysis Network on Boat Accident*

Modelling is intended as a representation or description of the characteristics of a focus or issue. Problems boat accident, some time getting attention from experts / specialists in several studies, particularly relating to the identification of the causes of the incident. Associated with the incidence of ship accidents, risk analysis becomes part of the areas of interest of late is used in various studies of transportation safety, both onshore sector(Huang, Abdel-Aty, and Darwiche, 2010), sea (Trucco, Cagno, Ruggeri, & Grande, 2008; Hanninen, Banda, and Kujala, 2014), Or rail (Liang, Ghazel, &Cazier, 2018), Risk analysis, according to(Weber, Medina-Oliva, Simon, &Iung, 2012), Is a technique of identification, characterization, quantification and evaluation of the occurrence of critical events. There is a method in which through quantitative risk assessment, it can be built a chance that describes the probability of a result consequently (Haimes, 2015) of an incident or event. Although the risk assessment can be done through a qualitative approach, but this approach can only identify factors that potentially without being able to show the amount of the contribution from the factors, so it can be practical design in an effort to improve safety (Liang, Ghazel, Cazier, and El-Koursi, 2017), In line with this, the risk is generally in the form of quantification through value formula hope / expectation mathematical (Haimes, 2015), However, the mathematical equation cannot indicate the consequences of a consequence of extreme events, necessitating additional measures in the form of a conditional expected value of risk (Haimes, 2015),

One model of risk analysis using conditional value that is Bayesian Network. Bayesian Network declared in graphs causal models that can describe the distribution of chance (probability distribution) of several dependent variables to the values of other variables(Tony, 2019), Bayesian Network consists of two main parts: Directional acyclic graph (Directed Acyclic Graph) in the form of a set of random variables declared in a knot (node) and a set of conditional probability distribution (conditional probability distribution) in eraser nodes (node) (Horný, 2014), The distribution of conditional probability (conditional probability distribution) is Through Bayesian Network, identified the causal relationship (causal) is effective, so we get the degree of contribution of each factor, which can then be identified factors that are most at risk(Liang et al., 2018), Bayesian Network is a representation of the distribution of the combined odds (joint probability distribution) of a set of random variables that have the possibility of a causal relationship reciprocal (Horný, 2014), A random variable is declared as vertices (nodes) and relations in the form of inter-node network, with distribution of conditional probability (conditional probability distribution) on each vertex (Horný, 2014), Drafting tables conditional probability (conditional probability tables) for each node (node) is a step in describing the quantification of relations on the nodes that are connected (connected nodes) as a representation of discrete random variables, where the acyclic graph trending (Directed Acyclic Graph) is basically a qualitative picture of Bayesian Network(Liang et al., 2018), Bayesian network is used with the primary purpose to construct a model of the distribution of conditional probability (conditional probability distribution) as the posterior of the variable cause (cause) that has not been observed by the observation of evidence / incident (evidence) hereinafter (Horný, 2014),

In a study conducted Afenyo, Khan, Veitch, & Yang, (2017), Bayesian Network is used for application to scenarios involving a collision occurring between ships and icebergs in the

Arctic in the north polar sea. The study aims to identifying the most significant causative factor in potential accident scenarios, so the results are expected to be the development of measures to prevent and control the shipping accident (Afenyo et al., 2017), Similarly, in a study conducted Akhtar &Utne (2014), Bayesian Network is used in modelling the risk of maritime accidents. In line with this, studies conducted Baksh, Abbassi, Garaniya, and Khan (2018) showed that the use of Bayesian Network as a model to investigate the possible risk of marine accidents involving multiple, sink and ran aground in the waters of the Arctic in the north kurub. In his study Baksh et al. (2018) Operational and environmental factors into account in the model, then found that the risk estimation, early warning (early warning) as a precautionary measure (preventive) and handling (mitigation) to improve the overall safety related to the operation in the cruise.

Bayesian Network formed based on combined data from empirical knowledge and statistics (Liang et al., 2018; Liang et al., 2017), Historical data (Wang and Yang, 2018) and expert assessment (Hanninen et al., 2014; Afenyo et al., 2017; Baksh et al., 2018; G. Zhang, Thai, Yuen Loh, & Zhou, 2018), Based on the use of such data, via Bayesian Network, historical data and expert assessment function in the predictive value of a variable that has not been observed, forecasting (forecasting) changes in actions or decisions or policies of the factors that can be controlled / controlled as well as maximizing the utility and impact evaluations of policies and interventions in the past(Tony, 2019),

To obtain the probability of each variable in the Bayesian Network is carried out in several stages. Horný (2014) stated Bayesian Network constructed based on the Bayes theorem, a theory of chance / probability, with the following formula:

$$P\ [cause|evidence] = \mathrm{P[evidence|cause]}.\frac{P[cause]}{P[evidence]} \quad (1)$$

According to Liang et al. (2018), When expressed in notation, assuming there is a set of mutually exclusive events B1, B2, ... Bn and the event A, such that P (A) as a representation chance / probability conditional A, the equation (1) can be formed into:

$$P\ (B_i|A) = \frac{P(B_i)P(A|B_i)}{\sum_{j=1}^{n} P(B_j)P(A|B_j)} \quad (2)$$

From equation (2), can then be converted into

$$P\ (B_i|A) = \frac{P(B_i)P(A|B_i)}{P(A)} \quad (3)$$

P (Bi)in this case the parameters of the opportunities which are viewed as the probability of early (prior probability), while P (Bi | A) is the posterior probability (posterior probability). Because of the complexity of the calculations using several factors / variables, so in this study will be simulated chances of shipwreck with the help of software MSBNx (Microsoft Bayesian Network Editor).

## 3.Research Methods

*3.0.Types of research*

The approach that will be implemented for this study is quantitative descriptive. Interest descriptive approach that is delivering or descriptions of phenomena, events or occurrences, which in this case is a shipwreck in Indonesia based on the NTSC investigation. To support the objectivity of the research results conducted a quantitative approach through numerical

data or numbers used as calculation and analysis. Analysis of Bayesian Network is used as a quantitative approach with a view to obtain an inference value of the probability of an event / incident to know the level of risk based on events / occurrences another or earlier.

3.1.*Data collection technique*

Data required in the research is the primary data and secondary data. The primary data obtained through interviews, which will be made to the relevant experts or specialists ship accident scene, while secondary data collected through the study of the accident investigation report documents the ship since 2007 to April 2019 of the National Transportation Safety Committee (NTSC). According to statistics of the National Transportation Safety Committee (NTSC) from 2007 until April 2019 occurred 117 accidents involving 139 vessels ship.

*3.2.Data analysis technique*

The analysis used in studies using Bayesian Network. Bayesian Network is used in several stages, where the goal is to get the posterior conditional probability distribution of the variables suspected to be the cause of shipwrecks.
Stage of data analysis, as follows:

3.2.1.*Identification of variables as a factor (cause).*

Identification of variables is done through consideration of the factors causing the boat accident in accordance with the data of the NTSC seconder form of investigative reports since 2007 to April 2019 as well as primary data in the form of expert opinion / expert (expert judgment). Factors causing considered to be formed in the model Bayesian Network among others include safety systems, technical and human nature, which can further be subdivided into factors more specific.

3.2.2.*Preparation of the structure of the relationship (network) between variables.*

The structure of the relationship (network) is formed based on the assumption of a causal relationship or causation between vertices (nodes) as a representation of variables. At this stage identified the causality between the causes (cause) and factor effect (consequence) which is illustrated by a diagram.

3.2.3.*The calculation of odds / probabilities of variables making up the structure of relationships*.

Chance / probability variables in the structure of Bayesian Network model relationships starting from the determination of prior probability value as a parameter. Prior probability obtained from the historical data in the form of a recapitulation of events along with the factors based on data from the NTSC ship accident investigation report as well as of the assessment of experts / specialists. The next thing to do is to give conditional probability value for each node (node) with the intent describes the quantification of the relationship at nodes connected (connected nodes). The conditional probability of an occurrence of each variable was obtained on condition if there are other events that preceded it.

3.2.4.*Risk factor assessment model based on Bayesian Network*.

Assessment of risk factors in the waters of Indonesia boat accident investigation based on the NTSC identified according to contributing risk factor to the accident scene ship. Such identification is further composed of a priority as recommendations related to preventive measures (preventive) and handling (mitigates) in the event of shipwrecks.

Annals of R.S.C.B., ISSN:1583-6258, Vol. 25, Issue 2, 2021, Pages. 3341 - 3356
Received 20 January 2021; Accepted 08 February 2021.

## 4.Results and Discussion

*4.0.Accident Data Description Ships in Indonesia Based on the Investigation of the NTSC*
Boat accident that occurred in Indonesia in this study obtained from the recapitulation report the investigation has been carried out by the National Committee for Transportation salvation. Observations were made on the ship crash data from January 2007 to April 2019. The data show that the accident had occurred some 117 cases involving 139 ships with other ship, the type of accident such as sinks, aground, fire, collision, explode. In the Indonesian Government Regulation No. 9 of 2019 On Boat Accident Investigation stated that accidents such ship sinking, fire, collision and the ship foundered. However, based on the NTSC investigation found that the incidence of vessel accidents not only 4 of these types, but There are also some events or cases that have the potential and create risk of ship accidents. The incident of which exploded, overturned, rolled, scratching, collision, fire, fire, etc. crew fatality. Vessel accidents by type is shown in Table 1 through Pie chart as shown in Figure 1.

**Table 1** The number and percentage Genesis Ship Accidents

| **Accidents** | **Number of events** | **Percentage (%)** |
|---|---|---|
| Fatality Crew | 4 | 2.88% |
| Grounded | 9 | 6:47% |
| Leakage | 2 | 1:44% |
| Explode | 8 | 5.76% |
| List | 1 | 0.72% |
| Pollution | 1 | 0.72% |
| Nudge/Scratch | 5 | 3.60% |
| Sinking | 26 | 18.71% |
| Burned / Fire | 36 | 25.90% |
| Capsized | 7 | 5:04% |
| Rolled | 1 | 0.72% |
| Collision | 39 | 28.06% |
| **Grand Total** | **139** | **100.00%** |

Annals of R.S.C.B., ISSN:1583-6258, Vol. 25, Issue 2, 2021, Pages. 3341 - 3356
Received 20 January 2021; Accepted 08 February 2021.

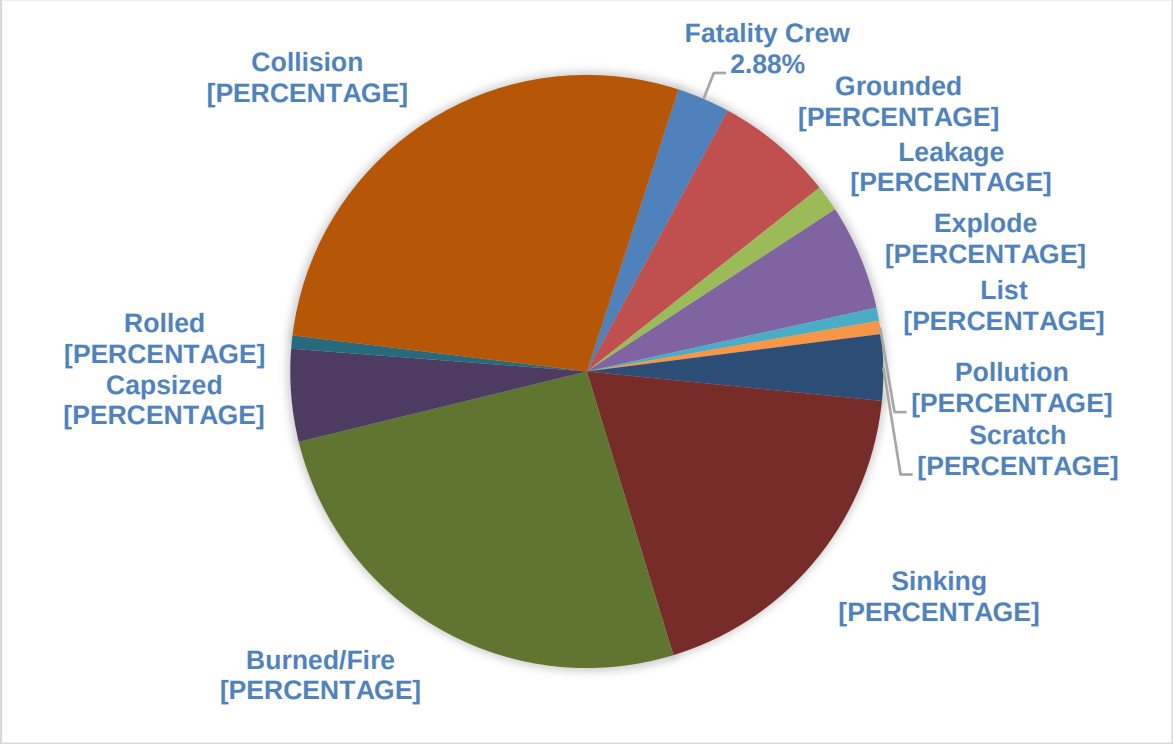


**Figure 1. Pie Chart Type Sailing Accident Investigation Based NTSC Years 2007-2019**

(source: processed data)

The diagram in Figure 1 shows that the largest percentage of accidents happen on the type of accident at a collision at 28.06%, and then burning / fire amounted to 25.90% and 18.71% sink. Based on the results of the investigation of the NTSC, the type of collision accidents caused by the causes and contributing factors associated with Watchkeeping, including mastery of the circumstances in ship navigation, pilotage, and emergency handling. On this kind of accident burns, which are caused by an open fire because of a charge of dangerous goods combustible (flammable), sparks electrical wiring of the engine room (short-circuiting), the accumulation of saturated gas fuel, cigarette butts discarded on other objects, leakage fuel engine room exposed hot surfaces etc.

Based on the type, the ship involved in the accident including barge shipping, bulk carriers, chemical tankers, container ship, ro-ro ferries, gas carriers, general cargo, etc. The large percentage of shipping accidents by type of vessel as shown in Table 2 is illustrated in the pie chart in Figure 1.

**Table 2 Number and Percentage of Accidents by Vessel Type**

| Boat type | Number of events | Percentage (%) |
|---|---|---|
| Asphalt Tanker | 1 | 0.72% |
| Barge | 3 | 2:16% |
| Bulk Carrier | 5 | 3.60% |
| Chemical Tanker | 2 | 1:44% |
| Container Ship | 11 | 7.91% |

Annals of R.S.C.B., ISSN:1583-6258, Vol. 25, Issue 2, 2021, Pages. 3341 - 3356
Received 20 January 2021; Accepted 08 February 2021.

**Table 2 Number and Percentage of Accidents by Vessel Type**

| Boat type | Number of events | Percentage (%) |
|---|---|---|
| Ro-ro ferry Pax | 26 | 18.71% |
| Gas Tanker / Gas Carrier | 2 | 1:44% |
| General Cargo | 33 | 23.74% |
| Fishing boats / fishing | 2 | 1:44% |
| Ship Tourism | 6 | 4:32% |
| Oil Tanker | 16 | 11:51% |
| Passenger | 24 | 17:27% |
| LCT / Landing Craft Tank | 2 | 1:44% |
| Tugboat | 5 | 3.60% |
| Floating Storage Offloading Unit | 1 | 0.72% |
| **amount** | **139** | **100.00%** |

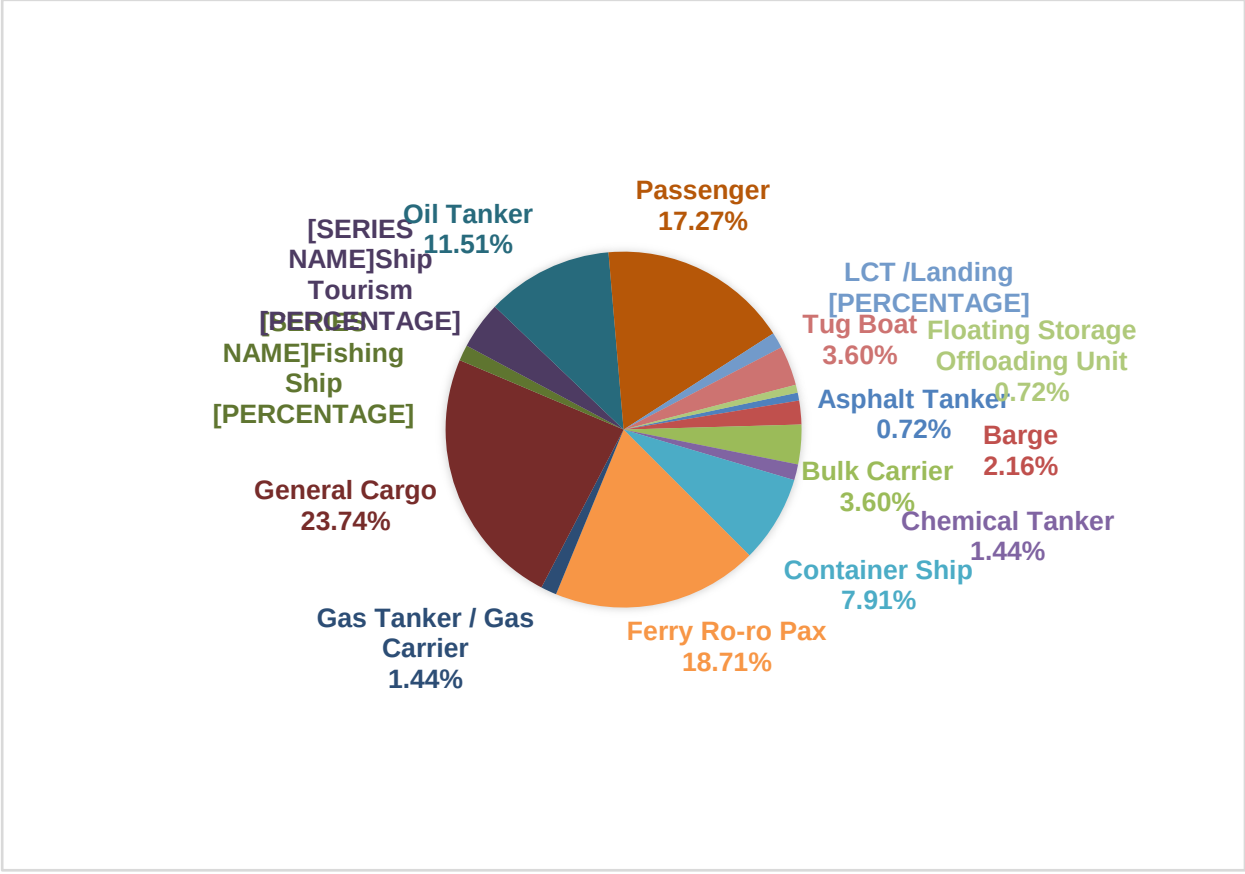


**Figure 2. Pie Chart Accidents Based Sailing Boat Type Year 2007-2019 (source: processed data)**

Annals of R.S.C.B., ISSN:1583-6258, Vol. 25, Issue 2, 2021, Pages. 3341 - 3356
Received 20 January 2021; Accepted 08 February 2021.

Figure 2 shows the percentage of shipping accidents by type of vessel. Based on the diagram in Figure 2 appears that the general cargo ship has the largest percentage is 23.74%, and then Ro-ro ferry by 18.70% and amounted to 17.27% of passenger ships, while ship like Floating Storage Offloading Unit, asphalt tankers, tugboats, and container ranges from 0.72% to 7.91%.

*4.2.Results Identification of Ship Accident Causes*

Identification of the factors causing the boat accident investigation results obtained by the NTSC as well as from the literature. Based on the investigation NTSC and literature, then identified the causes of shipping accidents which include human factors, technical nature, the perception of safety, traffic intensity maritime safety culture and regulations. Bayesian Network structure formed of influential factors. Factors influential in the safety of shipping is determined through questionnaires obtained from 57 respondents where 60% have had a long working experience in the field of shipping, ie more than 10 years. Factors that influence the respondents' assessment results obtained from the beginning of the value 1 as the scale of which claimed that these factors strongly affected to 5 as a very influential factor. The average (mean) of the respondents' assessment of the factors affecting shipping accidents is shown in Table 3.

**Table 3** Descriptive Statistics Ship Accident Factor

| No. | Commentary | Mean | Std. dev | Rank |
|---|---|---|---|---|
| 1 | Regulations / policies | 4:27 | 0.88 | 5 |
| 2 | Safety culture | 4.61 | 0:53 | 2 |
| 3 | Perception of safety (psychological) | 4:42 | 0:57 | 3 |
| 4 | The intensity of maritime traffic | 3.95 | 0.77 | 7 |
| 5 | Weather / Natural | 4:23 | 0.80 | 6 |
| 6 | Technical | 4:39 | 0:53 | 4 |
| 7 | Human | 4.68 | 0:51 | 1 |

Source: Processed Data

*4.3.Bayesian Network Model Structure*

Based on the results of the identification of factors affecting the shipping accident, then prepared a graphical model to determine causality or causal relationship between these factors. Factors in the graph represented by a node that has a direction which denote the relationship between factors. The causal relationship is illustrated through a directional diagram known as Bayesian Network. Bayesian Network is a model which is illustrated by a graph that includes nodes directional implies a relationship between factors. In preparing the Bayesian Network models used in this study are 7 factors that boat accident, human, safety culture, perceptions of technical safety, regulatory / policy, and nature, which is determined because of causes and contributing factors. Factors causing hereinafter be referred to as the independent variable / Predictor expressed in the graph as a parent node and a variable result is declared as dependent variables / responses are expressed as child nodes. Factors causing the independent variables are expressed as a human being, safety culture, perceptions of

Annals of R.S.C.B., ISSN:1583-6258, Vol. 25, Issue 2, 2021, Pages. 3341 - 3356
Received 20 January 2021; Accepted 08 February 2021.

technical safety, regulatory / policy, and nature, whereas a shipwreck as the response variable / non-free. To be able to create a model for Bayesian Network needed a category or state of each variable. Category or state intended as a statement about the chances for an occurrence at a factor. Category or state for Bayesian Network models are shown in Table 4.

**Table 4** Category of State Variables

| No. | Factors / Variable | Category / State |
|---|---|---|
| 1 | Shipwreck | □ yes (in case of shipwreck)<br>□ no |
| 2 | Human | □ yes (if there is a human factor)<br>□ no |
| 3 | Safety culture | □ yes (if there is a safety culture)<br>□ no |
| 4 | Perception of safety | □ yes (if there is a perception of safety)<br>□ no |
| 5 | Technical | □ yes (if there are technical factors)<br>□ no |
| 6 | Regulations / policies | □ No (if no rules / application of the rules)<br>□ no |
| 7 | Natural | □ yes (if there are natural factors)<br>□ no |

Table 4 shows the class / state which is then used to build a model structure Bayesian Network. Preparation of Bayesian model structure is based on a questionnaire distributed to respondents who are assumed to be an expert in the field of shipping. The questionnaire identifies the structure of the relationship between each variable. The results of calculations of descriptive statistics of the respondents of a Likert scale indicates a causal relationship between variables as shown in Figure 3. Causality for building Bayesian Network is done with the help of software MSBNX. From Figure 3, it can be seen causality or causal network each variable, either directly or indirectly.

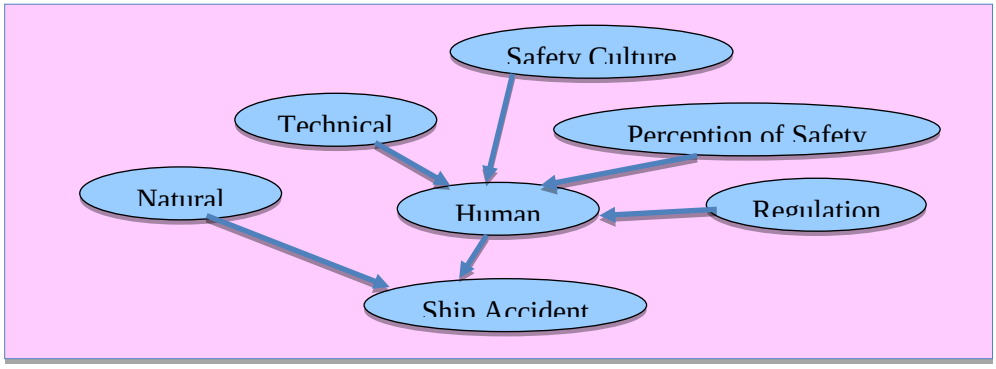


**Figure 3. Causality Diagram Boat Accident**

Annals of R.S.C.B., ISSN:1583-6258, Vol. 25, Issue 2, 2021, Pages. 3341 - 3356
Received 20 January 2021; Accepted 08 February 2021.

Bayesian Network structure is a representation of their relationship, either directly or indirectly, which suggested a causal influence of variables. The graph in Figure 3 shows that ship accidents directly cause by natural and human factors. The human factor is a factor that is influenced by technical factors, safety culture, the perception of safety. These factors are assumed to be the node as a factor that has a direct relationship with humans. Natural and human factors into a parent node that has a variable nature of parole for shipwrecks. It makes that the boat accident directly affected by natural factors and human factors are influenced by technical factors, safety culture, the perception of safety and regulation. After the Bayesian Network structure is formed, it is the determination of the initial opportunity (prior probability) as a parameter. Further arranged Conditional Probability (Conditional Probability) on every node that represents a variable.

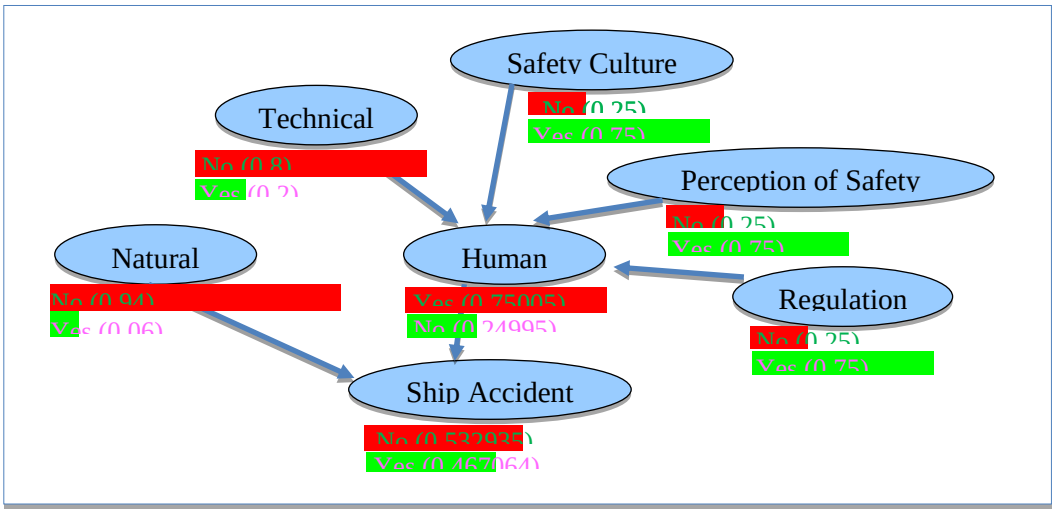


**Figure 4. Bayesian Network Model with the Variable Value Opportunities**

Because of the complexity of the relationships between factors, calculations carried out with the help of software opportunities MSBNX. After the probability values are given at each node, it can be arranged causality diagram showing the probabilities at each node or a factor, as in Figure 4.

Based on Figure 4 of the causality diagram, then the chances of the human factor in a boating accident in the amount of 75.00% which is influenced by the chances of a technical factor of 20%, 75% implementation of safety culture, the perception of the safety of 75% and 75% regulatory nature free. The amount of percentage on each of these factors is a risk that will have an impact on the percentage of their chances of human factors in a shipwreck. Figure 4 also shows that the chances of a shipwreck by 46.70% with effect of 6% of natural factors and human factors amounted to 75.06%. Human factors have been identified under the influence of other factors. Based on the diagram, it will be an opportunity probabilistic inference ship accident based on the value of trust or opportunities of other variables. Inference is a process simulation model evaluation as an opportunity based on the relationship between factors or variables in the model and the evidence obtained. Bayesian Network in this case is used to get the inference to identify the lowest value of the risk or chance accidents vessel conducted in the form of simulation opportunities. Natural factors are assumed to have a chance of 6% on the condition of other factors unknown to the ship accidents with the probability of 46.72%. Assuming chances natural factors (1) and technical factors for (0) then the chances of accidents increased by 93%, as shown in Figure 5.

*NTSC Investigation Results and Risk Mitigation Boat Accident*

Be aware that shipping accidents cannot be avoided altogether, the risk assessment is deemed necessary to identify the potential that may occur. Models Bayesian Network that factors that are assumed to have an influence on the occurrence of a shipwreck that is natural and human factors. Natural factors based on an investigation of the NTSC become a major factor in the incidence of ship that is the waves or high tides, extreme or bad weather and water conditions and currents that cannot be anticipated by the crew. Natural factors are not controllable, so that attempts to resolve it is through human factors, through attitudes emergency response, decision-making and awareness of weather and water conditions. Investigation NTSC indicate that a shipwreck that is influenced by technical factors such as the case for their generators are not functioning properly, causing overheating, pump bilge that may not work so it cannot dispose of water entering the engine room, cable cuts, the exposed wires, breakdown valve diesel fuel, the burst of thermal oil or gas saturation of a fuel leak. From a technical aspect, can be initiated from the vehicle in the form accuracy of ship design that can stand up to extreme weather, care, and maintenance of the vessel to prevent any damage to any part or component of the ship that cannot function properly, also of the navigation system, steering / maneuverings, or navigation of the ship. From the human side, shipwrecks contributions from the elements such as the absence of the waveguide as it moved toward the port, lack of control or supervision of the number of passengers, to overload or exceeding the limit of loading, distribution and unloading of ships already in operation but there is no reference loading through certificate waterline of BKI. In addition to these, matters related to the safety culture and regulations among which the Safety Management System ship is not in operation, there are no rules about loading the goods on the vehicle with a tub enclosed, simulated emergency drills are not carried out properly, the standard operating procedure is not yet clear, their ships sailing without an Approval Letter from the Chief of the Port Authority cruising etc. Based on these elements, the risk of shipwreck of the human factor can be minimized in terms of technical, safety culture, the perception of safety and regulation. Preventive measures (preventive) and handling (mitigative) can be implemented through minimizing risk factors that have been identified as the main cause or causes that contribute to a shipwreck. From the technical side of ship design including accuracy, care, and maintenance of ship components such as generators, bilge pumps, prevention of harmful gas, ship electrical system, navigation, and other technical means. Factor of safety culture is an attitude, beliefs, values, and safety systems that are inherent with organizations, institutions, or companies. Therefore, the safety culture needs to be invested by the agency or company to make such a policy towards the target of zero-accident and continuous improvement. Safety culture is formed from a climate of mutual support between employers and workers for mutual trust through communication, feedback, engagement of both sides, to encourage and emphasize the importance of their respective roles in growing responsiveness and safety awareness through training competence in maintaining the improvements continuously. Unlike the safety culture that are inherent to the organization, the perception of safety is personal and individually attached. Therefore, it is important from an organization or institution to create a climate or safety culture can bring impact on the perception of safety felt by each person or individual. Perception of safety is strongly associated with safety behavior at work, especially the risks, challenges and high demands in industry, shipping. It is expected that the perception of personal safety on every line in an organization can be achieved in a balanced manner. If there are significant differences between the lines, then organizations need to invest the time or expense to improve the perception of safety within the organization. Regulation is also seen to have contributed to the accident scene ship. The absence of regulations that govern whether the application of the regulation, may be a contributing factor on the accident scene ship. The shipping industry has a reference to national and international regulations, particularly regarding the safety of shipping. Any regulations that have been set by the International

Annals of R.S.C.B., ISSN:1583-6258, Vol. 25, Issue 2, 2021, Pages. 3341 - 3356
Received 20 January 2021; Accepted 08 February 2021.

Maritime Organization, naturally became the main reference for the state to adapt and further implementation. The existence of the incidents in which the factors contributing is the regulations need to be a concern, resulting in operational execution have guidelines and directions are clear and precise. Implementation of shipping safety regulations can be effective if there is a commitment and decisiveness relevant parties to enforce and comply with regulations. Ship accident investigation conducted NTSC find indications of the lack of regulations related to the loading of goods, lack of control, evaluation and monitoring to enforce the rules, a lack of understanding of the rules and a lack of anticipation in the application of a rule. In terms of regulation, then that needs to be followed, namely the need to formulate a regulation on the things that has been no source of legal, enforcement, increase understanding of the rules and measures in anticipation of the application of a rule. Observation the lack of control and enforcement, lack of understanding of the rules and a lack of anticipation in the application of a rule. In terms of regulation, then that needs to be followed, namely the need to formulate a regulation on the things that has been no source of legal, enforcement, increase understanding of the rules and measures in anticipation of the application of a rule. Monitoring the lack of control and enforcement, lack of understanding of the rules and a lack of anticipation in the application of a rule. In terms of regulation, then that needs to be followed, namely the need to formulate a regulation on the things that has been no source of legal, enforcement, increase understanding of the rules and measures in anticipation of the application of a rule.

## 5.Conclusion and Suggestion

*5.0.Conclusion*

The conclusions obtained from this study are:

- Based on the structure / pattern of the relationship between cause of the accident the ship using Bayesian Network found that the accident ship directly affected by natural factors and human factors. While technical factors, safety culture, safety and regulatory perception is directly related to the human factor.
- The causative factors are assumed in a shipwreck in the form of technical factors, safety culture, the perception of safety and regulation did not give a significant influence, but if maximized, it can minimize the chances of accidents vessel was increased to 46.42%.
- Efforts are being made to reduce the risk of ship accidents based on the structure / pattern probability predictions generated by Bayesian Network based on factors that influence the consideration that human factors contributed to reducing the chances of accidents on technical factors, safety culture, the perception of Salvation and regulation. Technical factors can be enhanced by an on the means or the hardware, while the factor of safety culture, perceptions of safety can be enhanced by continuously at the level of organization and personnel or individual, and regulation through enforcement, understanding and drafting rules or new regulation required.

*Suggestion*

Advice can be given in this research is the need to identify factors that have not been recognizable to potentially lower chance or risk of ship accidents in further research, such as factor level human resource capacity as well as the actor or actors as safety related shipping authorities. In addition, to be able to identify aspects that need to be done more in further observations on a category or state level are also variables that are more specific on the factors. The data required to identify opportunities accidents need to be propagated from a variety of sources. In addition, in analyzing the chances of a boat accident

**References**

[1] Afenyo, M., Khan, F., Veitch, B., & Yang, M. (2017). Arctic shipping accident scenario analysis using Bayesian Network approach. Ocean Engineering, 133, 224-230.
[2] Akhtar, MJ, &Utne, IB (2014). Human fatigue's effects on the risk of maritime groundings-A Bayesian network modeling approach. Safety Science, 62, 427-440.
[3] Almklov, PG, &Lamvik, GM (2018). Taming a globalized industry and counter-forces Forces Influencing maritime safety. Marine Policy, 96, 175-183.
[4] Arslan, V., Kurt, RE, Turan, O., & De Wolff, L. (2016). Safety culture assessment and implementation framework to Enhance maritime safety. Procedia Transportation Research, 14, 3895-3904.
[5] Baksh, A.-A., Abbassi, R., Garaniya, V., & Khan, F. (2018). Marine transportation risk assessment using Bayesian Network: Application to Arctic waters. Ocean Engineering, 159, 422-436.
[6] Bergheim, K., Nielsen, MB, Mearns, K., & Eid, J. (2015). The relationship between psychological capital, job satisfaction, and perceptions of safety in the maritime industry. Safety Science, 74, 27-36.
[7] Cho, HS, Lee, JS, & Moon, HC (2018). Seaport Maritime Risk in Operation: A Cross-Country Empirical Analysis with Theoretical Foundations. The Asian Journal of Shipping and Logistics, 34 (3), 240-248.
[8] Faturachman, D., & Mustafa, S. (2012). Sea transportation accident analysis in Indonesia. Procedia-Social and Behavioral Sciences, 40, 616-621.
[9] Haapasaari, P., Helle, I., Lehikoinen, A., Lappalainen, J., &Kuikka, S. (2015). A proactive approach for maritime safety policy making for the Gulf of Finland: Seeking best practices. Marine Policy, 60, 107-118.
[10] Haimes, YY (2015). Risk modeling, assessment, and management. John Wiley & Sons.
[11] Hanninen, M., Banda, OAV, and Kujala, P. (2014). Bayesian network models of maritime safety management. Expert Systems with Applications, 41 (17), 7837-7846.
[12] Horný, M. (2014). Bayesian networks. Boston University School of Public Health, 17.
[13] Huang, H., et al (2010). County-level risk analysis crashes in Florida: Bayesian spatial modeling. Transportation Research Record, 2148 (1), 27-37.
[14] Liang, C., et al (2018). Using Bayesian Networks for the Purpose of Risk Analysis at Railway Level Crossings. IFAC-PapersOnLine, 51 (9), 142-149.
[15] Liang, C., et al (2017). Risk analysis on level crossings using a causal Bayesian network-based approach. Procedia Transportation Research, 25, 2167-2181.
[16] Mullai, A., et al. (2011). A grounded theory models for analysis of marine accidents. Accident Analysis & Prevention, 43 (4), 1590-1603.
[17] Nævestad, T.-O., et al (2019). Safety culture in maritime transport in Norway and Greece: Exploring national, sectorial and organizational influences on unsafe Behaviors and work accidents. Marine Policy, 99, 1-13.
[18] Oltedal, HA, et al (2018). Managing Maritime Safety. Routledge.
[19] Pillay, M. (2015). Accident causation, prevention and safety management: a review of the state-of-the-art. Procedia Manufacturing, 3, 1838-1845.
[20] Tony, C. (nd). Learning Causal Graph Models from Data. Wiley StatsRef: Statistics Online Reference, 1-4.
[21] Trucco, P., et al (2008). A Bayesian Belief Network modeling of organizational factors in risk analysis: A case study in maritime transportation. Reliability Engineering & System Safety, 93 (6), 845-856.
[22] Wang, L., et al (2018). Bayesian network modeling and analysis of accident severity in waterborne transportation: A case study in China. Reliability Engineering & System Safety, 180, 277-289.

[23] Weber, P., et al (2012). Overview on Bayesian networks applications for dependability, risk analysis and maintenance areas. Engineering Applications of Artificial Intelligence, 25 (4), 671-682.
[24] Zhang, G., et al (2018). Addressing the epistemic uncertainty in maritime accidents using Bayesian network modeling with interval probabilities. Safety Science, 102, 211-225.
[25] Zhang, J., et al (2016). Maritime transportation risk assessment of the Tianjin Port with Bayesian belief networks. Risk Analysis, 36 (6), 1171-1187.

**Acknowledgments**

Authors wishing to acknowledge assistance or encouragement from colleagues, special work by technical staff or financial support from organizations should do so in an unnumbered Acknowledgments section immediately following the last numbered section of the paper.