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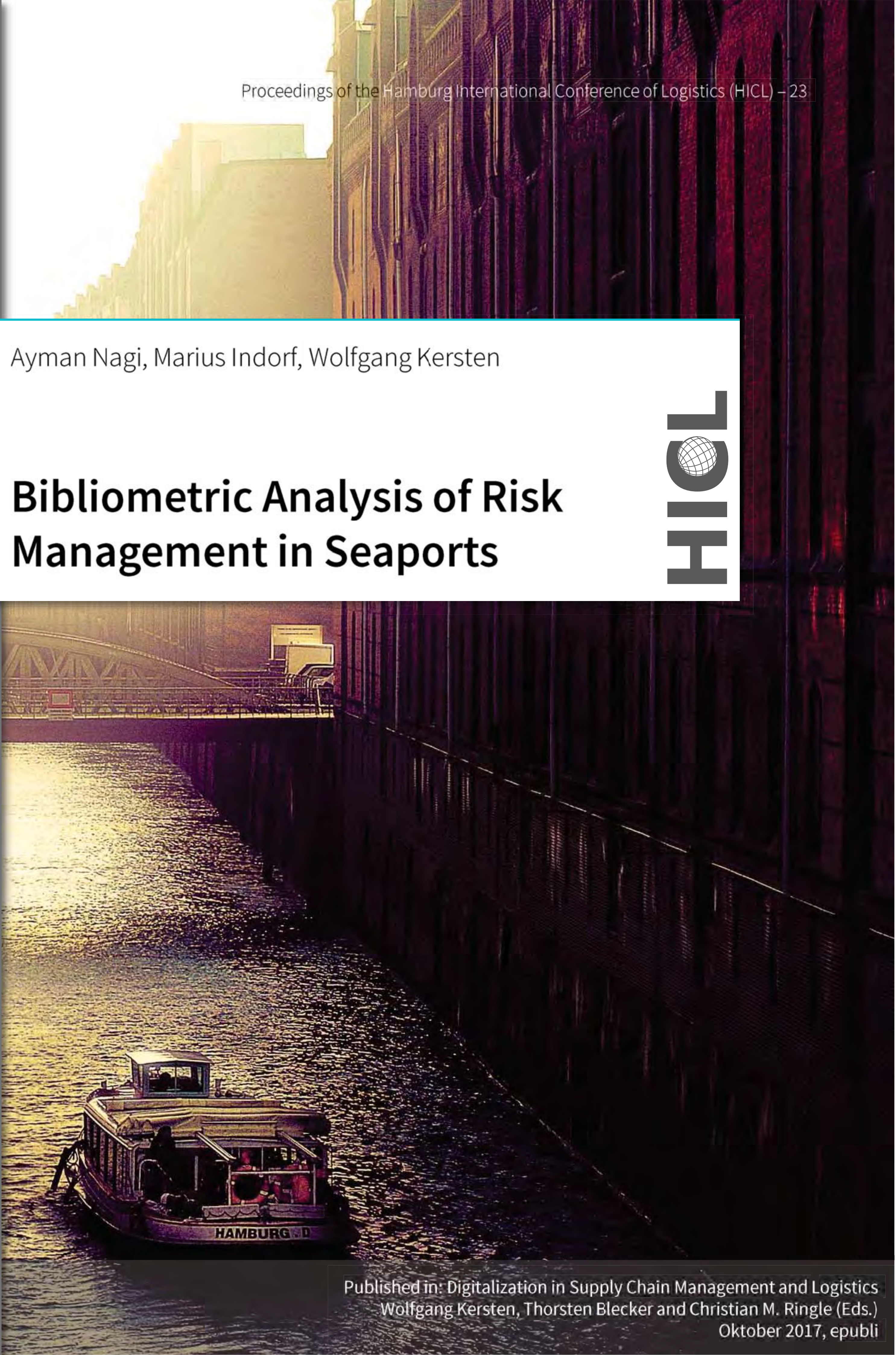

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Bibliometric Analysis of Risk Management in Seaports

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Seaports play an essential role in global supply chains. Incidents and accidents in such ports may lead to service delays, port closure as well as damage to people, property and the environment. Therefore, risk management in seaports plays an important role in mitigating and preventing possible accidents and disruptions. This paper aims to explore the structure of literature on risk management in seaports using co-citation analysis in order to reveal its current main research areas and gaps as well as its future trends. Document co-citation analysis is performed using the organization risk analyzer (ORA) software based on a specific threshold and employing the CoCit-Score method of calculation. Suggested future research areas on risk assessment and management methods as well as cooperative risk management are revealed based on the results of the co-citation analysis.

Keywords: Risk management; Seaports; Co-citation analysis; Supply chain risk management

1 Motivation and Introduction

More than 80 percent of global trade is forwarded by sea, making maritime transport the most important mode of transport and a key enabler for international commerce and globalization (UNCTAD, 2015, p. 22). This development is the result of the continuous growth of seaborne shipments throughout the last centuries and decades. Various commodities, such as oil, gas, iron ore, or grain are shipped, totaling 10,047 million tons of cargo in 2015 which is an increase of around 200 million tons compared to 2014 (UNCAD, 2016, p. 6). Naturally, all geographic regions, e.g. the Americas, Asia-Pacific, or Europe, are involved in global seaborne trade acting as exporter and importer in different extent. In any case, the cargo is handled in large seaport facilities at the point of origin and destination. Depending on the actual route, one or more transshipment ports are utilized in order to ensure a time-saving and economic transport. Seaports connect the seaside/foreland to the hinterland, where the cargo is further transported, handled, and finally consumed.

In Europe's top 20 cargo ports 1,723.4 million tons of goods were handled in 2015 based on its gross weight. Of this amount, 1,032.5 million tons were reported on the direction inwards and 690.9 million tons were reported on the direction outwards. In total, 3,838.3 million tons of goods (2,277.6 inwards and 1,560.7 outwards) were handled in all ports of the European countries in 2015 (Eurostat, 2017, pp. 2–3). On top of this, 395.4 million seaborne passengers embarked and disembarked in all of the ports of the European countries in 2015 (Eurostat, 2017, p. 6).

These figures illustrate the significance of seaports in the area of global trade and transport. To cope with this challenge, seaports have become highly complex systems involving various actors, such as operators, authorities, crews, port workers, passengers, and the public (Andritsos and Mosconi, 2010, p. 1). In addition, seaports comprise highly specialized physical installations and facilities, operated according to demanding processes and procedures. In many cases, seaports have a unique geographical location and have developed in immediate proximity to residential areas. The port of Hamburg for example is a tidal port located at the river Elbe and is the heart of Germany's second largest city. In total, the city of Hamburg and its metropolitan region are home to more than 5.2 million inhabitants (Statistical Office of the Free and Hanseatic City of Hamburg, 2017). As a result, seaports have to fit in their surrounding community and to follow a vast number of standards and regulations in order to become and remain a safe and secure area for its internal and neighboring stakeholders.

To summarize, seaports play an essential role in modern trade and mobility and are expected to continue growing also in upcoming decades in terms of volume and complexity. At the same time, seaports have to follow strict principles and have to burden enormous efforts in order to guarantee safety and security to its bordering entities. This means, already today and even more in future seaports face an extremely difficult situation, supporting global trade on the one hand and ensuring safe and secure operations for its internal actors and its external environment. Seaports face risk challenges from operational, technical and economic perspectives (Alyami, et al., 2016, p. 10). Examples for these risks include flooding, oil spills and fire explosions (Becker, et al., 2012; Valdor, Gómez and Puente, 2015; Zhao, 2016). The only way to cope with these major challenges is to install and maintain a proper risk management in those seaports. Due to its complex nature, seaports require special risk management processes and measures that in many cases span across multiple entities and organizations.

In scientific literature, the field of risk management in seaports has been present at least since the mid-1980s and has gained increased attention throughout the last decade. In contrast to most other objects considered by risk management research, seaports rarely comprise a single organization. Thus, risk management in the field of seaports needs to address these special circumstances. Reviewing the available research on risk management in seaports, we realized the broad range of perspectives and approaches in this field. In fact, they range from very practical aspects, e.g. ballast water or oil spill treatment, to rather academic risk management frameworks serving an overarching perspective. For this reason, this paper aims to explore and to structure the scientific literature on risk management in seaports. The methodological approach chosen for this purpose is a bibliometric analysis. Focusing on co-citations in particular, we identify main areas as well as gaps in the current literature and propose future research areas in the field of risk management in seaports.

In Chapter 1, we outline the motivation for our research and provide a brief introduction to the topic. Chapter 2 frames the theoretical background on seaports as well as risk management and shapes the scope of our work. Chapter 3 elaborates the methodological approach chosen which is foremost characterized by a co-citation analysis. The results of our research are presented in Chapter 4. Conclusions based on the findings of the work undertaken are presented in Chapter 5.

2 Theoretical Background

In this section, theoretical background in the area of seaports and risk management is provided. The aspects addressed create the basis for understanding and reflecting the chosen methodology and obtained results.

2.1 Seaports as Logistical Hubs for International Trade

Seaports are very complex systems and are critical elements of the global transportation infrastructure (Christopher, 2015, p. 21). Even though seaports are immobile conglomerations of different facilities and actors with a unique geographical position, they face severe competition within the international transportation network. As a result, seaports organizations strive to meet the market requirements in the best possible fashion. In this context, it is vital to understand that a port cannot be considered as an economic unit offering or producing a single service to its customers. Instead, a broad range of processes and services is carried out in the port area (Tovar, Trujillo and Jara-Díaz, 2004, p. 190). Hence, ports in general and seaports, in particular, must be considered as a semi-structured compound of individual organizations serving a wide diversity of customers.

Apart from rather large seaports, also a number of other ports exist. In fact, ports can range from small-sized marinas servicing sport boat enthusiasts, to a mid-sized company owned and operated industrial ports to the Port of Singapore, which handles more than 1,000 vessels at any time of the day. Another dimension to categorize ports apart from their size is their primary purpose. Ports can be used for civilian, commercial or military/security purposes (Christopher, 2015, p. 27). Obviously, ports can also have hybrid forms, serving multiple purposes at the same time. In addition, the ownership structure of a port is important to consider. Generally, two main types of ownership exist in view of the port's infrastructure, superstructure, and its staff. On the one side of the spectrum, ports are owned and operated by private organizations and on the other side of the spectrum, they are part of a complex body of local, state, or national government. Very commonly, ports are owned and operated as landlord/tenant ports in which a public authority rents the port areas to private actors, such as terminal operators, whom in return pay a usage fee (Christopher, 2015, p. 27). A landlord model is also a hybrid form of a fully public and a fully private port. The paper at hand solely focusses on seaports, which we consider to be commercial ports, located directly at or in close distance to the open sea.

The processes of transporting, handling, and storing cargo in a seaport involves numerous actors. During the port entrance and exit of a ship, many shipping companies rely on the assistance of pilots and tugboat companies for safely reaching the quay wall. At the mooring, the cargo is unloaded by a terminal operator, which also forwards the cargo to storing facilities and later passes it on to carriers transporting the cargo through the hinterland. At any point in time, the processes are controlled by the port authority. Apart from the mentioned actors, several others, such as safety inspectors, customs, and repairers might be involved as well (Martino, et al., 2013, p. 125; Huber, 2014, p. 98). Apart from the different processes and services performed in a seaport, the high number of actors involved clearly drive complexity. This also underlines the importance of a thorough risk management in seaports that serve as important logistical hubs for international trade. The next section provides a brief overview of the literature on risk management in seaports.

2.2 Risk Management in Seaports

There are many definitions for risk management in the literature. For instance, Coyle, et al. (2010, p. 294) defined risk management as the process of identifying risks along with its causes and effects in order to mitigate, prevent, transfer, or eliminate possible threats to the overall supply chain success. Since seaports play a core role in global supply chains, risk management is defined in this paper as "the identification and management of risks for the supply chain, through a coordinated approach amongst supply chain members, to reduce supply chain vulnerability as a whole" (Jüttner, 2005, p. 124). The risk management process normally includes risk identification, assessment, handling, and monitoring of the implemented measures. (Garvey, 2008, p. 5).

Even though risk management has gained increased awareness among the actors and has become a central point of attention in a seaport, universally applicable standardized processes and measures universally applicable do not exist. In fact, up to now, risk management is very port specific in terms of scope and substance. Presumably, differing geographical and economic conditions in seaports, among many others, are the main reasons in this context. In seaports, the actors employ different risk management systems and approaches that define risk handling initiatives in the case of an emergency, such as the explosion of gases or chemicals. Apart from an intrinsic motivation to rely on suitable safety and security measures, also various guidelines and standards oblige seaport organizations to conduct a thorough risk management. These guidelines and standards exist on local, national, and global levels. A few examples are presented below.

The ISO 31000, for example, provides principles and generic guidelines on risk management that are applicable not only to seaport organizations but to any public, private or community enterprise, association, group or individual (International Organization for Standardization, 2009). Apart from such generic standards, numerous additional approaches persist. One important document is the International Ship and Port Facility Code (ISPS), which was established by the International Maritime Organization (IMO). The ISPS Code contains minimum requirements for port facilities and ship security being applied in all countries that are part of the IMO convention. One aspect of the ISPS Code is that it regulates how and to which extent a ship is required to report freight and cargo to the port which it seeks to enter (International Maritime Organization, 2003). In order to implement the ISPS Code requirements, several legal provision, such as the Maritime Transportation Security Act of 2002 in the U.S., were established. This act contains regulations specifying requirements, e.g. for security assessments or annual exercises and/or drills (U.S. Department of Homeland Security, 2003), and defines the implementation of the ISPS on a national level. In the research literature, a broad range of approaches and perspectives in the area of risk management in seaports exists. In the following, selected approaches are presented.

Focusing on container terminal operational systems Alyami, et al. (2016) present a method to facilitate the application of the Failure Mode and Effects Analysis (FMEA) in assessing the safety performance. For this purpose, they develop a hierarchical structure for risk factors during terminal operations and integrate a Fuzzy Rule-Based Bayesian Network with Evidential Reasoning. This paper strongly concentrates on the methodological approach in a locally limited environment (Alyami, et al., 2016).

The paper of Bruzzone, et al. (2000) provides the development of an integrated interactive environment for risk analysis applied to port and maritime environments. The presented approach helps to design the port and maritime infrastructure including its resources, structures, and services potentially confronted with an emergency. The architecture of the tool developed is described and is being applied by the integration of a specific simulation module to an oil spill scenario.

In contrast to the aforementioned articles, the paper of Gharehgozli, et al. (2016) proposes a conceptual framework on seaport resilience in the event of weather disruptions. The suggested approach strategically helps ports to prepare for risks associated with these potential disruptions and to design relevant contingency plans. The proposed framework consists of four steps that port managers can apply in order to increase port resilience. This paper understands ports as communities of many stakeholders and consequently has a more holistic perspective.

As a result of a European Union-funded project, Karlsson, Olsson and Riedel (2016) present in their report several aspects of risk management. First, they discuss existing capability assessment approaches in the European Union (EU) and Baltic Sea Region. Second, empirical data in this field is presented and analyzed. Third, the EU document “Risk Management Capability Assessment Guidelines” (2015/C261/03)” and its potential use are discussed. Fourth, a methodology for risk and capability assessment is proposed as a result of the previous chapters. This report has a clear geographical focus and features conceptual as well as empirical elements.

The broad range of scientific approaches and perspectives in the area of risk management in seaports underlines the necessity for structuring the field. Such a structured overview would allow researchers to integrate their own activities much quicker and to discover relevant research streams for future opportunities. So far, the literature is lacking a quantitative study analyzing bibliometric information of available research work with the aim of framing the main research areas and identifying existing research gaps. For instance, a study conducted by Colicchia and Strozzi (2012) combined a SLR with a citation network analysis to identify directions for future research in the field of supply chain risk management with no focus on seaports. We address this fact with the work presented in this paper. The next chapter presents the methodology applied in the course of this research.

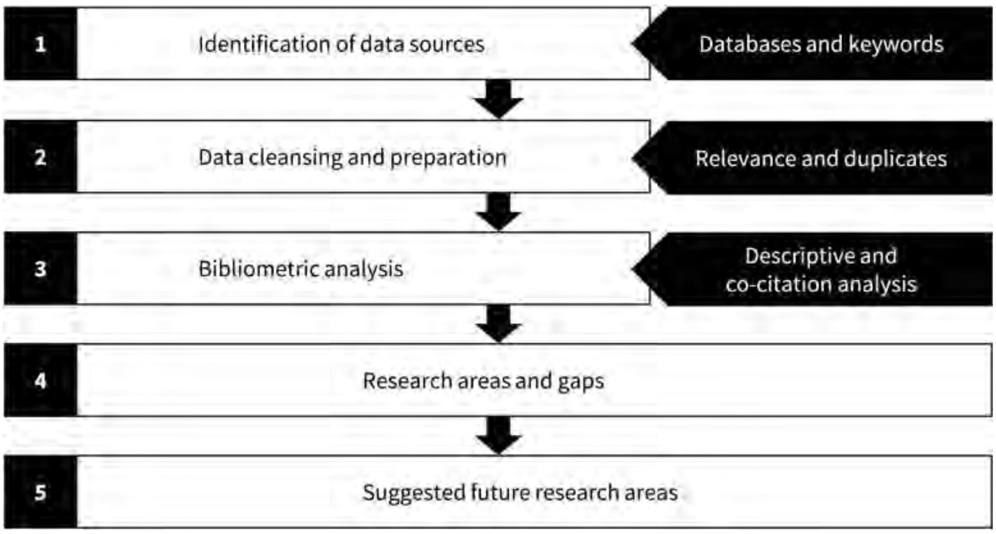

Figure 1: Research Design of the Performed Bibliometric Analysis

3 Methodology

The research design is developed according to specific research questions that address the objectives of this paper. The authors identified three research questions as follows:

1. What are the main and minor research areas of risk management in seaports?
2. What are the current research gaps in the existing literature on risk management in seaports?
3. What are future research areas in the field of risk management in seaports based on the current literature?

In order to answer these research questions, this paper employs a quantitative approach in terms of a bibliometric analysis with a co-citation analysis as the central methodological element. The overall research design of the performed analysis is adapted and further developed from Soni and Kodali (2011, p. 241) incorporating the bibliometric analysis as shown in Figure 1. The period of extracting, cleansing and analyzing the articles lasted from April to June 2017 and involved regular discussions and preparations among the authors.

First, a systematic identification of data sources is carried out by selecting scientific databases and adequate keyword combinations to extract relevant articles creating the data set for further analysis. Second, data cleansing and preparation follows to check for duplicates and irrelevant articles. Additionally, the data set obtained in this phase is transformed into a processible format. Third, the data is analyzed in terms of a descriptive as well as a co-citation analysis. Then the results of the co-citation analysis is further examined in order to reveal the main research areas and gaps of current literature on risk management in seaports. Fourth, future research areas for risk management in seaports are suggested. The steps performed in each phase mentioned above are further detailed in the following.

Two scientific databases were chosen in order to prepare the set of articles for the bibliometric analysis using co-citation analysis. Web of Science (WOS) and Scopus were selected since they provide the largest set of peer-reviewed papers including required citation information as well as valuable cited-in references. Google Scholar was used for extracting the cited-in references for each article. All information combined constitutes the essential input for the co-citation analysis.

Based on the objective of this paper, a specific set of keywords was defined enabling the extraction of suitable articles for the co-citation analysis. The keywords selected cover risk management, risk analysis, risk assessment, and seaport. The keywords were selected according to a related notion analysis that presents the top keywords used for risk management in seaports. These keyword combinations were entered in the search field of Scopus and WOS using the logical operators ”AND” and ”OR” as follow:

1. Risk Management AND (Seaport OR Sea Port),
2. Risk Analysis AND (Seaport OR Sea Port),
3. Risk Assessment AND (Seaport OR Sea Port).

The steps of data cleansing and preparation reflect the filtering mechanism that is required in order to obtain a set of articles that is relevant to the field under investigation. Duplications and articles with missing information were removed from the dataset. Afterward, the abstract for each article was carefully read and

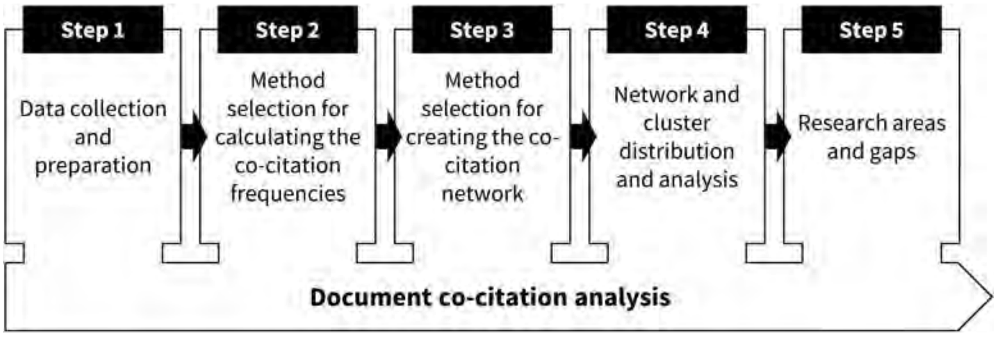

Figure 2: Steps of the Document Co-citation Analysis (based on Gmür, 2003)

examined to remove any irrelevant article. This final dataset of articles is used for the descriptive and co-citation analysis.

The co-citation analysis as a research methodology is based on a co-occurrence quantitative analysis technique that is used to measure the frequency of co-occurrence for a pair of authors, titles, or other keywords in a document to map the dynamics and structure of scientific research (Braam, Moed and van Raan, 1991, p. 24; Gmür, 2003, p. 27). The co-citation starts with defining the selected object and the choice of the approach that is limited to an author or document co-citation analysis. The document co-citation approach reflects the proximity in terms of content within a school of research by analyzing the co-citation between peer-reviewed selected documents. In contrast to this, author co-citation analysis is based on the assumption that any co-citation between documents by any two authors is a suitable measure for the proximity in terms of content in a certain school of research. As the document co-citation analysis promises better results in view of exploring the current research areas of risk management in seaports, this approach is selected for our analysis. The steps of the document co-citation analysis follow the steps shown in Figure 2.

After the data collection and preparation phase, specific methods are selected for calculating the co-citation frequencies as well as to generate the co-citation networks and clusters. Cluster distribution and analysis is followed by analyzing the research stream of each cluster individually via an associated co-citation network that shows the relationship between each reference in the given cluster. Organizational risk analyzer (ORA) is used as the main software to extract and analyze the clusters. ORA is a dynamic meta-network analysis and assessment tool developed by CASOS at Carnegie Mellon in Pittsburgh, U.S. The results of this paper based on the aforementioned methodology are presented in the following chapter.

4 Results

The results of this paper based on the elaborated methodology are presented in this chapter. They comprise the descriptive analysis of the selected articles as well as the process of clustering using the co-citation analysis.

4.1 Descriptive Analysis

Out of the 395 articles obtained from the database inquiries, 108 relevant papers were carefully selected in the phase of data cleansing and preparation. Descriptive figures are used in this subchapter to characterize this final dataset of relevant articles. This descriptive analysis consists of the chronological trend of articles since 1984, top 15 keywords of risk management at seaports as well as the top 10 cited authors.

There is an increasing trend of articles published containing aspects related to risk management, risk assessment, and risk analysis in seaports, particularly starting in 2008 with some deviations occurring in between. As observed in Figure 3, a lower number of articles is observed in 2017 since the analysis was carried out until April 2017.

An extraction of all author keywords from the selected databases was conducted in order to extract the top 15 frequent keywords related to risk management in seaports. Risk assessment and ballast water are frequent keywords that appear in the selected articles. Many articles used ’port’ as a keyword associated with the maritime environment whereas a set of other articles used ’seaport’ as a core identifier. Ballast water management as well as studies that discuss the various implications of climate change on ports and coastal cities are accompanied by the keywords ’ballast water’ and ’climate change’. Several studies are related to the concentration of heavy metals in sediments. All other keywords are presented in Figure 4.

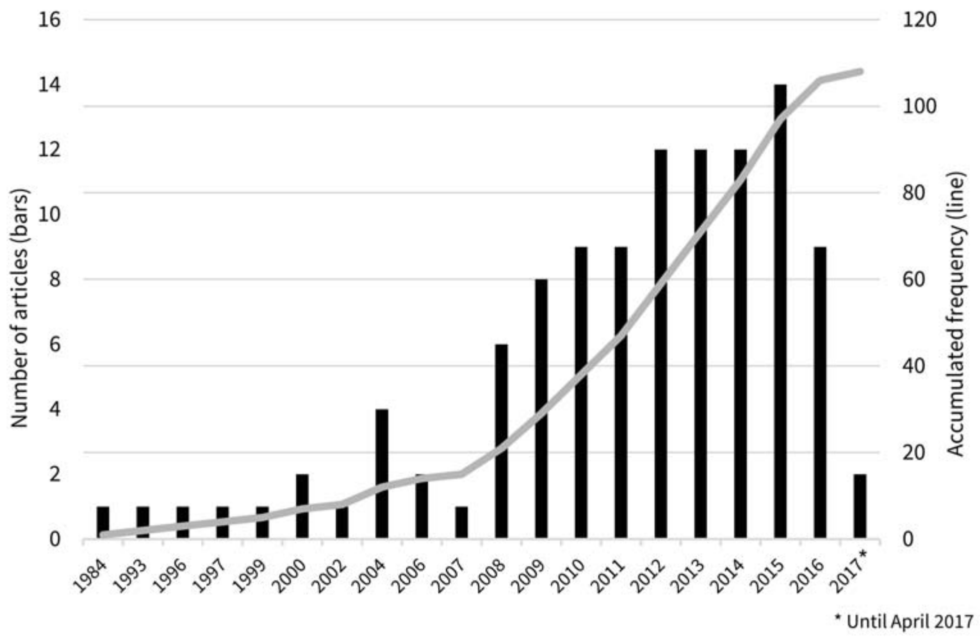

Figure 3: Number of Articles Identified per Year

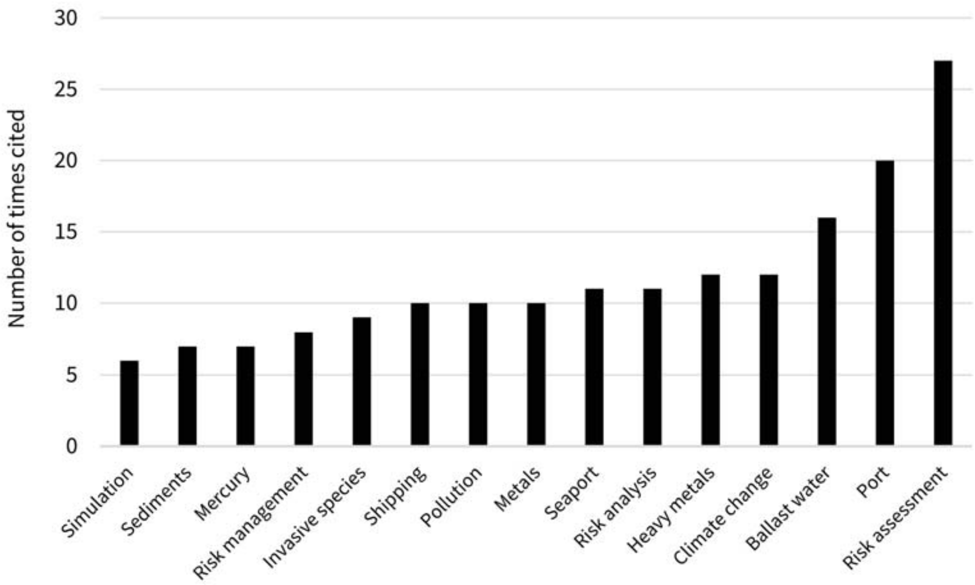

Figure 4: Top 15 Keywords associated with Risk Management in Seaports

The most cited first author based on the citation information from WOS and Scopus in the selected 108 articles focused on papers related to the impact of climate change and natural risks on seaports, such as flood losses in port cities is S. Hallegatte. Similarly, the authors R. L. Wilby, S. Hanson, C. B. Awuor, and H. Sterr, H presented studies related to climate change and flood risk as well as sea-level rise and its impacts on port cities. For instance, S. Hanson provided a related study on the assessment of exposure of large port cities to climate extremes such as flooding and storm surge.

In contrast to the aforementioned authors, P. Trucco focused on the integration of Human and Organizational Factors (HOF) into risk analysis by employing Fault Tree Analysis and a Bayesian Belief Network (BBN). BBNs are used in order to represent dependencies among a set of variables probabilistically (Cooper, 1990, p. 393). Decision support framework for risk management and analysis of accidents in seaports are topics that are as well highly cited (R. M. Darbra, K. Mokhtari). The other set of authors focused on assessment studies related to risk assessment of pollutant concentrations and collision avoidance (D. Haynes, J. M. Mou). The top 10 cited authors are revealed in Figure 5.

Following the descriptive analysis of the selected articles, the results of the cluster analysis based on the document co-citation are presented in the next section.

4.2 Co-citation Analysis

The results of the co-citation analysis are presented in this section based on the aforementioned described steps (see Figure 2).

An additional filtering mechanism was applied to the original list of 108 articles sorting out articles with less than two cited-in references. This means that articles that are not cited or cited only once in other articles in the literature are filtered out. Consequently, 15 articles are excluded from the final dataset. Additionally, all cited-in references for each article were stored separately in Excel worksheets that correspond to each article. These articles were downloaded using the library of Google Scholar and saved as CSV files. In total, 2,702 cited-in references are distributed among the 93 articles.

A 93 x 93 raw co-citation matrix was programmed using Visual Basic for Applications (VBA) in order to calculate the co-citation frequencies. The co-citation matrix is an essential input for the ORA software. A Microsoft Excel macro was

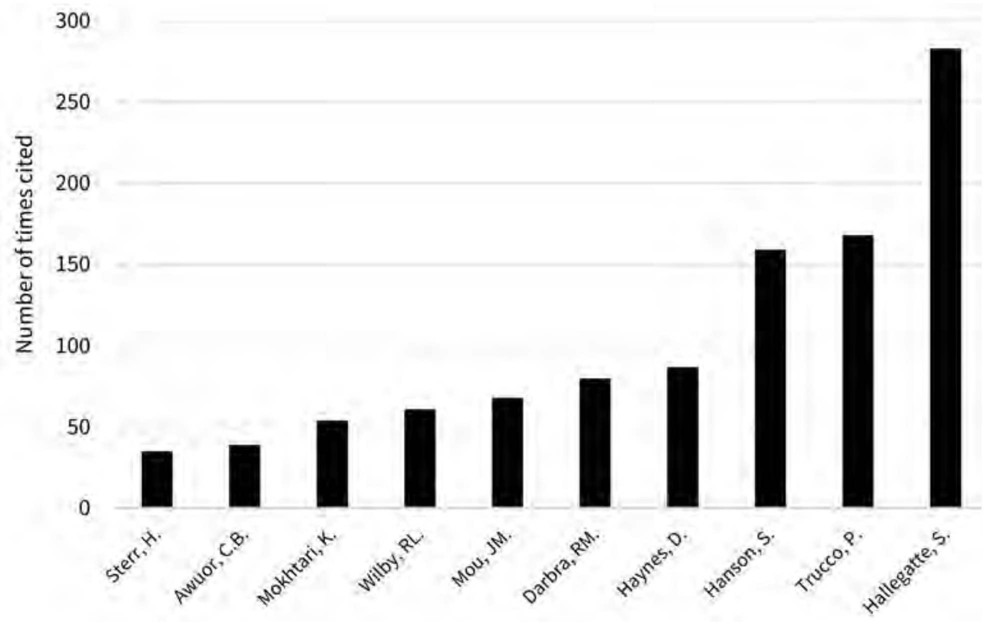

Figure 5: Top 10 Cited Authors in the Field of Risk Management in Seaports

programmed to generate the raw co-citation matrix by comparing the list of cited-in references for each article in each worksheet. The macro loops through each article and records the co-citation frequency in the relevant field in the co-citation matrix.

The CoCit score was chosen as the main method for generating the co-citation network and clusters. According to Gmür (2003, p. 40), the CoCit minimizes the citation relation of both co-citation partners. The method takes a value between 0 and 1. It relates the sum of the co-citation count in relation to the mean and minimum counts of the two individual citations. The CoCit is calculated using the following formula (Gmür, 2003, p. 41):

$$CoCit_{AB} = \frac{(co - citation)^2}{minimum(citation_A; citation_B) * mean(citation_A; citation_B)}$$

The analysis is done in the software ORA with a threshold value of 0.01. This threshold value is manually adjusted until a clear pattern is detected. The co-citation network as shown in Figure 6 has emerged with the associated identified eight clusters. Additional revision of the abstracts and introduction parts of the articles is conducted to extract the clusters from the network. Out of the total 67 co-cited articles in the final dataset, 36 are clustered references in the co-citation network. Therefore, the network has a penetration value of 53.7%, which is used to assess the coverage of the co-citation network. This is a higher value compared to the value achieved by (Gmür, 2003, p. 45) who achieved a penetration value of 48% using the CoCit score.

In the following sections, the clusters obtained are further described. The articles referenced as well as their associated reference number can be found in the appendix.

Cluster I: Risk Management of Ballast Water (3 articles)

The first cluster is associated with studies related to risk management of ballast water with a focus on the Baltic Sea. Ballast water management is a complex issue that requires careful assessment of various species that are transported in ballast water (Endresen, et al., 2004, p. 615). The cluster includes a risk assessment study for exemptions related to intra-Baltic shipping using different methods

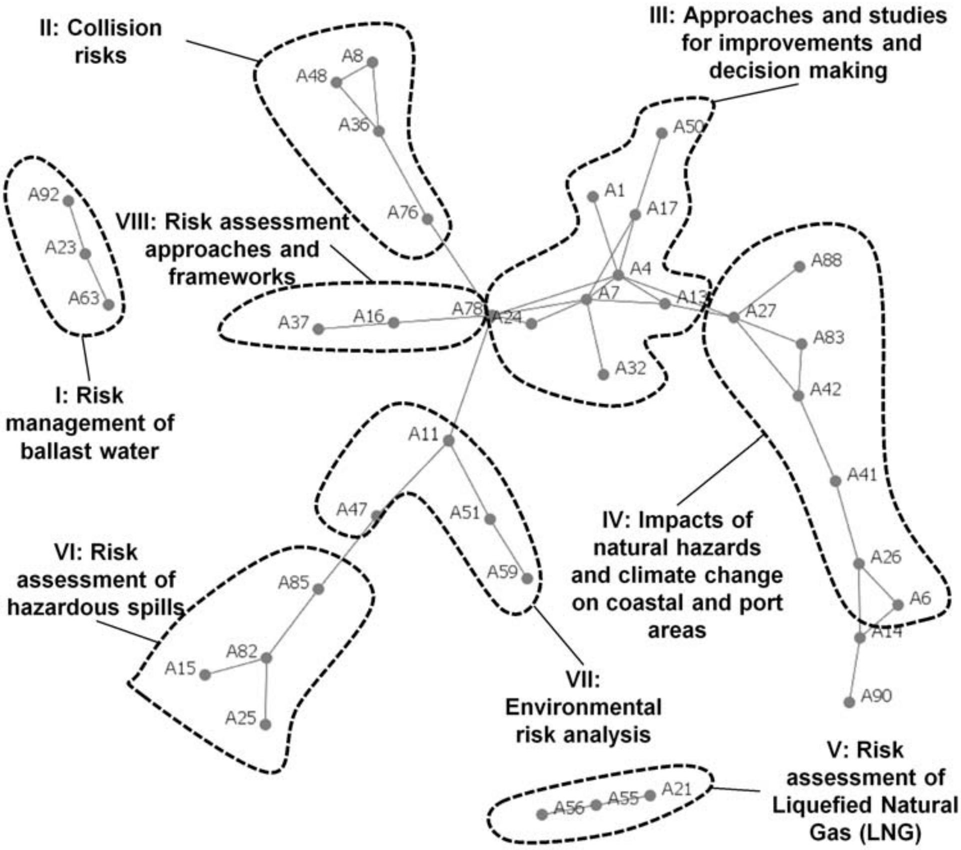

Figure 6: Clusters of the CoCit Co-citation Network

such as environmental matching (David et al. 2013 - A23). The risk assessment study of Gollasch and Leoppaskoski (2007 - A63) covers nine ports distributed in five countries around the Baltic Sea. It presents scenarios of ballast water management for intra-Baltic shipping as well as voyages outside the Baltic. A discharge assessment model for ballast water was developed by David, et al. (2012 - A92) to predict the possibility of ballast water discharge of vessels arriving at ports. This model is based on vessel dimensions and vessel cargo operations.

Cluster II: Collision Risks (4 articles)

This cluster comprises studies that analyze and evaluate collision risks. A marine complexity model was introduced by Wen, et al. (2015 - A2) to analyze the degree of crowding and risk of collision. A similar model was built by Debnath, et al. (2011 - A36) for collision risks using traffic conflicts. A binomial logistic model was derived from traffic conflicts and calibrated by the authors for the Singapore port fairways. As a proactive approach, a study for collision avoidance in busy waterways was conducted by Mou, et al. (2010 - A48). Concerning navigational collisions, Debnath and Chin (2009 - A76) used hierarchical modeling to analyze the relationships between perceived risks, pilot attributes as well as geometric and traffic characteristics of fairways.

Cluster III: Approaches and Studies for Improvements and Decision-making (8 articles)

The third cluster comprises articles that analyze improvement solutions to support decision maker in aspects related to port disruptions, economic losses, mitigation strategies, ship safety index, decision support frameworks, and recommendations for maritime safety. Economic losses of port disruptions, such as extreme wind events, are mentioned in Zhang and Lam (2016 - A1) as well as Zhang and Lam (2015 - A4). Li, et al. (2014 - A17) developed a ship safety index that can aid different parties, such as port authorities, in examining areas that should be inspected, repaired, and maintained based on a relative risk score. A short-term wind forecast is described by Burlando, et al. (2014 - A13) to improve the safety of the largest ports in Northern Tyrrhenian Sea. Lam and Su (2015 - A7) elaborated mitigation strategies based on proactive and reactive measures to minimize the probability of occurrence and severity of various types of port disruptions. A similar approach but related to inventory management for port-of-entry disruption risks including container seaports is discussed by Lewis, et al. (2013 - A24). The authors investigated potential economic and operational impacts with the focus on supply chain inventory as a mitigation strategy. Mokhtari, et al. (2012 - A32) developed a decision support framework using fuzzy set theory (FST) to analyze risk factors for ports and terminal operations and management (PTOM). FST is based on a mathematical framework that simplifies the study of vague conceptual phenomena (Zimmermann, 2011, p. 318). Knapp and Franses (2009 - A50) discussed the improvement in the risk profiling by combining data sources on inspections to improve the maritime safety system that comprises different players such as shipyards.

Cluster IV: Impacts of Natural Hazards and Climate Change on Coastal and Port Areas (7 articles)

Studies of the impact of natural hazards and climate change on coastal and port areas are the focus of this cluster. An economic model for the analysis of disaster prevention investments is developed by Xiao, et al. (2015 - A6). An evaluation framework for climate change and sea level rise potential impacts is presented by Messner et al. (2013 - A26). Hallegatte, et al. (2011 - A41) conducted a similar study by assessing the risks of sea level rise, climate change impacts and storm surge in port cities. Kron (2013 - A27) elaborated in his paper the threats and associated risks of natural hazards and recommended solutions and safeguards to provide an efficient protection. A ranking based on the estimation of the exposure of large port cities to storm surge and coastal flooding is presented by Hanson et al. (2011 - A42). Hallegatte, et al. (2011 - A83) and Raposeior, et al. (2013 - A88) elucidated in their papers the impacts of flood losses along with an assessment of the flooding risk of port and coastal areas.

Cluster V: Risk Assessment of Liquefied Natural Gas (3 articles)

This cluster comprises articles that focus on the risk assessment of Liquefied Natural Gas (LNG) carriers. Risk assessment of LNG carriers using fuzzy TOPSIS method for order preference was conducted by Elsayed, et al. (2014 - A21). Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS), according to Wang and Elhag (2006, p. 310), is one of the popular approaches for Multiple

Criterion Decision Making (MCDM). A software tool and a methodology for carriers during loading/offloading were developed by Elsayed, et al. (2009 - A55) based on utility theory and multi-attribute risk assessment. A similar approach for multiple attribute risk assessment based on fuzzy inference system (FIS) was developed by Elsayed (2009 - A56). FIS is expressed in terms of “IF-THEN” rules to predict uncertain systems (Kazeminezhad, Etemad-Shahidi and Mousavi, 2005, p. 1710).

Cluster VI: Risk Assessment of Hazardous Spills (4 articles)

This cluster comprises articles that is related to the risk assessment of hazardous spills. These spills include hazardous and noxious substances (HNS) as well as oil spills. Harold, et al. (2014 - A15) developed a methodology to prioritize HNS with a risk prioritization matrix to assess the acute risks of HNS spills. The classification of risk zones represented in risk maps for oil spills was carried out by Singkran (2013 - A26). This classification considered the number of ports and the frequency of oil spill incidents as well. Similarly, an oil spill hazard assessment was conducted by Garcia, et al. (2013 - A82) in Italian ports based on the development of an Oil Spill Hazard Index (OSHI) for hydrocarbons handled at ports and in transit. An assessment of hazards from oil ship discharges, based on oil hazard maps, was the focus of the study conducted by Liubartseva, et al. (2015 - A85).

Cluster VII: Environmental Risk Analysis (4 articles)

This cluster consists of four articles that elaborate the environmental analysis of harbors. A subjective and objective assessment of environmental risks of a tourist harbor in southern Italy was conducted by Irene, et al. (2010 - A51). A multistep indicator-based approach that comprises the development of a tool, suitable environmental quality indicators, and a user-friendly development scheme was carried out by Marin, et al. (2008 - A59) to monitor environmental quality and the associated risks of harbors. Environmental risk analysis of oil handling facilities is presented by Valdor, et al. (2015 - A11). The main pollutant sources and a numerical analysis of several pollution incidents are elaborated by Mestres, et al. (2010 - A47) in order to assess the potential environmental risks.

Cluster VIII: Risk Assessment Approaches and Frameworks (3 articles)

This cluster comprises three articles related to assessment approaches and frameworks for risks in seaports. A fuzzy risk assessment approach for seaports was carried out by John, et al. (2014 - A16) to analyze their complex structure of operations. Pak, et al. (2015 - A78) followed a fuzzy analytical hierarchy process to analyze risk factors that affect navigational safety with their associated implications in seaports. A generic bow-tie analysis framework combining Fault Tree Analysis (FTA) and Event Tree Analysis (ETA) was used by Mokhtari, et al. (2011 - A37) for the risk assessment phase in seaports and offshore terminals. Based on the results of the co-citation analysis, the main research areas and gaps are elaborated on in the next section.

4.3 Main Research Areas and Gaps

The main research areas and gaps in the current literature on risk management in seaports are elaborated in this subchapter based on the results of the co-citation analysis.

4.3.1 Main Research Areas

Two main research areas are revealed based on the third and fourth cluster which consist according to the clusters in the CoCit co-citation network of eight and seven articles respectively. Approaches and studies for analysis and decision-making are the first main research area which encompasses solutions and detailed analysis for improvements as an aid for decision makers. The main aspects considered in this cluster comprise economic, safety and operational aspects. Examples include studies related to economic losses, improvement in maritime safety and operational impacts of inventory management due to port disruptions.

The second main research area is represented by the fourth cluster that presents the impacts of climate change and natural hazards on coastal and port areas. Based on Becker, et al. (2012), anticipations and assessment with regards to the impacts of climate change should be taken into considerations to proactively prepare for different natural hazards such as flooding and sea-level rise.

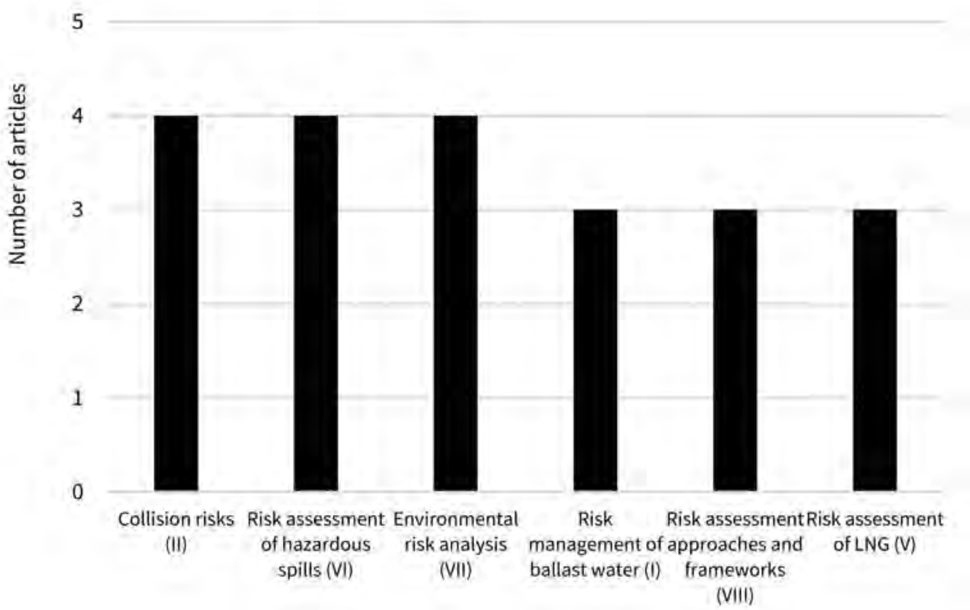

Figure 7: Minor Research Areas

4.3.2 Research Gaps

In order to detect the research gaps, the minor research areas were extracted from the clusters in the co-citation network. The threshold to distinguish major from minor research areas was set to be four articles. Figure 7 shows the minor research areas based on the results of the co-citation analysis.

There is a lack of studies with respect to risk assessment and management methods that can be used by the diverse actors in a seaport. No studies, from the dataset, covered risks such as the improper handling of dangerous goods and the explosions of gases and chemicals. Two research areas focused on the quantitative assessment of risks at seaports in general and specifically on the risk assessment of hazardous spills and LNG. This also includes the integration of cooperative risk management. According to Mokhtari, et al. (2012, p. 5088), appropriate techniques to support the risk management cycle in seaports is required in order to assess the overall risk level. These techniques should reflect the role of each stakeholder at the seaport with regards to the risk management process.

4.4 Suggested Future Research Areas

There is a need to conduct further research on quantitative and qualitative risk assessment and management methods that could be applied to the different operations and sources of risks in seaports. For instance, operations related to the loading, storage, and distribution of cargo. Additional research is suggested with regards to risk assessment methods for the handling of dangerous goods and the explosions of gases and chemicals along with case studies. Furthermore, simulation approaches such as Monte Carlo simulation can support in aggregating the various risks in the port system. Additionally, the future research work should consider cooperative risk management for the parties involved in the different operations of a seaport. A model for cooperative risk management will enable a better preparedness and visibility for risks that occur within the port system. A common language and understanding of risks should be developed and integrated into a database management system in order to increase the risk management know-how on one hand and to increase the visibility among the different members of a port system on the other hand. This will allow the different members to share an understanding of risks facing the seaport and guide them to implement effective proactive measures as well as contingency plans.

5 Conclusion

This research paper analyzes current literature on risk management in seaports and proposes a suitable structure. The methodological approach chosen in this regard is a bibliometric analysis focusing on documents co-citations. From this analysis, two main research areas were extracted: (1) Approaches and studies for improvements and decision-making and (2) Impacts of natural hazards and climate change on coastal and port areas. Besides already existing research streams, also potential research gaps were considered in our analysis. The first deficiency identified is a lack of studies about risk assessment and risk management methods that are suitable for the usage across the different stakeholders in a seaport. Additionally, a gap was detected concerning other types of risks, such as the improper handling of dangerous goods. Therefore, the future research areas should be tailored to quantitative and qualitative risk assessment and risk management methods that could be used by the various stakeholders in the different operations and sources of risk at seaports. This includes the consideration of a cooperative risk management to understand and better identify, assess, and manage the risks among the different stakeholders.

The study presented is limited to specific keywords in the data extraction phase and may hence not cover all scientific papers in the field of risk management in seaports. In addition, the dataset of the databases consulted may not be fully comprehensive. The cluster analysis performed relies on the CoCit score as main method for generating the co-citation network. The clusters created are based on a specific threshold that is manually adjusted. Future work should consider performing a co-citation proximity analysis to achieve a high penetration value. The articles not clustered in in the co-citation analysis presented here could be analyzed further in order to identify additional research trends and research areas. Future research could also consider combining a SLR with a co-citation analysis in order to provide an exhaustive overview of all possible research areas.

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Appendix Referenzes for the clusters

#	Reference	#	Reference
A1 (III)	Zhang, Y. and Lam, J.S.L., 2016. Estimating economic losses of industry clusters due to port disruptions. Transportation Research Part A: Policy and Practice, 91, pp.17-33.	A11 (VII)	Valdor, P.F., Gómez, A.G. and Puente, A., 2015. Environmental risk analysis of oil handling facilities in port areas. Application to Tarragona harbor (NE Spain). Marine pollution bulletin, 90(1), pp.78-87.
A2	John, A., Yang, Z., Riahi, R. and Wang, J., 2016. A risk assessment approach to improve the resilience of a seaport system using Bayesian networks. Ocean Engineering, 111, pp.136-147.	A12	Przywarty, M., Gucma, L., Marcjan, K. and Bąk, A., 2015. Risk analysis of collision between passenger ferry and chemical tanker in the western zone of the Baltic Sea. Polish Maritime Research, 22(2), pp.3-8.
A3	Vidmar, P. and Perkovič, M., 2015. Methodological approach for safety assessment of cruise ship in port. Safety science, 80, pp.189-200.	A13 (III)	Burlando, M., Pizzo, M., Repetto, M.P., Solari, G., De Gaetano, P. and Tizzi, M., 2014. Short-term wind forecast for the safety management of complex areas during hazardous wind events. Journal of Wind Engineering and Industrial Aerodynamics, 135, pp.170-181.
A4 (III)	Zhang, Y. and Lam, J.S.L., 2015. Estimating the economic losses of port disruption due to extreme wind events. Ocean & Coastal Management, 116, pp.300-310.	A14	Alyami, H., Lee, P.T.W., Yang, Z., Riahi, R., Bonsall, S. and Wang, J., 2014. An advanced risk analysis approach for container port safety evaluation. Maritime Policy & Management, 41(7), pp.634-650.
A5	Azmi, F., Hewitt, C.L. and Campbell, M.L., 2015. A hub and spoke network model to analyse the secondary dispersal of introduced marine species in Indonesia. ICES Journal of Marine Science: Journal du Conseil, 72(3), pp.1069-1077.	A15 (VI)	Harold, P.D., de Souza, A.S., Louchart, P., Russell, D. and Brunt, H., 2014. Development of a risk-based prioritisation methodology to inform public health emergency planning and preparedness in case of accidental spill at sea of hazardous and noxious substances (HNS). Environment international, 72, pp.157-163.
A6 (IV)	Xiao, Y.B., Fu, X., Ng, A.K. and Zhang, A., 2015. Port investments on coastal and marine disasters prevention: Economic modeling and implications. Transportation Research Part B: Methodological, 78, pp.202-221.	A16 (VIII)	John, A., Paraskevadakis, D., Bury, A., Yang, Z., Riahi, R. and Wang, J., 2014. An integrated fuzzy risk assessment for seaport operations. Safety Science, 68, pp.180-194.
A7 (III)	Lam, J.S.L. and Su, S., 2015. Disruption risks and mitigation strategies: an analysis of Asian ports. Maritime Policy & Management, 42(5), pp.415-435.	A17 (III)	Li, K.X., Yin, J. and Fan, L., 2014. Ship safety index. Transportation research part A: policy and practice, 66, pp.75-87.
A8 (II)	Wen, Y., Huang, Y., Zhou, C., Yang, J., Xiao, C. and Wu, X., 2015. Modelling of marine traffic flow complexity. Ocean Engineering, 104, pp.500-510.	A18	Filina-Dawidowicz, L., 2014. Rationalization of servicing reefer containers in sea port area with taking into account risk influence. Polish Maritime Research, 21(2), pp.76-85.
A9	Paulauskienė, T. and Jucikė, I., 2015. Aquatic oil spill cleanup using natural sorbents. Environmental Science and Pollution Research, 22(19), pp.14874-14881.	A19	Sany, S.B.T., Hashim, R., Salleh, A., Safari, O., Mehdinia, A. and Rezayi, M., 2014. Risk assessment of polycyclic aromatic hydrocarbons in the West Port semi-enclosed basin (Malaysia). Environmental Earth Sciences, 71(10), pp.4319-4332.
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A21 (V)	Elsayed, T., Marghany, K. and Abdulkader, S., 2014. Risk assessment of liquefied natural gas carriers using fuzzy TOPSIS. Ships and Offshore Structures, 9(4), pp.355-364.	A31	Chulkov, D.V., 2012. Managing new technology investment for underwater security of ports. Journal of Transportation Security, 5(2), pp.95-105.
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A23 (I)	David, M., Gollasch, S. and Leppäkoski, E., 2013. Risk assessment for exemptions from ballast water management–The Baltic Sea case study. Marine pollution bulletin, 75(1), pp.205-217.	A33	Vilko, J. and Hallikas, J., 2012. Origin and impact of supply chain risks affecting supply security. International Journal of Shipping and Transport Logistics, 4(2), pp.110-123.
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HAZARD project has 15 full Partners and a total budget of 4.3 million euros. It is executed from spring 2016 till spring 2019, and is part-funded by EU's Baltic Sea Region Interreg programme.

HAZARD aims at mitigating the effects of major accidents and emergencies in major multimodal seaports in the Baltic Sea Region, all handling large volumes of cargo and/or passengers.

Port facilities are often located close to residential areas, thus potentially exposing a large number of people to the consequences of accidents. The HAZARD project deals with these concerns by bringing together Rescue Services, other authorities, logistics operators and established knowledge partners.

HAZARD enables better preparedness, coordination and communication, more efficient actions to reduce damages and loss of life in emergencies, and handling of post-emergency situations by making a number of improvements.

These include harmonization and implementation of safety and security standards and regulations, communication between key actors, the use of risk analysis methods and adoption of new technologies.

See more at: http://blogit.utu.fi/hazard/

EU STRATEGY FOR THE BALTIC SEA REGION FLAGSHIP
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