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Identify the Trends on Maritime Safety Management System Studies: A Review

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ABSTRACT: Studies to understand the development of the theory and implementation of effective Maritime Safety Management are essential to examine its performance. Therefore, this study aims to identify trends that review Maritime Safety Management using the literature study design model. Data were collected from articles published in Scopus-indexed international journals from 2012 to 2022 and analyzed qualitatively using the Interactive data analysis model. This result showed that the trends responsible include the Effectiveness of the Safety Management System (SMS), developing the model, and identifying sources that raised safety problems. This study discussed these findings in detail, supported by the latest theory and empirical foundation. Furthermore, aspects not examined in preliminary studies were evaluated based on the trend with the evolution of a standard for a SMS, namely the ISM code. Irrespective of implementing this code, ships can still be detained for various reasons. This led to use the AHP-TOPSIS combination method to analyze all findings issued during periodical verification to evaluate the implementation of the SMS on board ship.

1 INTRODUCTION

Safety and health risks are problems that are inseparable from all types of work [1,2]. These risks can be either low or high and pose threats to a person's life [3,4]. Therefore, every worker must know the risks associated with a job function and ways to anticipate them [5]. They also have the right to protect themselves from these risks [6]. Every job has associated risks that must be properly managed in a logical chain of practices through proper planning, execution, and control. Rodrigues-da-Silva and Crispim [7] stated that these actions keep project implementation within certain parameters, such as time, cost, and quality. Risk management is an emerging area in management systems [8]. Therefore, creating protection has also long been intertwined with and managed through risk management tools and perspectives [9]. It ensures the safety and well-being of its workers, customers, and the work environment [10]. These work conditions include physical, organizational, and psychosocial factors [11]. According to Sorensen et al. [12], efforts to ensure and promote workers' safety, health, and well-being have increasingly focused on integrating the complex and dynamic systems of the workplace and work environment. These include strategies, policies, regulations, recommendations, or programs [13] that can significantly impact employees [14].

A lack of a safety culture can lead to public health or occupational medical problems [15]. Therefore, it is necessary to develop a sound safety management system (SMS) in businesses or organizations, specifically those industries with a high risk. The extent to which safety procedures and regulations are followed within an organization is influenced by the organization's dominant culture [4]. However,

irrespective of the industry, the parties involved should prepare tools to anticipate and manage the risk to prevent accidents and losses. This will lead to a groundbreaking study organization and a different way of performing job tasks, likely impacting the workers' health and safety [16]. Accidents can affect the overall results of the remaining employees and work teams, thereby necessitating reorganization, psychological and emotional support, with an impact on project productivity [17]. According to Gould and Bieder [18], safety has long been a major concern for organizations, specifically with the advent of hazardous technologies. Therefore, measuring the level of safety is a key challenge [19] because some have piqued the interest of many academics and practitioners for quite some time [20]. The safety management measure is important for each organization within each industry according to the necessities, and the risks faced. This management process is similar to other project risks [21]. Safety and health mechanisms are broadly defined as a collection of institutionalized, interconnected, and communicating elements designed to establish and obtain work safety objectives and goals [22]. It is critical to comprehend the content, components, and segments to gain a more detailed understanding of security and culture [23]. A barrier to safety improvement is the lack of data for an organization to evaluate [24]. Every organization needs to abide by the International standardized safety management policy to achieve the universal purpose of safety at work. A requirement is a guideline or structure to pursue when establishing and working these actions, whether it is a market risk for all activities on an enterprise or a specific risk evaluation for a critical operation [25].

SMS consists of organizations' guidelines and procedures to reduce workplace accidents. It is a systematic safety management method widely studied globally [26]. Organizations commonly use this method to assess their performance regarding the safety of citizens, property, and the ecological system [27]. This can be viewed as an overall organizational tool for developing, planning, measuring, analyzing, and controlling an organization's safety performance and its actions [28]. According to Jiang and Wang [29], the occurrence of economic losses and casualties can be reduced through safety management. In this context, system safety refers to interactive, newly emerging parameters of the system that is unlikely to cause loss or harm [30] and believed to positively impact safety culture [31]. A great Text messaging includes an organized strategy to risk control, such as organizational structure, accountability, policies, and procedures. Text messaging is scalable, hence, it can be designed to an organization's size and complexity. Several industries implemented SMS in their business process to achieve a safe and high-performance work environment. This aimed to prevent accidents from endangering the workers, customers, society, and even the environment.

One of the industries with various categories of safety and health risks is the marine industry [32, 33, 34]. These risks can occur due to human errors or natural disasters such as bad weather, tsunamis, etc [35,36]. Therefore, a system that helps industries identify and prevent or minimize health and safety issues, known as the SMS, is needed [37]. Chruzik [38] mentioned the relationship between the requirements for the management systems currently applicable in maritime transport resulting from legal requirements of Safety Management System. With the implementation of this system, marine industries are expected to operate optimally [39,40]. This industry copes with worldwide competition's difficulties and increasing efficiency needs [41]. This is because it facilitates commerce and trade by delivering valuable raw materials, components, and finished goods [42]. Therefore, a system is needed to help identify and prevent or minimize occupational health and safety problems among seafarers [43]. SMS is expected to assist marine industries in operating optimally and achieving the highest level of performance.

The International Safety Management (ISM) Code [44]has been designed to provide a framework for the marine industry to develop safety measures to reduce accidents caused by human error [45]. Bastug, Asyali, and Battal [46] stated that the ISM code provided an international standard for safe management. This means that the marine industry must pay attention to safety, security, efficiency, and a clean natural environment because it is responsible for 3% of global carbon emissions [47]. However, maritime transport is the backbone of international trade and globalization, including shipping and port [48]. It can transport over 80% of international trade and employ over 1.5 million seafarers [49], which led to the implementation of the ISM Code. Safety navigation can reduce maritime incidents and pollution costs with increased harbor productivity and competitiveness [50]. These global regulations aim to prevent or reduce accidents and their consequences, as well as ensure work safety in ships. ISM Code implementation is very important because there are several light and heavy onboard factors that pose a risk to crew members while working. The code tends to reveal the possible risks and consequences of the accident. The ISM code also specifies the steps needed to improve work safety for a ship's crew, as well as the strategies needed to prevent accidents. Some of the incidents obtained while working on the board and in the engine compartment include colliding with falling objects, electric currents, etc, due to not paying close attention and not prioritizing workplace safety.

The lack of attention and negligence in implementing SMS on board ship will likely cause various damage. Therefore, it is imperative to evaluate the implementation of SMS to decide whether a ship can continue its operation or be detained for further investigation to prevent accidents. In the process related to SMS, the authorities need to have an agile and swift ability to obtain the most suitable decision for the continuation of the ship operation. Therefore, it is necessary for SMS on board ship to be complemented with the compatible supported method to achieve the best possible outcome. It is imperative to propose a compatible method in SMS on an unexplored ship to gain more insight into the development. Several studies have been conducted on SMS to obtain a reliable process. Furthermore, this study determined the trends utilized by previous studies regarding safety management in the marine industry for further analysis. This study also implored the possibility of

implementing the AHP-TOPSIS method in SMS on ships to provide a more comprehensive knowledge of implementing the Maritime SMS for an effective and efficient process.

2 METHOD

This literature study was carried out in four stages, namely designing, reviewing, analyzing, and writing reports [51]. Data were collected from preliminary studies on the SMS published in international scientific journals using search engines and keywords related to SMS for marine industries. Several criteria were used in selecting these data, such as articles published from 2012 to 2022 by Scopus and those that examined the SMS in the marine industry.

The data collected were then analyzed qualitatively using interactive models consisting of three stages, namely reduction, display, and conclusion/verification [52]. The reduction process was conducted by selecting articles following the criteria set in this study to ensure they contained all the information needed to achieve the desired goals. This was followed by sorting the data according to the study purpose, such as grouping articles based on topics and providing the code for easy identification. The final stage is concluding data that have been grouped.

3 FINDING AND DISCUSSION

3.1 *Safety Management System (SMS) on Board Ship: ISM Code*

The ISM Code is an international global management code used to secure the boat business and avert contamination of the oceanic environment. The IMO Assembly authorized it with the possibility of future changes in the world of maritime changes by the same organization. The ISM Code is the final multinational and national guideline similar to the quality gold standards and is used for all shipping lines to ensure the safety and protection of their ships in the marine ambient. It consists of 16 components:

Figure 1. The ISM Code elements, source: [44]

The ISM Code must be adhered to by all shipping industries worldwide on their various types of ships through the SOLAS Chapter IX Convention. This increases competitiveness and ensures the viability of the company. The ISM Code aims to ensure safety at sea, prevent accidents and fatalities, and avoid damage to the environment and ships.

Therefore, every business must create, enforce, and preserve SMS, which is a technology designed by a shipping company to guarantee maritime security, completely prevent accidents, and control pollution, particularly in the surrounding environment. To accomplish this goal, the ISM Code underscores that SMS aims should include the following:

1. Organize safety exercises in ship operation and the work environment.
2. Create a defense or a safeguard against all dangers.
3. Continue to improve ship, land, and water transportation staff safety practices, such as emergency management for the security of the rescue team, the boat, and the surroundings.

SMS must ensure the following:

1. Compliance with regulations
2. Compliance with the applicable codes and guidelines recommended by organizations, administrations, categorization seafaring civilizations, and industry groups.

The company's responsibilities and authorities have limitations, including:

1. In situations where the individual in charge of the ship's operating condition is not its holder, the landlord must document the names and identification details to the administration.
2. The company must establish documents by the responsibilities, authorities, and interrelationships of all personnel who manage and carry out verification related to work and affect pollution.

As part of the ISM Code requirement, periodical verification must be carried out on board ship by the flag state or recognized organization to maintain the validity of the Safety Management Certificate. Furthermore, an intermediate verification must occur between the certificate's second and third-anniversary date. Finally, renewal verification must be completed within three months before the certificate's expiry date.

3.2 *Develop a Safety Management Model*

The most researched attribute in the SMS case is the associated model's development. Approximately 56% of the total studies collected discussed developing or modifying the SMS model, the detail can be found in Figure 2. In general, its development is carried out to enhance the quality of the existing models, thereby making it a model that is more effective in identifying and preventing accidents or other things that cause safety problems. A summary of findings regarding the development of an identified Safety Management model is shown in Table 1.

Furthermore, based on the data displayed in Table 1, it was found that there were various innovations to make the developed model more effective. These include utilizing technology, Bayesian Networks, Scientific Management, statistical analysis,

and fuzzy meters. It is imperative to know that using technology and other innovations can increase the effectiveness of existing systems. According to preliminary studies, the use of technology positively impacts the effectiveness of this model [53,54]. However, with the existing complex problems, the development of the model in accordance with the health and safety issues must still be carried out on an ongoing basis [55,56]. Table 1 shows the details about things that can be learned from the SMS model development.

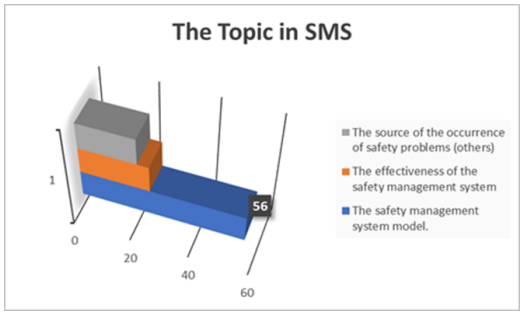

Figure 2. The most researched case in a SMS

3.3 *Evaluating the effectiveness of safety management*

The second most studied topic from the data collected within ten years in the Maritime Industry is the SMS effectiveness. It was found that 24% of the studies focused on evaluating systems from which several points can be learned. The important attributes include the success of SMS, influenced by the understanding and compliance of its users, as well as the various approaches used in measuring its effectiveness, and the detail of implementation can be found in Table 2 and Figure 3. Therefore, users' support is needed to realize an effective SMS for optimal performance [56, 71, 72, 73]. It is also important to properly evaluate this process to ensure the system runs well [74, 75]. The evaluation results can be used to improve the implementation of the system in the next stage to obtain better results. Based on the reviewed articles, some topics were discussed in evaluating the SMS implementation. However, none discussed the evaluation based on the result of periodical verification, specifically on evaluating findings during on-board verification.

Table 1. Things that can be learned from the safety management model development

No	Topics	Things that can be learned
1.	Technology improves safety	The use of technology can be crucial to improving safety and, at the same time, increasing excessive supervision in the workplace [57]
2.	A system engineering approach is used to implement SMS.	A system engineering approach improves the SMS effectiveness [58].
3.	Scientific management concepts impact on ISM Code	Scientific management is valid and influential within the content of the ISM Code [59]
4.	AIS data and accident reports were used in an exploratory statistical analysis.	This model is excellent for weather forecasting and for determining whether the accident was caused by navigation or some other factor. The above statistical likelihood was raised by some ship types, shortened ship length, poor visibility situations, and a flag of convenience. [60].
5.	Using a fuzzy matter element method	A fuzzy matter component procedure in the global shipping industry is a reasonable and efficient strategy for controlling and preventing total-loss marine casualties [61].
6.	Using Bayesian networks and a probabilistic approach to characterize the static risk of ships.	This process demonstrates the model's consistency with the Ship Risk Level metrics in addition to the findings of other studies based on historical PSC inspection reports [62].
7.	Design procedures to prevent marine accidents from the human factor side with Bayesian Networks and TOPSIS	From a human error perspective, three main things prevent marine accidents, namely information, clear orders, and a safety culture [63].
8.	Maritime safety management using a Bayesian network model	The use of the new application of the Bayesian network-based expert system proves that even though several subareas are operating well, the safety management of ships navigating in waters still has several attributes that need to be improved [64].
9.	Artificial intelligence can help determine ship owners and engine crews to manage ship engine crews and increase safety.	Use sophisticated tools to support and automate decision-making processes at sea [65].
10.	A systems-theoretical approach to improving the safety of sailing on passenger ships in Bangladesh	Factors likely to cause accidents can be identified and analyzed to ensure they are more easily understood by stakeholders, such as passenger ship crews, regulatory agencies, designers, etc. These categories of people are expected to be able to use this information to prevent factors responsible for insecurity on the passenger ship [66].
11.	A Badge design approach for maritime SMS	A STAMP-based approach improves the effectiveness of SMS [67]
12.	Digital modeling of traffic SMS	They can create large system sets from complex ones of different functional organizations. Furthermore, they can be displayed in digital format and utilized for systematic study even though no preliminary information was available [68].
13.	Factors that influence the use of ships safety management technologies	The technology innovations add to the body of awareness on the variables that influence the use of smart technologies to enhance fleet safety [69].
14.	Based on Bayesian building a model for fully electric risk control on RoPax ships	It is preferable not to enable electric vehicles to charge while being shipped by RoPax ships because it increases the risk of explosion [70].

Table 2. Things that can be learned from the evaluation of the effectiveness of SMS

No	Topics	Things that can be learned
1.	Managers' and seafarers' understanding and participation in ISM	The understanding and participation of users affect the effectiveness of ISM. [76].
2.	Possibility of assessing maritime traffic safety using non-accident critical events. 2020). Hybrid decision-making to assess the SMS performance [77]	Ways to assess SMS effectiveness [77].
3.	SMS efficiency increases safety	Efficiency is crucial in SMS [78].
4.	ISM Code improves company performance significantly	The ISM Code effectiveness can be evaluated in two aspects: continuous quality improvement and client satisfaction. These different dimensions are linked to increased company performance [79].
5.	Issues in SMS implementation from the anglers' and seafarers' perspectives	Although fishers are required to master practical and operational skills, many seafarers perform ineffective processes, detailed planning, and water quality that coastal fishermen lack [34].
6.	The human talent's impact on ISM Code performance	The ISM Code efficiency mediates the relationship between commitment from top management and the shipping company's profitability, while different expertise belief systems affect this relationship [80].

Table 3: The source of the occurrence of safety problems and what can be learned

No	Topics	Things that can be learned
1.	Accidents involving fire and explosion in maritimetransportation [86]	Human error, thermal reaction, electrical fault, and mechanical failures are the causal factors of fire and explosion accidents. Cryogenic natural gas (CrNG), liquefied natural gas (LNG), and methanol have properties that make them more suitable for reducing the risk of fire than traditional fuels. This is because, with proper risk management, they could be a safer option than conventional energy sources.
2.	Cause of casualties and incidents	The captain is responsible for the causes of casualties and incidents: resources and personnel, crew certifications, training, and interpersonal interactions. Others include failure to develop ship operations plans and inability to verify deviations from great practice procedures. This is particularly in instances classified as severe accidents due to a lack of future growth of instructions, procedures, and worksheets [45].
3.	The leading cause of oil spills in the tanker shipping industry	The correlation between explosion, collision, grounding, and other variables is higher, indicating that they have a greater influence on oil spillages.
4.	Factors responsible for engine room fire	Some such accidents occur because the materials used in maintenance and repair work are not original.
5.	Factors responsible for health problems	Several essential factors in the ship's work environment, such as high physical loads, heavy work postures, poor workplace design, and long working hours, contribute to health and safety issues. Others include limited time for recovery and mental and emotional burdens perceived as a result of unclear boundaries between work, as well as entertainment and social interactions with clients and work colleagues. Meanwhile, factors contributing to workplace safety and health include appropriate care, rest time, and managers' capacity to resolve issues and build positive working relationships.

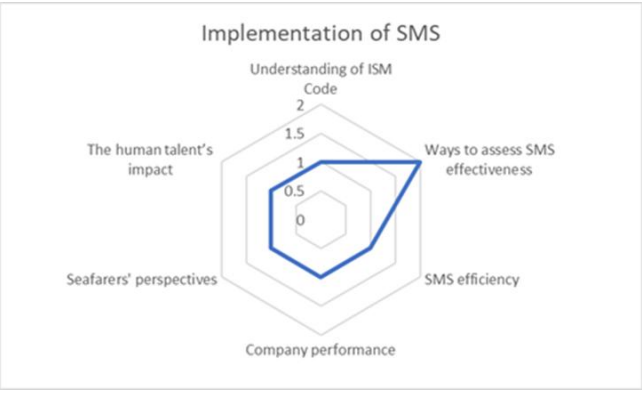

Figure 3. The topic in implementation of SMS

3.4 *The source of the occurrence of safety problems*

The third most common topic is the source of safety issues. The findings confirmed that the problems studied in SMS in the marine industry are generally related to fire, explosions, oil spills, and employee health problems. Various sources of issues have been identified in previous studies in terms of casualties and incidents. In general, the source of the problem can be categorized as natural disasters and human and technical errors. Knowing the sources of these problems is imperative to determine the right solution to resolve the issue [81-85]. Understanding the source of the problem is very important, however, when the implementation of SMS is properly done, it can be reduced or avoided. The sources of safety and health problems are detailed in Table 3.

3.5 *Ship Detention: Lack of Implementation of Safety Management System (SMS) on Board Ship*

When flaws capable of jeopardizing the safety or causing seaborne harm to the environment are discovered, Port State Control (PSC) has the power to hold the ship until the errors are corrected to protect the public and minimize carbon emissions threats [87]. The final punishment the Port State Control imposed on any ship was detention [88]. When a Flag State Control notices during the inspection that a ship has significant flaws affecting navigation systems safety, the inspector must apprehend it in accordance with the applicable regulations and expert expertise [89]. On the other hand, according to Article 292 of the United Nations 1982 Convention on the Law of the Sea (Convention), ship detention can occur when the authorities of a state party detain a ship flying the flag of another state party, and it is alleged that the detaining state has not complied with the provisions of the Convention [90]. PSC inspects and detains foreign ships, when a defect that poses safety risk is discovered [91]. This detention process plays an important role in PSC inspection. Although ship detention is an obligatory by the PSC inspection, it needs to be conducted in an efficient and accurate manner through the provision of early warning information to maritime traffic participants [92]. For example, crew members are exposed to various potential injuries when trying to handle dangerous equipment in confined spaces during repairs. This is in addition to when conducting heavy lifting and material handling in connection with loading or unloading operations. Adverse weather conditions will also increase the risk of collisions in such scenarios [93]. Furthermore, findings during PSC inspection which lead to ship detention must be evaluated, specifically when related to safety management requirements and implementation.

3.6 *The AHP-TOPSIS Method Combination*

Safety mechanisms enable the documentation of policies and best practices to decrease vocational hazards at work. The Occupational Safety and Health Assessment Series (OHSAS) is the preferred certification because an independent organization must audit the system. OHSAS is the most broadly used externally certificated Occupational Health and Safety Management System (OHSMS). It is essential to make choices when managing a health and safety system because the complexity stems from the innumerable qualitative and quantitative factors that influence choices. This makes it necessary to identify a decision-making methodology that empowers the best option. Health and safety-related key choices encompass various quantitative and qualitative factors. Analytical Hierarchical Procedures (AHP), Analytic Hierarchy Process (ANP), Specific instance Reasoning (CBR), Data Envelopment Analysis (DEA), Fuzzy set hypothesis, Simulated Annealing (GA), applied mathematics, simple inter scoring techniques (SMART), and their hybrids have all been proposed as broad multi-criteria decision-making approaches. Among the above-listed methods, one of the most popular is AHP, which is used to solve complex decisions. The strength of AHP is that it can divide a decision-making problem into several levels, thereby forming a hierarchy with a unidirectional centralized structure between them.

AHP is an inter-informed decision method with the ability to recognize and remove discrepancies in expert judgment. This method allows the use of consensus to determine the geometric mean of personal ratings while reducing decision-making bias and making group decisions. The Framework originates scores from pair-wise rating comparisons and is appropriate for several co, non-linear, and multi-actor decisions with multiple alternatives. AHP can model situations where no measures occur, such as modeling risk and uncertainty, due to its ability to score a scale rather than a measure. This method is based on three main principles, namely structure dissolution, judgment comparison, and hierarchical structure (or synthesis) of priority areas. The process of breaking down a decision-making process into its constituent parts makes it easier to remedy.

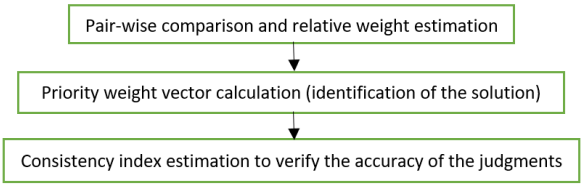

Figure 4. Three Steps of the AHP Model, source: [77]

TOPSIS is a helpful technique for dealing with multi-criteria decision-making problems and assisting decision-makers in organizing problems for solving, analyzing, comparing, and ranking. It is also a goal-oriented approach used to locate the nearest alternative to the ideal solution. Therefore, the selected alternative must be the one with the short focus range and greatest geometric distance from the positive and negative solutions, respectively. The spacing between the ideal solution and the ideal negative alternative is considered simultaneously. The alternative solutions are sorted in this method similarly to the ideal solution. It compares the similarity of options by measuring their distance to the ideal and quasi-solutions.

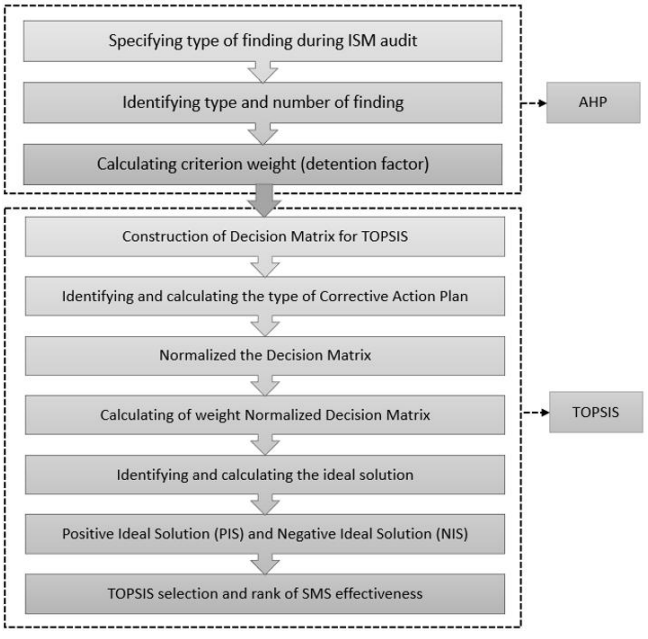

Figure 5. AHP – TOPSIS Model, source: [77]

4 CONCLUSION

The marine industry is associated with various categories of light to severe risks that can make workers experience problems in terms of health and safety. For this reason, good safety management is needed to minimize risk with a need for a certain standard for SMS called the ISM Code. Several preliminary studies have been conducted regarding SMS, which can be grouped into three. These include studies on the development, testing the effectiveness, and identifying the problem responsible for the occurrence of accidents. Furthermore, the three study groups were an inseparable circuit where the development of the source of safety problems is used to determine the model's effectiveness. In situations where the model is not optimal, it is necessary to analyze the source of other problems. Nevertheless, from various literatures, it is found that even with this standard, the ship can still be detained for various reasons. Therefore, this study suggests solving the problem by analyzing the finding during periodical verification using the combination method called AHP-TOPSIS

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