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Mapping of Marine Safety Publications Using VOSviewer

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Marine safety has promoted the non-violent transportation of goods and property through technological innovation, risk management, and regulations. Accordingly, the study of the evolution of the scientific domain in marine safety is vital. This study discusses the bibliometric review of academic publications performed in marine safety research over 58 years from 1962 till 2020. The assessment is based on the Scopus database and various bibliometric indicators, including publication output growth, citations, and author's keywords. This study also generated graphical visualisations of bibliometric mapping through VOSviewer software. This study showed that the number of publications on marine safety research has fluctuated with a hike publication in 2020. Moreover, the results tended to indicate that marine safety research is mainly based on engineering scopes. Therefore, the bibliometric review could provide a conscientious and comprehensive view of marine safety research that could benefit marine safety practitioners, academics, and researchers interested in fostering their future exploration in this field.

Keywords: Maritime; Graphical visualisations; Publication trends; Scopus; VOSviewer

I. INTRODUCTION

Marine safety is concerned with protecting maritime transport's lives and property through technology, management, and regulations. Kopacz *et al.* (2001) have described marine safety from the angles of appropriate conditions for human at the sea that does not threaten their life and stuff and not hazardous to the marine ecosystem. The marine ecosystem is daunting and could lead to a loss of business efficiency; ensuring that marine safety must be in place to track safety performance (Thieme & Utne, 2017).

The history of marine safety is marked by numerous modifications and revisions of maritime industry regulations and standards (Baalisampang *et al.,* 2018). This is because safety on the crew and ship equipment played a vital role in avoiding any accidents and protecting the marine ecosystem (Masnicki *et al.,* 2020). Besides, it has been reported that more than 90% of the world's cargo is shipped by merchant ships; thus, the elements of marine safety became a priority in the maritime industry (Al-Shammari & Oh, 2018).

The shipping industry is perceived to be a very high-risk industry, with this dangerous nature resulting in substantial casualties and making it crucial to investigate incidents to fulfil its function (Farid & Elashkar, 2020). Governments around the world are committed to maintaining coastal and marine safety. For example, the Republic of Korea's Government has progressively improved its maritime safety regulatory framework as a precautionary measure against marine accidents (Song *et al.,* 2018).

However, despite the legal system's continued development, the number of marine casualties has gradually risen, indicating that the legal system's efficiency remains inadequate. As for recent marine collisions, small fishing vessels account for 44.9% of maritime accidents over five years (Song *et al.,* 2018). Also, there have been several safety initiatives for marine safety since the ferry tragedy, but the number of collisions appears to have risen (Jang *et al.,* 2019). Deficiencies in the marine safety management system have resulted in severe detrimental and unusual accidents,

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mishaps or near-misses that lead to direct or unintended loss of life, severe environmental disruption, loss of material and machinery properties, and the degradation of the company's reputation (Adesina *et al.,* 2020).

In general, studies relating to trends and reviews of bibliometric research on marine safety have not yet been thoroughly undertaken. This may be attributed to comparatively limited disciplines relevant to marine safety and challenging to measure consistently. Through data mining, database analysis, information assessment and a graphical representation, bibliometrics showed patterns of growth and field theory and presented a detailed, holistic and vital chain for research in this area (Lang *et al.,* 2020).

Many scholars applied this approach to literature studies in numerous marine areas, such as marine geohazards (Camargo *et al.,* 2019), microplastics in marine ecosystems (Pauna *et al.,* 2019), ocean literacy (Costa & Caldeira, 2018), submarine groundwater discharge (Ma & Zhang, 2020) and marine science research (Chellapandi & Sangeetha, 2016). To properly understand marine safety research's patterns, this study uses information framework mapping methods to examine the research situation and arrange the current theoretical structure from a bibliometric viewpoint.

This study aims to learn from the bibliometric review of marine safety research from the angle of (i) global trend of publications, (ii) most influential countries, (iii) most influential source titles, (iv) most productive and influential authors, (v) most productive and influential institutions, (vi) analysis of research areas and (vii) mapping marine safety research with VOS Viewer Software.

The information provided in this study is expected to deliver a clear overview of a marine safety research direction that could enable readers and researchers to gain knowledge that benefits their studies. The approach to this bibliometric review could create significant contributions to existing marine safety research.

II. MATERIALS AND METHOD

A. Data Collection

The Scopus database was searched for specific keywords using a command of TITLE-ABS-KEY ("marine safety") on November 11, 2020. The Scopus database was selected due to reliable and extensive documents compared to the Web of Science and Pubmed (Sweileh *et al.,* 2017) and has also been frequently cited in previous studies (Khiste & Paithankar, 2017). A total of 588 marine safety publications were found from 1962 to 2020. Out of the 588 publications, 305 were conference papers, 216 were various journal sources, 28 were trade journals, 20 were book series, and 19 were books. The retrieval data produced 571 publications written in English and less than ten in other languages such as Chinese, Croatian and German.

B. Data Analysis

The review was initiated by exporting Comma-separated Values (CSV) and Research Information Systems (RIS) data to Microsoft Excel, Publish or Perish (PoP), and VOSviewer software. The retrieved data consists of the following information: author's name, document source, year of publication, the title of publication, countries, journals, subject area, and type of articles. Bibliometric review and mapping of marine safety research were carried out using the VOSviewer program developed by Van Eck and Waltman (2010). According to Van Eck and Waltman (2010; 2019), VOSviewer applied visual elements based on mapping techniques, which converts data related to CSV format into diagrams or clusters. Also, mapping techniques help the researcher analyse specific information such as authors, locations, institutions, citations, co-citations, and other refining aspects (Khalil & Crawford, 2015).

III. RESULT AND DISCUSSION

A. Growth Trend of Publications

The number of publications is an essential element for developing any research field. Figure 1 indicates the number of marine safety publications from 1962 to 2020. The publication of marine safety research rose by ten academic works in 2004. More precisely, marine safety research

development began after four decades, with 80.61% of the total publications. Publishing climbed by more than 50 documents in 2005 but plummeted dramatically to 10 publications in 2006. The publications climbed slowly until 2009 and dropped in 2010.

In 2015, the publications soared rapidly until 2020. It is indicated that the increases in publications are primarily due to the rising interest in marine safety between 2015 and 2020. This is because several marine accidents were used to establish acceptable risk models to analyse marine collisions (Berg, 2013; Khan *et al.,* 2018).

This aspect led to the rise in marine safety studies and became a beneficial method for detecting human-related issues and promoting accident prevention, and improving marine safety (Kulkarni *et al.,* 2020). Also, the number of researchers worldwide and the increased number of marine safety publications in the Scopus database have undoubtedly affected the number of publications. By witnessing the exponential growth observed in marine safety research between 2015 and 2020, it can be construed that this research area is pertinent and reputable.

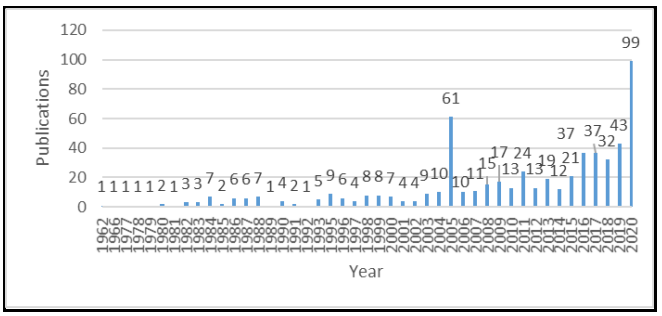

Figure 1. Research trend on marine safety research

B. Most Influential Countries

A network analysis was carried out to classify the countries of authors who have made the most contribution to marine safety research. Figure 2 shows that the citations network consists of 15 countries and is divided into four clusters (red, blue, yellow, and green). The countries served by the nodes and represented that the higher the nodes have led to many publications. In this scenario, among the others, the United States had more significant nodes. It has been revealed that the United States has a considerable number of citations (609). The second rank goes to the United Kingdom with 559 citations, and in the third position was China with 353 citations. It has been discovered that these countries play an important role in developing scientific contact in marine safety research and act as a gateway to information.

The most productive ten countries of the network are shown in Table 1. The United States has been listed as the most productive country with 112 publications. In comparison, China is the second most productive country with 91 publications, and Indonesia is the third most productive country with 73 publications.

This study found that Indonesia, as a developing country in Southeast Asia, has had published a significant number of marine safety research. In this situation, the Indonesian government is working hard to directly raise marine safety standards (Muhibat *et al.,* 2020). However, in terms of citation, Indonesia received 198 citations in total, below the United Kingdom, Canada, South Korea, and Greece. This finding would help future researchers study the trend to increase the citation of marine safety publications among Indonesian authors.

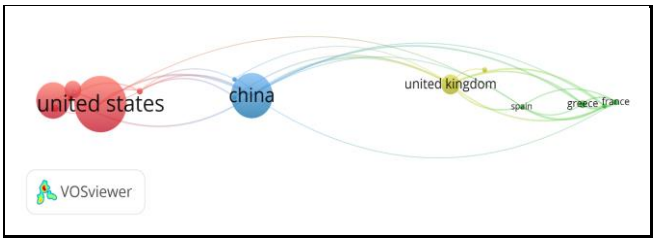

Figure 2. Countries that have contributed to the publication of marine safety research

Table 1. Status of the top ten countries

Rank	Country	Publications	Percentage (%)
1	United States	112	15.75
2	China	91	12.80
3	Indonesia	73	10.27
4	United Kingdom	40	5.63
5	Canada	36	5.06
6	South Korea	20	2.81
7	Greece	16	2.25
8	Australia	15	2.11
8	Japan	15	2.11
9	Germany	14	1.97
9	Poland	14	1.97
10	Finland	13	1.83
10	Netherlands	13	1.83

C. Most Influential Source Titles

Table 2 presents a list of the eight source titles, ranked from the most to the least cited. Considering the number of publications, IOP Conference Series Earth and Environmental Science and the International Oil Spill Conference IOSC 2005 seem to be the most influential source titles in this field, with 77 and 44 publications, respectively. Other relevant sources are Ocean Engineering in the third rank and Safety Science at the fourth rank. Based on this finding, it is suggested that the publications have been contributing useful knowledge that will allow prospective researchers to refer to and be beneficial for their future marine safety research. The information provided also conveys a message that marine safety research has been widely published in various type of conferences and proceedings.

Table 2. The eight most influential source titles with at least five publications

Rank	Source Titles	Publications
1	IOP Conference Series Earth and Environmental Science	77
2	International Oil Spill Conference IOSC 2005	44
3	Ocean Engineering	14
4	Safety Science	8
5	Proceedings of SPIE The International Society for Optical Engineering	7
6	Lecture Notes in Computer Science	5
6	Naval Architect	5
6	Proceedings of The International Offshore and Polar Engineering Conference	5

D. Most Productive and Influential Authors

The next step is to recognise the most active and successful authors in the field of marine safety. A list of the five most-cited documents is provided in Table 3. In general, citing an article's influence on the scientific community is viewed as a fair assessment of its popularity and significance (Merigó & Yang, 2017). As indicated in Table 3, the 1999 paper by Gaines *et al.* stands as the most cited publications of all times, with 144 citations for an article entitled "Oil spill source identification by comprehensive two-dimensional gas chromatography" published by Environmental Science and Technology. Next in the raking was Lee and Ramster work in 1981, with 117 citations for an article entitled "Atlas of the seas around the British-Isles."

Table 3. The five most cited-documents in marine safety research

Cites	Authors	Year	Title
144	R.B. Gaines, G.S. Frysinger, M.S. Hendrick-Smith, J.D. Stuart	1999	Oil spill source identification by comprehensive two-dimensional gas chromatography Source: Environmental Science and Technology
117	A.J. Lee, J.W. Ramster	1981	Atlas of the seas around the British-Isles. Source: Atlas of the seas around the British-Isles.
92	C. Bueger	2015	What is maritime security? Source: Marine Policy
82	Z.L. Yang, S. Bonsall, A. Wall, J. Wang, M. Usman	2013	A modified CREAM to human reliability quantification in marine engineering Source: Ocean Engineering
78	E. Eleftheria, P. Apostolos, V. Markos	2016	Statistical analysis of ship accidents and review of safety level Source: Safety Science

One of the most relevant issues in a bibliometric review is determining the most influential authors in the field. Table 4 lists nine authors with more than five publications concerning marine safety. Artana, K. B. has led in the list with 13 publications, followed by Dinariyana, A. A. B. (11 publications), Handani, D. W. (10), and Ariana I. M. (7 publications). The authors were affiliated to the Institut Teknologi Sepuluh Nopember, Surabaya, Indonesia. Other authors are Glässer, U. from Simon Fraser University, Burnaby, Canada and Ventikos, N.P. affiliation of the

National Technical University of Athens, Greece, with seven publications respectively. Brigham, L.W. (University of Alaska, Fairbanks, United States), Jackson, P. (Thompson Rivers University, Kamloops, Canada), and Sui, H. (Wuhan University, Wuhan, China) have published six works related to marine safety. It is noteworthy that over the last 58 years, Indonesian authors associated with Institut Teknologi Sepuluh Nopember, Surabaya, Indonesia, have been the most active authors to publish marine safety works.

Table 4. Status of top five authors published marine safety research

Rank	Author	Articles	Affiliation
1	Artana, K. B.	13	Institut Teknologi Sepuluh Nopember, Surabaya, Indonesia
2	Dinariyana, A. A. B.	11	Institut Teknologi Sepuluh Nopember, Surabaya, Indonesia
3	Handani, D. W.	10	Institut Teknologi Sepuluh Nopember, Surabaya, Indonesia
4	Ariana, I. M.	7	Institut Teknologi Sepuluh Nopember, Surabaya, Indonesia
4	Glässer, U.	7	Simon Fraser University, Burnaby, Canada
4	Ventikos, N.P.	7	National Technical University of Athens, Greece
5	Brigham, L.W.	6	University of Alaska, Fairbanks, United States
5	Jackson, P.	6	Thompson Rivers University, Kamloops, Canada
5	Sui, H.	6	Wuhan University, Wuhan, China

E. Most Productive and Influential Institutions

Figure 3 offers a list of institutions with at least ten publications. It is interesting to note that three universities from China, Wuhan University of Technology, Shanghai Maritime University, and Wuhan University, were the leading institutions in this study. The Institut Teknologi Sepuluh Nopember, Surabaya, Indonesia, had 50 publications and headed the most prominent marine safety research institutions. The U.S. Coast Guard produced 41 publications to comply with the second place, and the Wuhan University of Technology achieved the third rank. This result showed that institutions in Asian became the top leader institution in publishing marine safety research. It is indicated that Asia's specific maritime geography faces distinct safety challenges and plays an essential role in all Asian countries' economies (Dung, 2020). By crossing remarks from Tables 4 and Figure 3, the correspondence observed between prominent authors and academic institutions was noted. Specifically, four leading researchers in marine safety (Artana, K. B., Dinariyana, A. A., Handani, D. W., and Ariana I. M.) were affiliated with Institut Teknologi Sepuluh Nopember, Indonesia. It is indicated that the Institut Teknologi Sepuluh Nopember, Indonesia is an institution that excels in marine safety research and could be a prominent institution in the Southeast Asian region and the world.

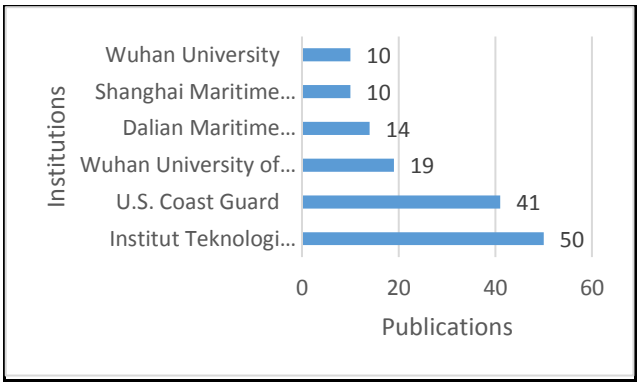

Figure 3. Top institutions publishing articles on marine safety research

F. Analysis of Research Areas

The review of research articles on a specific area is also essential. This method facilitates the recognition of the critical disciplines under which marine safety research has been performed. Table 5 provides 14 study areas with at least ten publications categorised according to the Scopus. "Engineering" has been found to be the most researched area, with 344 publications. This finding has been expected, as the subject under this review is relevant from an engineering perspective, which focuses on the relationship between technology, management, and regulations.

Besides, engineering disciplines incorporate scientific concepts into practice-oriented science, offering structures and processes that provide ways to learn new knowledge. Another field of study that stands out is "Earth and

Planetary Sciences," with 145 publications. Another related field of study is "Environmental Science," with 141 publications. These two issues demonstrate that marine safety also involves environmental discussions, such as marine contamination, marine and human life's toxicity, and the degradation of marine habitats of concern to researchers today.

Table 5. Research area in marine safety with at least ten publications

Rank	Subject Area	Publications
1	Engineering	344
2	Earth and Planetary Sciences	145
3	Environmental Science	141
4	Social Sciences	92
5	Computer Science	82
6	Energy	40
7	Mathematics	35
8	Medicine	23
8	Physics and Astronomy	23
9	Business, Management and Accounting	22
10	Decision Sciences	17
10	Materials Science	17
11	Agricultural and Biological Sciences	10
11	Chemical Engineering	10

G. Mapping Marine Safety Research with VOS Viewer Software

This section provides a visual description to deepen the conclusions of the previous parts. The VOS viewer software is used to evaluate co-citation, bibliographic coupling, and the author's keyword's co-occurrence.

Figure 4 displays the journals' co-citation analysis findings with a threshold of 20 citations and 26 sources. The Marine Pollution Bulletin is the most-cited journal with the best network links (blue cluster) and a total link strength of 5209 and 72 citations. The marine Pollution Bulletin was congregated in a similar cluster with the Journal of Fluid Mechanics, Journal of Physical Oceanography, and Journal of Geophysical Research.

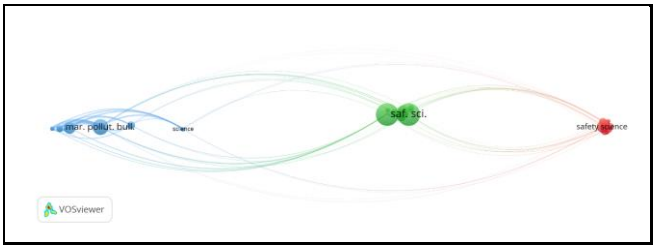

Figure 4. The Co-citations map of sources cited in marine safety research

It is worth exploring how a bibliographical coupling of institutions connects the most productive institutions. Figure 5 indicates the findings of a minimum number of publications and a citation of four. The number of organisations to be chosen is five. It is stated that there are two clusters: green, representing the Center of Excellent in Maritime Safety and Marine Installation, Institut Teknologi Sepuluh Nopember, Indonesia. The red cluster represents the Department of Marine Engineering, Faculty of Marine Technology, Institut Teknologi Sepuluh Nopember, Surabaya, Indonesia. Thus, it is clear that Institut Teknologi Sepuluh Nopember in Indonesia serve as the main actors to develop networking in publishing marine safety research in this study.

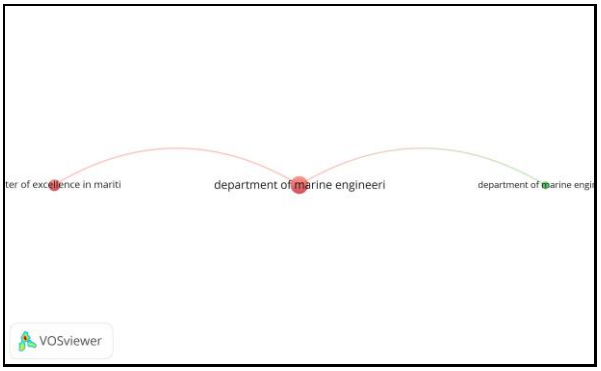

Figure 5. Bibliographic coupling of the most productive institutions

VOS viewer allows for the analysis of the most common keywords and each keyword's frequency in a given set of publications. In this analysis, the keywords of the authors were mapped. Figure 6 provided a network diagram of the author's keywords in which various colours, node sizes, font sizes, and the thickness of the connecting lines illustrate the relationship with other keywords (Sweileh *et al.,* 2017). The keyword "marine safety" in red nodes are the most frequent

keywords. Some different popular keywords in terms of co-occurrence are “maritime safety”, “risk assessment”, “risk analysis”, and “e-navigation”. This confirms that marine safety research connects with various fields, including risk assessment and analysis, electronic navigation, and maritime safety.

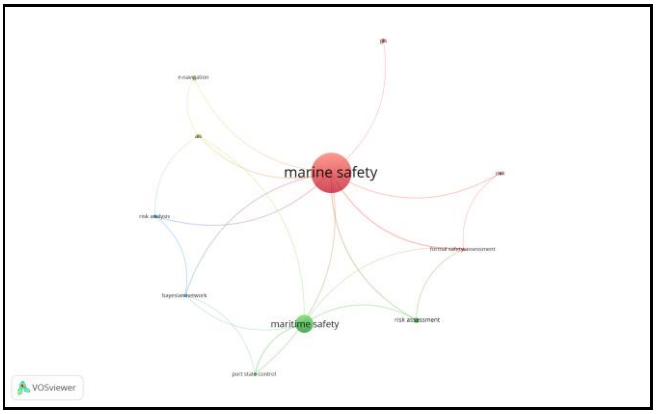

Figure 6. Network visualisation map of author keywords in the articles

IV. CONCLUSION

This bibliometric review promotes examining and integrating established directions in marine safety research, and new trends are emerging. Based on a bibliometric review of 58 years of marine safety research, this review found that the information below will be able to provide readers, marine safety practitioners, and researchers with the related facts as below:

1. The number of publications on marine safety had steadily increased after four decades, and the highest number of publications was 99 in 2020.
2. In terms of countries, the United States, China, and Indonesia were active publishing countries. Besides, Indonesia has been identified as one of the developing countries actively involved in marine safety research.
3. The IOP Conference Series Earth and Environmental Science and the 2005 International Oil Spill Conference IOSC seem to be the most influential source titles in marine safety research.
4. The Institut Teknologi Sepuluh Nopember, Surabaya, Indonesia, was the leading institutions in this study. The Institut Teknologi Sepuluh, Nopember, Surabaya, Indonesia, had published 50 publications and headed the most prominent institutions in marine safety research.
5. Artana, K.B. affiliated to the Institut Teknologi Sepuluh Nopember, Surabaya, Indonesia, led on the list of the most productive authors with 13 publications.
6. “Engineering” became the most researched area, with 344 publications in marine safety research.
7. Research on marine safety is multidisciplinary, as it connects with many subjects, such as risk assessment, analysis, and electronic navigation.

A bibliometric review allows for an overview of the scientific inquiry’s current state in a specific field. Still, a range of constraints related to the analysis approach pursued and how records have been classified cannot be overlooked. In this regard, it is essential to note that there are many other databases that may have been used for the review, such as Microsoft Academic, Dimensions or Google Scholar. Also, the essence of a bibliometric review per se is minimal. Only publications that meet the search criteria and refining specifications set out in the methodology (“marine safety”) have been included. This is the main shortcoming of this study, limiting empirical findings and which does not allow various organisations to understand marine safety research fully. Confining the results of the Scopus database is another limitation. Further studies should be conducted to determine the trend of marine safety publications in a real context, such as marine safety programs or interventions.

Thus, progressive marine safety research is inevitably a critical and necessary element in promoting and developing crucial marine safety knowledge and skills for communities worldwide to co-exist at a safer and better level. Consequently, based on this bibliometric review, readers, marine safety practitioners, and researchers would be better able to identify essential information to assess marine safety in their future studies.

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