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Analyzing the Structure of Port Stakeholders in Port Risk Management

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Abstract : *This study aimed to assess the strength of stakeholder engagement in risk mitigation within seaport activities. Specifically, we focused on operational risk caused by strong winds, a significant risk factor in port operations. Our results indicated that stakeholders play a crucial role, contributing up to 81% in risk monitoring effects to alleviate risk caused by strong winds. The study's findings also showed the significance of the influence of each stakeholder involved in operational risk mitigation due to strong winds. Additionally, we introduced a model that can be applied to various risk conditions and port situations. This model was determined by Bayesian network analysis with Genie software.*

Key words : *port stakeholders, port risk, risk management, structural analysis, Bayesian networks*

1. Introduction

Ports play a vital role within supply chains, acting as key components where various logistics and transport operators collaborate to deliver value to the ultimate customers (Denktas-Sakar and Karatas-Cetin, 2012). Besides, ports are integral components of intricate systems that function within an unpredictable logistics environment. They serve as locations where stakeholders offer products and deliver services, ultimately contributing to the creation of value (Ha et al., 2017). Hence, coordination and cooperation are needed at ports and this coordination and cooperation may be considered from the viewpoint of ports' relationships and interactions with its stakeholders (Denktas-Sakar and Karatas-Cetin, 2012).

A stakeholder is any individual or group having an interest or being affected by the port. A port both technologically and economically is in fact a node for contacts and contracts, whereby every stakeholder is driven by its own interests and priorities (Henesey et al., 2003). Apart from the complex stakeholder structure, various risks can occur near residential and industrial areas at seaports, potentially exposing people to the consequences of accidents. Approximately 50% of all marine causalities and incidents take place in ports or their nearby areas (Nagi and Kersten, 2022). Despite a growing commitment to safety in port terminals, accidents like falling crane spreaders and crane-ship collisions persist, despite safety guidelines and laws, resulting in a 4.2% annual increase in casualties from 2016 to 2019 (Sim et al., 2023). In maritime studies, risk is a central issue because it is often coupled with the safety, efficiency, and reliability of transport (Mabrouki et al., 2014). In addition, usually, many parties or stakeholders in the seaport have to be involved in the process of risk management in order to reduce the occurrence probability and impact severity in an effective manner. Establishing thorough risk management in seaport requires, hence, extensive and reliable cooperation between many organizations (Pileggi et al., 2020).

To ensure effective risk management at all levels of the organization's structure, it is imperative to establish a well-defined approach to communication and consultation. This approach will not only bolster the risk management framework but also streamline its practical implementation. Communication, in this context, pertains to the dissemination of information to specific audiences. Furthermore, it is essential that both the methods and the contents of the communication and consultation should align with the expectations of relevant stakeholders (ISO 31000, 2018). Furthermore, it is crucial to pinpoint the sources of risks for effective risk mitigation. However, as noted by Yang and Zou (2014), there are challenges when

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using risks identified to track their sources:

1) Many risks are overly broad and pertain to various stakeholders, making it more challenging for practitioners to devise specific risk response strategies.

2) Lack of a comprehensive range of stakeholder groups which resulted in the omission of many risks associated with external project stakeholders, excluding government bodies.

These challenges highlight the need for a more nuanced and inclusive approach to identifying and managing risks within projects and their associated stakeholder landscape.

Hence, this work aims to evaluate the strength of stakeholders' engagement in the risk mitigation process in the port activity by proposing a modeling approach based on the Bayesian Networks to identify the shareholders' participation in the risk-reducing process.

The rest of the paper is organized as follows. Section 2 presents a literature review of the risk management and port stakeholders. Section 3 describes the research methods applied in this work. Results and conclusions are drawn in section 4 and section 5, respectively.

2. Literature review

In ports and terminals, high-quality risk management is necessary for their sustainable development (Mokhtari et al., 2011). In the industrial environment, port activity is one of the more complex components of the supply chain where risk management is present on financial, technological, organizational, and operational aspects. This study aims to identify which port stakeholders are involved in the risk mitigation process. Hence, the literature review examines both of port risk management literature and the analysis of the structures of the port stakeholders.

2.1 Risk management

Risk management in seaports is defined as the cooperation among partners within the network of a seaport by applying risk management process methods and tools to deal with risks that might have considerable impacts on the economy, the environment, and the health and safety of people. A clear understanding of different sources should be achieved to define appropriate measures, tasks, and responsibilities (Nagi and Kersten, 2022). Due to a vast number of hazards and risk sources in seaports, efficient and effective risk management is gaining further importance. Study on the risk management in seaports has a wide scope and covers several different aspects such as risk factors, risk assessment, natural hazards, management of disruption, disaster response planning, empirical data, and frameworks (Pileggi et al., 2020).

Risk management is based primarily on the analysis and assessment of all relevant and available information. This process is usually structured around five phases, and for instance, (Mabrouki et al., 2014) considered (1) Risk identification, (2) Risk analysis, (3) Planning and scheduling preventive and corrective actions (4) Monitoring and implementation of action plans and (5) Effectiveness monitoring of measures taken via a mechanism of prevention and protection. They also mentioned that communication is essential throughout the process of risk management.

In accordance with ISO 31000 (2018), the purpose of communication and consultation in risk management is to aid relevant stakeholders in comprehending the nature of risks, the underlying factors influencing decision-making, and the rationale behind specific actions that need to be taken. Communication aims to foster awareness and a deeper understanding of risks, whereas consultation involves actively seeking feedback and gathering information to inform decision-making. Consequently, it is imperative not only to involve appropriate external and internal stakeholders at every stage of the risk management process but also to ensure their engagement and awareness for the successful implementation of the risk management framework. This approach allows organizations to explicitly address uncertainty in their decision-making while also being prepared to consider and address any new uncertainties that may arise.

To gain a comprehensive understanding of the potential risks linked to port operations, it's crucial to conduct a thorough analysis of the port's operational procedures. The operational aspect of port terminals is marked by extensive infrastructure and critical resources operating within a limited and rapidly changing traffic environment. This complexity has resulted in multiple points of vulnerability across various domains, including administrative activities, operations management, incident management, facilities management, and infrastructure management. Addressing these challenges necessitates a specialized methodology to identify and evaluate operational risks effectively, enabling the implementation of preventive measures within port terminals (Mabrouki et al,. 2014). Operational risks have garnered significant attention in numerous scholarly works due to their potential to impact an organization's processing capacity. In accordance with John et al. (2014), the port infrastructure and systems cannot tolerate disruptions stemming from unforeseen risks. Given their intricate operations, any incident during system operations can result in both property and environmental damage, as well as pose a threat to human life. In some literature, operational risk factors that can lead to disruptions in port environment activities are outlined as follows:

Table 1 Review of risk factors.

Risk factors		Source
Operational risks	Loading/unloading, processing, documentation capacity	Berle et al. (2011)
	Port equipment/machinery failure, coargoes spillage	John et al. (2014)
	Port equipment failures, vessel accident/grounding, cargo spillage, human errors	John et al. (2016)
	Transportation of dangerous goods, port/terminal congestions, trade imbalance on container shipping routes	Wan et al. (2019)
	Loading and unloading equipment damage (broken, stratched, crooked, etc.)	Budiyanto and Fernanda (2020)
	Operational and safety risks	Nagi et al. (2021)
	Inadequate lifting accessories	Dhahri et al. (2022)
	Terminal equipment malfunction	Nyamjav and Ha (2023)

Source: Authors

Furthermore, Nyamjav and Ha (2023) conducted research about identifying interrelationships between risk factors and have determined strong winds resulting from natural disasters as a significant influencing factor contributing to terminal equipment malfunctions (as operational risk in this work) within the operational risk context. As well, the entirety of maritime infrastructure is impacted by the ever-changing conditions of the natural environment. These influences have the potential to disturb maritime operations, rendering them susceptible to dangers. Among the primary perils attributed to natural elements are hydrological (e.g. heavy rainfall, flooding, and snow), atmospheric (e.g. hurricanes and cyclones), and geological (e.g. tsunamis and earthquakes) factors. The consequences of these perils consistently contribute additional expenses to the maintenance, rebuilding, and readiness of maritime infrastructure systems on an annual basis (John et al., 2016). According to Lee and Ha (2022), it was evaluated that 'port operational risk caused by the strong wind' SW is the factor with the highest risk level among the other factors. Hence, we consider SW as a risk factor in this work.

2.3. Port stakeholders

A stakeholder is defined as any group or individual that can either be impacted by or have an impact on the attainment of an organization's objectives. In the context of ports, the social dimension is primarily examined through the lens of stakeholder relationships (Denktas-Sakar and Karatas-Cetin, 2012). Seaport stakeholders engage in various interactions within different risk scenarios, and each seaport possesses its distinct network structure (Nagi et al., 2021). However, four stakeholder groups in the port community are broadly classified as follows:

Table 2 Port stakeholders

Internal stakeholders:	Managers Employees Board members Shareholders
External stakeholders	Terminal operators Stevedoring companies Freight forwarders Shipping agencies Industrial companies in the port area Supporting industries (such as ship repairers and port labor pools)
	Port customers Trading companies Importers/exporters
Legislation and public policy stakeholders	Government departments responsible for transport and economic affairs Environmental departments Spatial planning authorities
Community stakeholders	Civil society organizations The general public The press and the other non-market players

Source: Denktas-Sakar and Karatas-Cetin(2012)

Except for the community group, the first three groups contain stakeholders who are decision-makers in the port environment and development matters at various authoritative levels (Lam and Yap, 2019). The internal stakeholders are part of the comprehensive port authority organization. Then the group of external stakeholders encompasses both in-situ and ex-situ economic participants. The in-situ category comprises various port companies and supporting industries that make direct investments in the port area, thereby creating value-added activities and employment opportunities. The next set of legislative and public policy participants encompasses not just government entities overseeing transportation and economic matters at different administrative levels - local, regional, national, and supranational - but also includes environmental departments and spatial planning authorities across various geographic decision-making tiers. In the final category, community stakeholders encompass community groups, civil society organizations, the general public, the media, and other non-commercial entities. They express a keen interest in the development of the port, primarily focusing on its expansion initiatives due to concerns related to the overall community's well-being (Henesey et al., 2003).

Managing a port is a complex task due to the substantial number of stakeholders involved. It necessitates careful consideration and ongoing monitoring of the concerns raised by all stakeholders. When making specific decisions and acting, port managers should prioritize the interests of those stakeholders who have the closest and most significant ties to the port's operations (Wagner, 2017). Risk management is an integral part of port management, helping to ensure the safety, security, efficiency, and compliance of port operations while building trust among stakeholders. Efficient risk management decisions in ports are largely determined by choices related to resource allocation. With a limited budget and a pool of available personnel, a port's risk management strategy must allocate funds, human resources, and materials to the most critical tasks within a specified timeframe, with the goal of mitigating risks. The definition of risk mitigation in seaports hinges on various factors, including the stakeholders engaged in the decision-making process, the significance attributed to their interests, their willingness to tolerate risks, and the engineering or institutional mitigation solutions that are at their disposal (Gregory et al., 2012). Furthermore, as highlighted by Starr et al. (2003), apart from risk management, it's important to acknowledge that not all risks can be predicted in advance, but they can be effectively managed. This necessitates collaborative efforts among senior executives, boards, and stakeholders to establish a resilient enterprise. In today's business landscape, stakeholder expectations are higher than ever, and enterprises that are more resilient will experience more rewards.

Therefore, this research aims to determine which stakeholders can participate in the risk reduction activities associated with the 'strong wind (SW)'[1] concerned. This work also adopts the productive approach of Bayesian Networks methodology to effectively understand the role of stakeholders' engagement in the risk mitigation process in the seaport environment. The data processing is made using the Genie software. The research methodology is developed in the following section.

3. Methodology

In order to assess the impact of individual variables on the risk mitigation process within a seaport environment, we propose the Bayesian Networks methodology. This approach serves to visually depict the engagement of all stakeholders when addressing a particular risk event.

3.1. Bayesian Networks

Bayesian Networks (BNs) have become one of the most commonly used models for the modeling and reasoning of uncertain systems (Chen et al., 2019). BNs are also known as the framework for drawing uncertain conclusions from uncertain evidence. The primary distinction in constructing BNs lies between two approaches: one that derives the networks and conditional probabilities directly from data, employing various learning algorithms, and the other that relies on stakeholder input (Barbrook-Johnson and Penn, 2022). The reason for employing BNs in the analysis of potential outcomes stemming from situational factors, which represent observable aspects of the system under study, is to gain insight into how various nodes or components influence the dynamics of the system (John et al., 2016). The description of the BNs method outlines its characteristics as a Directed Acyclic Graph (DAG) comprising nodes and arcs. In this representation, nodes correspond to random variables, representing events with values drawn from specified domains. Arcs serve to depict direct probabilistic dependencies between variables; an arc links an influencing (parent) node to an influenced (child) node. The parent node pertains to preceding variables, while the child node signifies dependency on other variables. Each node contains a Conditional Probability Table (CPT), which collectively forms a system of associated probability tables within the DAG (Rahman, 2013). Quantitative probability information is specified in the form of CPT.

In this work, the development of the CPT consists of two steps which include the identification of influencing

1) In section 2.1, an explanation of 'port operational risk caused by strong wind' has been provided, and it is abbreviated as (SW).

factors (stakeholders) and the quantification of the strength of their participation in the risk mitigation process.

3.2. Modelling using a BN approach

For the purpose of identifying influencing factors, we conducted following steps.

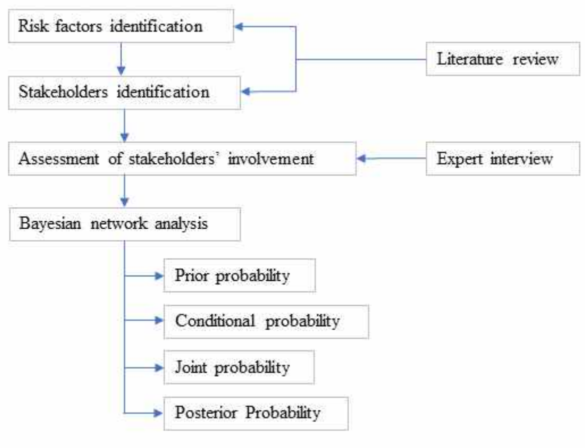

Fig. 1 Flowchart of the methodology. Source: Authors

3.1.1. Risk factor selection: This study employs risk factors as indicators to ascertain stakeholder involvement and calculate CPT likelihood for nodes. As previously discussed in section (2.1), natural disasters emerge as crucial factors influencing the entire port system, necessitating consistent preventive measures from the perspective of stakeholders. Consequently, the factor labeled SW has been chosen and assigned a weight of 0.29 (Lee and Ha, 2022).

3.1.2. Interviews: The purpose of interviews is to address two primary issues: identifying the stakeholders involved in the risk mitigation process within the port environment when the risk of SW occurred and assessing the extent of their involvement in this process.

To determine the information needs, we invited eight experts with more than 10 years of experience[2] in the maritime industry. The experts were presented with the stakeholder engagement questionnaire, and they discussed engagement intensity. In other words, experts need to assess the extent of involvement of all stakeholders in the questionnaire. Here, stakeholders in the questionnaire are based on Table 2, and stakeholder engagement rates range from 'never involved' (rated as '0') to 'highly involved' (rated as '4').

According to the result of the interviews, the experts consider that Internal stakeholders as one factor, and the normalized weights are modified (Rahman, 2013).

Table 3 Result of interviews.

Stakeholders	ID	Rate	Converted weight
Internal stakeholders	SH1	3	0.6
Terminal operators	SH2	2	0.4
Stevedoring companies	SH3	2	0.4
Rail, road, and barge operators	SH4	0	0
Shipping lines/shipping agents	SH5	3	0.6
Freight forwarders	SH6	1	0.2
Towage/pilotage	SH7	4	0.8
Industrial companies in the port area	SH8	0	0
Supporting industries (such as ship repairers and port labor pools)	SH9	2	0.4
Trading companies	SH10	0	0
Importers/exporters	SH11	0	0
Government departments	SH12	1	0.2
Environmental departments	SH13	2	0.4
Spatial planning authorities	SH14	0	0
Civil society organizations	SH15	0	0
The general public	SH16	1	0.2
The press and the other non-market players	SH17	1	0.2

Source: Authors

3.1.3. Evaluating the probabilities of variables in CPT; For building that interdependence model, parent and child nodes in CPT need to be provided. The CPTs of parent nodes as shown in Fig. 2 were based on the information presented in Table 3. Hence, the framework of this model in this work is structured in two scales input nodes and decision node. In other words, it is structured that stakeholders stand for input nodes (based on Table 3, the interdependence model has 11 input nodes) as influence factors in activities to reduce the consequences of the risk. As well, the decision node is considered in this work to illustrate the involvement of stakeholders as problems raised by the SW are solved or not.

Aforementioned BNs are a DAG that specifies a joint distribution over X ($X=(X_1,\ldots,X_n)$) as a product of local conditional distributions, one for each other. Then, CPT which forms DAG describes the relationship between a decision node and input nodes which is calculated by 4 steps as follows.

a. Prior probability of random variables $P(x_i)$

In this step, converted weights from Table 3 and the weight of SW in Section (3.1.1) are assigned as prior

2) Four experts from container terminals, two experts from academia and two experts from port authority, respectively.

probability.

b. Local Conditional distribution P(y|x_i): Result of (b) used as fills conditional table of x_i and base of (c).

c. Joint probability P($y \cap x_i$) can be calculated by following formulas: Joint probability can be used where posterior probability calculation.

d. Posterior probability can be calculated by Bayes theorem of P(y|x_i)=$\frac{P(x_i \mid y)P(y)}{P(x)}$

In this work, we have 11 independent events (parents), hence can reach the result:

$$P(y|x_{1,\ldots,}x_{11}) = \frac{P(x_1 \mid y)\ldots P(x_{11} \mid y)P(y)}{P(x_1)\ldots P(x_{11})}$$

But, as the denominator remains constant for a given input, we can remove that term:

$$P(y|x_{1,\ldots,}x_{11}) \propto P(y)\prod_{i=1}^{11} P(x_i \mid y)$$

From this term, it can be created a classifier model. For this, we find the probability of the given set of inputs for all positive values of the class variable and pick up the output with maximum probability. This can be expressed mathematically as:

$$y = \mathrm{argmax}_y P(y)\prod_{i=1}^{11} P(x_1 \mid y)$$

where y represents (Solve) and x_i is the (SH1...SH12). Hence, posterior probabilities which fill CPT can be calculated as the following pattern.

$P(Solve|SH_i{=}involve)=P(Solve)*p(SH_1{=}involve|Solve)*....*p(SH_{17}{=}involve|Solve)$; $P(Solve|SH_i{=}notinvolve)=P(Solve)*p(SH_1{=}notinvolve|Solve)*P(SH_2{=}involve|Solve()*\ ....\ *p(SH_{17}{=}involve|Solve)$.

4. Results

In this section, we discussed the analysis of the interdependence model. A total of 11 factors were used to build an influencing diagram which was drawn without considering element names but using element IDs. There are 11 factors (stakeholders) as input nodes build the model. In order words, all input nodes influence in result of the decision node as an equivalent tier but different strength of their weight. But in this work, we aimed to evaluate the engagement of all factors in the risk mitigation process.

Hence, according to the result of the study in Fig.2, the strength to diminish SW risk in port operation evaluated up to 81% possibility. To clarify if all 11 stakeholders can potentially be involved in the management of operational risks caused by ‘strong wind’, the success rate of the risk reduction process is 81%.

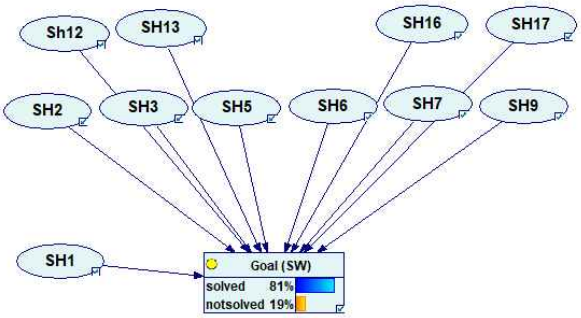

Fig. 2 BN analyses result of SW for GOAL

Consequently, if the level of stakeholder engagement were to decrease (or if some stakeholder is not engaged), the duration of the risk's consequences could be prolonged. The software can present an opportunity to eliminate the influence of any factors. To assess stakeholders' involvement, each factor is examined (parent nodes) individually, gauging how much their absence would affect ‘Goal Solving’.

Table 4 Stakeholders involving percentage in risk reduction

Stakeholders	Code	Percent
Internal stakeholders	SH1	14%
Terminal operators	SH2	12%
Stevedoring companies	SH3	12%
Shipping lines/shipping agents	SH5	14%
Freight forwarders	SH6	9%
Towage/pilotage	SH7	18%
Supporting industries (such as ship repairers and port labor pools)	SH9	12%
Government departments	SH12	9%
Environmental departments	SH13	12%
The general public	SH16	9%
The press and the other non-market players	SH17	9%

Source: Authors

Table 4 shows stakeholders' likelihood of influencing risk reduction efforts. In essence, it quantifies how engaging stakeholders in risk management activities can amplify the prospects of risk reduction. For instance, in the event of a SW, it becomes evident that the Towage/pilotage's participation yields the most significant positive impact, amounting to an impressive 18% reduction in risk.

5. Conclusion

This study evaluated the interdependence between the risk mitigation process in the seaport and the strength of its stakeholders' engagement and analyses are conducted by Genie software using the BNs approach.

The research result shows that stakeholders' participation in the risk mitigation process is crucial. According to the result, the risk mitigation process in the seaport environment depends on stakeholders' engagement is up to 81%. Hence, considering the research results, it is imperative for port authorities to consider the participation of stakeholders in their risk management activities and associated responsibilities. Due to the port's structure is not same, the output might be different in every situation: 1) different country, 2) different number of stakeholders 3) different possibility of natural disaster (weight of strong wind).

This work also provides stakeholders' influencing capacity in the risk mitigation process. The result shows that Towage/pilotage, Internal stakeholders, and Shipping lines/agents have a great amount of likelihood which can influence productively on the risk management process. Hence, when port managers effectively guide the relevant stakeholders′ focus toward disruptions in port operations triggered by any risk, they not only conserve valuable time and energy but also expedite the resolution of these disruptions. Consequently, this proactive approach could not only lead to swift intervention but also serve as a preventive measure, mitigating potential losses stemming from such risks.

This study focused exclusively on one risk factor SW, and the identification of different types of risk factors may alter the role and engagement of the influencing groups of stakeholders. Therefore, future research should address this limitation.

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