University of South-Eastern Norway
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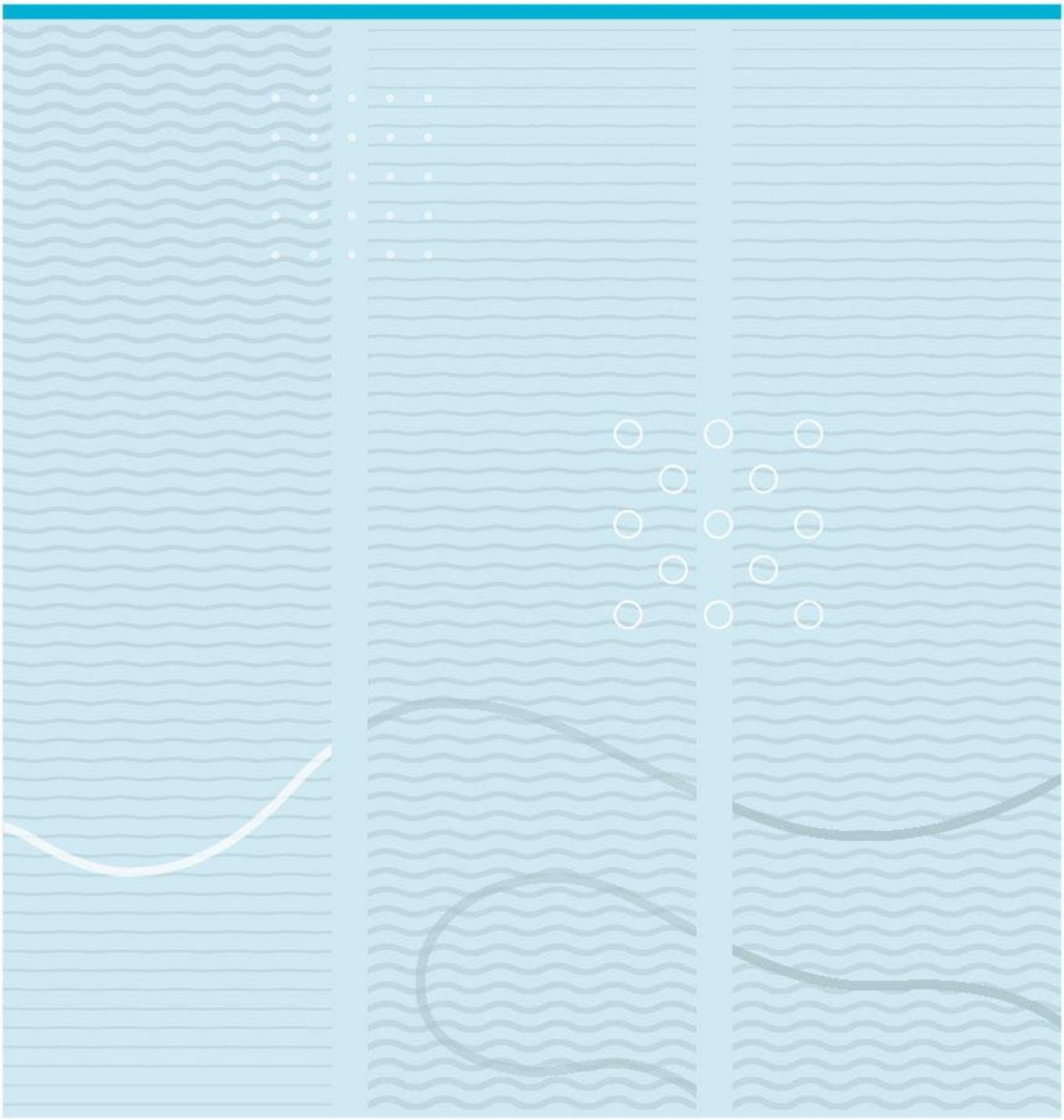
Human factors in maritime accidents: a bibliometric review



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Abstract

Maritime transport is often associated with high risk. Accidents at sea can have major consequences, it can lead to the loss of ships, loss of cargo, loss of human life and pollution of the oceans. Human factors or human error is the leading cause of maritime accidents. The aim of this thesis is to obtain an overview of the bibliometric features from scientific publications on human factors in maritime accidents. The study uses various bibliometric methods to identify the most influential publications. Through the Web of Science database, 376 publications in the research field were identified. To analyse and visualize the data, the software tool VOS viewer was used. The study revealed a small number of influential journals, productive countries, and notable publications. This paper contributes to research on human factors in maritime accidents by identifying important publications and important concepts related to human error.

Keywords

Human factor, human error, maritime accidents, maritime safety, bibliometric analysis, co-author analysis, bibliometric coupling, co-occurrence analysis, text mining.

Foreword

This master's thesis represents the end of the master's degree in Maritime Management at the University of South-Eastern Norway. This thesis is based on the knowledge I have acquired through the Maritime Management study, as well as knowledge I have acquired while working on this thesis. The work process has been demanding, but at the same time exciting and educational. The work on this master's thesis has strengthened my professional and personal competence.

With that said, I would like to thank my supervisor Umar Burki for the guidance on this master thesis. I am also very grateful for all the support and encouragement I have received from family, friends, and my partner Magnus, during the work with my master thesis.

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1 Introduction

Humans can make mistakes, and many maritime accidents are caused by human error. In 2021, the ship Golden Ray capsized, resulting in total loss of the ship and the cargo is was carrying. The cause of the accident was human error, the ship did not meet international stability standards and the ship was less stable than the chief officer had calculated (Juliano, 2021). In addition, watertight doors were open, so that the ship quickly took in water when it capsized. In 2018, the frigate KNM Helge Ingstad collided with the tanker MT Sola, the cause of the accident is mainly due to negligence from the bridge crew, which can be seen as a human error (Riise, 2023).

The outcome of a maritime accident can be catastrophic. It can lead to the cargo and vessels being lost, destroy the ecosystem in the ocean, cause great damage and in the worst case, loss of human life. Although the worlds merchant fleet is increasing, there is a decrease in maritime accidents that have led to loss of ships. In 2012, 132 ships were completely lost, while in 2020, 58 ships were completely lost (Lloyd's List Intelligence & DNV, 2022, p 32). This is a decrease of over 50 percent. Nevertheless, there are far more incidents that did not lead to total loss of vessels (Lloyd's List Intelligence, n.d.). Maritime accidents can occur for many different reasons, but according to Hasanspahic et al. (2021), over 80 percent of maritime accidents are due to human error.

For thousands of years, people have used the sea to transport goods between different cities, countries, and continents. Large parts of global trade are transported by sea. As of today, around 90 percent of international trade is transported by sea and the world is largely dependent on sea transport (Ocean Shipping and Shipbuilding, n.d.). As of 2022, the world's merchant fleet consists of over 58,000 ships. Ro-Ro and general cargo ships dominate the world's merchant fleet, and counts for 31% of the world merchant fleet (Statista Research Department, 2022). These ships often cross the world's oceans and pass-through narrow channels. The demanding journeys entail a significant risk and can be dangerous. If something goes wrong on a ship in the middle of one of the world's oceans, help is far away and probably will not arrive until it is too late.

Maritime accidents can lead to major damage, both material damage, damage to nature and human injury which in the worst case leads to loss of life. Maritime accidents can create a bad reputation and serious financial consequences for shipping companies. Human factors seem to be the triggering cause of maritime accidents in many cases. Human factors are about understanding human work and the connection between people and the work they do. Alphonse Chapanis (1980, p. 17) defines it as follows: "Human factors engineering is concerned with ways of designing tools, machines, jobs, operations, and environments so that they match human abilities and limitations". In many ways, the human element is therefore about making work more efficient by adapting the work to the worker. An important goal of human factors is also to reduce errors and increase safety.

The maritime industry is a global industy that involves people from all continents. At the same time the industry that is in constant developement. As mentioned, one of the aims of human factors is to increase safety. The number of maritime accidents caused by human error may indicate that there is little focus on human factors in the maritime industry. The International Maritime Organization (IMO) has laws and regulations on how ships must be operated to ensure safe operation and avoid loss of life (International Maritime Organization, n.d.). This is further elaborated in chapter 2.2. International regulations are important to avoid maritime accidents.

Considering all the nationalities on board ships and everyone involved in the running and operations of ships, it is obvious that misunderstandings can occur. In addition, different nationalities have different cultures, which can affect how individuals' approach to safety. This paper will examine published academic literature in the area, the research questions are defined in the next section.

1.1 Research question

The high percentage of maritime accidents caused by human error is an exciting field, and there are many academic publications in the field. This thesis will investigate academic publications on human factors related to maritime accidents, using various bibliometric analysis methods. The framework that will guide the bibliometric analysis is defined in the following research questions:

1) Identifying and visualize the research publication trend, top leading journals, organizations, countries, and authors.
2) What are the most frequently cited publications and their impact?
3) Which focus areas is important in the field?

1.2 Structure of the paper

The structure of the thesis is defined in this section. In chapter 2, human factors in maritime accidents are defined, both the percentage of accidents caused by human error from what various researchers have found in their studies and human factors that can lead to maritime accidents. In chapter 3, the method used in this study is introduced, and the data collection process is shown. Furthermore, in chapter 4 the analysis is carried out and the results are presented. In chapter 5, the findings from the analysis are discussed. Chapter 6 provides a summary of the most important findings from this study.

2 Human factors and maritime accidents

In maritime literature, the terms human element, human factor and, in some cases, human error are often used interchangeably (Barnett & Pekcan, 2017). In this thesis, the term *human factors* will be used most often, and the term human error will be used for errors caused by humans that result in accidents or undesirable situations.

In maritime literature, it is widespread that around 80 percent of maritime accidents occur as a result of human error. Nevertheless, there are some differences in the results from various surveys. Hasanspahic et al. (2021) claim that 80-85 percent of maritime accidents are due to human error. Wagenaar and Groeneweg (1987) found that only 4 out of 100 investigated incidents were not due to human error. In a survey of Turkish search and rescue areas Erol & Başar (2015) found that 60 percent of maritime accidents are due to human error. The difference between the two latter percentages is significant but could possibly be due to the definition of human error, as well as which actions are included or excluded in the studies. Table 1 shows the definition of human error used by the various studies.

Table 1: Defining human error

Author	Definition
Rothblum (2000)	Human error is caused by mistakes people make, through making wrong decisions, performing tasks incorrectly or lack of action. People must interact with technology, the environment and organizations. If these are not adapted to human abilities and limitations, human errors can occur.
Erol & Başar (2015), Reason (1990)	"Human factors … cover all actions reveal relationships between humans and machines." Human error occurs due to lack of action in unforeseen events.
Wagenaar and Groeneweg (1987)	Identifies all interactions between humans and machines as human factors. Classifies human errors according to cognitive system, social system, and situational system.
Hasanspahic et al. (2021)	Defines "all actions revealing the relationship between people and machines" as human factors. Classifies human errors according to external factors, organizational influences, unsafe supervision, predictions, and unsafe acts and identifies the most frequent factors.

2.1 Human factors in the maritime sector

From a maritime perspective, the human factors consists of "the entire spectrum of human activities performed by ships crews, shore-based management, regulatory bodies, recognized organizations, shipyards, legislators, and other relevant parties" (International Maritime Organization, n.d.-b). Based on this definition, one understands that the human factors do not just consist of an individual worker or a single organization. The maritime industry is an international industry, which consists of many organizations. Ships must, for example, follow laws and regulations issued by legislative bodies, I will return to this in the next sub-chapter. Also in the maritime industry, an important goal of the human factors is to reduce errors and increase safety. This is done through adapting and designing equipment, operations, technology, procedures, and environment to match human capabilities and limitations (Rothblum, 2000). An important factor in the maritime industry is technological development. If the new technology is not adapted to the workers and the workers do not understand how this technology works, unsafe situations will potentially arise which could have disastrous consequences.

2.2 Safety regulations to ensure maritime safety

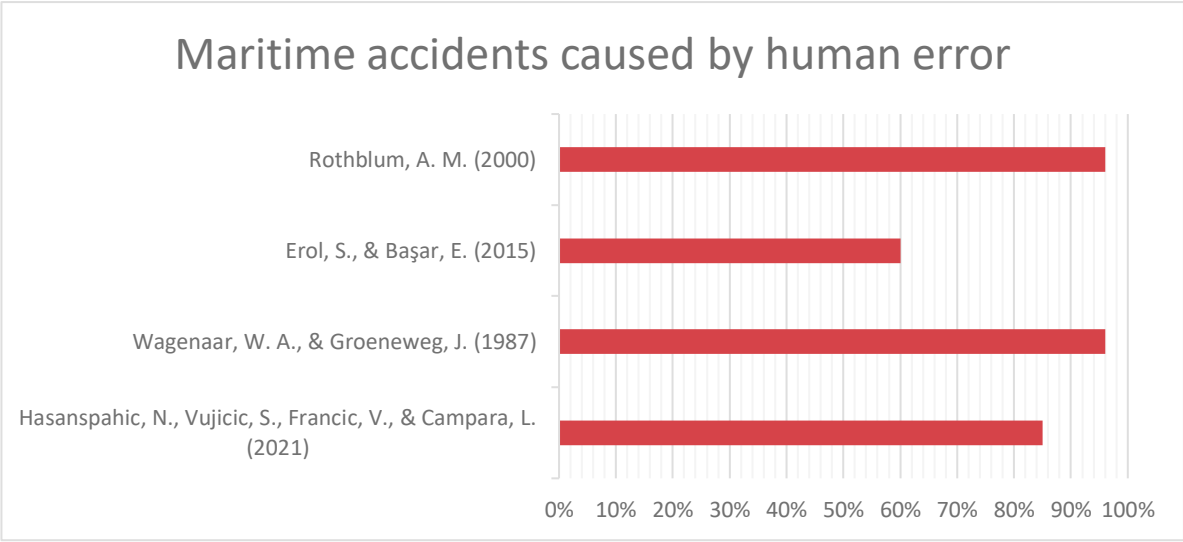
As previously mentioned, maritime operations can be critical and dangerous. The ships are often far out at sea, where help is far away, and may not arrive until it is too late. Therefore, safety at sea is very important. The International Maritime Organization is a sub-organisation of the United Nations. They are responsible for safe international shipping and pollution from ships (International Maritime Organization, n.d). The IMO is responsible for the regulations that apply to ships over a certain size (Sánchez-Beaskoetxea et al., 2021). The SOLAS (Safety Of Life At Sea) convention is a set of regulations that define minimum standards for the "construction, equipment and operation of ships" (International Maritime Organization, n.d). An important part of SOLAS is the International Safety Management (ISM) code which is regulated in SOLAS chapter IX. The purpose of the ISM code is to ensure the safe management and operation of ships, to avoid damage and loss of life, as well as the prevention of pollution (International Maritime Organization, n.d). It is important to point out that the International Maritime Organization legislation is only minimum standards and ship owners are free to introduce stricter rules for their ships. According to Tzannatos & Kokotos (2009) safety regulations, such as the ISM code have resulted in fewer accidents caused by humans.

2.3 Maritime accidents caused by human error

The technological development of the last two decades have led to reduced manning on ships (Hetherington et al., 2006). New technology has taken over work that was previously dependent on humans to carry out, while in many ways it has led to increased safety on board. Nevertheless, Lützhöft and Dekker (2002) argues that new technology creates new human weaknesses and at the same time reinforces the existing weaknesses. Because new technologically advanced systems do not necessarily replace human work but change the task the system is set to do and, in that way, potentially create new problems and potential undesirable situations. This means that the work is not adapted to human limitations. By adapting the new technology to human abilities and limitations, one will possibly strengthen the human resources and achieve increased efficiency and safety.

Maritime accidents that occur as a result of human error can be direct or indirect. Direct human error can, for example, be an inattentive watchkeeper that leads to a collision, the person has then simply acted irresponsibly. While indirect human errors can, for example, be unclear communication with others in the crew that leads to misunderstandings and thus potential accidents. Rothblum (2000) found that 75-96 percent of maritime accidents are due to human error made by one or more persons. She also points to the importance of preventing human error in order to reduce serious maritime accidents. But to be able to do this, the human errors that lead to maritime accidents must be identified. Figure 1 shows the percentages of accident caused by human error from the mentioned papers.

Figure 1: Maritime accidents caused by human error



In maritime literature, there is thus a broad consensus that human error is the biggest factor in the occurrence of maritime accidents. Based on the previously mentioned percentages from various articles, it can be said that 60 to 96 percent of maritime accidents are due to human error.

2.4 Human factors leading to maritime accidents

Despite the high proportion of maritime accidents caused by human error, the trend as previously mentioned is decreasing, and with an increasing world trade fleet, it is positive that the maritime accident trend is decreasing. By identifying human errors, preventive measures can be taken to reduce the number of maritime accidents. If one succeeds in reducing the number of accidents caused by human error, the total number of maritime accidents will be reduced considerably.

Maritime accidents can also occur for other reasons, such as natural disasters or technical failures. But human error is the most dominant cause of accidents in the maritime domain. Accidents that occur because of human error can, for example, be that the operator is tired or fatigued, poor communication between workers, poor training or a poor working environment that causes the workers to be unhappy. Working on a ship can be demanding for many. The workplace is far from home, seafarers are often away for several months at a time without the opportunity to see their family, they can experience a lot of bad weather, in addition to often working shifts (Hetherington et al., 2006). Missing family members or friends can distract workers from performing their work adequately. Distractions can be a contributing factor to maritime accidents and bad weather can affect workers health (Sánchez-Beaskoetxea et al., 2021). Health and stress are also human factors that can be a contributing cause of maritime accidents (Hetherington et al., 2006). Shift work can lead to not always getting enough sleep. At the same time, noise from machines and other systems can make it difficult to sleep on board a ship. Fatigue is a human factor that is often repeated in the studied literature and is said to be a contributing cause of maritime accidents. Chan et al., (2016) suggests that shipping companies should focus on the number of hours of rest and quality sleep for seafarers and try to increase their motivation.

There is much pointing on that human error leading to maritime accidents is a complex and composed problem. Chauvin et al., (2013) has found that most collisions are due to

decision errors. But the reason why seamen make the wrong decision can be many, it can be both due to individual and organizational factors. Individual factors can be exhaustion, fatigue, health, and stress. While organizational factors can be, for example, the safety climate/safety culture on board the ship. Unsafe organizational actions can lead to human errors resulting in accidents (Chan et al., 2016). According to Hetherington et al., (2006), safety climate is an important factor that can be a contributing cause of accidents, because it affects how individuals relate to safety.

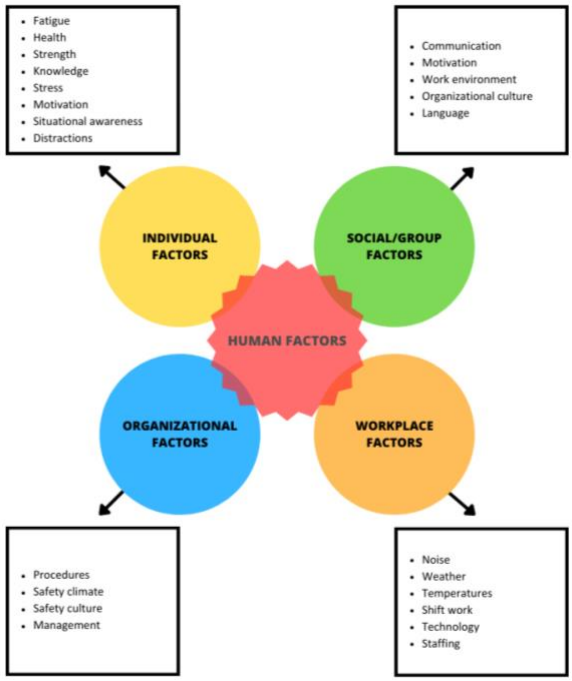
Communication is a human factor that often recurs in the studied literature and is referred to as a contributing cause of accidents (Chauvin et al., 2013; Hetherington et al., 2006; Sánchez-Beaskoetxea et al., 2021). Communication through walkie-talkies and radios can be unclear, as there is often a lot of noise on board a ship. In addition, the size of the boat and the material the ship is built from can affect signal strength and lead to interference. At the same time, people can give unclear messages to each other, which leads to misunderstandings. Another element that can lead to poor communication is language. As mentioned earlier, the maritime industry is international, and several ships have workers from different countries. If a shipping company has several employees who do not speak a common language, miscommunication quickly arises and can potentially lead to accidents. Therefore, more than two nationalities on board a ship can have a negative effect on maritime safety (Håvold, 2007). As mentioned, it can lead to miscommunication if the different nationalities do not have a common language to communicate in, which can result in unwanted situations arising. At the same time, the different nationalities can have different cultures because they come from different countries. This can lead to negative friction between the workers and in that way affect safety on board. Different nationalities' position on safety can also differ. People from some nations may take safety much more seriously than people from other nations. Due to these factors, in modern times there are several shipping companies that avoid employing more than one nationality on their ships. In this way, they reduce the risk of accidents or unwanted situations arising as a result of misunderstandings between the workers and different national cultures crashing and thus causing friction between the workers.

2.5 Dimensions of human factor

Human factors have a broad definition but are largely about adapting the work to the person's abilities and limitations. And in that way reduce the frequency and consequences of

human error. Human factors consist of many elements, in order to better understand human factors, a figure has been developed that defines different aspects of human factors. The figure is based on reviewed theory and will be useful for later analyses. Figure 2 shows the different dimensions of human factors.

Figure 2: Dimensions of human factors



The figure consists of four different dimensions, or categories, of human factors and is based on reviewed literature. These dimensions are individual factors, social/group factors, organizational factors, and workplace factors. The various dimensions consist of several elements that can affect people in a work situation, especially in the maritime industry. Individual factors consist of physical and psychological elements that influence human factors. Social/group factors consist of the work group and are defined through elements that can affect the individual in a work context. Organizational factors consist of elements that the company controls. Workplace factors are environmental elements in the workplace that have an external effect on the individual. It can be argued that workplace factors are external factors that are not included in human factors. But here this category is included because these can have a direct effect on human factors. For example, bad weather could affect the individual in a negative sense through, for example, acute sickness.

Accidents or unwanted situations caused by human error can occur because of, among other things, individuals personal health conditions or new technology in the workplace that confuses the worker. Human factors are a complex concept. The identified dimensions can influence each other and often have a connection. For example, the groups motivation to carry out the work can affect the individuals motivation to carry out the work. At the same time, shift work and low staffing can make individuals exhausted and stressed. The physical stresses that individuals experience in the workplace can also affect their health and stress levels. New technology in the workplace and the individuals level of knowledge are also elements linked to human factors. If the individual's level of knowledge does not match the required level of knowledge to master the technology, undesirable situations may arise. The organization’s safety culture and safety climate can influence individuals views on and relationship to safety. In the case of a sloppy safety culture, accidents could potentially occur.

3 Methods

In this chapter, the choice of method and the search process for this paper is presented. The aim of this thesis is to obtain an overview of the bibliometric features from scientific publications on human factors in maritime accidents. To do this, bibliometric analysis was chosen as the method. A bibliometric analysis is a quantitative analysis of results in the research field (Liang & Liu, 2018). There are various bibliometric methods, these are citation, co-citation, bibliographic coupling, co-occurrence, co-authorship analysis, and text mining. Based on the methods, one can analyse various units of the publications, for example in a citation analysis one can use countries as the unit of analysis, and in that way analyse trends and links between countries publications based on citations. Using the various methods, networks that make it possible to explore trends and connections between keywords, number of citations, organisations, journals and authors can be developed (Liang & Liu, 2018). In addition, the network analysis helps to identify clusters that are thematically similar. The chosen analysis method is largely about visualizing academic results to be able to identify important contributions and research gaps in the research field. The chosen bibliometric methods in this paper are citation analysis, co-author analysis, bibliographic coupling, co-occurrence analysis and text mining.

3.1 Study design

Bibliometric analysis is a quantitative method that involves analyzing large amounts of scientific data by using bibliometric software tools to analyze data from scientific databases (Donthu et al., 2021). In this thesis, the software tool VOS (visualization of similarities) viewer is used to analyze data from the scientific database Web of Science. When carrying out a bibliometric analysis, VOSviewer is a useful software tool. VOS viewer has been developed to construct and graphically present bibliometric maps, and in contrast to other bibliometric tools places great emphasis on visualization as the program makes it easier to interpret large bibliometric maps (van Eck & Waltman, 2010).

Bibliometric analysis is based on bibliometric characteristics from previously published literature, and can thus be considered a secondary study (Kitchenham et al., 2009). Web of Science is known to be a reliable database that publishes scientific literature from well-known publishers. Donthu et al. (2021) recommends using only one scientific database in

bibliometric analysis, this to avoid filtering large data sets, as well as reduce the likelihood of errors occurring in the analysis. Bibliometric analysis helps researchers see the big picture by visualizing large amounts of scientific data.

3.1.1 Bibliometric methods

A citation analysis is based on citations and measures the influence of the publication based on the number of citations received (Donthu et al., 2021). In this analysis, one can choose documents, sources (journal), authors, organizations, and countries as the unit of analysis. If one use organization as the unit of analysis, one will find the most influential organization, i.e., the organization that has received the most publications in the research field. A high number of citations to a publication indicates that it is an influential publication with important findings. The citation analysis is used in this thesis to identify leading journals, organizations, countries, and authors within the research field.

A co-author analysis examines relationships between authors and shows collaboration between authors, organizations, or countries (Donthu et al., 2021). Based on the analysis, a co-author network is formed, which visualizes the collaboration. If two authors are connected in the network, this means that they have collaborated, the thickness of the line indicates how many documents the authors have collaborated on. In this thesis, co-author analysis is used to measure collaboration between countries that have published documents in the field. The relationship between the countries is established as a result of joint publication of one or multiple documents (Lu & Wolfram, 2012).

A bibliographic coupling analyzes the relationship between publications based on their shared references, publications that share references are assumed to be thematically similar (Kessler, 1963). In this analysis too, one can choose document, source (journal), authors, organizations, and countries as the unit of analysis. A bibliographic link occurs because two publications cite the same publication. In this thesis, a bibliographic link analysis was carried out with authors as the unit of analysis. The bibliographic link between the authors shows which authors have shared references. The thicker the line between two authors, the stronger the bibliographic link between them, which means that they have more shared references in common (van Eck & Waltman, 2014).

A co-occurrence analysis explores relationships between topics in the research field, based on the keywords that appear in the documents, i.e., the written content of the publications (Donthu et al., 2021). The relationship between two keywords is based on the number of times the keywords occur together in publications. Co-occurrence analysis "is a content analysis technique that uses the words in documents to establish relationships and build a conceptual structure of the domain" (Zupic & Čater, 2015). In this paper, co-occurrence analysis is used to analyze co-occurrences of authors' keywords.

Text mining is a technique that makes it possible to analyze large amounts of written content from many publications (van Eck & Waltman, 2011). The text mining function in VOS viewer was used to create term maps. The text mining technique is used to find relevant terms related to human factors and maritime accidents. The variable content on which the analysis is based is the publication's title and abstract. VOS viewer identifies the most relevant terms and includes these in the term map. The term map shows how the various terms are related to each other.

3.2 Search and process

After choosing the Web of Science as a database, the search term was developed. In a bibliometric analysis, it is important to define search terms that give large enough search results, but still focus on search terms that are relevant to the research field. To be sure that no articles were excluded, synonyms and related words were used in the search. For example, instead of only searching for articles that contained "shipping", "maritime" was also included. Then Web of Science searches for articles that contain both words. In order to find as relevant articles as possible, Web of Science was set to search the articles' "title, abstract and keywords" by selecting "topic" as the search target. Table 2 shows the search terms used in Web of Science.

Table 2: Search term in Web of Science

Search field	Search terms
Topic	“shipping” OR “maritime”
Topic	“accidents” OR “disasters”
Topic	“human factors” OR “human errors”

The search was carried out on 31 December 2022 and the search term resulted in a total of 391 articles in Web of Science. After the first search, some of the articles were filtered out. Only articles written in English were included, i.e., articles published in other languages were excluded. In addition, the document types "article, review article, early access and proceeding paper" were included and the document types "correction and editor material" were excluded. This led to a total of 376 articles, which will be used in the bibliometric analysis.

Table 3: The data collection process

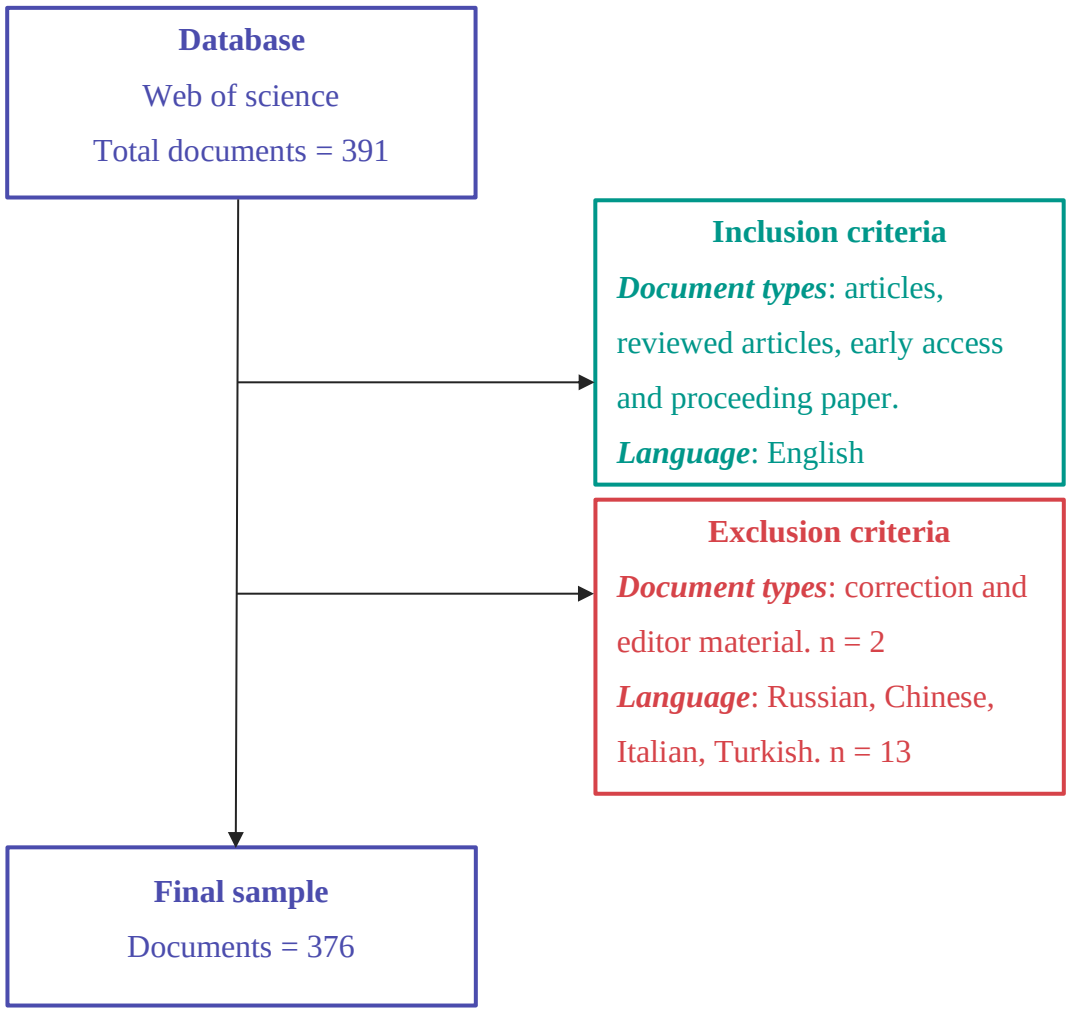


Table 3 shows the process of collecting data from Web of Science. Documents in other languages were excluded because its not be possible to use them in the analysis of data with the software tool VOS viewer, as in some bibliometric methods it can only handle data from English-language publications. In total, 15 documents were excluded, and the final sample consists of a great number of articles for the bibliometric analysis.

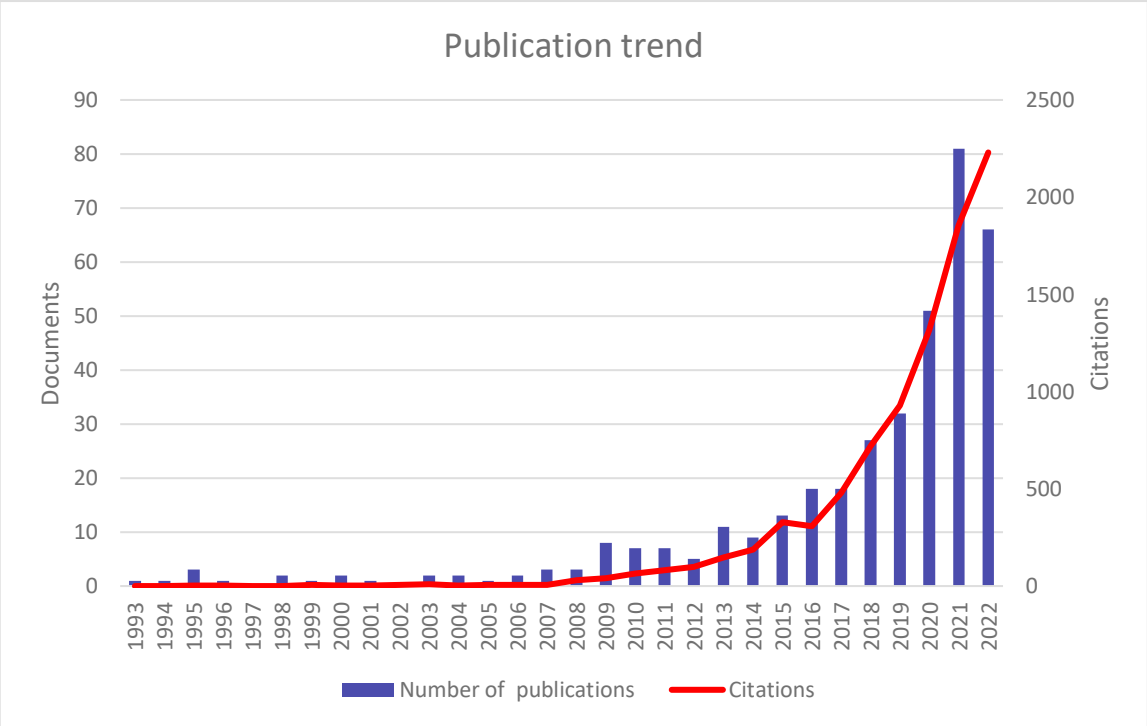
4 Analysis and results

In this chapter, the bibliometric analysis of the documents from the VOS viewer is carried out using various bibliometric methods. First, the publication trend of the documents in the research field is presented in chapter 4.1. The analysis itself is then carried out on the bibliometric data and the results are presented in chapter 4.2.

4.1 Initial analysis – The publication trend

The publication trend provides a presentation of how research activity has developed in the research field over the years. Figure 3 shows the number of publications and citations per year from 1993 to 2022. The line defines the number of citations, and the columns in the figure defines the number of publications. The numbers are obtained from Web of Science using their Analyze Results function. This function can be used to analyse different characteristics in the research sample. According to Web of Science, the first article in the field was published in 1993. The first article in the research sample is about the air transport industry. The authors study the design and use of cockpit checklists and believe that the findings in the article are transferable to other high-risk industries, such as maritime transport (Degani & Wiener, 1993).

Figure 3: The publication and citation trend



In the period 1993 to 2022, 376 documents were published. From figure 3, one can see that in the period 1993-2012 the number of publications were under 10 documents annually. From 2014, the publication trend is increasing, until 2022, where the number of publications is somewhat reduced. Over 83 percent of the published articles within the research field have been published in the last nine years. It shows that human factors linked to maritime accidents have received a lot of attention in recent years. The number of citations per year also shows an increasing trend in the figure. The number of citations has more than tripled in the past five years, from 721 citations in 2018 to 2,230 citations in 2022. The increased attention in recent years may indicate greater acceptance within the research field, while at the same time showing the importance of human factors in maritime accidents.

4.2 Bibliometric analysis

4.2.1 Top leading journals

The final sample consisted of 376 documents. These have been published by a total of 122 journals. Table 4 shows the 10 leading journals within the research field and is ranked by total number of citations (total citations). The table also includes the number of documents published by the journals, average citation, and total link strength. Total citations show how many times the journal has been cited by others in the research field. Average citation shows how many citations the journal has on average, based on the number of published documents and total citations. Total link strength shows the total connection the given journal has with other researchers. How many published documents a journal has says something about how productive they are (Donthu et al., 2021). A journal that has many publications in the research field is said to be productive, but one cannot say that they have a great influence in the field. The number of citations, on the other hand, is often used as a measure of influence. A journal that has many citations is considered to be important in the research field (Zupic & Čater, 2015).

The number of published documents, total citations and total link strength have been found by carrying out a citation analysis with source as the unit of analysis in VOS viewer. A minimum of five documents per journal was set as threshold criteria in the analysis. Out of the 122 journals, only 14 have published more than five documents.

Table 4: Top 10 leading journals

Journal	Documents	Total citations	Average citations	Total link strength
Safety Science	45	2048	45,51	375
Reliability Engineering & System Safety	31	1602	51,68	328
Accident Analysis and Prevention	6	724	120,67	165
Ocean Engineering	37	661	17,86	297
Journal of Navigation	16	568	35,50	71
Risk Analysis	7	441	63,00	87
Maritime Policy and Management	13	328	25,23	112
Journal of Marine Science and Engineering	20	116	5,80	84
Applied Ocean Research	5	100	20,00	36
Applied Science-Basel	6	47	7,83	27

From table 4, one can see that the leading journal when it comes to total citations is *Safety Science*, with 2048 total citations. *Safety Science* also has the highest total link strength, which is 375. The next journal is *Reliability Engineering & System Safety*, with 1602 total citations. The third largest ranked in terms of number of citations is *Accident Analysis and Prevention*, with 724 total citations.

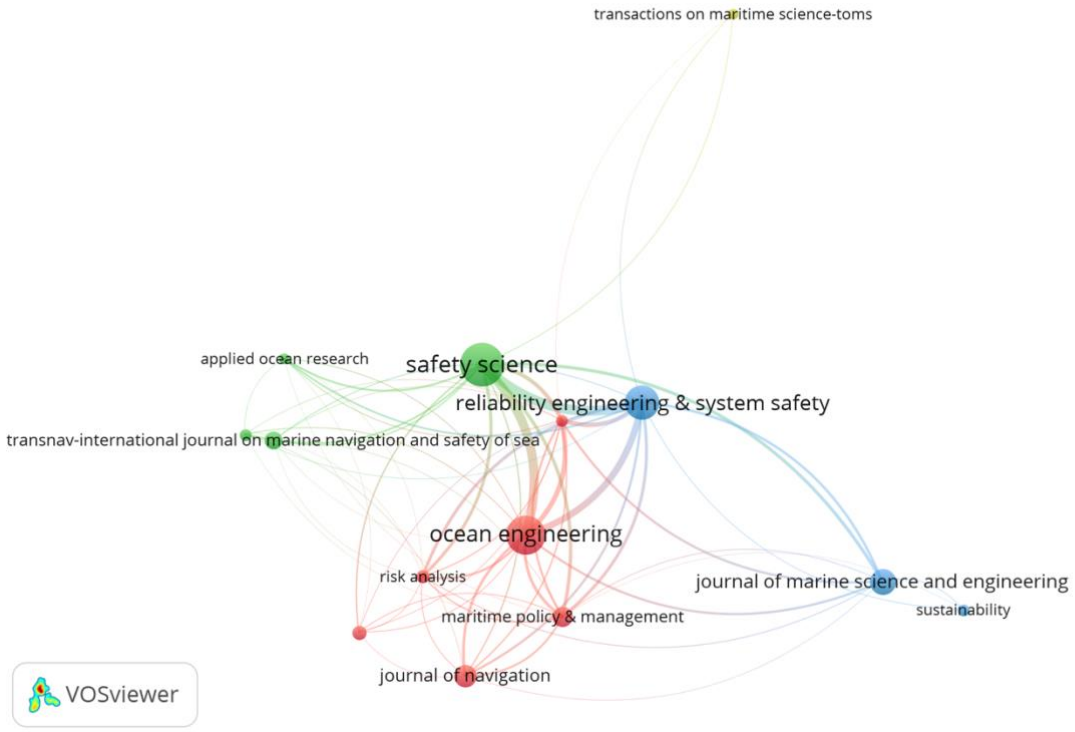
If the leading journals is ranked according to the number of published documents, *Safety Science* is still at the top, with 45 documents. The second largest journal is then *Ocean Engineering*, with 37 published documents and 661 total citations. The third largest ranked by the number of published documents is *Reliability Engineering & System Safety*, with 31 published documents. Together, these three journals have published 113 articles, that is 30 per cent of the published articles in the research field.

If the journals are ranked by average citations, *Accident Analysis and Prevention* is clearly the largest, with an average citation of 120.67 per published documents. The second largest is then *Risk Analysis* with an average citation of 63 per published documents. Accident Analysis and Prevention has almost twice as many average citations to its documents than Risk Analysis. This may suggest that Accident Analysis is an influential and important

journal within the research field. The third largest is then *Reliability Engineering & System Safety*, with an average citation of 51.68 per published documents.

Figure 4 provides a visualization of the most influential journals in the research field and is constructed using the same criteria as in table 10. The circles indicate how many publications the journal has (van Eck & Waltman, 2014). The larger the circle, the more publications the journal has. The position on the circles says something about how the journals are related to each other (van Eck & Waltman, 2014). The closer the circles are to each other, the more strongly they are related to each other. The thickness of the line between the circles indicates the link between the two journals (van Eck & Waltman, 2023). The thicker the line, the stronger the link between them.

Figure 4: Citation network of journals



Based on figure 4, one can see that four clusters are formed, respectively red, green, blue, and yellow. These indicate that the journals within the same cluster are relatively strongly related to each other. The red cluster has six journals, the green cluster has four journals, the blue cluster has three journals, and the yellow cluster has only one journal. From the figure one can see that the journals Safety Science, Reliability Engineering & System

Safety and Ocean Engineering have strong links to each other and that Transactions on maritime science has few connections to the other journals.

4.2.2 Top leading organizations

In total, there are 315 research organizations that are associated with one or more of the 376 published documents within the research field. In order to get an overview of the leading organisations, a citation analysis was carried out with organizations as the unit of analysis in VOS viewer. A minimum of nine documents per organization was set as threshold criteria in the analysis. Out of 315 organisations, only 14 organizations have published more than 9 documents in the research field and therefore meet the threshold criteria. Table 5 shows the 10 leading organizations, ranked by total number of citations. The table also includes the number of documents published by the organizations, average citation, and total link strength.

Table 5: Top 10 leading organizations

Organization	Documents	Total citations	Average citations	Total link strength
Liverpool John Moores University (England)	21	875	41,67	277
Wuhan University of Technology (China)	27	836	30,96	206
Aalto University (Finland)	13	744	57,23	127
Istanbul Technical University (Turkey)	35	694	19,83	282
Memorial University of Newfoundland (Canada)	12	382	31,83	125
Karadeniz Technical University (Turkey)	16	380	23,75	202
University of Tasmania (Australia)	12	309	25,75	91
Shanghai Maritime University (China)	24	306	12,75	146
Norwegian University of Science and Technology (Norway)	9	163	18,11	40
Ordu University (Turkey)	11	134	12,18	168

From table 5, one can see that the leading organization when it comes to total citations is Liverpool John Moores University (England), with 875 citations and 277 in total link strength. The next organization is Wuhan University of Technology (China), with 836 citations and 206 in total link strength. The third largest organization ranked by number of citations is Aalto University (Finland), with 744 total citations and 127 in total link strength.

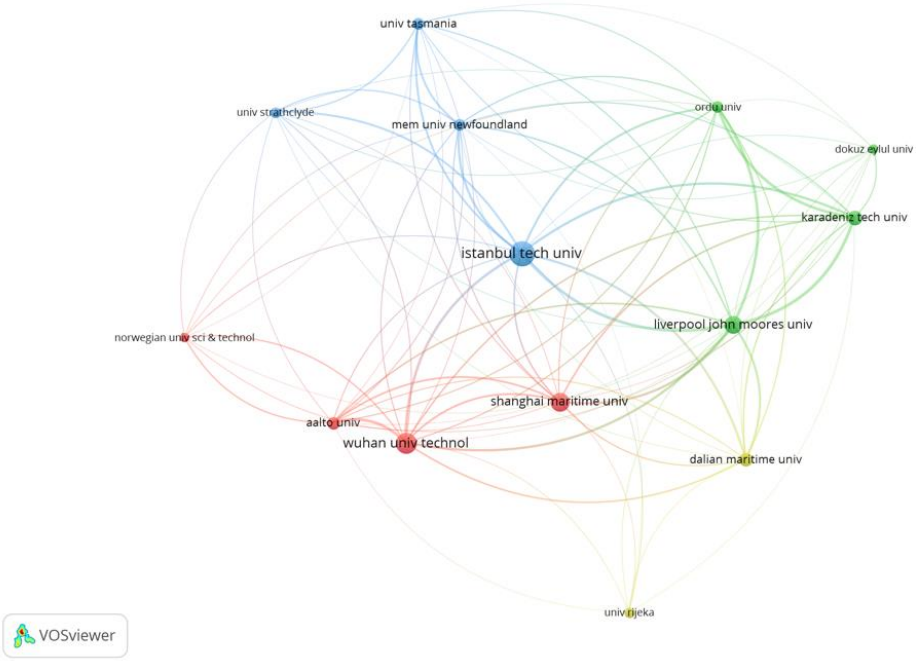
These three organizations are geographically dispersed, with two in Europe and one in Asia. The ten leading organizations have published a total of 180 documents, which corresponds to 47.9 percent of the articles in the research field.

The most productive organization, based on the number of published documents, is not ranked in the top three by number of citations. Istanbul Technical University (Turkey) is considered the most productive organization, with 35 published documents and the highest total link strength of 282. The second most productive organization is Wuhan University of Technology (China), with 27 published documents. The third largest organization ranked by the number of published documents is Shanghai Maritime University (China), with 24 published documents.

Ranking leading organizations by average citations, Aalto University (Finland) is the leading organization, with an average of 57.23 citations per published document. The second largest is then Liverpool John Moores University (England), with an average of 41.67 citations per published document. The third largest organization is Memorial University of Newfoundland (Canada) with an average of 31.83 citations per published document.

Figure 5 is a visualization of leading organizations in the research field, the figure corresponds to table 5. The circles represent how many publications the organizations have, and the lines indicate the links between the organizations and shoes how the organizations are related. From figure 5 one can see that many of the organizations have strong links to each other and that several of the organizations have links to all the other organisations, such as Istanbul Technical University (Turkey) and Liverpool John Moores University (England). Out of the leading organizations, the University of Rijeka (Croatia) is the one with the fewest links to the other organizations.

Figure 5: Citation network of organizations



In figure 5 one can see that four clusters emerged, red, green, blue, and yellow. The red, green, and blue cluster has four organizations, while the yellow one has only two organizations. In the green cluster there are mainly Turkish universities, which shows that these are strongly related to each other. From the figure, Wuhan University of Technology (China) and Aalto University (Finland) are located close to each other, which suggests that they are strongly related to each other. This can be seen in the context of the fact that these universities have collaborated on a published document.

4.2.3 Top leading countries

As can be seen from table 6, the research organizations are geographically dispersed. Furthermore, a citation analysis is carried out with countries as the unit of analysis, so that the leading countries within the research topic can be identified. A total of 52 countries have contributed to research within human factors and maritime accidents. A minimum of nine documents per country was set as threshold criteria in the analysis, 15 countries met this criterion. Table 5 shows the 10 leading countries, ranked by total number of citations. The table also includes the number of documents published by the organizations, average citation, and total link strength.

Table 6: Top 10 leading countries

Country	Documents	Total citations	Average citations	Total link strength
Turkey	74	1477	19,96	733
People´s Republic of China	79	1370	17,34	793
England	37	1227	33,16	444
Finland	13	744	57,23	213
USA	26	634	24,38	190
Scotland	13	575	44,23	219
Norway	18	522	29,00	195
Australia	20	519	25,95	186
Canada	15	513	34,20	226
Portugal	9	434	48,22	194

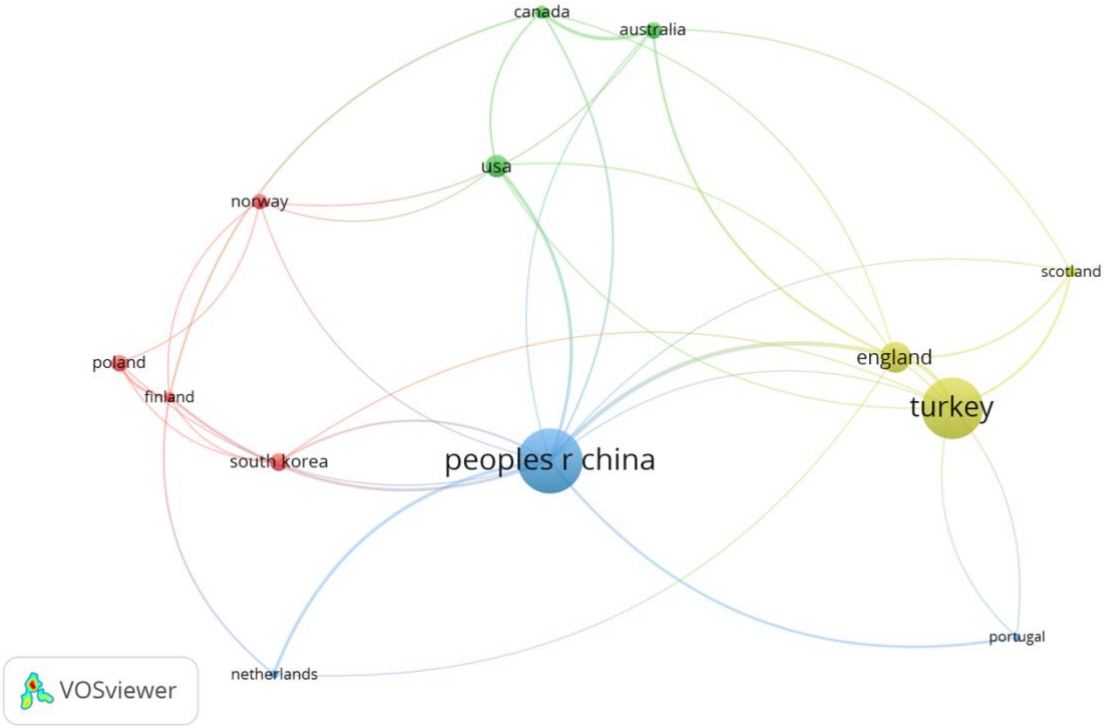
Based on table 6, Turkey, the People's Republic of China and England are the top three leading countries based on total citations. Turkey ranks highest based on total citations, with 1477 citations and 733 in total link strength. The People's Republic of China has 1370 total citations and the highest total link strength of 793. England has 1227 total citations and 444 in total link strength.

Based on the number of published documents, the People's Republic of China ranks highest, with 79 documents, and is thus the most productive country in the research field. Turkey comes close behind, with 74 published documents. The third largest publishing country is England, with 37 published documents. Both the People's Republic of China and Turkey have published twice as many documents as England. The three leading countries have published over 50 percent of the documents in the research field and can thus be said to be very productive. As these three countries also have the most citations, they can also be said to be influential within the research field.

Ranked by average citations, Finland is the leading country, with an average of 58.23 citations per published document. Although Finland and Scotland have published the same number of documents, Finland's documents are more often cited on average. The second leading country based on average citations is Portugal, with an average of 48,22 citations per published document.

Furthermore, a co-authorship network has been developed, using VOS viewer. The network visualizes how authors across national borders have collaborated on published documents. The co-authorship network analysis has been developed using countries as unit analysis. At least eight documents per country was set as the threshold criterion in the analysis, with full counting as the counting method. Figure 6 shows the co-authorship network of countries.

Figure 6: Co-authorship network of countries



The countries in the network are connected to each other based on the number of publications they have collaborated on. Figure 6 shows the People's Republic of China has collaborated on publications with all the other countries in the network (Links = 12). The thickness of the links between the countries shows that the People's Republic of China has strong connections to England, the USA and the Netherlands. They have collaborated on nine and five publications respectively. Four clusters are formed under the criterion. The red cluster consists of four countries, while the green, blue, and yellow cluster consists of three countries. Croatia is not included in the co-authorship network, as the country had a total link strength equal to zero. In other words, Croatia has not cooperated with any of the other countries in the network visualization.

4.2.4 Authors

There are many authors who have published documents related to human factors and maritime accidents. In order to find the most influential authors in the research field, a citation analysis was carried out, with the author as the unit of analysis. The threshold criterion in the analysis was set to one, i.e., all authors were included, in order to include the most influential authors in the research field. There are a total of 838 authors who have published articles within the research topic.

Sometimes the author has published documents under different names. For example, this could be that in some cases the author has included their middle name in the publication, in other cases not. At the same time, the author's full name can also appear in some documents, while in other documents only the author's initial is written as their first name. This means that an author can be repeated in the list of authors. To avoid this, the data has been cleaned, using a VOS viewer thesaurus file. The thesaurus file enables the researcher to combine different variants of an author's name into one (van Eck & Waltman, 2023). Before the merge, VOS viewer identified 881 authors who have contributed to publishing the 376 documents. After the thesaurus file was added, there were, as previously mentioned, a total of 838 authors, which means that 43 duplicates were removed, see appendix 1. Table 7 shows the top ten authors, ranked by the number of citations.

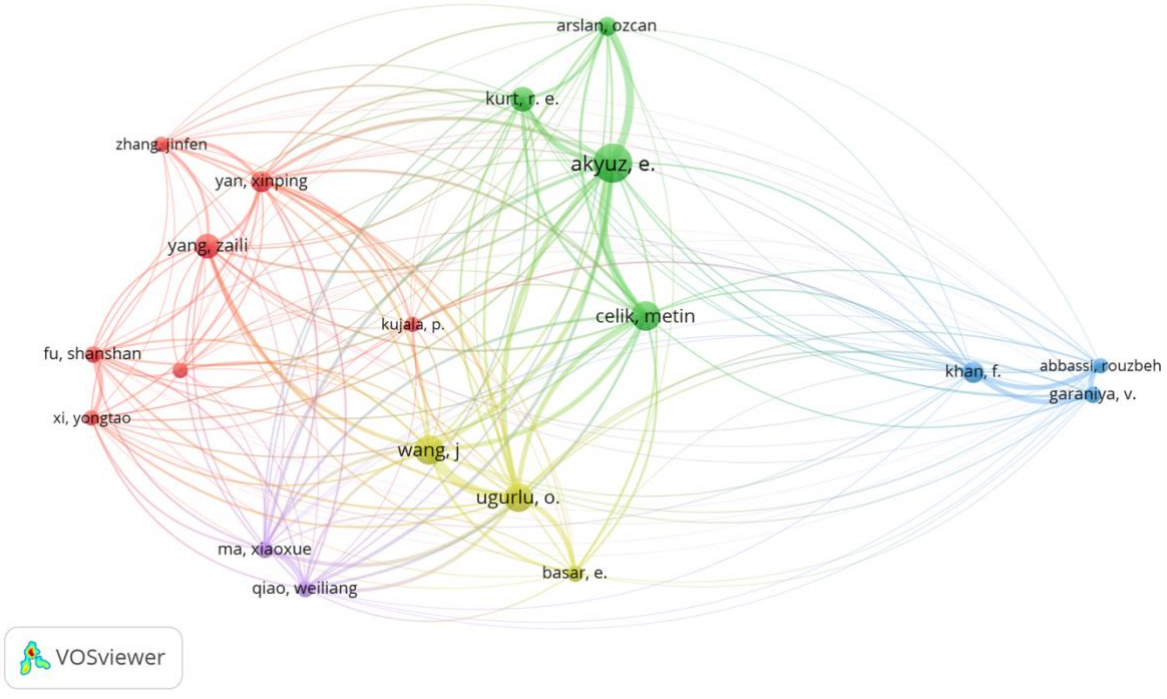
Table 7: Top 10 cited authors

Author	Documents	Total citations	Average citations	Total link strength
Wang, Jin	14	695	49,64	887
Kujala, Pentti	6	619	103,17	415
Celik, Metin	14	572	40,86	923
Akyuz, Emre	20	499	24,95	1016
Yan, Xinping	9	444	49,33	625
Ugurlu, Ozkan	13	396	30,46	1061
Flin, Rhona	1	385	385,00	253
Hetherington, Catherine	1	385	385,00	253
Mearns, Kathryn	1	385	385,00	253
Goerlandt, Floris	4	363	90,75	274

From table 7, one can see that Wang is the leading author, based on the number of citations, with a total of 695 citations. Next is Kujala and Celik with 619 and 572 citations respectively. The positions on the top can largely be attributed to collaboration. Through the analysis function in the VOS viewer, it was found that Wang has collaborated with Ugurlu on seven documents, while Kujala has collaborated with Goerlandt on three documents, where one of these documents is also with Yan. Celik has collaborated with Akyuz on five published documents. Flin, Hetherington and Mearns have collaborated on one of the most influential documents within the research topic and have the same number of citations, published documents, average citations and total link strength. This means that none of these have published any other documents within the research field. The document they have published is called *Safety in shipping: The human element.*

Akyuz is the most productive author in the research field and has published a total of 20 documents. Next is Wang and Celik, who have published the same number of documents, 14 each. The next is Ugurlu, who has published 13 documents, and has the highest total link strength of 1061.

Figure 7: Bibliographic coupling network of authors



Furthermore, a bibliographic coupling network has been developed to illustrate links and relations between authors who tends to cite the same publications in the research field. Figure 7 visualizes the bibliographic coupling between the authors. The bibliographic link analysis has been developed using authors as the unit of analysis. Only authors who have published five or more articles are included in the network, the bottom four on the top ten list are therefore not included in the network. The thesaurus file developed for the citation analysis was also used in this analysis.

Authors who are linked to each other in the network are bibliographically coupled because both in one or more of their publications cited a third publication (Kessler, 1963). The more common documents two authors cite, the greater the bibliographic link between the authors. In figure 7, this is shown with the line between authors, we can see that Akyuz often cites the same publications as Celik, Arslan and Kurt. Hence, Akyuz has a strong bibliographic link to these authors. From the figure, we can also see that Akyuz is the author with the most publications, because that circle is the largest. Based on the criteria, five clusters are formed, which are based on the authors' shared references. The red cluster consists of seven authors, while the green one consists of four authors, the blue and yellow clusters consist of three authors, while the purple cluster consists of only two authors. There is a strong relation between authors in the same cluster (van Eck & Waltman, 2014).

4.2.5 Top leading articles

Table 8 shows the ten most cited documents in the research field. The documents have been identified using Web of Science's filter, where you can select the most cited documents. The publication trend showed that in the last ten years there has been a large increase in the number of publications, yet one can see that almost all the top cited articles were published more than 10 years ago. The first published article in the research field which was published in 1993 is also among the top ten cited articles, it is ranked the ninth most cited. The article is called *Cockpit checklists - Concepts, design, and use* and is written by Degani and Wiener and has a total of 151 citations. As this study examines published articles up to 2022, average citations per year are calculated from the year the document was until the year 2022. Average citation equals the total number of citations divided by 2022 minus the year of publication.

Table 8: Top 10 cited publications

Rank	Document	Author	Citations
1	Safety in shipping: The human element	Hetherington, Flin and Mearns (2006)	385
2	A Bayesian Belief Network modelling of organisational factors in risk analysis: A case study in maritime transportation	Trucco, Cagno, Ruggeri and Grande (2008)	312
3	Human and organisational factors in maritime accidents: Analysis of collisions at sea using the HFACS	Chauvin, Lardjane, Morel, Clostermann and Langard (2013)	294
4	A review on improving the autonomy of unmanned surface vehicles through intelligent collision avoidance manoeuvres	Campbell, Naeem and Irwin (2012)	247
5	Automatic identification system (AIS): Data reliability and human error implications	Harati-Mokhtari, Wall, Brooks and Wang (2007)	216
6	Traffic simulation based ship collision probability modeling	Goerlandt and Kujala (2011)	206
7	Analytical HFACS for investigating human errors in shipping accidents	Celik and Cebi (2009)	185
8	An Overview of Maritime Waterway Quantitative Risk Assessment Models	Li, Meng and Qu (2012)	152
9	Cockpit checklists - Concepts, design, and use	Degani and Wiener (1993)	151
10	Review of Collision Avoidance and Path Planning Methods for Ships in Close Range Encounters	Tam, Bucknall and Greig (2009)	149

The most cited article is *Safety in shipping: The human element*, written by Hetherington, Flin and Mearns. It was published in 2006 and has a total of 385 citations and can be said to be one of the most important documents in the field. The article examines how human factors affect safety at sea, through a literature review (Hetherington et al., 2006). The article has an average of 24.06 citations per page. Their study found that “fatigue, automation, situation awareness, communication, decision making, team work, and health and stress” are human factors that influences maritime safety (Hetherington et al., 2006).

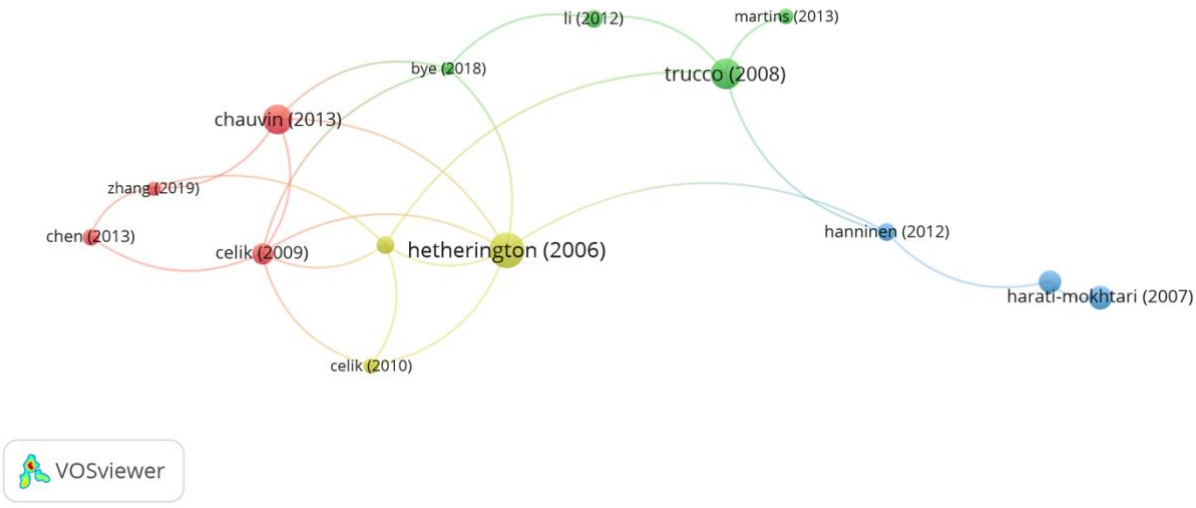
The second most cited article is called *A Bayesian Belief Network modeling of organizational factors in risk analysis: A case study in maritime transportation* and is written by Trucco, Cagno, Ruggeri and Grande. The article has 312 citations and was published in 2008, average citations per year is 22.29. The authors provide an approach on how the Bayesian Belief Network can be used to develop better risk models in the maritime industry (Trucco et al., 2008).

The third most cited article in the research field is *Human and organizational factors in maritime accidents: Analysis of collisions at sea using the HFACS*, written by Chauvin,

Lardjane, Morel, Clostermann and Langard. The article was published in 2013 and has a total of 294 citations and an average of 32.67 citations per year, and thus has the most citations per year. The authors use the Human Factor Analysis and Classification System (HFACS), which is a tool for analysing human factors in accidents, to study contributing factors, both human and organizational, in maritime accidents (Chauvin et al., 2013).

Figure 8 provides a visualization of the most influential publications in the research field and has been developed by doing a citation analysis with document as the unit of analysis in VOS viewer. As a threshold criterion in the analysis, the minimum citations per document is set to 100. There are 17 publications that meet the criterion, but Degani and Wiener's (1993) publication are not included because the total link strength is equal to zero, the publications by Campbell et al. (2012) and Tam et al. (2009) are also not included because they are only connected to each other. They therefore have no links to the other publications in the research field, given the criteria. Therefore, there are only 14 publications in the network. It is important to mention that the VOS viewer only includes the publication's first author, even if there are several co-authors.

Figure 8: Citation network of documents



The publications in the network are linked to each other based on citations. For example, the publication by Hetherington (2006) is cited by, among others, Celik et al. (2010) and Bye and Aalberg (2018). The publications with the highest links to the other publications in the network are Celik et al. (2009) and Hetherington (2006), each of which is associated

with six other publications in the network. Based on the criteria, four clusters are formed, the publications in the various clusters have several similarities. The red cluster consists of four publications that use the HFACS tool to investigate human error in maritime accidents. The green cluster consists of four publications that investigate the risk of maritime transport. The blue cluster consists of four publications that investigate collisions. The yellow cluster consists of three publications, where the authors mainly focus on human factors in maritime accidents.

4.2.6 Co-occurrence analysis of author keywords

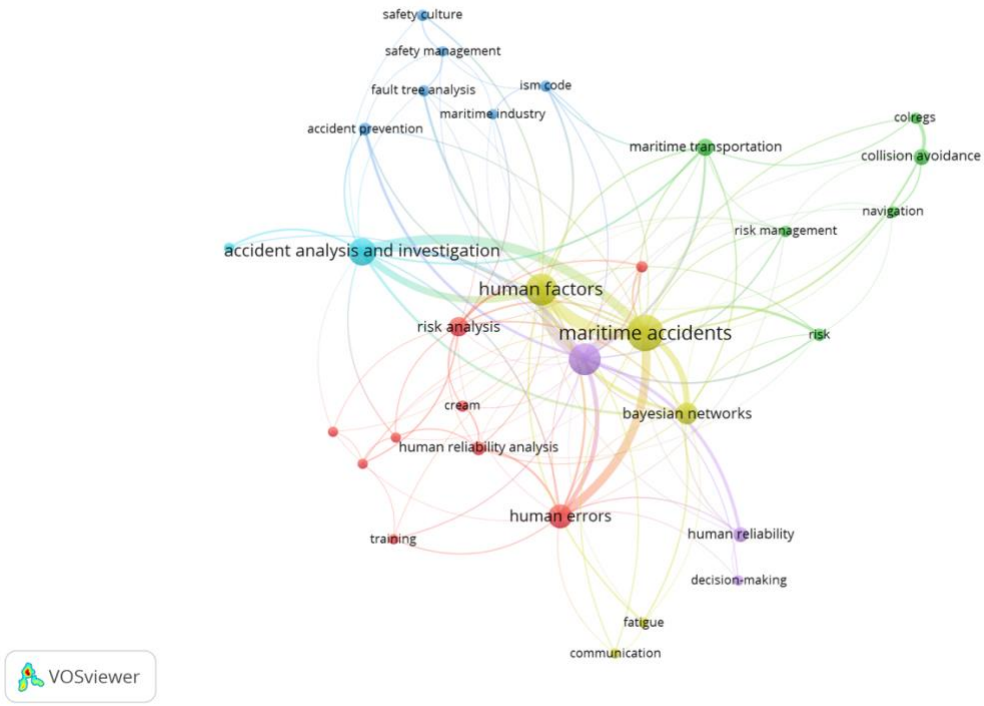
In order to find the most occurred keywords in the research field, a co-occurrence analysis was carried out with the authors' keywords as the unit of analysis. Here, a thesaurus file was also used to merge keywords of equal meaning, for example safety and safety at sea are merged with maritime safety, human error is merged with human errors and similar. All the keywords that have been merged can be found in the appendix 2. Combining similar keywords provides a better visualization of the network, as several of the keywords have the same meaning. The threshold criterion in the analysis was set at a minimum of four occurrences of a keyword, of which 35 keywords met the criterion. Certain keywords were removed because they had little significance in the co-word network. The keywords that were removed are data mining, maritime, fuzzy logic, and ship. Table 9 shows the ten most frequently occurring keywords.

Table 9: Top 10 author keywords

Keyword	Occurrence	Total link strength
Maritime accidents	98	79
Maritime safety	70	53
Human factors	69	60
Accident analysis and investigation	47	39
Human errors	35	27
Risk analysis	20	16
Bayesian network	17	14
Maritime transportation	14	11
Collision avoidance	12	8
Human reliability	10	7

Table 9 shows that *maritime accidents* are the most frequently occurring keyword, and it has a total link strength of 79. There are many keywords that are combined with maritime accidents, and that may be one of the reasons why it occurs most often. The second most frequent keyword is *maritime safety*, which occurs 70 times and has a total link strength of 53. Human factors are the third most frequent keyword, occurring 69 times and has a total link strength of 60. Figure 9 visualizes the co-occurrence analysis.

Figure 9: Co-occurrence analysis network of author keywords



Several of the keywords used in the search in Web of Science are the very core of the network. The keywords that occur most often are placed close to each other, i.e., they are strongly related to each other, and often occur at the same time (van Eck & Waltman, 2014). In addition, these have a strong connection to each other, which we can see from the thickness of the line between the keywords. The keywords *fatigue* and *communication* are located close to each other, this indicated that these two keywords often occur together. The keywords are related with human factors that potentially can lead to maritime accidents. The colour of the circles indicates which cluster the keyword belongs to. Based on the criteria, VOS viewer has grouped the keywords into six clusters. Furthermore, the VOS viewer's text mining function will be used to perform a text mining analysis and create a term map that are based on the

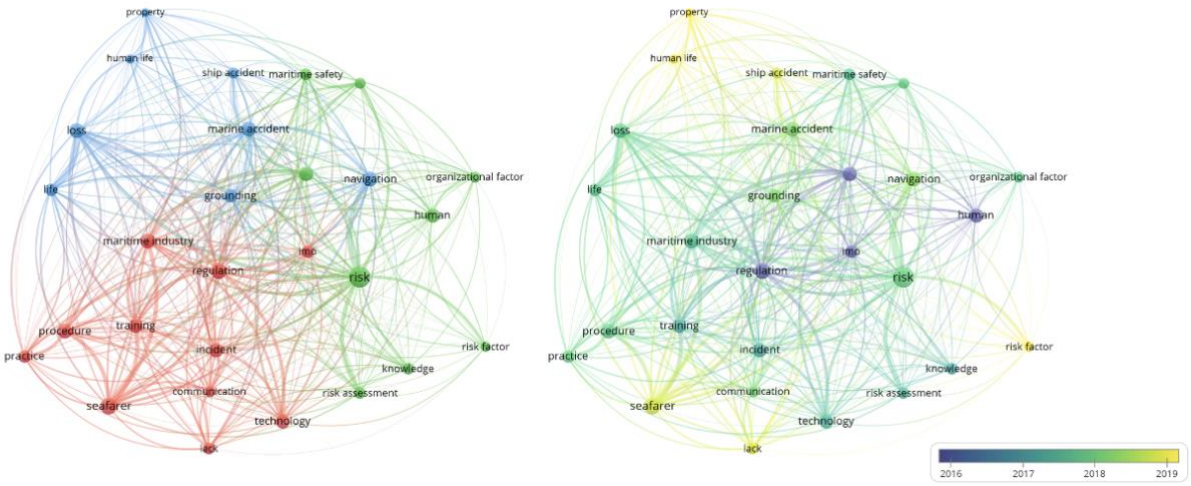
documents' core text materials. The function gives a more accurate picture of the concepts and the theoretical framework in the research field than when using the authors' own keywords.

4.2.7 Text mining and clusters

With the help of VOS viewer's text mining function, a term map has been constructed, which also helps to identify thematically similar clusters. The terms are taken from the abstract and title of the 376 documents in the research field. Binary counting was used as the counting method, which means that only the presence of the term matters, the number of times the term occurs in the title or abstract is not considered (van Eck & Waltman, 2014). A minimum of ten occurrences of a word was set as the threshold criterion. Out of a total of 8,638 terms, 129 met this criterion. Again, a thesaurus file was used to combine words of equal meaning, see appendix 3. VOS viewer calculates a relevance score for each of the terms, and only includes the most relevant ones for further analysis. 60% of the most relevant terms are included as it is set as the default choice in the VOS viewer. It results in 73 terms. In addition, 45 terms were removed because they would have had little significance in the term map. The reason why so many terms were removed is because many of them are general and cannot be interpreted in an analysis. This includes terms such as article, author, model etc. In addition, there were several terms linked to the analysis methods the authors have used, this applies for example to HFACS, Bayesian network, Human Factor analysis etc. Other terms of general importance such as, for example, concept, consequence, importance, etc. were also removed. All the excluded terms are listed in appendix 4. A total of 28 terms have been identified through VOS viewer.

The text mining analysis identifies the most relevant terms and research themes that occur in the publications from the research field. The term map to the left in figure 10 visualizes the links and the relationship between the terms. The overlay visualization to the right shows the same links and relations, but here the timewise publication trend for the terms is visualized. Each circle represents a term, and the distance between the circles defines the relationship between them (van Eck & Waltman, 2011). If two circles are located close to each other, this means that the terms often appear together in a document. The size of the circles indicates how many times the terms occur, the more often a term occurs, the larger the circle. The link between the terms that connects them together indicates the number of times the terms occur together in documents (van Eck & Waltman, 2023).

Figure 10: Text mining network and overlay visualization



From the figure to the left, the network visualization, one can for example see that the terms *human* and *organizational factor* are located close to each other. In addition, there is a link between these, the link strength is equal to seven, that means both of these terms occur together in seven documents. Based on the criteria, three clusters are created by VOS viewer - red, green, and blue. Which cluster the terms are placed in is shown in table 9, all the terms in each cluster are listed. The terms are ranked according to how many times they occur, and the terms relevance score is also shown. From the figure on the right, the overlay visualization, one can see that the average publication year for all terms is between 2016 and 2019. The timeline is determined automatically by VOSviewer. The grouping of clusters, i.e., the colour of the circles, is here based on the terms' average publication year. The yellow cluster represents keywords that has a average publication year as of 2019.

From table 10, one can see that *risk* is the term that occurs most often. It occurs 94 times, and has a total link strength of 205, which means that that the term co-occurs with 205 other terms in total. The second most frequent term is *seafarer*. It occurs 57 times and has a total link strength of 156. The term that occurs the third most often is *regulation*, it occurs 50 times and has a total link strength of 170. The terms' relevance score indicates its relevance. A high relevance score indicates that the term tends to represent specific topics, while a low score indicates that the term is more general (van Eck & Waltman, 2023). The term *human life* has the highest relevance score, which may indicate that human factors is important to prevent loss of human life in maritime accidents.

Table 10: Clusters and terms with occurrence and relevance score

Cluster 1 The human element in shipping			Cluster 2 Human and organizational factors			Cluster 3 (Blue) Risks of shipping		
Term	**T.O**	**R.S**	**Term**	**T.O**	**R.S**	**Term**	**T.O**	**R.S**
Seafarer	57	0.66	Risk	94	0.67	Navigation	47	0.27
Regulation	50	0.89	Maritime transportation	43	0.40	Loss	44	0.75
Maritime industry	49	0.69	Human	40	0.47	Marine accident	44	0.69
Procedure	45	0.72	Maritime safety	29	0.28	Grounding	34	0.38
Incident	41	0.73	Knowledge	27	0.43	Life	31	0.59
Technology	41	1.00	Decision making	26	0.27	Ship accident	25	0.31
Training	41	0.58	Risk assessment	26	1.67	Human life	17	2.07
Practice	33	0.45	Organizational factor	23	1.23	Property	17	1.65
IMO	30	0.41	Risk factor	21	1.46			
Lack	28	0.66						
Communication	25	1.44						

T.O = Total occurrences. R.S = Relevance Score

As previously mentioned, three thematic clusters emerged from the 28 terms, based on the criteria in the analysis. The term from the clusters is presented in table 10. Each of the clusters represents terms that are thematically similar and that often occur together. In chapter 2, based on reviewed literature, a figure was developed for different dimensions of human factors, the different dimensions of human factors were individual, social, organizational and workplace factors. Keywords in clusters that can be related to any of these dimensions will be mentioned.

Cluster 1 is the largest cluster and consists of a total of 11 keywords. The cluster represents the human element and human errors in shipping. The keywords *seafarer* and *training* are closely related to individual human factors. Seafarer refers to individuals and can define unwanted actions that these undertake and mistakes they make. Training can be related to a person's individual knowledge and qualifications to carry out the work, so that unwanted actions do not occur. The cluster also represents an important keyword related to social human factors. The key word is communication, which can be related to challenges with communication on board ships, which can lead to accidents or unwanted incidents. Another important keyword that occurs in this cluster is technology. Technology can be linked to workplace factors, and how shipping companies implementing new technology, but can also

be related to how individuals adapt to the new technology. The keyword *lack* is linked among others communication and training. This may indicate that there is lack of communication between workers onboard ships. This corresponds with the results of Chauvin et al. (2013) analysis of human factors in collision accidents.

Cluster 2 is the second largest cluster and contains a total of nine keywords. The cluster appears to represent keywords related with human and organizational factors. The keywords *decision making* can be related to an individual's actions in a critical situation but can also be related to the management's focus on safety. The management's focus on safety is crucial for how the humans in the organization handle critical and risky situations. Many risky situations can arise in shipping. It is therefore important that the employees in the shipping organization have the right *knowledge* they need to carry out the work. It is also important that both workers and management have knowledge of how to handle critical situations. Incompetence can be a contributing factor to maritime accidents (Celik & Cebi, 2009).

Cluster 3 is the smallest cluster and consists of a total of eight keywords. The cluster represents risks related with shipping. *Marine accidents*, *ship accident*, and *grounding* are all keywords related to maritime accidents, i.e. potential dangers associated with shipping. A consequence of maritime accidents is related to the keyword *loss*, it can apply to the loss of ships, *property*, goods or, in the worst case, *human life*. Safe and secure *navigation* is a critical element when it comes to maritime safety.

5 Discussion

This thesis aimed to identify and visualize the research publication trend, leading journals, organizations, countries, and authors, identify, and study the most frequently cited publications and their impact, as well as to define the important research areas in the field, through various bibliometric methods. In chapter 4, data collected from the Web of Science was analyzed using the bibliometric software tool VOS viewer. The results of the analysis are shown in the same chapter.

The publication trend showed that there has been a large increase in the number of published articles in recent years. It shows a great interest in the research field, while also showing the importance of knowledge about human error in maritime accidents. The number of publications in 2022 was somewhat decreasing, nevertheless the citation for documents in the research field is still increasing. The fall in the number of publications may be random but could also be due to the research field being saturated, but this is unlikely as the number of citations are still increasing. The first publication in the research field was aimed at the aviation industry, which indicates that the focus on human factors started earlier in other industries than in the maritime industry. But based on the number of publications and citations, one can see that human factors have received a lot of attention in the maritime industry in recent years.

There are many journals that have published documents in the research field, but only seven of these have published more than ten documents. It suggests that only a small number of the journals are productive and have a great interest in the field. Six of these journals are also in the top ten list of most cited journals, which suggests that they have a large influence in the research area. The journal in second place, Reliability Engineering & System Safety, ranked by number of citations, has published the second and the sixth most cited documents in the research field, which may explain the number of citations the journal has. The journal in third place, ranked by number of citations is Accident Analysis and Prevention. They have published the third and the seventh most cited document. The Journal of Navigation, which is ranked as the fifth leading journal based on the number of citations has published the fifth and tenth most cited document. This suggests that these productive journals have a great influence on the research field. The different clusters of journals represent journals that are thematically

similar. One of the clusters represents safety, while another represents engineering and another navigation. This indicates that human factors are important on many levels.

The leading organizations or universities are very geographically dispersed, which suggests that the research field is interesting regardless of geographical location. The leading organizations can be seen in the context of the leading countries. Three of the leading universities are located in Turkey. Based on the number of citations, Turkey is the leading country. Two of the leading universities are located in China. Based on the number of published documents, China is the leading country. There are many organizations that have published documents in the research field, but based on the number of published documents and citations one can see that there are only a few leading organizations. The organizations that are most productive and influential are located in countries that can be considered major shipping nations. The co-authorship analysis revealed that several of the countries have had close collaboration on published articles. Among other things, it showed that Norway and Finland have collaborated on a published document, which is natural as both countries are located in Scandinavia and are partly surrounded by the Nordic Seas. In addition, the analysis revealed that China has collaborated with many countries on published documents, and that China has collaborated with England on multiple documents. China is considered a major shipping nation and most likely has large amounts of data related to maritime accidents or unwanted situations, research collaboration with skilled organizations in other countries may result in strong findings.

There are many researchers who have contributed to publications in the research field, and some of these are linked to various organizations and journals. The bibliographic link between authors revealed which authors tend to cite the same publications, it gives an indication of the authors' different research areas. Many of the leading authors have been co-authors on some of the most cited documents in the research field, but the most productive author is not a co-author on any of the most cited publications. The fact that this author has published 20 documents in the research field indicates that he is an eager researcher who has gained great influence in terms of the number of citations achieved on his publications. The most cited publication in the research field is *Safety in Shipping: The human element* written by Hetherington, Flin and Mearns. They have written an important and influential publication. Although the authors have only published one document in the research field, they are still in the top ten list of leading authors, which says something about the impact their article has had

on the research field. The large number of highly cited publications suggests that there are several influential and important authors in the research area. The citation network of documents showed that the most cited documents have different research areas and research methods. Some of the publications used HFACS as a method to analyze human errors in maritime accidents, some publications study the risks of maritime transport, some publications investigate collisions at sea and the last one studies human factors in maritime accidents. Analyzing and identifying potential risks in maritime transport is important in order to prevent accidents from occurring.

The co-occurrence analysis of the authors' keywords showed that the most used keywords are maritime accidents, maritime safety, and human factors. It points to the importance of the focus on human factors in the maritime industry. By identifying and reducing the number of human errors, the number of maritime accidents can most likely be reduced, as most accidents are caused by human error. In addition, the co-occurrence analysis showed several analysis methods that authors have used to analyze human factors in the maritime industry. The text mining analysis showed that risk, seafarer, and regulations were the terms that occurred most often, based on the document's title and abstract. The terms in the text mining network are relatively centralized, the terms have a strong connection to each other and are located close to each other. The text mining network identified three clusters that are thematically similar. They represented the human element and human error, human and organizational factors, and risks related to shipping. It shows that human factors are complex and that there are many elements that come into play to achieve increased maritime safety, but also to other important aspects. It is not always easy to identify risks that could potentially lead to maritime accidents.

The authors study factors influencing maritime accidents in different areas using different methods. The various areas being researched are maritime accidents caused by collisions, grounding, and general accidents. Hetherington et al. (2006) uses a framework for the various levels at which errors can occur, these are organizational and management issues, personnel issues and design issues. Chauvin et al. (2013) use the HFACS model and categorize human errors according to unsafe acts errors, predictions for unsafe acts, unsafe leadership, organizational influences and outside factors. The studies have a different approach to human factors, but they mainly consist of the same categories. Important focus areas for studies on human factors in maritime accidents are organizational factors, external factors, individual

and social factors, as figure 2 showed in chapter 2. The most cited articles in the field use different analysis methods and theories to explore different aspects of human factors related to maritime accidents.

Different dimensions of human factors are an important focus area in the research field. The focus is on individual factors such as training, practice, and knowledge. The terms training and practice indicate that maritime organizations must focus on training of seafarers and maintaining their knowledge through practice. In addition, there is a focus on social factors such as communication. It is important that the communication is clear, both between managers and workers, but also communication with other ships. Multiple nationalities on board a ship can cause language barriers. Words can mean different things in different languages. Dialects and accents can affect pronunciation, which in turn can lead to misunderstandings. An important cause of maritime accidents also seems to be organizational factors. These factors are aimed at how shipping companies leads and manages in order to achieve increased safety. Human error is about more than a mistake made by a single individual. Human errors are connected to the attitudes, procedures, training, etc. of the organization's management. In addition, it is about peoples individual factors, such as stress, health, fatigue, etc. People's ability to understand and use new technology is also an important factor in avoiding human errors.

There is a lot of money involved in the maritime industry, and the loss of property such as ships can have significant financial consequences for the shipping companies. Shipping companies focus on human factors and human errors should therefore be greater. By adapting the job to peoples abilities and limitations, shipping companies can achieve increased maritime safety and thus avoid financial losses, and even more importantly, loss of human life.

5.1 Limitations and future research

The analysis includes all documents published in the research field from the scientific database Web of Science. Although the database contains many documents from peer-reviewed publishers, there are far more articles in the field than those published in Web of Science. A limitation of this study is therefore that only one scientific database was used. There are several scientific databases, such as, for example Science Direct or Scopus. By

including publications from several databases, the analysis would have been more comprehensive, and the research findings would have been strengthened. Therefore, in the future it would be interesting with a similar study that includes publications from several scientific databases. As a form of secondary study, a bibliometric analysis is based on previously published documents, therefore it is very important that authors publish the most important findings from their studies. This study is therefore limited to the authors having published their most important findings in their publications.

The maritime industry is constantly developing and there is a lot of new technology that is taking over human tasks in the shipping industry, and research is being done on unmanned vessels. If unmanned vessels become a reality in the future, it will be interesting to research human factors related to autonomous ships. The dangers of a potential accident on an unmanned ship are great, as there will be no one on board the ship to rectify the fault or damage. Therefore, it is even more important that everything is done correctly when the ship sets to sail, and that those who control the ship from shore carry out the work correctly.

6 Conclusion

The number of maritime accidents has decreased in recent years. The increased focus on safety and introduction of stricter regulations has been important in increasing maritime safety. Nevertheless, catastrophic accidents that result in the total loss of ships and loss of human life still occurs. Human error is the leading cause of maritime accidents, and human error accounts for 60-96 percent of all maritime accidents.

This study contributes to research on human factors and maritime accidents by identifying the publication trend, leading journals, organizations, countries, authors, and publications in the research field. The publication and citation trend shows a growing interest in the research field. It is a large research field with many publications, where different studies have different focus areas. Based on leading journals, a few with great influence were identified, which also turn out to be the most productive journals in the research field. The most influential countries in the research field are mainly Turkey, China, and England. Many important authors were identified, but three influential ones in particular stand out, namely Hetherington, Mearns and Flin, who together have published the most influential publication in the field of research. The co-occurrence analysis showed many of the analysis methods researchers in the field have used, but also identified important keywords such as maritime accidents, maritime safety, and human factors. Maritime safety can be said to be the very essence of identifying human factors related to maritime accidents. This study has identified several factors that are important to avoid human errors that can result in maritime accidents. Important focus areas are individual and social human factors, organizational factors, regulations, but also losses, which can be related to the loss of property such as ships and human life.

The fact that human factors are responsible for such a large proportion of maritime accidents indicates that the maritime industry should continue to focus on human factors and arrange so that the work is adapted to people's abilities and limitations. By identifying human factors that lead to maritime accidents, it will be possible to increase maritime safety.

References

Barnett, M. L., & Pekcan, C. H. (2017). The Human Element in Shipping. *Encyclopedia of Maritime and Offshore Engineering*, 1–10. https://doi.org/10.1002/9781118476406.emoe033

Celik, M., & Cebi, S. (2009). Analytical HFACS for investigating human errors in shipping accidents. *Accident Analysis & Prevention*, *41*(1), 66–75. https://doi.org/10.1016/j.aap.2008.09.004

Chan, S. R., Hamid, N. A., & Mokhtar, K. (2016). A Theoretical Review of Human Error in Maritime Accidents. *Advanced Science Letters*, *22*(9), 2109–2112. https://doi.org/10.1166/asl.2016.7058

Chapanis, A. (1980). Human factors engineering for safety. *Professional Safety*, *25*(7), 16–25.

Chauvin, C., Lardjane, S., Morel, G., Clostermann, J.-P., & Langard, B. (2013). Human and organisational factors in maritime accidents: Analysis of collisions at sea using the HFACS. *Accident Analysis & Prevention*, *59*, 26–37. https://doi.org/10.1016/j.aap.2013.05.006

Degani, A., & Wiener, E. L. (1993). Cockpit Checklists: Concepts, Design, and Use. *Human Factors: The Journal of the Human Factors and Ergonomics Society*, *35*(2), 345–359. https://doi.org/10.1177/001872089303500209

Donthu, N., Kumar, S., Mukherjee, D., Pandey, N., & Lim, W. M. (2021). How to conduct a bibliometric analysis: An overview and guidelines. *Journal of Business Research*, *133*, 285–296. https://doi.org/10.1016/j.jbusres.2021.04.070

Erol, S., & Başar, E. (2015). The analysis of ship accident occurred in Turkish search and rescue area by using decision tree. *Maritime Policy & Management*, *42*(4), 377–388. https://doi.org/10.1080/03088839.2013.870357

Hasanspahic, N., Vujicic, S., Francic, V., & Campara, L. (2021). The Role of the Human Factor in Marine Accidents. *Journal of Marine Science and Engineering*, *9*(3), 261. https://doi.org/10.3390/jmse9030261

Håvold, J. I. (2007). National cultures and safety orientation: A study of seafarers working for Norwegian shipping companies. *Work & Stress*, *21*(2), 173–195. https://doi.org/10.1080/02678370701424594

Hetherington, C., Flin, R., & Mearns, K. (2006). Safety in shipping: The human element. *Journal of Safety Research*, *37*(4), 401–411. https://doi.org/10.1016/j.jsr.2006.04.007

International Maritime Organization. (n.d.-a). *Frequently Asked Questions*. Retrieved November 24, 2022, from https://www.imo.org/en/About/Pages/FAQs.aspx

International Maritime Organization. (n.d.-b). *Human Element*. Retrieved January 25, 2023, from https://www.imo.org/en/ourwork/humanelement/pages/default.aspx

International Maritime Organization. (n.d.-c). *International Convention for the Safety of Life at Sea (SOLAS), 1974*. Retrieved February 15, 2023, from https://www.imo.org/en/About/Conventions/Pages/International-Convention-for-the-Safety-of-Life-at-Sea-(SOLAS),-1974.aspx

International Maritime Organization. (n.d.-d). *The International Safety Management (ISM) Code*. Retrieved November 24, 2022, from https://www.imo.org/en/OurWork/HumanElement/Pages/ISMCode.aspx

Juliano, M. (2021). *Human error caused Golden Ray to capsize, say US safety officials*. TradeWinds. https://www.tradewindsnews.com/casualties/human-error-caused-golden-ray-to-capsize-say-us-safety-officials/2-1-1068223

Kessler, M. M. (1963). Bibliographic coupling between scientific papers. *American Documentation*, *14*(1), 10–25. https://doi.org/10.1002/asi.5090140103

Kitchenham, B., Pearl Brereton, O., Budgen, D., Turner, M., Bailey, J., & Linkman, S. (2009). Systematic literature reviews in software engineering – A systematic literature review. *Information and Software Technology*, *51*(1), 7–15. https://doi.org/10.1016/j.infsof.2008.09.009

Liang, T.-P., & Liu, Y.-H. (2018). Research Landscape of Business Intelligence and Big Data analytics: A bibliometrics study. *Expert Systems with Applications*, *111*, 2–10. https://doi.org/10.1016/j.eswa.2018.05.018

Lloyd's List Intelligence. (n.d.). *Maritime Casualty Incidents*. Retrieved February 15, 2023, from https://www.lloydslistintelligence.com/knowledge-hub/data-storytelling/maritime-casualty-incidents

Lloyd's List Intelligence, & DNV. (2022). *Maritime Safety 2012-2021: A decade of progress*. Lloyd's List Intelligence.

Lu, K., & Wolfram, D. (2012). Measuring author research relatedness: A comparison of word-based, topic-based, and author cocitation approaches. *Journal of the American Society for Information Science and Technology*, *63*(10), 1973–1986. https://doi.org/10.1002/asi.22628

Lützhöft, M. H., & Dekker, S. W. A. (2002). On Your Watch: Automation on the Bridge. *Journal of Navigation*, *55*(1), 83–96. https://doi.org/10.1017/S0373463301001588

Organization for Economic Co-operation and Developement. (n.d.). *Ocean shipping and shipbuilding—OECD*. Retrieved February 15, 2023, from https://www.oecd.org/ocean/topics/ocean-shipping/

Reason, J. T. (1990). *Human error*. Cambridge University Press.

Riise, I. L. (2023). *Helge Ingstad-ulykken Sola TS-kapteinen: - Jeg kunne ikke gjøre noe*. TV 2. https://www.tv2.no/nyheter/innenriks/sola-ts-kapteinen-jeg-kunne-ikke-gjore-noe/15547258/

Rothblum, A. M. (2000). *Human Error and Marine Safety*. National Safety Council Congress and Expo, Orlando.

Sánchez-Beaskoetxea, J., Basterretxea-Iribar, I., Sotés, I., & Machado, M. de las M. M. (2021). Human error in marine accidents: Is the crew normally to blame? *Maritime Transport Research*, *2*, 100016. https://doi.org/10.1016/j.martra.2021.100016

Statista Research Department. (2022). *Global merchant fleet—Number of ships by type*. Statista. https://www.statista.com/statistics/264024/number-of-merchant-ships-worldwide-by-type/

Trucco, P., Cagno, E., Ruggeri, F., & Grande, O. (2008). A Bayesian Belief Network modelling of organisational factors in risk analysis: A case study in maritime transportation. *Reliability Engineering & System Safety*, *93*(6), 845–856. https://doi.org/10.1016/j.ress.2007.03.035

Tzannatos, E., & Kokotos, D. (2009). Analysis of accidents in Greek shipping during the pre- and post-ISM period. *Marine Policy*, *33*(4), 679–684. https://doi.org/10.1016/j.marpol.2009.01.006

van Eck, N. J., & Waltman, L. (2010). Software survey: VOSviewer, a computer program for bibliometric mapping. *Scientometrics*, *84*(2), 523–538. https://doi.org/10.1007/s11192-009-0146-3

van Eck, N. J., & Waltman, L. (2011). *Text mining and visualization using VOSviewer*

van Eck, N. J., & Waltman, L. (2014). Visualizing Bibliometric Networks. *Measuring Scholarly Impact* (pp. 285–320). Springer International Publishing. https://doi.org/10.1007/978-3-319-10377-8_13

van Eck, N. J., & Waltman, L. (2023). *VOSviewer Manual*.

Wagenaar, W. A., & Groeneweg, J. (1987). Accidents at sea: Multiple causes and impossible consequences. *International Journal of Man-Machine Studies*, *27*(5), 587–598. https://doi.org/10.1016/S0020-7373(87)80017-2

Zupic, I., & Čater, T. (2015). Bibliometric Methods in Management and Organization. *Organizational Research Methods*, *18*(3), 429–472. https://doi.org/10.1177/1094428114562629

Appendix

Appendix 1: Thesaurus file – authors

Label	Replace by
akyuz, emre	akyuz, e.
altinpinar, ishak	altinpinar, i.
arce, m. carrera	arce, m. c.
arslan, omer	arslan, o.
baric, mate	baric, m.
basar, ersan	basar, e.
bielic, toni	bielic, t.
bowo, ludfi pratiwi	bowo, l. p.
celik, erkan	celik, e.
duarte, heitor oliveira	duarte, heitor
fiskin, remzi	fiskin, r.
furusho, masao	furusho, m.
garaniya, vikram	garaniya, v.
garcia maza, jesus a.	garcia maza, j. a.
goerlandt, floris	goerlandt, f.
grabowski, martha	grabowski, m
hekkenberg, robert g.	hekkenberg, robert
hu shenping	hu, shenping
islam, rabiul	islam, r.
jeong, jungsik	jeong, jung-sik
jiang, danchi	jiang, dan
khalid, hassan	khalid, h.
khan, faisal	khan, f.
khan, faisal i.	khan, f.
kujala, pentti	kujala, p.
kurt, rafet	kurt, r. e.
kurt, rafet emek	kurt, r. e.
martins, marcelo ramos	martins, marcelo r.
maturana, marcos coelho	maturana, marcos c.
ozdemir, unal	ozdemir, u.
schroder-hinrichs, jens-uwe	schroder-hinrichs, jens u.
smith, doug	smith, d.
turan, osman	turan, o.
ugurlu, oezkan	ugurlu, o.
ugurlu, ozkan	ugurlu, o.
veitch, brian	veitch, b.
ventikos, np	ventikos, n. p.
vujicic, srdan	vujicic, s.
wang, j.	wang, j
wang, jin	wang, j
yang, ming	yang, m.
yildirim, umut	yildirim, u.
yuksekyildiz, ercan	yuksekyildiz, e.

Appendix 2: Thesaurus file – coword analysis

Label	Replace by
accident	maritime accidents
accident analysis	accident analysis and investigation
accident investigation	accident analysis and investigation
accident investigations	accident analysis and investigation
accidents	maritime accidents
accimap	accident analysis and investigation
analysis of accidents	accident analysis and investigation
analytical hfacs	accident analysis and investigation
arctic shipping	maritime transportation
collision	maritime accidents
collision accidents	maritime accidents
collisions at sea	maritime accidents
grounding	maritime accidents
hfacs	accident analysis and investigation
human element	human factors
human error	human errors
human factor	human factors
human failure	human errors
marine accident	maritime accidents
marine accident analysis	accident analysis and investigation
marine accidents	maritime accidents
marine safety	maritime safety
maritime accident	maritime accidents
risk assessment	risk analysis
safety	maritime safety
safety at sea	maritime safety
ship accident	maritime accidents
ship collision	maritime accidents
ship collisions	maritime accidents
ship safety	maritime safety
shipping	maritime transportation
shipping accident	maritime accidents
shipping accidents	maritime accidents
shipping safety	maritime safety
maritime risk	risk
ship accidents	maritime accidents
bayesian network	bayesian networks

Appendix 3: Thesaurus file: merged keywords

Label	Replace by
Collision accident	Collision
Grounding accident	Grounding
Industry	Maritime industry
International Maritime Organization	IMO
Shipping	Maritime transportation
Person	Seafarer
International regulation	Regulation
Ship collision	Collision

Appendix 4: Removed keywords for text mining

Term	Occurrences	Relevance score
Accident report	25	1.37
Account	22	0.48
Area	37	0.42
Article	35	0.26
Author	18	0.64
Bayesian network	31	3.01
Board	27	1.11
Challenge	24	0.45
Classification system	38	4.96
Combination	18	0.44
Concept	28	0.99
Consequence	43	0.83
Context	35	0.45
Evidence	22	2.13
Framework	53	0.84
HFACS	32	6.81
Human factors analysis	22	5.60
Identification	27	0.43
Implementation	23	0.56
Importance	41	0.41
Issue	40	0.50
Literature	26	0.34
Methodology	51	0.45
Model	127	0.44
Number	53	0.51
Occurence	47	0.39
Outcome	24	0.38
Performance	48	0.51
Probability	73	0.91
Reason	32	0.88
Recommendation	22	0.75
Relationship	47	0.26
Review	42	0.25
Role	51	0.46
Scenario	52	0.53
Sea	63	0.59
Sensitivity analysis	17	4.08
Task	39	0.55
Term	30	0.46
Time	41	0.77
Uncertainty	17	1.68
Way	33	0.44
Work	41	0.23
World	20	0.86
Year	54	0.49