A Bibiliometrics using R-Bibiloshiny Analysis of E-Navigation in Maritime Industry on Scopus Database (2018-2024)

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The advancement of maritime safety is fundamentally dependent on precise and cohesive electronic navigation (e-navigation) systems. This study conducts a systematic analysis of 155 publications indexed in Scopus from 2018 to 2024, employing bibliometric methods through the R-Biblioshiny package. The study examines scientific production trends, leading contributors, institutional roles, collaborative networks, and research themes in e-navigation. Results indicate a peak in scholarly output around 2020 followed by a decline, reflecting the stabilization of foundational topics and a shift towards practical implementation and standards development. Thematic research include maritime transportation, collision avoidance, and Automatic Identification Systems, complemented by emerging interest in the Maritime Internet of Things. Highly cited studies prioritize integration of wireless communication and autonomous navigation for enhanced maritime safety, while pointing to cybersecurity as a critical emerging concern. This research enriches the understanding of e-navigation's academic landscape by identifying influential actors and thematic gaps. The findings highlight the necessity for ongoing research into cyber security measures, human factors, and regulatory policies to underpin safer, more efficient maritime navigation. This bibliometric mapping provides valuable guidance for researchers and stakeholders seeking to address current challenges and drive innovation in maritime e-navigation.

Keyword: *Bibliometric Analysis, Maritime Internet of Things, Scopus, Electronic Navigation,*

1. INTRODUCTION

In general, ship operations aim to create safe shipping. Navigation is something that plays an important role in the world of shipping, especially in determining the movement of a ship. The accuracy of estimating the position, speed, acceleration, and direction of ship movement is an important part of the navigation system to predict the position and direction of the ship and improve navigation safety (Perera & Guedes Soares, 2015). Many factors affect ship navigation and are the cause of ship accidents (Demirci et al., 2023). Human error has been identified as the main cause of maritime accidents but many new methods have been developed to accommodate human behavior (LUO & SHIN, 2019).

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The development of electronic navigation (E-Navigation) aims to combine human participation with navigational advances in an effort to improve maritime operational reliability (Jeevan et al., 2020). In contemporary electronic navigation, the obligation to use paper nautical charts is replaced by the utilization of Electronic Chart Display and Information Systems (ECDIS) operated using Electronic Navigational Charts (ENC) (Palikaris & Mavraeidopoulos, 2020). Electronic navigation is a system of collecting, integrating, exchanging, presenting, and analyzing harmonious maritime data electronically both on board ships and on land (Baldauf et al., 2011). The International Maritime Organization (IMO) has launched the idea of electronic navigation as a framework for information services designed to enhance and promote maritime safety and security, as well as overall environmental protection (Park & Park, 2015).

E-Navigation was developed to establish a system capable of collecting, integrating, analyzing, and electronically presenting maritime information relevant to both the ship's side and the shore side. The electronic navigational chart (ENC) effectively displays the conditions of navigation for the vessel (Zheng et al., 2023). The implementation of electronic navigation equipment on contemporary vessels can mitigate the incidence of maritime accidents; however, this technology also possesses vulnerabilities to cyber security threats (Visky et al., 2024). The International Maritime Organization (IMO) is advancing e-navigation, which incorporates dynamic data as part of initiatives aimed at enhancing situational awareness, thereby aiming to improve navigational safety and environmental protection (Bergmann, 2013).

Previous studies on e-navigation have indicated that the concept may be effectively proposed to align with advancements in unmanned navigation technology and navigation aids (Zhang et al., 2021). There is a requisite for cyber security testing within electronic navigation systems (Svilicic et al., 2020). Operators of navigation equipment must gain familiarity with the voyage plans generated by Electronic Chart Display and Information System (ECDIS) as well as the underlying principles of electronic navigation (Sandu et al., 2024). Substantial opportunities exist for development and learning in electronic navigation to facilitate the establishment of safe voyages. Nevertheless, further analysis is essential to observe trends and systematically map progress within this domain. The existing database of research articles pertaining to electronic navigation encompasses a broad spectrum of topics and is examined from various perspectives, thereby necessitating the application of bibliometric methods to delineate the extant literature.

Through this analysis, further studies can be conducted to support the development of more effective e-navigation and to contribute to the existing literature by identifying gaps in the existing research. Some aspects that can be explored through this bibliometric method include: What are the potential challenges and barriers to bibliometric studies in e-navigation studies? What is research implications of bibliometric structures in e-navigation?

The main objective of this research is to conduct a bibliometric analysis of the literature available on electronic navigation in the maritime industry indexed in the Scopus database from 2018 to 2024. This analysis will be carried out using the R-Biblioshiny package in R software, which allows researchers to process and present data in a visual format that can provide a deeper understanding of existing trends and patterns. Bibliometric is a method commonly used for large-scale literature analysis. Databases like Scopus provide a robust platform for storing extensive research data. Biblioshiny is an R tool that exports data in its raw format from databases and generates figures, charts, and tables (Sandu et al., 2024). Biblioshiny facilitates the understanding of knowledge areas, research patterns, and trends. This research has the following specific objectives:

1) Deskriptive: annual scientific production, most relevant source, most relevant author, most relevant affiliation, country scientific production and document.

2) Science mapping: Trend Topic, Co-Accurance Network, Thematic Map, and Collaboration World Map.

2. METHODOLOGY

This study examines publications in the Scopus database related to electronic navigation in the maritime sector from 2018 to 2024 applying a bibliometric approach. The bibliometric approach is used because of its ability to statistically analyze qualitative and quantitative research publications stored in journal databases such as Scopus (Zyoud, 2016). Bibliometric methods are used to analyze how disciplines and fields of study, specializations, and individual articles are interconnected (Zupic & Čater, 2015). The objective of this approach is to identify research gaps that still need to be explored regarding electronic navigation. The process stages utilized by this study refer to the research by (Zupic & Čater, 2015) as below:

The search was carried out using the following query in the Scopus database's article title field in order to make the data collection procedure more clear:

(TITLE-ABS-KEY ("electronic navigation" OR "E-NAVIGATION" OR "E NAVIGATION") AND TITLE-ABS-KEY (maritime)) AND PUBYEAR > 2017 AND PUBYEAR < 2025 AND (LIMIT-TO (LANGUAGE , "English"))

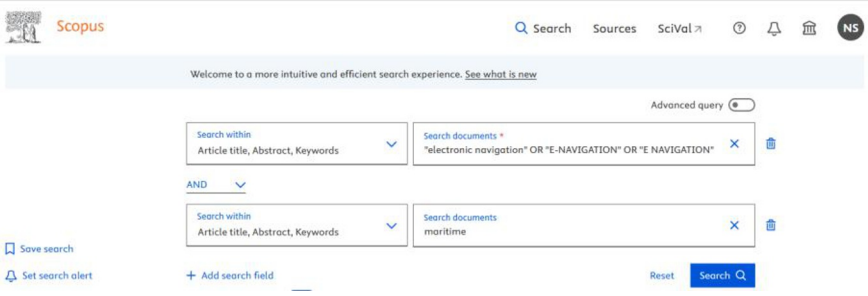

Figure 1. Scopus Database Keywords

This stage is used to ensure that the data collected matches to the research topic.

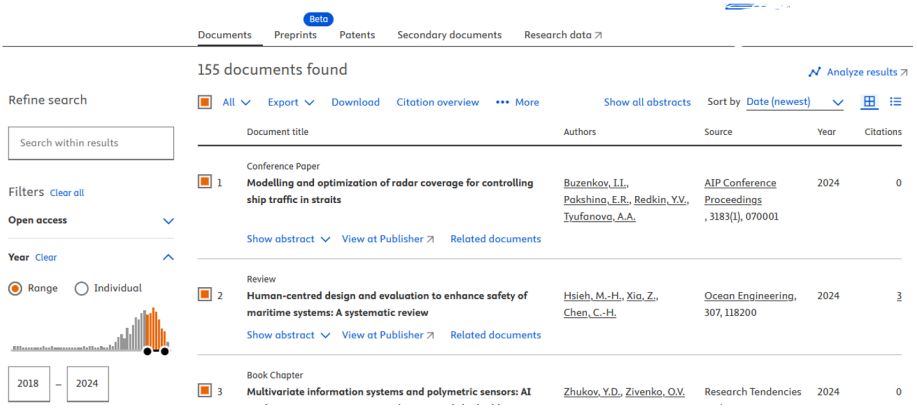

Figure 2. Results of searching

OpenRefine was used to check the data after it was collected. This is a good tool for cleaning and rearranging data so that it can be analyzed more easily. Using OpenRefine helps with the identification process, links to outside data sources, and makes it easier to export data in TTL (Turtle) format (Ngootip et al., 2023). This validation process ensures that the analysis is based on accurate and reliable data, making the research findings more valid.

The data analysis techniques used in this study are a combination of VoS Viewer, OpenRefine, Rstudio, and Biblioshiny. VoS Viewer is used to visually represent the research that has been conducted (Au-Yong-oliveira et al., 2024) and could be used for trend analysis of publications based on country, institution, journal, author, reference, and keyword (Au-Yong-oliveira et al., 2024), OpenRefine is used for data cleaning (Liman et al., 2022), R Studio for statistical data analysis (Mohammed et al., 2024), BiblioShiny for bibliometric data analysis to make information interpretable (Vătămănescu et al., 2024). The data was initially refined with OpenRefine, and afterwards analyzed using RStudio and BiblioShiny. The results were eventually visualized using VoS Viewer.

3. DISCUSSION

Table 1 illustrates the distribution of electronic navigation articles in the maritime world each year. This research is limited to articles published in the Scopus database from 2018 to 2024.

Table 1. Distribution of electronic navigation articles

Description	Results
Main Information About Data	
Timespan	2018:2024
Sources (Journals, Books, etc)	100
Documents	155
Annual Growth Rate %	-11,51
Document Average Age	4,46
Average citations per doc	8,781
References	4200
DOCUMENT CONTENTS	
Keywords Plus (ID)	828
Author's Keywords (DE)	483
AUTHORS	
Authors	368
Authors of single-authored docs	17
AUTHORS COLLABORATION	
Single-authored docs	24
Co-Authors per Doc	3,18
International co-authorships %	12,9
DOCUMENT TYPES	
article	82
book	3
book chapter	7
conference paper	56
conference review	3
review	4

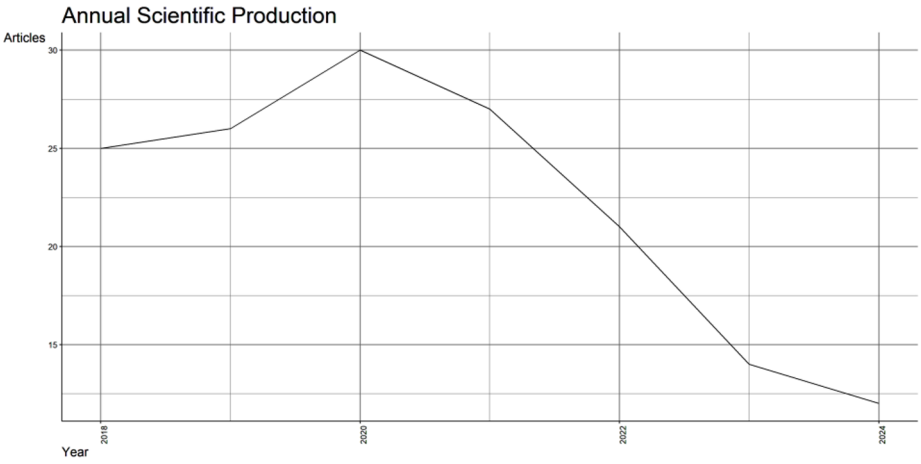

Figure 3 Annual Scientific Production

Data indicates an increasing trend in the number of articles published about electronic navigation in the maritime industry from 2018 to 2024. In 2018, there were approximately 25 articles, indicating an early stage of academic focus on this topic. In 2019, this number slightly increased to 26 articles, reflecting a relatively low level of interest among researchers. This trend continued with a slight increase in 2020, reaching 30 articles, which was the peak number of publications during the observed period. There was a decline in research related to electronic navigation after 2020, with the number of articles decreasing to 27 in 2021, 21 in 2022, 14 in 2023, and continuing to decline to 12 in 2024. The 11.51% decrease in the growth rate of research articles on electronic navigation indicates that the level of interest and participation from researchers is declining year by year. Although electronic navigation is becoming increasingly important and is mandated by the International Maritime Organization (IMO), researchers are developing other things related to electronic navigation. This is in line with what was stated by (Bistrović & Komorčec, 2015) that the implementation of e-navigation requires adjustments to existing navigation and communication systems to align with the new concept. Currently, in the context of electronic navigation (e-navigation), the International Hydrographic Organisation (IHO) is currently focused on developing new standards (S-100) aimed at ensuring homogeneous management of maritime domain data (Palma et al., 2023).

The documents retrieved from the Scopus database totaled 155, consisting of 82 articles published in journals (52.9%), 56 conference proceedings articles (36.2%), and the remainder published in books and proceedings review.

Analysis shows the top 10 journals that most frequently publish articles on electronic navigation in the maritime industry. The most productive journal is the Journal of Marine Science and Engineering, with a total of 10 articles, making it a primary source in this field. Transnav is in second place with 9 articles, followed by the Journal of Navigation in third place with 7 articles. Next, fourth place is shared by three journals: IEEE Access, Ocean Engineering, and the WMU Journal of Maritime Affairs, each publishing 5 articles. Fifth place is held by the Journal of Physics: Conference Series with 4 articles. Sixth place is also shared by Polish Maritime Research, Rina, the Royal Institution of Naval Architects - Human Factors 2018, Papers, and Sustainability (Switzerland), each contributing 3 articles.

Table 2. The Most Top 10 Relevant Sources

Sources	Articles
Journal of Marine Science and Engineering	10
Transnav	9
Journal of Navigation	7
IEEE Access	5
Ocean Engineering	5
WMU Journal of Maritime Affairs	5
Journal of Physics: Conference Series	4
Polish Maritime Research	3
Rina, Royal Institution of Naval Architects - Human Factors 2018, Papers	3
Sustainability (Switzerland)	3

These results demonstrate the significant contribution of these journals to research related to electronic navigation in the maritime industry, while also illustrating the breadth and depth of topics discussed in this field.

Tabel 3 Most Top 10 Relevant Affiliation

AFFILIATION	ARTICLES
Dalian Maritime University	69
University of Rijeka	22
Chalmers University of Technology	19
National Institute of Telecommunications	16

AFFILIATION	ARTICLES
World Maritime University	15
Norwegian University of Science and Technology	11
Tianjin University	11
Notreported	10
Southeast University	9
Wuhan University	9

Based on the analysis results, several institutions have made significant contributions to research related to electronic navigation in the maritime industry. Dalian Maritime University ranks first with a total of 69 publications, making it the most productive institution in this field. The University of Rijeka is in second place with 22 publications, followed by Chalmers University of Technology in third place with 19 publications.

The National Institute of Telecommunications ranked fourth with 16 publications, while the World Maritime University and the Norwegian University of Science and Technology contributed 15 and 11 articles respectively. Tianjin University, Southeast University, and Wuhan University complete the list of the top ten affiliates. This distribution highlights the crucial role of these institutions in supporting the development of academic literature and global contributions to electronic navigation, particularly in the maritime industry. This result also reflects significant international collaboration in this field.

Additionally, these results also indicate the potential for international collaboration to enrich and expand the impact of research in the field of electronic navigation in the maritime industry.

Tabel 4 Articles Impact

Paper	DOI	Total Citations	TC per Year
Aslam S, 2020, IEEE Internet Things J	10.1109/JIOT.2020.2993411	184	30,67
Zhang X, 2021, Ocean Eng	10.1016/j.oceaneng.2021.109380	172	34,40
Xia T, 2020, IEEE Wirel Commun	10.1109/MWC.001.1900322	97	16,17
Akdağ M, 2022, Ocean Eng	10.1016/j.oceaneng.2022.110920	66	16,50
Goudossis A, 2019, J Marine Sci Technol	10.1007/s00773-018-0561-3	63	9,00

Paper	DOI	Total Citations	TC per Year
Wang Mm, 2020, IEEE Commun Surv Tutor	10.1109/COMST.2020.3015694	54	9,00
Xia T, 2019, IEEE Access	10.1109/ACCESS.2019.2919253	43	6,14
Zhang J, 2020, IEEE Access	10.1109/ACCESS.2020.2990830	29	4,83
Baldauf M, 2019, Transnav	10.12716/1001.13.03.02	27	3,86
Kitada M, 2019, Adv Intell Sys Comput	10.1007/978-3-319-94709-9_32	27	3,86

Table 4 presents citation data for various articles on electronic navigation available in the Scopus database from 2018-2024. Research articles by Aslam. S received the highest number of citations with 184 citations, totaling 30.67 citations per year. This indicates that the research results have a significant impact on studies in this field. The article by Zhang X received 172 citations, which is equivalent to 34.40 citations per year. This number of citations reflects the relevance and academic impact of these studies in supporting the development of electronic navigation in the maritime industry.

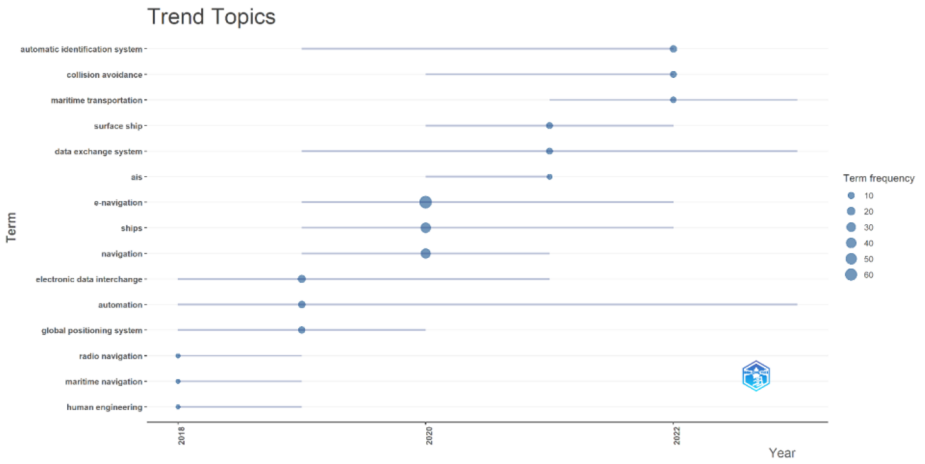

Figure 4. Trend Topics

Trending topics provide an overview of the most popular and sought-after themes during a specific period. The image above shows a visual representation of topic trends in electronic navigation from 2021 to 2024. Data shows that topics such as "maritime transportation," the Automatic Identification System, and collision avoidance have become frequently discussed themes with high frequency in recent years. Additionally, topics such as "electronic data interchange," "global positioning system," and "automation" began to receive significant attention, indicating a connection between electronic navigation. Other topics such as "collision avoidance," "data exchange systems," and "maritime navigation" remain a primary focus, reflecting the importance of matters related to shipping safety and the environment in the maritime world.

Nevertheless, it is important to note that this data is based on the number of articles published and does not necessarily reflect the true popularity of a topic. However, this trend analysis provides valuable insights for researchers and practitioners to understand the current state of the electronic navigation field in the maritime industry and make strategic decisions for future research.

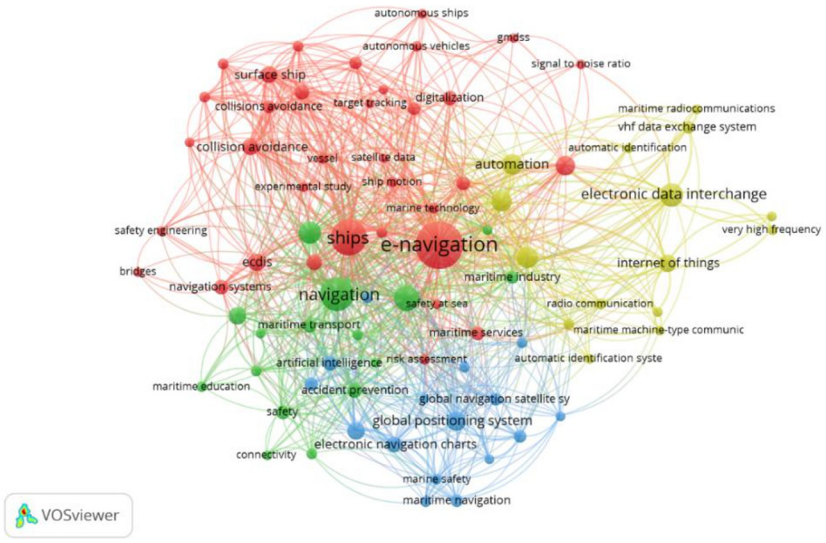

Figure 5. Co-Accuracy Network

The results of the bibliometric analysis of keywords in electronic navigation in the maritime industry show three main clusters. The red cluster focuses on topics such as "Autonomous Navigation", "Collision Avoidance", "Marine Technology", "Navigation System", and "digitalization", reflecting their influence on e-navigation. The green cluster covers maritime and navigation themes, such as "Maritime industry", "electronic navigation", and "navigation equipment". The blue cluster highlights the Global Positioning System in the maritime world, including "Automatic Identification System", "Radio Navigation", and "navigation Chart". This analysis provides insights into research trends and the future development direction of electronic navigation.

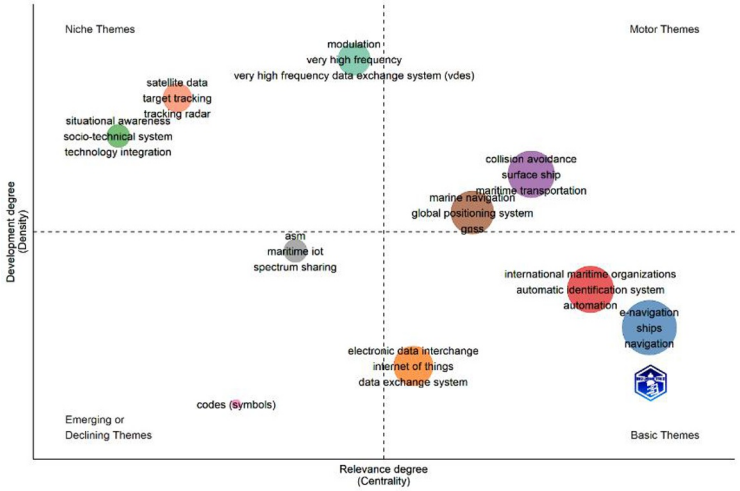

Figure 6 Thematic Map

Thematic maps provide a visual overview of research themes by dividing them into four quadrants. The upper right quadrant, "Motor Themes," includes topics with high centrality and density such as "Marine Navigation," "Collision Avoidance," and "Maritime Transportation," indicating well-established and extensively researched themes. The lower right quadrant, "Basic Themes," includes topics like "e-navigation," "Automatic Identification System," and "Electronic data Interchange," which are central themes but still have potential for further exploration. The lower left quadrant, "Emerging or Declining Themes," includes themes such as "Maritime Internet of Things," which may be emerging or declining, thus requiring further study. The upper left quadrant, "Niche Themes," includes topics like "tracking radar" and "Very High Frequency data Exchange System," which have high density but are less central, indicating potential for further development in specialized areas. This analysis helps identify research focus and future opportunities in electronic navigation.

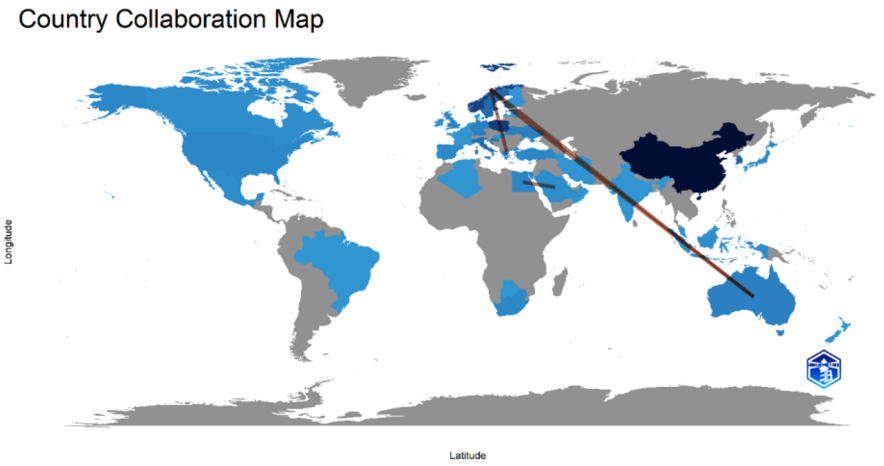

Figure 7. Collaboration World Map

The Collaboration World Map shows the network of international collaboration in electronic navigation research within the maritime industry. Countries like China, Sweden, Croatia, Korea, and Poland demonstrate high productivity in international research collaboration, characterized by a significant number of connecting lines. The thicker the line formed, the more frequently collaboration occurs between those countries. This map also indicates that most of the research is cross-continental, with strong connections between countries in Europe, Australia, and Asia. This reflects the global nature of research in this field.

This bibliometric analysis gives a description of how research on electronic navigation (e-navigation) in the maritime industry has changed in 2018 to 2024 period. The previous study shows that scholarly production started to increase in the early years, peaked around 2020, and then decreased significantly in the last few years. This pattern probably shows a shift in the field from exploratory research to periods of consolidation and implementation. The decrease in the publication growth rate, which is about -11.51%, could mean that some of the basic parts of e-navigation, like core technologies and standards, have matured. This could mean that researchers are shifting focus on more practical problems, like system integration and cyber security (Bistrović & Komorčec, 2015). This is in line with the International Hydrographic Organization's current focus on the S-100 standard, which aims to standardize the handling of maritime data and improve the compatibility of e-navigation systems (Palma et al., 2023).

The several variety of publications, including journal articles and conference papers, shows that e-navigation is being studied from many different fields, including new technical ideas, safety rules, and information systems (Zhang et al., 2021). The

Journal of Marine Science and Engineering and TransNav are two top journals that serve as critical platforms for sharing information. This shows that the academic community is focused on improving marine navigation safety and integrating new technologies. The international collaboration map shows that European and Asian countries work well together on research, especially China, Sweden, Poland, and South Korea. This illustrates that problems with maritime navigation are worldwide and those countries need to work together across borders to fix them. (Sandu et al., 2024).

The research was divided into three groups through thematic analysis: autonomous navigation and avoiding collisions; the maritime industry and navigation equipment; and global positioning and related technologies. The importance of collision avoidance and marine transportation challenges within maritime safety frameworks highlights their significance (Perera & Guedes Soares, 2015). The focus on Automatic Identification Systems (AIS) and electronic data interchange underlines the necessity of seamless data sharing for delivering real-time navigational information, increasing situational awareness, and facilitating decision-making (Baldauf et al., 2011). The increase of the Maritime Internet of Things (IoT) as a prospective topic of research demonstrates the improvement of maritime equipment's connectivity. field of research indicates how connected maritime equipment are getting better, which could result in enhanced operational flexibility and more accurate monitoring (Bergmann, 2013). However, the changing or declining significance of these topics suggests that further empirical investigation is required to evaluate their practical use and scalability.

Citation metrics indicates that foundational works, including Aslam's (2020) research on IoT applications and Zhang X.'s (2021) study on collision avoidance for autonomous surface ships, have significantly influenced subsequent research, establishing a focus on the integration of sophisticated wireless communication with maritime safety systems (Aslam, 2020; Zhang et al., 2021). These significant publications provide theoretical frameworks and empirical validations important for the development of next-generation e-navigation systems.

In practice, e-navigation projects are transforming how safe and efficient marine operations are by authorizing you integrate data from multiple devices and charting tools into one electronic file. The transformation from traditional paper charts to electronic navigational charts (ENC) and Electronic Chart Display and Information Systems (ECDIS) provides a significant enhancement in navigational accuracy, reducing human error, which remains a primary contributor to maritime incidents (Demirci et al., 2023; Palikaris & Mavraeidopoulos, 2020). The use of complex electrical systems, however, makes boats more vulnerable to cybersecurity threats. This is a risk factor that hasn't been studied enough, but is quite important, as shown by recent academic research (Svilicic et al., 2020; Visky et al., 2024). Dealing with cybersecurity in e-navigation is a critical issue that requires a collaborative multidisciplinary study between the maritime engineering and information security fields.

This bibliometric approach faces specific limitations, including its reliance on the Scopus database, which may exclude significant non-indexed literature or industry reports. This may affect the analysis less comprehensive. External factors, such as the COVID-19 pandemic, may have influenced publication trends.

Empirical research that investigate human issues, such as the establishment of comprehensive regulatory frameworks to supervise technological uptake and operator training for e-navigation equipment, should be included in future research (Sandu et al., 2024). Additionally, it is imperative to conduct thorough investigations into cyber security concerns, conduct resilience assessments of e-navigation frameworks, and integrate autonomous surface vessels into existing navigational systems. Flexibility and safety will be enhanced in future maritime navigation systems by emphasizing collaboration among disciplines. The deep mapping of academic activity established an important basis for the enhancement of long-lasting, safe, and intelligent maritime operations worldwide.

This discussion entails a comprehensive bibliometric analysis, aligns with established literature, and adheres to the standards set by esteemed international publications in the maritime technology sector.

4. CONCLUSION

This bibliometric study deliberately outlines the research landscape on electronic navigation (e-navigation) in the marine industry from 2018 to 2024, revealing important trends, main contributors, and thematic goals. The main results suggest that research output increased very quickly at initially and subsequently went down, which is likely a sign that the discipline is becoming more mature. There is also a growing concern about issues with implementation, standards, and cyber security. Maritime transportation, collision avoidance, and Automatic Identification Systems are still important themes. However, new topics like the Maritime Internet of Things show where research is going in the future. This analysis improves the understanding of by revealing worldwide cooperation trends and identifies gaps in research. The consequences for maritime safety, operational efficiency, and environmental preservation are significant, emphasizing the importance of interdisciplinary research that is focused on human aspects and resilience. Future research should focus on practical implementation, cyber security resilience, operator education, and regulatory frameworks to enhance the safety and intelligence of e-navigation systems. This investigation provides a comprehensive, evidence-based framework for the direction of ongoing industrial and academic initiatives

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