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Maritime Safety Bibliometric Mapping and Analysis using VOSviewer

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ABSTRACT

The aim of this research was to examine the unique characteristics of publications, show the scope of knowledge, and chart research directions in the field of maritime safety. This was achieved through a reference search made in the Scopus database using the keyword "maritime safety" based on the criteria that the research articles were open-access and published in English. The search led to the retrieval of 476 articles stored in RIS format followed by the completion of the data using Mendeley. The data were subsequently analysed using VOSviewer software and a total of 3349 authors were found including a minimum of 5 used in most of the articles and another 99 with full co-author relationships in addition to being counted. Moreover, 99 authors had the largest total link strength and were further divided into 9 clusters.

1. Introduction.

Maritime transportation is a manifestation of globalization and considered very important for world stability. This is because shipping activities facilitate global trade and this further influences the economies of developed and developing countries. Moreover, shipping activities enable massive trade in natural resources and commodities needed by humans, including energy, foodstuffs, raw materials, and other manufactured goods using ships. This was showed by the report showing that international trade was physically around 98,140 vessels operated by more than 1.5 million seafarers (Maes et al., 2022). However, 60.06% of the accidents in most transportation systems, including land, sea, and air were reported to be caused by human factors (Xia et al., 2021). This means working onboard ships is a risky occupation and has become a matter of public concern due to the high level of safety uncertainty identified from safety science perspective. Therefore, quality and reliable human resources are very important to ensure safety at work. This is necessary because 30.77% of ship accidents have been identified to be caused by poor communication and coordination while poor supervision and support from ineffective ship management contributed 32.69% (Fan et al., 2020).

Seafarers are currently being faced with the problems associated with workload pressure from continuous operation, supervision and administration while the ship is sailing. Moreover, the reduction of crew members in modern shipping systems was reported to have the capacity to create new challenges related to risk assessment on ships (Liu et al., 2022). The idea intended to reduce labour costs for the company but it could lead to certain risks in workload and technological capabilities. Furthermore, the development of automation systems does not guarantee a lower workload for seafarers and excessive reliance on automatic navigation systems and satellite navigation systems can result in less than optimal supervision (Hannaford & Hassel, 2021).

Several factors are observed to be influencing human behaviour in decision-making processes and these include mental workload, emotions, and fatigue (Coraddu et al., 2020; Ramos et al., 2018). Effective communication is considered essential to reduce the risk of operational errors (Wadhera et al., 2010). This means the crew of a ship needs appropriate and continuous training to understand safety culture as well as effective and efficient communication in order to improve shipping safety. Another point is that the attitudes and behaviour associated with the personality, perception and mental attitudes of an individ-

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ual can influence performance. This is confirmed by the results of a previous research that individual and behavioural factors have a positive influence on the performance of ship crew in achieving effective and efficient ship operations (Ahvenjärvi, 2016). It has been stated that the attitudes of the management of a shipping company towards safety, knowledge, regulations, and employee satisfaction are very important to the operations of the company (Håvold, 2005).

Safety culture is defined as the collective beliefs and values within an organization that pertain to safety. Establishing an effective safety culture includes proactively preventing accidents and incidents, which often result from the accumulation of unsafe actions or procedural misuse. This means shipping companies should formulate policies and undertake continuous improvements in pursuit of a zero Accident environment to prioritize the well-being of the crew during their work (Ahuja & Khamba, 2008; Giannelou, 2019). Safety culture is shaped by several factors, including the ship owner, the ship's flag, the nature of the work, the age of the ship, and the country of origin of the crew. It is important to state that there is no significant difference between different types of tankers but some cultural and organizational factors have a substantial impact on safety culture (Håvold, 2010).

Bibliometric research has gained widespread prominence in recent years due to its ability to provide comprehensive insights into various topics. It is useful in analysing the research conducted in different scientific disciplines and allows the visualization of global trends and further research (Ahmed et al., 2022; Guo et al., 2021; Song et al., 2016). This means bibliometric analysis allows readers to identify past research trends with an indication of the progress and the space for further research (Durieux & Gevenois, 2010). Co-citation analysis was proved to have been used in most of the methods to determine the scientific foundation in a particular field and this focused on exploring the cited documents, authors, and literary sources (Kumar & Goel, 2022). Moreover, some relevant analyses related to the research topic have been combined with cluster method to identify research directions and development trends in certain fields based on the keywords determined (Buber & Koseoglu, 2022).

VOSviewer is the software commonly used for bibliometric analysis because it allows co-citizen and co-occurrence network analysis across a wide spectrum of scientific disciplines including maritime. This method normally supports the efforts to determine and identify the knowledge base, research direction, and development trends in certain scientific discipline domains by analysing the relationship between quotations and keywords appearing together in the literature (Perumal & Muthuramalingam, 2022).

This research was conducted by combining several methodological methods including statistical, co-citation, and cluster analyses. The statistical analysis was used to describe the annual distribution of publications and identify new trends to provide key contributions. Co-citation analysis was used to present important research domains as well as to operationalize the structure of academic networks. The identification of a large size showed the accumulative citation frequency of a particular document (Van Eck et al., 2010) and showed the existence of a greater number of citations for the document. Meanwhile, cluster analysis was applied to provide insight into the research direction based on the trends, keyword frequency, and cluster distribution in the co-occurrence network graphs (Buber & Koseoglu, 2022; Van Eck et al., 2010). The main objective of this research was to examine the unique characteristics of publications, show the scope of knowledge, and map directions about the studies conducted in relation to maritime safety. The purpose was to provide insights for scholars interested in further research in the field.

2. Method.

The data used were collected quantitatively by searching for literature reviews on maritime safety in the Scopus database. The first stage was focused on searching titles and abstracts using the keywords "maritime AND safety" and the selection of filter criteria including the fields of engineering and environmental science, journal articles, English language, and open access. This was achieved using the search query: TITLE-ABS-KEY (maritime AND safety) AND (LIMIT-TO (LANGUAGE, "English")) AND (LIMIT-TO (OA, "all")) AND (LIMIT-TO (DOCTYPE, "ar ")) AND (LIMIT-TO (SUBJAREA, "ENGI") OR LIMIT-TO (SUBJAREA, "ENVI")) AND (LIMIT-TO (SRCTYPE, "j")). The search was made on October 10, 2023 at 09.30 and produced 1083 published articles with an h-index of 58.

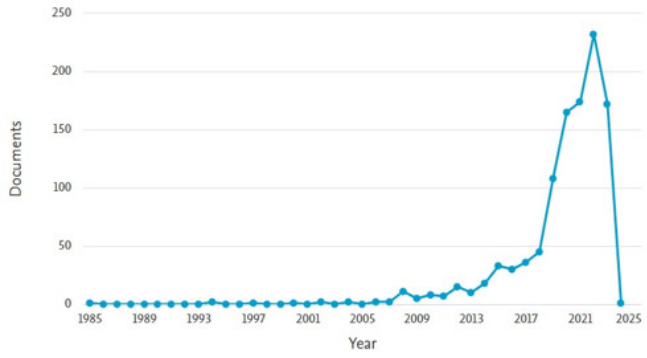
The second stage was the application of the Scopus analyser to determine the number of documents per year based on the journal type, author, affiliation, country, and subject. The data obtained were stored in RIS format and updated with Mendeley. Meanwhile, the third stage was focused on data processing using VOSviewer 1.6.1.9 software in order to map and visualize the relationship between the variables with keywords related to maritime safety and other materials. This was used to produce more comprehensive and easier-to-use articles.

3. Results and Discussion.

Research analysis conducted through searches on the Scopus database showed a consistent upward trend in maritime safety publications from 1985 to 2023. The literature surveyed included journal articles in English from open-access journals, with a focus on the selected keywords "maritime safety." A total of 1083 articles were identified through the comprehensive search.

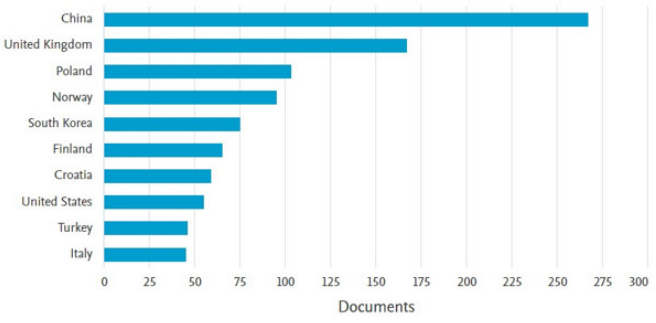
Figure 1 shows that the development of publications document regarding maritime safety began to appear in 1985 with 1 article and the number increased to 11 in 2008 but remained stagnant at 45 up to 2018. The number later increased significantly to 108 in 2019 and peaked at 232 in 2022. The number of publications based on country is presented in Figure 2 and it was discovered that China had the highest with 267 articles followed by the United Kingdom with 167, Poland had 103, South Korea with 75, Finland with 65, Croatia with 59, United States 55, Turkey 46, and Italy 45.

Figure 1: Number of publications according to year.



Source: Authors.

Figure 2: Number of publications according to country of author.



Source: Authors.

Bibliometric research are also advantageous due to their ability to determine the most prominent authors in a particular field of science (McCain, 1990; Nerur et al., 2008; White & McCain, 1998). It was discovered from the number of articles cited that several authors have published articles related to the topic such as Okino, Goerlandt, Montewka, Wrobel, and Bueger. This was found to be in line with the argument of this research that maritime safety was a new concept as showed by the 15 articles observed to have the highest number of citations in Table 1.

VOSviewer series 1.6.19 software was used to process the data obtained through the selection of a map to determine the reference data on co-authorship, keyword co-occurrence, citation, bibliographic coupling, or co-citation. This was followed by the selection of the article data in RIS form from the Reference Manager. Moreover, analysis was conducted based on c-authorship and the indication of authors as the unit at full counting. The results showed a total of 3349 authors with a minimum of 5 discovered to have been used while 99 had full co-author relationships in addition to being counted. It was further observed that 99 authors had the greatest total link strength.

The 99 items identified from the visualization results of VOSviewer were divided into 9 clusters as shown in Figure 3. Cluster 1 consisted of AIS, Automatic Identification System, ColRegs, Cyber Security, Deep Learning, Marine Accident, Marine Navigation, Marine Safety, Maritime Navigation,

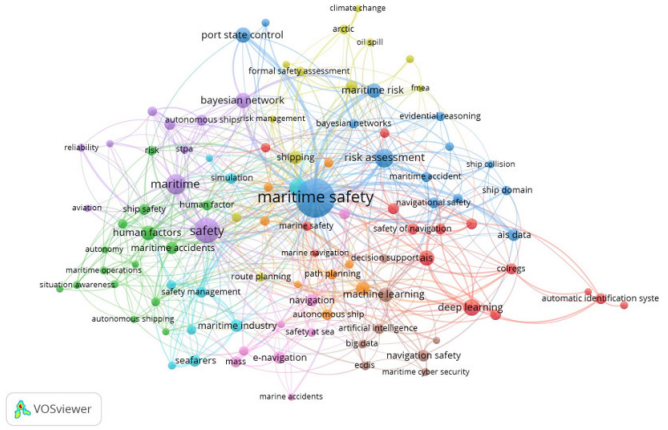
Table 1: Articles with the most citations.

No	Document title	Author	Journal	Year	Citations
1	Evolution of the Shikoku Basin	Okino, K., Shimakawa, Y., & Nagaoka, S.	Journal of geomagnetism and geoelectricity, 46(6), 463-479.	1994	292
2	Maritime transportation risk analysis: Review and analysis in light of some foundational issues	Goerlandt, F., Montewka, J.	Reliability Engineering and System Safety, 138, pp. 115–134	2015	246
3	A framework for risk assessment for maritime transportation systems - A case study for open sea collisions involving RoPax vessels	Montewka, J., Ehlers, S., Goerlandt, F., Hinz, T., Tabri, K., & Kujala, P	Reliability Engineering & System Safety, 124, 142-157.	2014	194
4	Towards the assessment of the potential impact of unmanned vessels on maritime transportation safety	Wróbel, K., Montewka, J., & Kujala, P.	Reliability Engineering & System Safety, 165, 155-169.	2017	192
5	A framework for risk analysis of maritime transportation systems: A case study for oil spill from tankers in a ship-ship collision	Goerlandt, F., & Montewka, J.	Safety Science, 76, 42-66.	2015	185
6	What is maritime security?	Bueger, C.	Marine Policy, 53, 159-164.	2015	177
7	A constrained A* approach towards optimal path planning for an unmanned surface vehicle in a maritime environment containing dynamic obstacles and ocean currents	Singh, Y., Sharma, S., Sutton, R., Hatton, D., & Khan, A.	Ocean Engineering, 169, 187-201.	2018	172
8	Systemic accident analysis: Examining the gap between research and practice	Underwood, P., & Waterson, P.	Accident Analysis & Prevention, 55, 154-164		167
9	Vessel collision frequency estimation in the Singapore Strait	Weng, J., Meng, Q., & Qu, X.	The Journal of Navigation, 65(2), 207-221.	2012	133
10	A dimensionality reduction-based multi-step clustering method for robust vessel trajectory analysis	Li, H., Liu, J., Liu, R. W., Xiong, N., Wu, K., & Kim, T. H.	Sensors, 17(8), 1792.	2017	129
11	Generalized velocity obstacle algorithm for preventing ship collisions at sea	Huang, Y., Chen, L., & Van Gelder, P. H. A. J. M.	Ocean Engineering, 173, 142-156.	2019	126
12	Collision avoidance on maritime autonomous surface ships: Operators' tasks and human failure events	Ramos, M. A., Utne, I. B., & Mosleh, A.	Safety Science, 116, 33-44.	2019	117
13	Spatio-temporal vessel trajectory clustering based on data mapping and density	Li, H., Liu, J., Wu, K., Yang, Z., Liu, R. W., & Xiong, N.	IEEE Access, 6, 58939-58954.	2018	117
14	Realising advanced risk-based port state control inspection using data-driven Bayesian networks	Yang, Z., Yang, Z., & Yin, J.	Transportation Research Part A: Policy and Practice, 110, 38-56.	2018	113
15	An analysis of ship escort and convoy operations in ice conditions	Goerlandt, F., Montewka, J., Zhang, W., & Kujala, P.	Safety Science, 95, 198-209	2017	109

Source: Authors.

Maritime Risk and Safety, Maritime Security, Maritime Traffic, Safety of Navigation and Trajectory Prediction. Cluster 2 was made up of Automation, Autonomous Shipping, Autonomous Vehicle, Autonomy, Human Element, Human Error, Human Factor, Human Factors, Maritime Accidents, Maritime Education and Training, Maritime Operations, Risk, Ship Safety, Situation Awareness, and Situational Awareness. Cluster 3 included AIS Data, Bayesian Networks, Collision Risk, Maritime Safety, Maritime Traffic Safety, Navigation Safety, Port State Control, Risk Assessment, Ship Collision, and Ship Domain. Cluster 4 is composed of Arctic, Climate Change, FMEA, Formal Safety Assessment, Maritime Autonomous System, Oil Spill, Polar Code, Risk Analysis, Rest Management, Route Planning, as well as Ship and Shipping. Cluster 5 consisted of Accident Analysis, Autonomous Ships, Aviation, Bayesian Network, LNG Bunkering, Maritime, Reliability, Safety, Stamp, and STPA. Cluster 6 had the ISM Code, Key Performance Indicators, Maritime Industry, Maritime Transport, Regulation, Safety Culture, Safety Management, Seafarer, and Simulation. Cluster 7 was observed to have Autonomous Ship, Collision Avoidance, Decision Marking, Deep Reinforcement Learning, Fuzzy Logic, Marine Environment, Maritime Autonomous Surface, and Path Planning. Cluster 8 was made up of Artificial Intelligence, Big Data, Decision Support, ECDIS, Machine Learning, Maritime Cyber Security, Maritime Risk Assessment, and Navigational Safety. Meanwhile, Cluster 9 had e-Navigation, IMO, Marine Accidents, Maritime Transportation, Mass, Navigation, Safety at Sea, and Sustainability.

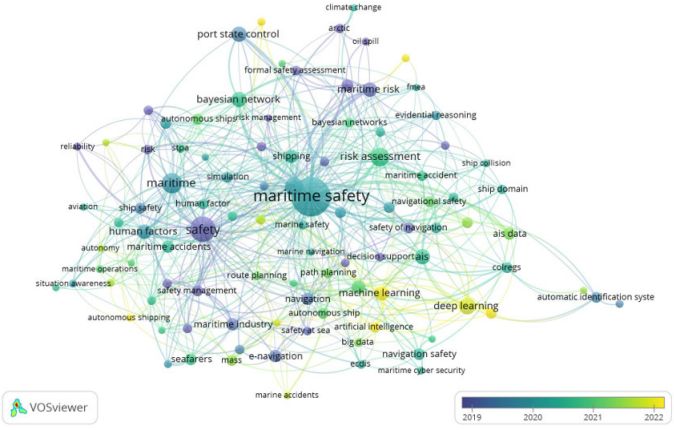
Figure 3: Network visualization.



Source: Authors.

The visualization overlay in Figure 4 showed that the topics of maritime industry, safety management, and reliability were discussed up to 2019. The topics related to maritime safety, risk assessment, and Bayesian networks were widely researched in 2021 while those focused on deep learning, machine learning, autonomous shipping were researched towards 2022.

Figure 4: Overlay visualization.



Source: Authors.

The density visualization results in Figure 5 show that several nodes are close to each other. Bright yellow nodes with maritime safety, safety, and human factor show the wide focus on these keywords while those in dim green such as ship collision, autonomous shipping, and simulation have not been researched comprehensively.

Conclusions.

In conclusion, this research achieved the objectives of examining the unique characteristics of publications and determining the scope of knowledge by identifying the 99 topics and themes which were further grouped into 9 clusters. It was further discovered that the objective of mapping research directions within maritime safety was also fulfilled. The topics

Figure 5: Density visualization.

Source: Authors.

studied up to 2019 were focused on maritime industry, safety management, and reliability. Moving forward to 2021, the focus expanded to include maritime safety, risk assessment, and Bayesian networks. Looking beyond 2022, the research landscape extended to cover deep learning, machine learning, and autonomous shipping. Moreover, research on maritime safety started growing in 2004 and has increased significantly since 2018, specifically in the last few years, thereby contributing to the treasury of literature.

The limitation of this research was that the documents were sources from only the Scopus database. Therefore, it is recommended that future research expand the scope to others such as Google Scholar and Web of Science to have more information.

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