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MAPPING RESEARCH ON PPE USE AND RISK PERCEPTION IN THE MARITIME INDUSTRY: A BIBLIOMETRIC APPROACH

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ABSTRACT

Occupational safety in the maritime industry relies heavily on the use of Personal Protective Equipment (PPE) and the understanding of risk perception by ship crews. Despite this, there is still a gap in a comprehensive understanding of research patterns and developments in this area. This study aims to map and analyze research trends related to the use of PPE and risk perception in the maritime industry using a bibliometric approach. The research method used the Publish or Perish application to identify 50 relevant articles from the period 2014-2024, which were then analyzed using VOSviewer with the application of occurance 4 and term 23 criteria to produce network, overlay, and density visualizations. The results showed the dominance of Scandinavian countries in publications, with Sweden (9 publications) and Norway (7 publications) as the main contributors. Analysis of publication types showed a predominance of empirical research articles (34 publications), with peak productivity in 2018. VOSviewer identified three main clusters of research: operational aspects of PPE, regulation and compliance, and analysis and evaluation. The highest keyword frequencies were found in "safety" (21), "ship" (17), and "personal protective equipment" (16), indicating a major focus on safety aspects. Research gaps were identified in the aspects of integration of modern technologies, harmonization of international standards, and longitudinal evaluative studies. This study concludes that although the field has grown significantly, there are still substantial opportunities for more comprehensive research development, especially in the aspects of research methodology, impact analysis, and compliance evaluation of PPE use in the maritime industry.

Keywords: Personal Protective Equipment, Bibliometrics, Maritime Safety, Risk Perception, VOSviewer

INTRODUCTION

The maritime industry is a high-risk sector in terms of occupational safety, especially for crew members operating in complex and potentially hazardous environments. The use of Personal Protective Equipment (PPE) is one of the critical steps in reducing the risk of injury and ensuring the safety of individuals on board. However, the effectiveness of PPE depends not only on the availability and quality of the equipment, but also on the user behavior, safety culture, and risk perception of the crew members.

The use of Personal Protective Equipment (PPE) in the maritime industry is an important aspect of maintaining occupational safety and health. In this context, an understanding of crew behavior and risk perception is crucial to reducing accidents at sea. According to Prasetiawan (2023), good safety behavior among ship crews can significantly reduce the likelihood of accidents, which are often caused by human factors. This research aims to map the existing literature on PPE use and risk perception in the maritime industry, focusing on the various safety factors that influence crew compliance.

Boat crews often work in high-risk environments, where the proper use of PPE can be the last barrier against injury or death. This is reinforced by findings from Maritime Mutual (2023) which state that although the law requires the provision of PPE, many crew do not use PPE consistently. This situation creates an elevated risk scenario, making it important to understand the factors that influence PPE use behavior and risk perception among crew members.

In addition, safety culture among the crew also plays an important role in determining the level of compliance with the use of PPE. Research by Jung (2021) shows that a high awareness of safety culture among seafarers can improve their safety behavior. Thus, this study will explore the relationship between safety culture, safety training and compliance with PPE use in the context of maritime safety management.

While a number of studies have been conducted to explore the factors influencing PPE use in the maritime sector, there has been no comprehensive analysis that maps the related literature using a bibliometric approach. By identifying trends, themes and gaps in existing research, this study aims to provide a clearer picture of how PPE is used in the context of maritime safety and how risk perception may influence compliance with PPE use.

In this study, we will use keywords such as PPE, behavior, crew members, maritime safety, and safety training to collect and analyze relevant publications. The bibliometric approach that will be applied is expected to reveal patterns of research, relationships between variables, as well as the contribution of each study in building knowledge about factors affecting PPE use and risk perception in the maritime industry.

Through this research, it is expected to provide useful insights for stakeholders in the maritime industry, including policy makers, safety managers and researchers, to improve safety practices and promote a better safety culture in the maritime work environment.

THEORETICAL STUDIES

Personal Protective Equipment (PPE) is a very important piece of equipment in protecting workers from the risk of injury and illness that can arise from exposure to hazards in the workplace. In the context of the maritime industry, where the work environment is very risky, the use of PPE is mandatory. Workers are often exposed to a variety of hazards, ranging from chemicals to the possibility of

falling heavy objects. Therefore, according to Indonesian Law No. 1 of 1970, companies are obliged to provide appropriate PPE to maintain worker health and safety (Dzaky & Jar, 2024).

In the maritime industry, PPE can be categorized based on the part of the body being protected and the type of hazard being faced. For example, head protection such as safety helmets protect against impact, while ear protection, such as earplugs, is useful for reducing the impact of noise. Eye and face protection, such as goggles, help protect against chemical splashes. In addition, respirators are used to prevent inhalation of harmful dusts and gases, while safety gloves and shoes provide protection from physical risks and heavy objects. Finally, flame-resistant clothing and coveralls are used to protect the body from overheating and chemical splashes (Maritime Mutual, 2023; HSE, 1992).

The importance of PPE use in the maritime industry lies not only in the prevention of physical injuries, but also in reducing the risk of occupational diseases. The use of masks and respirators, for example, can significantly reduce exposure to harmful dust and chemicals that can cause long-term health problems (Ek et al., 2021). In addition, the proper wearing of PPE can increase safety awareness among workers. When wearing PPE, they become more aware of the risks around them and more disciplined in complying with safety procedures (Wright et al., 2019). Compliance with PPE use also helps companies meet applicable safety regulations, reducing the risk of legal sanctions and costs related to workplace accidents (Maritime Mutual, 2023). Thus, consistent application of PPE is an integral part of an effective safety strategy.

However, crew members' compliance in using PPE is influenced by various factors, both individual and organizational. One of the main factors is awareness and understanding of the importance of PPE use. Research shows that crews who have good knowledge of the risks and benefits of PPE tend to be more compliant in using it (Wisdha et al., 2021). The safety culture on board also plays an important role; a culture that supports safety will encourage crew members to comply with safety procedures, including the use of PPE (Maritime Mutual, 2023).

The availability and condition of PPE also matters. If PPE is not available or is in poor condition, crew members may be reluctant to use it (Putri & Hadi, 2014). In addition, weak supervision and policy enforcement can result in non-compliance with PPE use among crews (Ginandi et al., 2021). Environmental factors, such as bad weather or extreme working conditions, can also affect crew comfort and willingness to use PPE (Putri & Hadi, 2014).

The Theory of Planned Behavior (TPB) can help explain individuals' decisions to comply with PPE use. The TPB states that individual behavior is influenced by three main components: attitude toward the behavior, subjective norms, and perceived behavioral control (Ajzen, 1991). Positive attitudes towards PPE use, supportive norms, and the perception that they have control to use PPE effectively can increase compliance. By understanding these three components, companies can design more effective interventions to increase compliance among crew members.

Risk perception also plays an important role in individual safety measures. Risk perception refers to the subjective assessment of the likelihood of experiencing an accident or injury due to a particular hazard. Individuals with high risk perception tend to be more cautious and more likely to comply with safety procedures, including the use of PPE (Putri & Hadi, 2014). In contrast, individuals with low risk perception may neglect the use of PPE, thereby increasing the likelihood

of occupational accidents (Ginandi et al., 2021). Therefore, raising awareness about existing risks is an effective strategy to improve workplace safety.

Safety culture refers to the values, beliefs and norms held by individuals in an organization regarding occupational safety and health. In the maritime industry, safety culture is very important as it can influence the behavior of crew members and reduce the risk of accidents at sea. Organizations that have a good safety culture are characterized by effective communication and a shared perception of the importance of safety (Gadd & Collins, 2002). When safety culture is prioritized, crew members are more likely to comply with safety procedures and use the PPE provided.

Safety training also plays an important role in increasing crew members' awareness and compliance with PPE use. Effective training not only provides knowledge of the risks involved, but also exercises practical skills in using PPE correctly (Maritime Mutual, 2023). Clear policies on PPE use and regular monitoring and evaluation of crew members' compliance are essential to create a work environment that supports consistent PPE use (Gadd & Collins, 2002).

Safety regulations and standards, such as the International Safety Management (ISM) Code and the International Ship and Port Facility Security (ISPS) Code, provide a framework for maritime companies to ensure safe vessel operations. Strict policies regarding the use of PPE can improve compliance among crew members. Research shows that clear policies on PPE use contribute to the reduction of occupational accidents (Ek et al., 2021). Therefore, effective policy implementation is essential for risk management in the maritime industry.

Environmental factors also have a significant influence on PPE use. Ergonomic vessel design can facilitate access to protective equipment, while adverse weather conditions can hinder comfort in using PPE (Wisdha et al., 2021). Crew members often face challenges in implementing PPE use, including discomfort when wearing protective equipment under certain conditions or a lack of understanding of the importance of PPE use. Research shows that lack of support from management is also a significant barrier to compliance with PPE use (Putri & Hadi, 2014).

Overall, the use of PPE in the maritime industry is essential to protect workers' health and safety. Despite numerous studies demonstrating the importance of PPE use, there are still gaps in the literature regarding the specific factors that influence compliance across different maritime contexts. Therefore, further research is needed to understand variables such as local culture and individual work experience as well as the effectiveness of training interventions that can improve compliance with PPE use. With the right measures in place, companies can create a safe working environment and support occupational safety in the maritime industry.

RESEARCH METHODS

This research method began with the use of the Publish or Perish (PoP) application, which is a tool designed to assist researchers in analyzing citations and academic literature. In the context of this research, the first step was to conduct a search for relevant articles within the time span of 2014 to 2024, focusing on 50 articles relating to keywords such as Personal Protective Equipment (PPE), behavior, crew members, maritime safety, safety factors, compliance, individual safety, passenger vessels, safety management, risk perception, safety culture, safety training, safety

supervision, and port regulations. The search process was conducted on Google Scholar, which is recognized as a trusted source for scientific literature. By using a predetermined combination of keywords, the researcher was able to browse through various articles, journals and academic publications relevant to the topic under study.

After obtaining the initial list of articles, the next step was to select and screen the articles based on relevance and thematic fit. The researcher assessed each article to ensure that the discussion was in line with the broader research focus on PPE use and risk perception in the maritime industry. The selected articles were further analyzed to identify important aspects related to crew members' behavior in using PPE. This includes factors that influence compliance, challenges faced, and recommendations in the literature.

The data retrieved from the PoP application includes a number of important parameters, which are then distributed based on year of publication, country of publication, publisher, number of citations, and article type. By categorizing the data based on these categories, researchers can identify publication trends, collaboration patterns between authors, and contributions from different research institutions in the field of maritime safety. Researchers can also analyze the contribution of certain countries to the development of literature in this field, as well as see if there is a higher concentration of research in certain countries.

After the data collection and distribution stage, the information was stored for further processing using the VOSviewer application, which is a tool specifically designed for bibliometric analysis. In this application, we applied occurance criteria of 4 and terms of 23, which allowed for a more focused and in-depth mapping of important elements in the literature under study. These criteria helped in identifying the most frequently occurring keywords, as well as the relationship between the keywords and the articles.

The use of VOSviewer in this study is essential because this tool allows researchers to produce in-depth visualizations of bibliometric networks. Through Network Visualization, researchers can see the relationships between various elements such as authors, articles, and keywords in the scientific literature more clearly. This visualization helps in identifying clusters of interrelated research, so that researchers can understand the dynamics of collaboration among researchers around the world. In addition, the Overlay Visualization provides additional information regarding the time progression of the various elements involved, allowing researchers to track research trends from year to year. The Density Visualization, on the other hand, shows the intensity and concentration of research in specific areas, allowing researchers to highlight the most actively researched topics in the context of maritime safety and PPE use.

As such, VOSviewer not only assists in mapping emerging research trends, but also reveals patterns of collaboration among researchers. This provides valuable insights into how researchers in different countries contribute to the understanding and improvement of safety practices in the maritime industry. This analytical process is expected to provide a comprehensive picture of PPE use and risk perception in maritime work environments, while enriching the

existing literature by highlighting key topics for further research.

In conclusion, this study utilized a bibliometric approach to explore various aspects related to PPE use and risk perception in the maritime industry. By utilizing advanced tools such as PoP and VOSviewer, the researcher hopes to make a significant contribution to the development of knowledge in the field of maritime safety, as well as offer useful recommendations for best practices in the use of PPE by crew members. The findings from this study are expected to provide a foundation for further research as well as better policies in safety management in the maritime sector.

RESEARCH RESULTS

Country

Based on the available data, it is possible to see publication trends related to PPE use and risk perception in the maritime industry spread across various countries. Sweden occupies the highest position with a total of 9 publications, indicating the high attention to this topic in their academic research. Norway also shows significant interest with 7 publications, followed by China with 5 publications. This could indicate the focus of Northern European countries, particularly Sweden and Norway, in researching safety aspects and PPE use in the maritime sector, which may be related to the strict occupational safety regulations in the region.

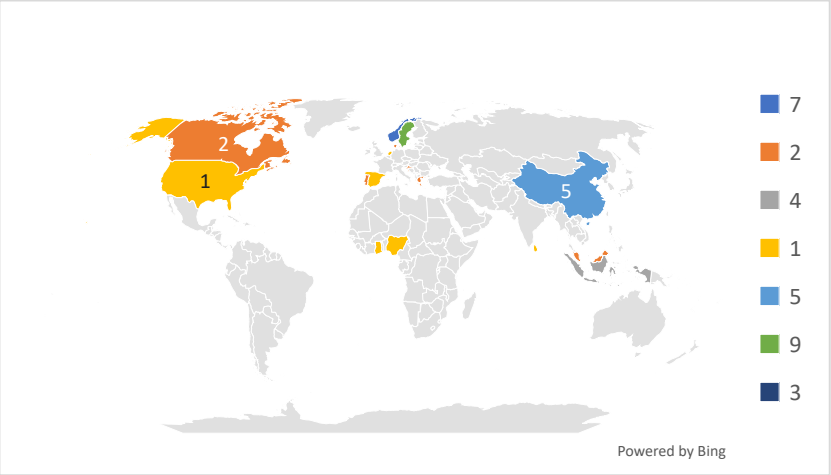

Figure 1. Country

By Article Type

Based on the data regarding the type of publication, it can be seen that the majority of publications related to PPE use and risk perception in the maritime industry are in the form of research articles with a total of 34 articles. This shows that most research in this field tends to be empirical, where researchers collect data and conduct direct analysis to understand the various factors that influence PPE use and safety in the maritime environment. Research articles generally provide richer data and in-depth analysis, thus contributing greatly to the development of knowledge in this field.

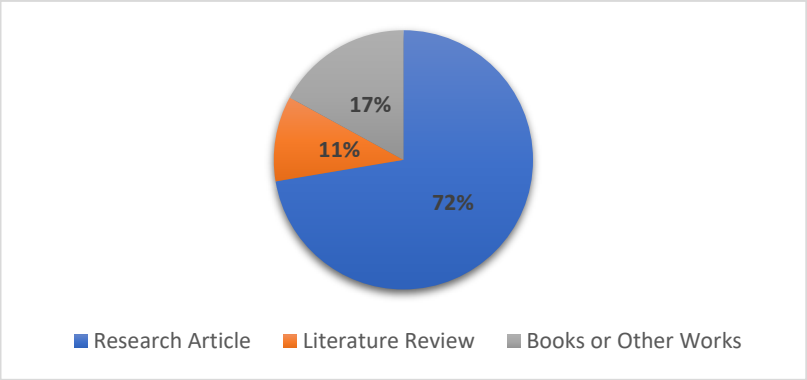

Figure 2. By Article Type

By Year

Based on research publication data on PPE Use and Risk Perception in the Maritime Industry from 2014 to 2024, the development trend can be analyzed as follows:

This research started with 4 publications in 2014, but experienced a significant decline to only 1 publication in 2015. There was a rebound to 4 publications in 2016, followed by a decline to 2 publications in 2017. The research momentum peaked in 2018 with 8 publications, which marked the year with the highest productivity in this period.

After 2018, the number of publications tends to be stable with minor fluctuations: 5 publications (2019), 6 publications (2020), 5 publications (2021), 6 publications (2022), and 5 publications (2023). At the beginning of 2024, there were already 4 publications, which shows a positive trend considering that the year has not yet ended.

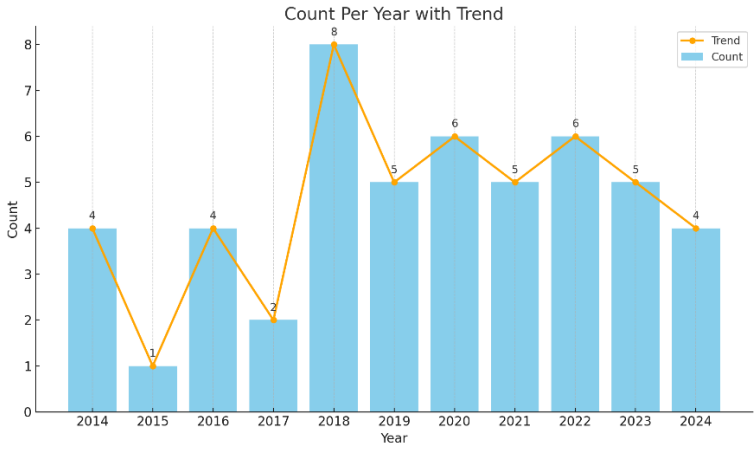

Figure 3. By Year

Based on Publisher

Based on the publisher data, it can be seen that Elsevier tops the list with a total of 6 publications, signifying the dominance of this publisher in the dissemination of research related to PPE use and risk perception in the maritime industry. Elsevier is a leading publisher that focuses on high-quality scientific publications, so many maritime safety-related studies are published in their journals.

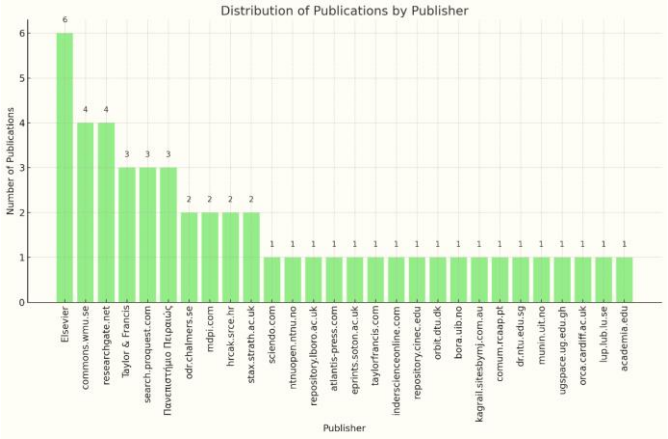

Figure 4. Based on Publisher

Based on Keyword Occurrence

From the table above, it can be seen that the word "safety" has the highest frequency of occurrence (21 times), followed by "ship" (17 times) and "personal protective equipment" (16 times). This shows that safety and the use of PPE are the main focus of maritime research. Meanwhile, words such as "conduct" and "research" had the lowest frequency of occurrence (4 times), which may indicate areas that still require further research development.

Table 1. Based on Keyword Occurrence

Keywords	Occurrences
safety	21
ship	17
personal protective equipment	16
ppe	15
supervision	14
passenger	12
vessel	11
training	10
safety culture	9
risk	9
crew	9
accident	8
compliance	7
seafarer	6
procedure	6
work	6
analysis	5
impact	5
use	5
passenger ship	5

conduct	4
research	4

From the table above, it can be seen that the word "safety" has the highest frequency of occurrence (21 times), followed by "ship" (17 times) and "personal protective equipment" (16 times). This shows that safety and the use of PPE are the main focus of maritime research. Meanwhile, words such as "conduct" and "research" had the lowest frequency of occurrence (4 times), which may indicate areas that still require further research development.

VOSviewer Network Visualization Discussion

Based on the VOSviewer network visualization displayed, I can provide a narrative analysis of the research mapping on the Use of PPE (Personal Protective Equipment) and Risk Perception in the Maritime Industry as follows:

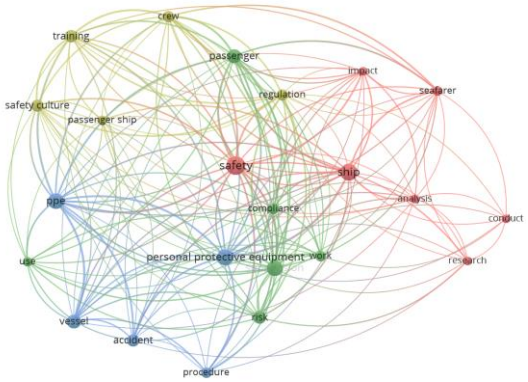

Figure 5. VOSviewer Network Visualization Discussion

VOSviewer Overlay Visualization Discussion

Based on the VOSviewer overlay visualization, I can provide a narrative analysis of the research mapping on PPE Use and Risk Perception in the Maritime Industry. This visualization shows three main cluster groups that have different characteristics in their publication development:

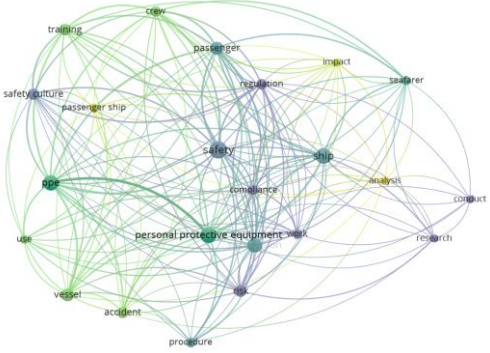

Figure 6. VOSviewer Overlay Visualization Discussion

VOSviewer Density Visualization Discussion

Based on the VOSviewer density visualization, I can provide an in-depth analysis of the density of research publications related to PPE Use and Risk Perception in the Maritime Industry:

The areas with the highest density (red-orange color) are centered on several main keywords namely "safety", "ship", "personal protective equipment", and "ppe". This indicates that the most intense research focuses on basic safety aspects and the use of personal protective equipment on ships. The strong red area around "personal protective equipment work" indicates the high intensity of research on PPE implementation in the context of maritime work.

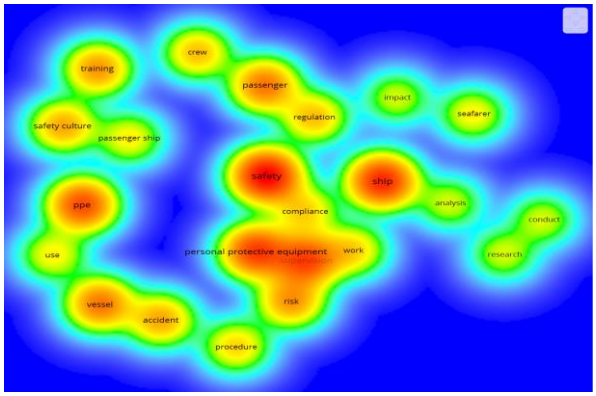

Figure 7. VOSviewer Density Visualization Discussion

DISCUSSION

Country

Based on the available data, it is possible to see publication trends related to PPE use and risk perception in the maritime industry spread across various countries. Sweden occupies the highest position with a total of 9 publications, indicating the high attention to this topic in their academic research. Norway also shows significant interest with 7 publications, followed by China with 5 publications. This could indicate the focus of Northern European countries, particularly Sweden and Norway, in researching safety aspects and PPE use in the maritime sector, which may be related to the strict occupational safety regulations in the region.

Indonesia comes next with 4 publications, indicating that this topic is also gaining attention in the Southeast Asian region. On the other hand, some countries such as the UK, Croatia, Greece, Malaysia, Denmark and Canada have 2 publications each. These countries show moderate interest in this research, perhaps due to maritime security or occupational safety factors in their local industries.

Other countries such as Genova, Spain, Scotland, Turkey, Netherlands, Sri Lanka, USA, Portugal, Nigeria, Gambia and Ghana have only 1 publication each, indicating a relatively lower or limited interest in this field. This could be due to different research priorities or lack of funding for maritime safety-related studies.

Overall, this trend suggests that research related to PPE and risk perception in the maritime industry remains centered in a few key countries with significant maritime

interests or experience. This clustering of research underscores the importance of geographic context in safety research priorities, with European and Asian countries showing a strong interest in developing safety practices in the maritime industry.

The figure above shows the distribution of the number of publications related to PPE use and risk perception in the maritime industry by country. Sweden takes the top spot with 9 publications, followed by Norway and China with 7 and 5 publications respectively. This shows the high interest of Northern European countries and China in the topic of maritime safety.

Indonesia also has a significant contribution with 4 publications, which shows the increasing attention to safety in the maritime sector in Southeast Asia. Countries such as the United Kingdom, Croatia, Canada, Portugal, Denmark and Malaysia contributed 2 publications each, while other countries, such as the United States, the Netherlands and some African countries, had 1 publication each.

This distribution indicates that maritime safety research and PPE use are more prominent in European countries, which may be related to the strict occupational safety standards and advanced maritime industry in the region.

By Article Type

Based on the data regarding the type of publication, it can be seen that the majority of publications related to PPE use and risk perception in the maritime industry are in the form of research articles with a total of 34 articles. This shows that most research in this field tends to be empirical, where researchers collect data and conduct direct analysis to understand the various factors that influence PPE use and safety in the maritime environment. Research articles generally provide richer data and in-depth analysis, thus contributing greatly to the development of knowledge in this field.

Furthermore, there are 8 publications in the form of books or other works that include practical guides, safety manuals or other texts that support the understanding of safety concepts in the context of the maritime industry. These books and works often serve as references for practitioners and academics to access comprehensive information on safety procedures and best practices in the industry.

There are 5 publications in the literature review, which shows the researchers' efforts in summarizing and analyzing the results of previous studies. Literature reviews help build a strong theoretical framework and point out research gaps that can be followed up in future studies. Finally, there are 3 publications in the form of reports or white papers, which are generally published by organizations or institutions to provide insight into specific policies or findings related to maritime safety.

This distribution shows that research in the field of maritime safety and PPE use is still dominated by direct research (empirical), but publications in the form of books and literature reviews also play an important role in providing theoretical foundations and practical references.

The graph above illustrates the distribution of the number of publications by article type. Research articles dominate with a total of 34 publications, indicating that most research in the field of maritime safety and PPE use is conducted empirically. Followed by books or other works totaling 8 publications, which serve as guides

or broader references for academics and practitioners. Literature reviews amounted to 5 publications, which provide theoretical foundations and develop theoretical frameworks related to this topic. Finally, reports or white papers numbered 3 publications, indicating a contribution from an organization or institution in disseminating insights related to specific policies or findings.

This distribution shows that empirical research is still the main focus in understanding PPE use and safety in the maritime industry, while publications in the form of books and literature reviews also play a role in providing theoretical and practical references that support the development of this field.

By Year

Based on research publication data on PPE Use and Risk Perception in the Maritime Industry from 2014 to 2024, the development trend can be analyzed as follows:

This research started with 4 publications in 2014, but experienced a significant decline to only 1 publication in 2015. There was a rebound to 4 publications in 2016, followed by a decline to 2 publications in 2017. The research momentum peaked in 2018 with 8 publications, which marked the year with the highest productivity in this period.

After 2018, the number of publications tends to be stable with minor fluctuations: 5 publications (2019), 6 publications (2020), 5 publications (2021), 6 publications (2022), and 5 publications (2023). At the beginning of 2024, there were already 4 publications, which shows a positive trend considering that the year has not yet ended. This publication pattern shows some important characteristics:

1. Stability: Although there are fluctuations, since 2019 the number of publications has remained relatively stable between 5-6 publications per year.
2. Consistency: This topic continues to interest researchers with continuous publications over the past 11 years.
3. Momentum: 2018 was a turning point with a significant surge, marking increased attention to the topic.
4. Sustainability: The consistent publication trend until 2024 demonstrates the continued relevance of this research topic.

The visualization above helps to illustrate the dynamics of the development of this research more clearly, showing an up-and-down pattern that has finally reached stability in recent years.

Based on Publisher

Based on the publisher data, it can be seen that Elsevier tops the list with a total of 6 publications, signifying the dominance of this publisher in the dissemination of research related to PPE use and risk perception in the maritime industry. Elsevier is a leading publisher that focuses on high-quality scientific publications, so many maritime safety-related studies are published in their journals.

ResearchGate.net and commons.wmu.se have 4 publications each, demonstrating the important role these research sharing platforms play in disseminating research results in the field of maritime safety. Platforms like ResearchGate make it easy for researchers to access and share information directly, while commons.wmu.se, managed by the World Maritime University, highlights a specific focus on the maritime sector.

Furthermore, Taylor & Francis, search.proquest.com, and Πανεπιστήμιο Πειραιώς have 3 publications each. Taylor & Francis is also a well-known academic publisher, while ProQuest provides access to a

wide range of scholarly articles. Πανεπιστήμιο Πειραιώς, which is the University of Piraeus in Greece, shows a high interest in safety research in the maritime sector, possibly because Greece has a long history in the shipping industry.

Some other institutions, such as stax.strath.ac.uk and mdpi.com, have 2 publications. Meanwhile, there are a number of publishers and repositories with only 1 publication, such as eprints.soton.ac.uk, dr.ntu.edu.sg, orca.cardiff.ac.uk, and academia.edu. The wide distribution across publishers and repositories shows that research in this field is not only centered on one major publisher but also spread across various open access platforms and academic institutions.

This distribution indicates the importance of research accessibility through open platforms and university repositories, allowing more researchers to access information and study results related to maritime safety.

The following is a visual illustration in the form of a bar graph showing the distribution of the number of publications by publisher. The graph above shows the distribution of the number of publications by publisher. Elsevier dominates with 6 publications, followed by ResearchGate.net and commons.wmu.se with 4 publications each. This shows the important role publishers and open platforms play in disseminating maritime safety-related research. Taylor & Francis, search.proquest.com, and the University of Piraeus in Greece (Πανεπιστήμιο Πειραιώς) have 3 publications each, indicating the great interest of these academic publishers in maritime topics.

Other publishers and platforms, such as mdpi.com, stax.strath.ac.uk, and some university repositories, show a more dispersed distribution of publications, each with 2 or fewer publications. This reflects the breadth of access and diversity of platforms used to publish research in this area, with involvement from large publishers to specific academic repositories.

Based on Keyword Occurrence

From the table above, it can be seen that the word "safety" has the highest frequency of occurrence (21 times), followed by "ship" (17 times) and "personal protective equipment" (16 times). This shows that safety and the use of PPE are the main focus of maritime research. Meanwhile, words such as "conduct" and "research" had the lowest frequency of occurrence (4 times), which may indicate areas that still require further research development.

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Based on the frequency analysis of keywords in research publications on PPE Use and Risk Perception in the Maritime Industry, there are some significant patterns. The word "safety" emerged as the dominant theme with 21 occurrences, followed by "ship" (17 occurrences) and "personal protective equipment" (16 occurrences). This indicates that the main focus of the research lies on safety and the use of personal protective equipment in the context of shipping.

The medium-frequency word groups include "ppe" (15 occurrences), "supervision" (14 occurrences), and

"passenger" (12 occurrences), indicating considerable attention to the aspects of passenger supervision and safety. Meanwhile, words such as "vessel" (11 occurrences), "training" (10 occurrences), and the combination of "safety culture", "risk", and "crew" (9 occurrences each) indicate the importance of training, safety culture, and risk management in the context of ship crews.

It is interesting to note the relatively low frequency for some important aspects such as "compliance" (7 occurrences), "work" and "seafarer" (6 occurrences each), as well as "analysis", "impact", and "use" (5 occurrences each). The lowest frequency was found for the words "conduct" and "research" (4 occurrences each), which may indicate the need for further research in the aspects of research methodology and conduct.

This distribution pattern illustrates that while safety and PPE use have been a major focus, there is still room for research development in areas such as compliance, impact analysis and research methodology. It also indicates potential research gaps that could be filled with in-depth studies on aspects that currently have a low frequency of occurrence in the literature.

VOSviewer Network Visualization Discussion

Based on the VOSviewer network visualization displayed, I can provide a narrative analysis of the research mapping on the Use of PPE (Personal Protective Equipment) and Risk Perception in the Maritime Industry as follows:

The network visualization shows three main interconnected clusters, marked with different colors (red, green, and blue). At the center of the network, the keyword "safety" has a large node size, indicating that safety is the main focus and link in this research. The green "personal protective equipment work" node also has a significant size, indicating its role as a central theme in this study.

The first cluster (red) connects the related aspects of "ship", "seafarer", "impact", "research", and "analysis", reflecting the research focus on the impact and analysis of seafarer safety on ships. The second cluster (green) integrates "risk", "compliance", "passenger" and "regulation", reflecting the regulatory and compliance aspects of risk management in the maritime industry. While the third cluster (blue) connects "ppe", "accident", "vessel", "use", and "procedure", indicating a focus on the implementation of procedures for the use of PPE and accident prevention on ships.

Interestingly, there is a strong connection between "safety culture" and "training" with "crew", indicating the importance of training and safety culture in crew development. The connection between "passenger ship" and various other nodes indicates a special attention to safety aspects on passenger ships. The density of connecting lines between nodes indicates the high interconnectivity between research themes, reflecting the complexity and close interrelationship between PPE use, risk perception and various aspects of safety in the maritime industry.

This overall visualization illustrates that research on PPE use and risk perception in the maritime industry has evolved into a comprehensive field, covering aspects of safety, regulation, training, and procedure implementation, with a particular focus on crew and passenger protection.

Based on the VOSviewer network visualization, the following is a summary of the main research gaps related to PPE Use and Risk Perception in the Maritime Industry:

1. The lack of research on the integration of modern technology (smart PPE and IoT) in the monitoring system for PPE use on ships.
2. There are limited studies on the relationship between psychosocial

factors (work stress, fatigue) and ergonomic aspects with PPE compliance.
3. Lack of research evaluating the effectiveness of PPE training programs and harmonizing standards across cultures/jurisdictions.
4. Gaps in economic/cost-benefit analysis of PPE program implementation and its integration with risk management systems.
5. Limited research on PPE adaptation to environmental change and multi-stakeholder collaboration models.

This gap opens up research development opportunities to improve the effectiveness of PPE use in the maritime industry.

VOSviewer Overlay Visualization Discussion

Based on the VOSviewer overlay visualization, I can provide a narrative analysis of the research mapping on PPE Use and Risk Perception in the Maritime Industry. This visualization shows three main cluster groups that have different characteristics in their publication development:

The first cluster (green color) indicates a focus on the operational aspects of PPE use, which includes nodes such as "ppe", "use", "vessel", and "accident". This cluster indicates earlier and more fundamental research, focusing on the basic implementation of PPE use on vessels and accident prevention. The strong connection between "ppe" and "use" suggests that the practical aspects of PPE use were a major concern in the early period of research.

The second cluster (blue) centers on regulatory and compliance aspects, characterized by nodes such as "regulation", "compliance", and "risk". This cluster represents a more recent research development, where the focus shifts to regulatory aspects and standardization of PPE use. This reflects the evolution of research towards a more systematic and structured approach to maritime safety management.

The third cluster (yellow to purple shading) covers aspects of advanced analysis and research, with nodes such as "research", "analysis", "impact", and "conduct". This cluster illustrates recent research trends that are more complex and in-depth, focusing on impact evaluation and analysis of PPE program effectiveness. The connection between "impact" and "analysis" indicates an increased interest in measuring and evaluating the results of safety program implementation.

The "safety" node at the center of the visualization with connections to various clusters shows that safety remains a central theme that connects various aspects of research over time. Meanwhile, "personal protective equipment work", which has a large node size, indicates that this topic has become a major focus in recent research developments.

The overlay visualization also shows the temporal evolution of the research, where lighter colours (green) indicate earlier publications, while darker colours (purple) indicate more recent publications. This shows how the research focus has evolved from basic operational aspects to more comprehensive and systematic analysis of the maritime industry.

Based on the VOSviewer overlay visualization, the following is a summary of the main research gaps in the study of PPE Use and Risk Perception in the Maritime Industry:

1. The lack of studies on the integration of modern technology (smart PPE, IoT, digital monitoring) in the development of PPE systems in the maritime industry.
2. Limited research on the harmonization and effectiveness of PPE regulation implementation in a cross-border maritime context.
3. Gaps in standardized measurement methods and longitudinal studies for PPE program evaluation.

4. There is a lack of research on the interaction between human and technological factors, including acceptance and cultural aspects in the adoption of PPE innovations.
5. There are limited studies on the adaptation and sustainability of PPE systems to changes in the maritime industry.

These gaps provide research development opportunities to improve the effectiveness of PPE systems in the maritime industry.

VOSviewer Density Visualization Discussion

Based on the VOSviewer density visualization, I can provide an in-depth analysis of the density of research publications related to PPE Use and Risk Perception in the Maritime Industry:

The areas with the highest density (red-orange color) are centered on several main keywords namely "safety", "ship", "personal protective equipment", and "ppe". This indicates that the most intense research focuses on basic safety aspects and the use of personal protective equipment on ships. The strong red area around "personal protective equipment work" indicates the high intensity of research on PPE implementation in the context of maritime work.

The medium density zone (yellow-green color) includes several groups of interconnected keywords. The first group includes "training", "crew" and "safety culture", indicating a significant research focus on training and safety culture development. The second group includes "passenger", "regulation" and "compliance", indicating moderate attention to regulatory and compliance aspects in the context of passenger safety.

Areas with lower density (blue-green color) are seen in keywords such as "research", "conduct", "analysis", and "impact". This suggests that the analytical and evaluative aspects still have room for further research development. Similarly, the keyword "seafarer" in the low density area indicates that seafarer-specific research still needs to be improved.

This density pattern also reveals interesting connections between different aspects of research. For example, the gradual transition from the "vessel" and "accident" areas towards "risk" and "procedure" shows how research has evolved from a focus on accident occurrence towards a more proactive risk management approach. Meanwhile, the strategic position of "compliance" among the high-density areas reflects its role as a link between regulatory aspects and practical implementation of PPE.

This density visualization also reveals some areas that require more attention in future research, especially in integrating aspects currently in the low-density zone with established key themes. This could include the development of more comprehensive research methodologies, long-term impact analysis, and in-depth studies of factors influencing compliance with PPE use in maritime environments.

Based on the VOSviewer density visualization, the following is a summary of the research gap in the study of PPE Use and Risk Perception in the Maritime Industry:

1. The low-density (blue-green) areas of "research" and "analysis" indicate a lack of comprehensive methodological and evaluative research.
2. The lack of density in the "impact" area indicates limited studies on the long-term impact of PPE implementation.
3. The low-density "seafarer" area indicates a lack of specific research on seafarers' needs and behaviors related to PPE use.
4. Gaps were seen in the integration between "compliance" and "safety culture", indicating the need for research on the relationship between safety culture and compliance.

5. The low density between "procedure" and "risk" indicates a lack of research on the effectiveness of procedures in PPE risk management.

These gaps provide opportunities for more

CONCLUSIONS

Based on a bibliometric analysis on PPE Use and Risk Perception in the Maritime Industry, research is dominated by Scandinavian and Asian countries, with Sweden (9 publications) and Norway (7 publications) as the main contributors. Empirical research articles dominated (34 publications), with peak productivity in 2018. In terms of publishers, Elsevier (6 publications) and ResearchGate (4 publications) are the main platforms for research dissemination.

VOSviewer analysis showed three main clusters focusing on operational aspects of PPE, regulation and compliance, and analysis and evaluation. The highest keyword frequencies were found in "safety" (21), "ship" (17), and "personal protective equipment" (16), illustrating the main focus of the study on safety and PPE use. Meanwhile, the low frequency of words such as "compliance" (7), "analysis" (5), and "research" (4) indicate areas that still need development.

Research gaps were identified in several aspects: integration of modern technology in PPE systems, harmonization of international standards, longitudinal evaluative studies, and adaptation of systems to changes in the maritime industry. Although research in this area has progressed significantly, there is still ample opportunity for the development of more comprehensive and integrated studies, especially in aspects of research methodology, impact analysis, and compliance evaluation.

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