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Analysis of risk factors influencing the safety of maritime container supply chains

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Abstract

This paper aims to identify the major risk factors influencing the safety and security of maritime container supply chains (MCSCs) to aid the effective management of the associated risks. By doing so, the definition and classification of supply chain risks in a general context are first reviewed to provide a reference for the understanding and analysis of risk factors in MCSCs. A novel risk classification framework, incorporating a Delphi survey and a risk matrix approach, is proposed to identify the major risk factors of significant safety concerns from five perspectives, including society, natural environment, management, infrastructure and technology, and operations. As a result, different types of risk factors in MCSCs are identified through a systematic review of previous studies. Then, a Delphi expert survey is undertaken to explore the emerging hazards that have not yet been raised/studied in the literature. The survey is carried out by interviewing different groups of maritime stakeholders, who own the world leading commercial container fleets and container ports. Relevant data for the assessment of all identified risk factors are collected through a large-scale questionnaire survey, and the identified risk factors are quantitatively evaluated regarding their occurrence likelihood and consequence severity. This paper extends the risk analysis from the segment level (e.g. nodes and links) to a supply chain level, and realises the hazard identification and risk evaluation of different MCSC segments on the same plate so that they can be better understood and managed from a systematic perspective. The research results will provide useful insights for risk control and accident prevention, which is beneficial to different types of stakeholders involved in the shipping industry.

Keywords: Maritime risk, container shipping, maritime safety, maritime security, Delphi

1. Introduction

The expanding scale and increasing volume of international trade, development of transportation infrastructure, and technology innovation in the last several decades have contributed to the rapid and significant growth of container shipping worldwide. However, the growth in globalisation and complexity of international container transportation systems also bring uncertainties into maritime container supply chains (MCSCs), thus making it difficult yet necessary to manage risks properly and efficiently. Various kinds of risk factors may appear at different stages of container shipping operations, such as fluctuation of fuel price (Notteboom, 2006), dynamic customer demands (Das and Dutta, 2013), political instability (Vilko et al., 2016), and transportation accidents (Vernimmen et al., 2007), which will result in different types of risks that hinder the safe and efficient operations of an MCSC.

The statistics show that in the past decade, container supply chain risks caused loss of billions of dollars in European Union (EU) only and the number of accidents and severity of the consequence are growing fast because of the growth of container transportation. For instance, the theft of high-value products moving through supply chains in Europe costs businesses in excess of € 8.2 billion a year (TAPA, 2017). Cargo crime accidents doubled in EU in 2014-2016 with an annual increase rate of 115% (Lloyd's list, 2017). In terms of container loss at sea, based on the results of the nine-year period (2008-2016) survey, the World Shipping Council (WSC) estimated that there were on average 568 containers lost at sea each year, without concerning catastrophic events. The figure went up to 1,582 when catastrophic events were counted. On average, 64% of containers lost during the last decade were attributed to a catastrophic event (WSC, 2017a). For example, on 21 February 2010, the 657 TEU container ship Angeln capsized and sank after leaving the Port of Vieux-Fort. The accident was caused by insufficient stability resulting from the improper loading and stowage of containers (RINA, 2017). A post-Panamax container ship called MOL Comfort broke into two due to bad weather on its way from Singapore to Saudi Arabia, losing 4,382 containers in the accidents on 17 June 2013. On 12 August 2015, a series of explosions occurred at a container storage station at the Port of Tianjin, China. Altogether 173 people were killed, and 797 were injured in the accident, causing a direct economic loss of 6.86 billion Chinses Yuan (equivalent to more than 1 billion USD), and severe environmental damages as well (BBC, 2015). The above evidence shows that risk studies of MSCSs are necessary and urgent.

Analysis of risk factors is critical to the success of effective safety management, as it can help identify the hazards/threats a company is facing with priority, understand where a risk may emanate from, and evaluate how much a company is exposed to uncertainties, so that rational mitigation strategies can be developed to ensure the performance of a whole supply chain. There are a number of studies addressing maritime safety issues with special attention from different perspectives including human factors (e.g. Lu and Shang, 2005; Yang et al., 2013a; Xi et al., 2017), transportation operational factors (e.g. Chang et al., 2014; Yang et al., 2013b and 2014), and shipping safety- and security-related political factors (e.g. Yang, 2010; Yeo et al., 2014). Although valuable insight has been provided by previous studies into the identification and analysis of risk factors faced by container shipping industries, they have usually been identified from a single aspect focusing on, for example, human errors, operational risks and managerial risks. Moreover, most of these risks are still dealt with at an individual component level of MCSCs (e.g. port and container shipping), leading to their importance not being measured at the same plate and not comparable. Hence, safety resources cannot be rationalised from a global system perspective. It shows a research gap to be fulfilled, particularly given the increased container transport accidents along with the fast growth of containerised multi-modal transportation in MCSCs.

In view of this, the work tries to identify all the potential risk factors faced by an MCSC from a broader perspective and uses a uniformed scale to evaluate the existent and emerging risk factors influencing MCSCs as a whole on the same measurement scales so that they can be better managed from a systematic level. In this study, a large scale of a questionnaire survey in the container shipping industry is conducted to measure the level of the identified risks with respect to their occurrence likelihood and consequence severity. This study aims to answer the following questions:

RQ1. What are the risk factors in the whole process of an MCSC?

RQ2. Which risk factors are more significant than the others in the container shipping industry?

The remainder of this paper is organised as follows. Section 2 consists of a review of the literature concerning the definition and classification of supply chain risks. Section 3 introduces the methods used in this study for the identification, measurement and validation of risk factors. A framework for risk classification is proposed in Section 4, along with all the risk factors identified based on the proposed classification framework. Section 5 describes the empirical investigation of risk factors based on the descriptive statistical analysis and a risk matrix method. The research results, implications, and main contributions are concluded in Section 6.

2. Literature review

In risk studies, a clear definition of an investigated system and reasonable classification of the risk factors aid effective risk analysis. The definition of container supply chain risks and the classification of the associated risk factors are reviewed in this section.

2.1 Definition of MCSC risks

Although the research on supply chain risk management showed an increasing trend in the last decade, only a few authors explicitly answered the question of what a supply chain risk is, and what characteristics it has. Yu and Goh (2014) regarded supply chain risks as the probability of occurrence of an adverse event during a certain period within a supply chain and the associated consequences which affect supply chain performance. Kull and Closs (2008) carried out a risk assessment in a simulation environment to examine supply risk issues within the context of a second-tier supply failure. In their study, the grounded definition of supply risks based on Zsidisin (2003) was "*the potential occurrence of an incident associated with the inbound supply from individual supplier failures or the supply market in which its outcomes would result in the inability of the purchasing firm to meet demand or threaten customer well-being and safety*". Other research of supply chain risk management adopting similar definitions includs Goh et al. (2007), and Kähkönen et al. (2016). To minimise the supply chain cost with embedded risks, Kumar et al. (2010) defined supply chain risk as the potential deviations from the initial objective, which would result in the decrease of value at different levels. Overall, among the research with an explicit definition of supply chain risk, analysis of supply chain risk was generally approached from three aspects (Heckmann et al., 2015), including a) the probability of occurrence of triggering events and their adverse outcomes, e.g., Chen and Yano (2010) and Yu and Goh (2014), b) a deviation from the expected objective or value (which was often profit-, or cost-oriented), e.g., Bogataj and Bogataj (2007) and Kumar et al. (2010), and c) the supply risk defined by Zsidisin (2003), which arose from individual supplier failures or market factors. However, most conceptual work with no explicit definition implied the risk to be a triggering event or a probability. An in-depth discussion on the definition of supply chain risks refers to Heckmann et al. (2015).

The MCSC refers to the maritime container transport logistics in this paper, involving container port/terminal operations and container seaborne transportation[1]. Compared to previous studies, it not only presents the two segments of ports and shipping in the context of the same supply chain due to their high association in operations, but also integrates two traditional separate dimensions of operational and business/financial risk analysis in the same universe. It becomes very necessary in today's container business model in which shipping and port operators come into each other's business and consider safety management from a whole supply chain perspective involving multiple dimensions of operational, managerial and financial risks. As a result, MCSC risks refer to the combination of the occurrence of a triggering event (or a certain situation) during the maritime transport of containers and the associated outcomes which have the potential to negatively influence any component/process of an MCSC, such as damaging port infrastructure, container ships, cargos, and/or environment, causing injury of seafarers, interrupting container shipping business, and damaging reputation of shipping companies and maritime authorities.

2.2 Classification of risks in a maritime supply chain

As the starting point of traditional risk management process, risk classification and identification have been extensively discussed within the context of supply chains. The classification process clarifies the relationship among different risk sources and the relevant dimensions of potential disruptions in a supply chain as well, providing a basis for the identification of risk factors and the following assessment. Various ways of sorting risk sources coexist. One of the most basic and straightforward ways is to classify risks into two categories, which are internal and external risks. For instance, Kumar et al. (2010) argued that internal risks arose due to improper coordination among different levels, including factors like demand, production, and supply risks. External risks usually result from interactions between a supply chain and its environment, comprising factors such as terrorist attacks, natural disasters, and exchange rate fluctuations. In a review of enterprise risk management, Olson and Wu (2010) pointed out that internal risks contained those from available capacity, internal operations, and information systems, while external risks evolved from nature, political systems, competitors, and markets. Another similar method is to classify risks as endogenous and exogenous origins, depending upon whether the risk sources lie within or beyond the investigated supply chain boundaries. Examples were found in Trkman and McCormack (2009), Wagner and Neshat (2012), and Vilko et al. (2016). Other binary classification methods include those considering, for example, operational and disruption risks (Tang 2006), quantitative and qualitative risks (Svensson, 2000), macro- and micro-risks (Ho et al. 2015), and systematic and non-systematic risks (Baghalian et al., 2013). It is worth noting that, in general, different interconnected organisations/companies are involved in a supply chain. Therefore, endogenous risk sources were further distinguished as "beyond company borders" and "corporate-wide" sources by Götze and Mikus (2007). In this way, supply chain risks can be divided into three categories (Jüttner et al., 2003), which were environmental risks, network-related risks, and organisational risks. Organisational risks were those inside the organisational boundaries, whereas network-related risks were raised from interactions between organisations and other partners within the same supply chain.

[1] Although the landside logistics of containers is beyond the scope of this paper, the proposed framework for risk factors analysis can be and has been applied to other container transport modes (e.g. road and rail) in the authors' on-going research project.

Environment risks comprised uncertainties existing in the external environment. An illustration is shown in Figure 1. Another classification of supply chain risks which had also attracted a lot of attention addressed risk factors from the perspectives of three main logistics flows, namely, physical/material flow, information flow, and financial/payment flow (Chopra and Meindl, 2010). On the basis of Tang's (2006) research, Tang and Musa (2011) identified supply chain risks in terms of material, information and financial flows. In the study, material flow risks were investigated from the stages of the source, production and delivery. Financial flow risks involved exchange rate risk, price and cost risk, financial strength of supply chain partners, and financial handling and practice. Risk factors related to information flows lied in the information accuracy, information system security and disruption, intellectual property, and information outsourcing. Additional risk classification methods can be found in the studies that categorised supply chain risks according to their influence on supply chain performance, controllability of risks, roles within a supply chain, and uncertain parameters in relation to supply chain activities (Cavinato, 2004; Bogataj and Bogataj, 2007; Blackhurst et al., 2008; Mentzer and Manuj, 2008;Tang and Tomlin, 2008; Tummala and Schoenherr, 2011; Samvedi et al., 2013; Martino et al., 2017), to name but a few.

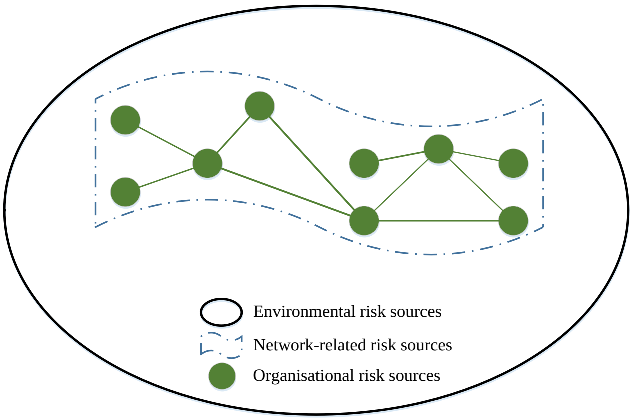

Figure 1 Illustration of risk sources in a supply chain

Source: adapted from Jüttner et al. (2003)

By incorporating multiple dimensional risk classification methods, this study categories MCSC risks into two main groups (i.e. external and internal) composed of five major risk sources (i.e. society, natural environment, management, infrastructure and technology, and operations). See Section 4 for detailed information.

3. Research methods

A statistics of global trade shows that in 2016, China is ranked at the first in terms of the merchandise exports and at the second in terms of merchandise imports. According to another recent statistics report (WSC, 2017b), among the top ten world's busiest container ports by a total number of actual twenty-foot equivalent units (TEUs) transported through the port, seven of them are from China. Given the fact[2], the data is collected from the maritime stakeholders in China, including the COSCO SHIPPING Lines Co., Ltd and its branches (such as COSCO Beijing International

[2] It is also to improve the efficiency of data collection and address language barriers in the questionnaire design, timeliness of this research, and consensus issues of the primary data.

Freight Co., Ltd., COSCO Tianjin Shipping Agency Co., Ltd., COSCO shipping Logistics Co., Ltd., and COSCO Shipping Development Co., Ltd.), local maritime safety administrations (such as Changjiang Maritime Safety Administration), and major container ports in China (such as Port of Shanghai). It is believed that the findings are meaningful in the region and can also provide insights for other regions given the involved fleets and ports in China are world leading, involving global MCSCs.

Table 1 Top three countries by imports and exports in 2016

Rank	Importers	USD (millions)	Exporters	USD (millions)
1	Unites States	2,248,209	China	2,097,637
2	China	1,587,921	Unites States	1,450,457
3	Germany	1,060,672	Germany	1,340,752

Source: International trade statistics (http://www.intracen.org/itc/market-info-tools/trade-statistics/)

In order to systematically identify and analyse the risk factors in MCSCs, several methods are utilised in this study in a combined way. A Delphi expert survey is conducted to develop a risk classification framework, to validate the risk factors identified from literature review, and to explore the emerging ones, which are not available from the current literature. A large-scale questionnaire survey is conducted to collect data for measuring the occurrence likelihood and consequence severity of each identified and validated risk factor. Finally, the risk matrix method is applied to analyse the relative importance of each risk factor and rank them according to their risk index values. A detailed description of these research methods and the key steps are presented in the following sub-sections.

3.1 Delphi expert survey

Given the difference between academic studies and industrial applications, as well as potential ambiguities when presenting those risk factors, it is necessary and helpful to involve judgements from experts who are most familiar with the reality to validate the identified risk factors from the literature. Based on the review of previous studies, considering the complexity of MCSC systems and the reliability of data collected from experts' survey, this study uses the Delphi method to validate the identified risk factors and explore emerging ones.

The Delphi method is a structured communication technique which relies on the results of questionnaires being sent to the panel of experts. Normally, several rounds of questionnaires need to be sent out, and an anonymous summary of responses from previous rounds as well as the reasons they provided for their judgements are aggregated and shared with the group after each round. The experts are allowed to revise their earlier answers in subsequent rounds according to the replies of other members of the panel. Since multiple rounds of questions are undertaken, and the panel is advised on what the group thinks as a whole, the Delphi method is believed to be able to obtain a reliable and consistent response to a problem from a group of experts through consensus. It is well suited, as a research instrument, to model incomplete knowledge (Skulmosji et al., 2007). It thus especially works well in this study given the uncertainties of various risk factors and the complexity of an MCSC system. As a flexible research approach, Delphi-based methods have been successfully used in industrial risk management, particularly in the identification of risk factors where subjective inputs are largely depended (e.g. Chapman, 1998; Markmann et al., 2013).

Different Delphi processes have been introduced and applied (Linstone and Turloff, 1975). According to the specific research background and objectives in our research, a brief flow chart of the main processes of the Delphi method is shown in Figure 2, while the specific steps applied in this study are introduced as follows. The Delphi expert survey started in January 2017, and it took three months to reach the final results of an accepted consensus.

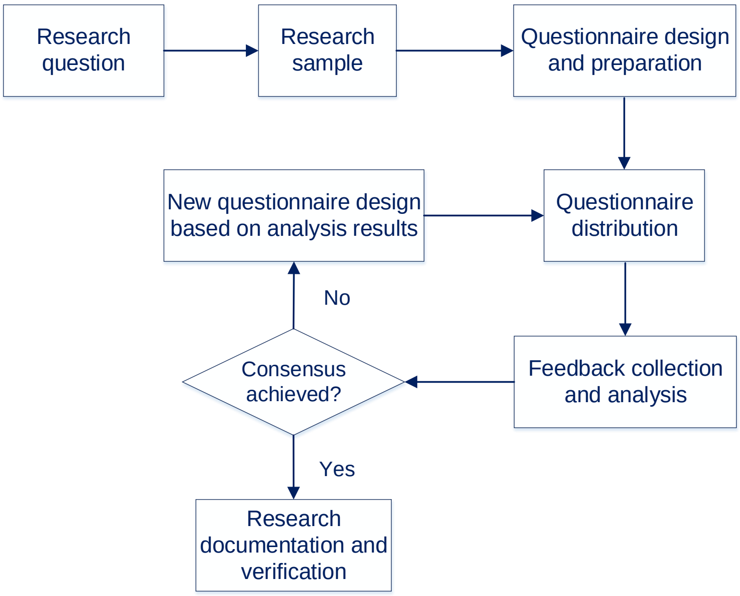

Figure 2 Flow chart of Delphi process

- Step 1: Define the problem

Research questions are generally derived in accordance with the main research purpose. In this study, we aim to propose a classification framework for the identification of risk factors in MCSCs from a systematic perspective and evaluation of their risk levels. Thus, two issues that need to be dealt with through the Delphi method are: 1) establishment of the classification framework and 2) exploration and validation of risk factors of MCSCs. It is worth noting that before all questions are finalised for the formal Delphi expert survey, a pilot study is firstly rquired to identify the possible ambiguities and vagueness in the designed questions. Based on the results and comments of participants in the pilot survey, the invitation letter of the survey is improved, and the layout of the questionnaire is modified to provide a clearer instruction.

- Step 2: Research sample

Selecting research participants is a critical component of the Delphi method since it is expert opinions that contribute to the final outputs of the Delphi (Skulmosji, Hartman and Krahn, 2007). In terms of the sample selection of the Delphi survey in this study, 28 experts from different countries had been connected. Ten of them from eight organisations replied to the authors within the given time window (2-29 January

2017), showing their willingness to serve as a member of the Delphi expert group in this work. The profile information of participants involved is listed in Table 2.

Table 2 Profile of participants in Delphi expert group

No.	**Type of organisation**	**Year of working**	**Department/ professional area**	**Position**	**Country**
1	University*	32	International shipping business management	Professor	China
2	University*	26	Supply chain management marketing and operations	Professor	UK
3	Port authority	21	Port safety and operation management	Senior officer	Saudi Arabia
4	Maritime authority	27	Maritime transportation, environment, and energy	Senior advisor	USA
5	Maritime authority	33	Maritime safety and waterway traffic accident investigation	Senior marine investigator	China
6	Shipping company	25	Contract logistics	Senior manager	China
7	Shipping company	27	Supply chain development and project management	Senior manager	Singapore
8	Shipping company	27	Marketing and sales	Vice present	China
9	Shipping company	29	Marine operating centre	Senior captain	China
10	Shipping company	26	Container ships more than 10,000 TEU	Senior captain	China

* Both of them also had rich working experience in the MCSC industry.

A single panel of experts with different backgrounds (e.g., academics, industry experts, and administrators) are selected in this study for the completeness of the judgements from different stakeholders' perspectives. Their professional areas are balanced in the Delphi expert group, thus being able to reasonably represent a general understanding of an MCSC and provide reliable outputs.

- Step 3: Round one Delphi expert survey

In the first round survey, some semi-structured questions are developed to collect opinions on the rationality of the risk factor classification structure and the identified risk factors. We can then figure out whether the structure of the framework for risk factor categorisation is appropriate, whether these identified risk factors really exist, and whether there are any other risk factors that should also be considered. The questionnaire is distributed to the ten Delphi participants separately, and they are given four weeks to return their comments. During the defined period, they can revise their responses at any time, and they are also advised to provide the reasons for the changes to make.

- Step 4: Round two Delphi expert survey

All opinions of the participants from the first round survey are summarised, based on which some modifications are made to the initially proposed framework and identified risk factors. The main changes lay on the structure of the framework for risk factor classification. Besides, some risk factors are modified/deleted, and new ones are added. The round-two questionnaire is developed according to the responses from round one and then released to each participant in the Delphi expert group.

In the second round survey, the participants are first given the opportunity to check if their responses in round one indeed reflect their opinions and then asked to evaluate the extent to which they agreed with (if not agree, explain the reason) the changes made in the previous survey in this round. This process may be repeated for several times until the convergence on the agreement of the participants is obtained. A time limit of two weeks is set for the second round survey since all participants had already been familiar with the study, and this process would not take as much time as the previous one. Again, a similar process of analysis was conducted based on all responses from the second round survey.

- Step 5: Round three Delphi expert survey

The statements that do not reach the consensus from the last round will be reformulated based on the panel's comments and included in the next round. The round-three questionnaire is developed according to the responses of all participants from the second round and then is distributed to each participant. Again, these participants are given the opportunity to change their answers and to comment on the emerging and modified risk factors according to other participants. In this study, the round three Delphi expert survey is the final one. According to their feedback, the consensus on the structure of the framework for risk factor classification and the identified risk factors is reached.

- Step 6: Verify and document research results

For the validation purpose, a revision report generated from the three-round Delphi survey is sent to each Delphi expert. The revision report presented the difference between the original statement and the modified one in terms of the structure of the framework for risk factor classification and the identified risk factors, along with the reasons for all the modifications. No more modification is needed according to the experts' feedback, revealing an acceptable consensus level of their opinions on the results.

In this study, the research steps are developed based on the distinct phases introduced by Linstone and Turloff (1975) which have proven to be reliable over the years. Moreover, a sufficient number of participants who have an academic, industrial or administrative background are chosen and involved in a three-round Delphi survey. All the participants have rich working experience (more than twenty years) in container shipping or related industries/research areas with a senior position in their fields. In addition, a pilot survey is conducted to improve the quality of the questionnaire. Thus, the validity and reliability of the Delphi expert survey are guaranteed.

3.2 Questionnaire survey

This paper conducted a survey, in the form of a questionnaire to elicit expert opinions on the likelihood and consequence of the identified risk factors in the MCSC domain due to the lack of accurate industry-specific risk data. As recommended by the International Maritime Organisation (IMO), a seven-point Likert scale is used for measuring likelihood and a four-point scale for measuring consequence severity, as shown in Table 3 and Table 4, respectively. This kind of scale has already been applied for risk analysis research, especially in the field of maritime safety, e.g., Wang and Foinikis (2001) and IMO (2013). Based on the results of the Delphi expert survey, the questionnaire is constructed consisting of six major parts: the respondents' profile, the measurement of risk factors associated with the society, the natural environment, management, infrastructure and technology, and operations.

Table 3. Definitions of the occurrence likelihood of risk factors (Yang, 2010; Alyami et al., 2014)

Likelihood	Likert scale	Definition
Extremely Rare	1	Has never or rarely happened
Rare	2	Not expected to occur for a few years; May only occur in exceptional circumstances
Unlikely	3	Trivial likelihood, however, could occur at some time
Possible	4	Might occur at some time; Expected to occur every few months
Likely	5	Will probably occur in most circumstances; Expected to occur at least monthly
Frequent	6	Expected to occur at least weekly
Very Frequent	7	Can be expected to occur in most circumstances; Occur daily

Table 4. Definitions of the consequence severity of risk factors (Hu et al., 2007)

Consequence severity	Likert scale	Definition
Minor	1	Cause some inconvenience with minor impacts such as small cost/schedule increase.
Moderate	2	Cause some disruptions with medium impacts such as moderate cost increase, delay, and minor environmental damage.
Severe	3	Cause some disruptions, or sometimes failures with severe impacts such as major cost increase, major environmental damage or injuries.
Catastrophic	4	Cause complete and irrecoverable failures (thus the minimum requirements cannot be achieved), long-term environmental damage, or death.

The questionnaires for the measurement of risk factors are developed in English at the early stage and translated into Chinese. The target sample for the questionnaire survey is selected from the top ten shipping companies in China (and their branch companies worldwide), shipping agencies, freight forwarders, maritime safety administrations, port authorities, and other organisations related to the container shipping industry. Several questionnaires were sent to the relevant departments of each company in person or through emails. The questionnaire was also coded to an online questionnaire via e-survey creator (https://www.diaochapai.com/survey2539536,) to ensure that more validated participants can be involved in the questionnaire survey easily.

3.3 Risk matrix analysis

The risk matrix approach has been widely applied in various areas to evaluate risk factors in a quantitative way. A risk matrix table is composed of two dimensions- one vertical dimension consisting of several likelihood categories, and one horizontal dimension made up of several consequence categories. In this study, seven categories are developed for likelihood, and four for consequence. Based on that, a 7×4 risk matrix can be constructed. According to the IMO (IMO, 2013), the likelihood and consequence indices are defined on a logarithmic scale to facilitate the ranking and validation of ranking. Consequently, Eq. 1 can be obtained.

$$\text{Log}\,(Risk) = \text{Log}\,(occurrence\ likelihood) + \text{Log}\,(consequence\ severity) \qquad \text{Eq. 1}$$

Then, the Risk Index (RI) is established by adding the Likelihood Index (LI) and Consequence Index (CI) (Wang and Foinikis, 2001).

$$\textbf{R}\text{isk } \textbf{I}\text{ndex} = \textbf{L}\text{ikelihood } \textbf{I}\text{ndex} + \textbf{S}\text{everity } \textbf{I}\text{ndex} - 1 \qquad \text{Eq. 2}$$

To classify the risk levels and quantitatively compare the importance of each risk factor, the Average Risk Index (*ARI*) is defined in this paper, which can be calculated using Eq. 3.

$$\begin{aligned} ARI_r &= \frac{1}{N}\sum_{i=1}^{N} RI_{ri} \\ &= \frac{1}{N}\sum_{i=1}^{N}(LI_{ri} + SI_{ri} - 1) \qquad (r = 1, 2, \ldots, M;\ i = 1, 2, \ldots, N) \qquad \text{Eq. 3} \\ &= \frac{1}{N}\sum_{i=1}^{N} LI_{ri} + \frac{1}{N}\sum_{i=1}^{N} SI_{ri} - 1 \\ &= \overline{LI}_r + \overline{SI}_r - 1 \end{aligned}$$

where, M is the number of risk factors, and N is the number of respondents. $\overline{LI}_r$ is the average Likelihood Index of the r^{th} risk factor, and $\overline{SI}_r$ is the average Severity Index of the r^{th} risk factor. LI_{ri} is the Likelihood Index of the r^{th} risk factor by the i^{th} respondent, while SI_{ri} is the Severity Index of the r^{th} risk factor by the i^{th} respondent. Both of them are obtained through the aforementioned questionnaires survey.

According to the numerical risk outcomes, identified risk factors can generally be classified into three or four different risk categories (Markowski and Mannan, 2008). In this work, considering both the suggestions from the industry experts and the "As Low As Reasonably Practicable (ALARP)" principle (HSE, 2001), we apply four risk categories to support a more flexible and reasonable decision-making process in the risk management. The risk levels can be determined according to the *ARI* value of each risk factor. They are, a) low-risk level, in which $ARI \in [1, 4)$ and is coloured in green. Risk factors of this level have a minor impact on an MCSC which can be ignored, and thus no further action needs to be taken by managers; b) low-moderate level, $ARI \in [4, 6)$, in yellow colour; c) high-moderate level, $ARI \in [6, 8)$, in orange colour. Both the two levels belong to a moderate risk level, to which certain attention needs to be paid. According to the ALARP principle, risk reduction measures are needed until they are no longer reasonable according to the cost-benefit analysis; and d) high-risk level, where $ARI \in [8, 10]$, and it is represented in red colour. Risk factors falling into this region have high occurrence likelihood with serious consequence, which will severely influence the safety of the whole supply chain. Thus, they have to be either forbidden or reduced to an acceptable risk level. The risk matrix method and the associated risk classifications are employed in a combined way in this work, as illustrated in Figure 3.

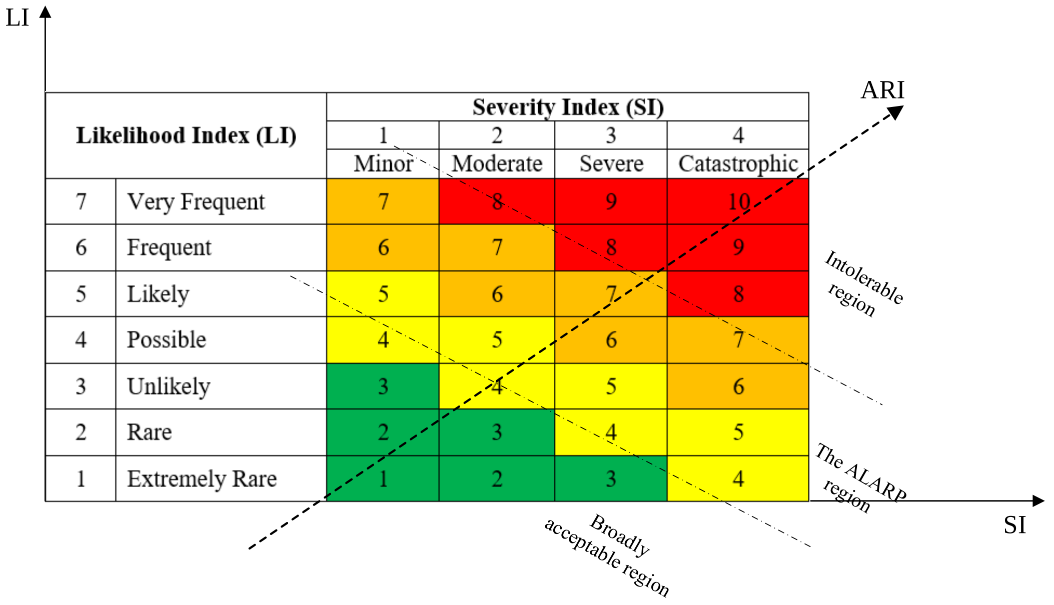

Figure 3 Incorporating the ALARP principle into risk assessment matrix

Source: Developed by authors based on Wang and Foinikis (2001), and HSE (2001)

4. Classification and identification of risk factors in MCSCs

4.1 Framework for risk factors classification in MCSCs

Based on a systematic review of the previous studies (e.g., Rao and Goldsby, 2009; Acciaro and Serra, 2013; Ho et al., 2015; Zhao et al., 2016) and an in-depth discussion with domain experts through the Delphi survey, the framework for risk factors classification is proposed, and shown in Figure 4. It is a top-down structure framework, which helps to clarify the relationship among different risk sources step by step. It provides the basis for the identification of risk factors. It is composed of four levels (Level I, II, III, and IV). Level I, as the starting point, presents the purpose of this study, that is, to rationally classify risk factors of MCSCs. Level II divides all possible risk factors into two general categories, which are external risks and internal risks. The external risks usually result from an interaction between supply chains and the environment, while internal risks arise due to improper coordination among different levels within a supply chain. In the next level, five main risk perspectives are identified from external and internal environments respectively, which are society, natural environment, management, infrastructure and technology, and operations. However, society offers a relative broad concept composing of a variety of human-related activities which may not enough to support a specific risk factor identification. In view of this, the society is further subdivided as economic environment (Heckmann et al., 2015), political environment (Yang, 2011), and security (Yang, 2010). Similarly, management and operations are also expanded, making up Level III. Such new development in MCSC risk classification is supported by the Delphi expert group. Finally, 64 risk factors in Level IV are identified based on the risk perspectives. Details of the 64 identified risk factors are introduced in Section 4.2.

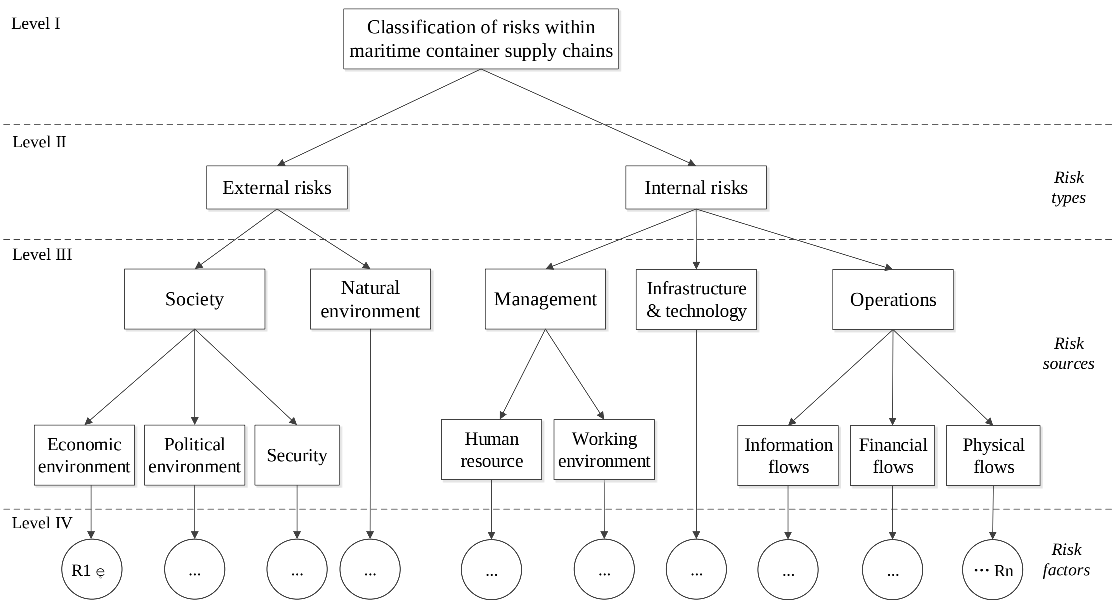

Figure 4. Framework for risk factors classification in MCSCs

4.2 Identification of risk factors in MCSCs

Based on the framework proposed in Section 4.1, the identification of risk factors in MCSCs is undertaken through two main steps of literature review and Delphi survey in Section 3, as shown in Table 5.

Table 5 Identified risk factors of MCSCs

Risk source		**Risk factor**	**Reference**
Society	Economic environment	Financial crisis	Vilko and Hallikas (2012); Chang et al. (2015)
		Change of interest rates	Samvedi et al. (2013)
		Change of exchange rates	Samvedi et al. (2013); Chang et al. (2015)
		Fluctuation of fuel price	Cucchiella and Gastaldi (2006); Manuj and Mentzer (2008)
		Unattractive markets	Vilko and Hallikas (2012)
		Fierce competition	Vilko and Hallikas (2012); Samvedi et al. (2013)
		Monopoly	Vilko et al. (2016)
	Political environment	Trade policy instability	Samvedi et al. (2013); Vilko et al. (2016)
		Maritime security initiatives	Yang (2010); Acciaro and Serra (2013)
		Regulations and measures	Vilko and Hallikas (2012)
		Regional political conflicts	Vilko et al. (2016)
	Security	Terrorism	Tummala and Schoenherr (2011); Vilko et al. (2016)
		Piracy/maritime robbery	Acciaro and Serra (2013); Chang et al. (2015)
		Sabotage	Manuj and Mentzer (2008)
		Smuggling	Vilko and Hallikas (2012); Zhao et al. (2016)
		Spying/espionage	Vilko and Hallikas (2012)
		Epidemic	Vilko and Hallikas (2012); Vilko et al. (2016)

		Refugees	From the Delphi expert survey
Natural environment		Unstable navigational condition	Notteboom (2006); Vilko et al. (2016)
		Natural disasters	Vilko and Hallikas (2012); Ho et al. (2015)
		Climate change	Vilko and Hallikas (2012)
Management	Human resource	Lack of skilled workers	Mateusz and Świeboda (2014); Vilko et al. (2016)
		Lack of motivation	Vilko and Hallikas (2012); Vilko et al. (2016)
		Mental health of seafarers	Hetherington et al. (2006)
		Human errors	Hetherington et al. (2006)
		Low wages	From the Delphi expert survey
	Working environment	Language and cultural diversity	Hetherington et al. (2006)
		Lack of cooperation among departments	Yang et al. (2008)
		Poor safety culture/climate	Lu and Shang (2005); Hetherington et al. (2006)
		Low degree of safety leadership	Lu and Yang (2010)
		Poor ergonomics at the workplace	From the Delphi expert survey
Infrastructure & technology		Lack of intermodal equipment	Vilko and Hallikas (2012)
		Poor entrance channels of a port	Vilko and Hallikas (2012)
		Limited storage ability	Yang et al. (2008)
		Low technical reliability	Ho et al. (2015)
		Undeveloped ground access system	Hsieh et al. (2014)
		Lack of regular maintenance of equipment	From the Delphi expert survey
		Insufficient berthing capability	From the Delphi expert survey
Operations	Information flows	Information delay	Cucchiella and Gastaldi (2006); Chang et al. (2015)
		Information inaccuracy	Tummala and Schoenherr (2011); Chang et al. (2015)
		IT vulnerability	Chang et al. (2015); Vilko et al. (2016)
		Internet security	Wu et al. (2006)
		Poor information sharing	Vilko et al. (2016)
		Lack of information standardisation and compatibility	Chang et al. (2015)
	Financial flows	Payment delay from partners	Seyoum (2014); Chang et al. (2015)
		Break a contract	Chang et al. (2015)
		Shippers going into bankruptcy	Chang et al. (2015)
		Partners with bad credit	Vilko and Hallikas (2012); Chang et al. (2015)
		Charter rates rise	From the Delphi expert survey
		Cash flow problem	From the Delphi expert survey
	Physical flows	Inaccurate demand forecast	Manuj and Mentzer (2008); Ho et al. (2015)
		Transportation of dangerous goods	Vilko and Hallikas (2012); Chang et al. (2015)
		Container shortage	Chang et al. (2015)
		Port strikes	Notteboom (2006); Chang et al. (2015)
		Port/ terminal congestions	Notteboom (2006); Chang et al. (2015)
		Lack of flexibility of designed schedules	Chang et al. (2015); Vilko et al. (2016)

		Problems with customs clearance	Vilko and Hallikas (2012); Chang et al. (2015)
		Electricity failure	Chang et al. (2015); Vilko et al. (2016)
		Bottlenecks/ restriction on transportation routes	Notteboom (2006); Vilko et al. (2016)
		Improper container terminal operations	Moon and Nguyen (2014)
		Incorrect container packing	Mateusz and Świeboda (2014);
		Transport accidents	Yang et al. (2005); Ellis (2011)
		Trade imbalance on container shipping routes	From the Delphi expert survey
		Improper management of container storage area	From the Delphi expert survey

5. Survey results and analysis

In this section, domain experts in container maritime logistics from 44 organisations (such as shipping companies, maritime safety administrations, customs, port authorities, and maritime university, etc.) are contacted using the membership directories of the research institute where the authors belong to. Also, domain experts with knowledge on risk management of any part of the process of an MCSC are contacted to elicit their opinions.

In total, 267 questionnaires were sent out in April 2017, and 101 replies were received by 13 June 2017. There were 71 valid questionnaires and 30 invalid ones (containing incomplete or conflicting information). The overall valid return rate is 26.59% (with a valid return rate of 64.10% for in-person distribution, and that of 20.18% for email distribution). To ensure the involvement of more validated experts, the questionnaire was also converted to an online edition via an e-survey creator. The website link to the online questionnaire was distributed to all potential participants (including those who did not reply the email questionnaires) through instant messaging apps for the easiness of finishing the questionnaire. The contacted researchers can sign in the e-survey creator and view the given answers when they complete. 61 more valid replies were received by the end of June 2017. As a result, in total 132 valid responses were collected from the questionnaire survey. These data are firstly used to provide a statistics of the likelihood and the consequence of each risk factor and then used to compute their *ARI*s.

5.1 Profile of questionnaire respondents

More than 75% of respondents have worked in the container shipping industry for more than 10 years (11-15 years: 12.12%; 16-20 years: 35.61%; over 20 years: 28.79%), and meanwhile, more than 90% of respondents hold a middle-class job title or above, which reveals that the majority of the respondents have long professional working experience and abundant knowledge reserves in container shipping business, contributing to the reliability of the results of this questionnaire survey.

In this survey, the “academia” refers to researchers who work in, for example, maritime universities and research institutes with experience of conducting research projects on container shipping safety related issues. Most of the respondents from industry work in container shipping companies, while the rest work in companies including container shipping agencies, freight forwarding companies, and container terminals, which play important roles in maritime container logistics. Governmental bodies in this study represent maritime transportation authorities, including maritime safety administrations, shipping administrations, and port authorities. The category of "other" includes non-governmental organisations (NGO) in relation to the shipping industry such as China Logistics Association (CLA), and China Ship-owners' Association (CSA), etc. As an empirical study, respondents from industry (80.30%) hold a dominant position. The others, however, which account for nearly one-fifth of the total respondents (academia: 5.30%; governmental body: 12.12%; other: 2.27%), also provide a complementary view on the overall understanding of the whole MCSC from different perspectives. Among all the respondents, 8.33% and 31.82% of them take part in port operations and maritime transportation, respectively. The rest of them (59.85%) are involved in the whole process of MCSCs.

In terms of the size of the participating organisations, only 15.91% of the respondents work in small companies/organisations (fewer than 50 employees). More than 60% of the respondents work for a company or an organisations of more than 200 employees, as the target sample is mainly selected from super-giant enterprises in the maritime shipping industry or their branches or agencies worldwide. The profile of 132 respondents in the survey is presented in Table 6.

Table 6. A summary of respondents' profile

Respondent Profile		**Number**	**%**
What is the type of your organisation?	Academia	7	5.30%
	Industry	106	80.30%
	Governmental body	16	12.12%
	Other	3	2.27%
Which part of the process of a maritime container supply chain are you involved in?	Port operations	11	8.33%
	Maritime transportation	42	31.82%
	Whole supply chain process	79	59.85%
What is your job title/ position?	Primary (technical) job title[3]	10	7.58%
	Middle (technical) job title[4]	44	33.33%
	Advanced/Senior (technical) job title[5]	78	59.09%
For how many years have you worked in the container shipping or related industry?	1-5 years	12	9.09%
	6-10 years	19	14.39%
	11-15 years	16	12.12%
	16-20 years	47	35.61%
	Over 20 years	38	28.79%
How many employees are in your company/ organisation?	1-50 people	21	15.91%
	51-100 people	17	12.88%
	101-200 people	6	4.55%
	201-500 people	36	27.27%
	Over 500 people	52	39.39%

5.2 Basic statistical analysis

[3] Such as research assistant, assistant lecturer, assistant customs supervisor, and clerk.
[4] Such as research associate, lecturer, engineer, customs supervisor, and captain.
[5] Such as professor, senior engineer and above, senior customs supervisor, senior captain, and manager.

The perceived level of likelihood and severity of risk factors can be seen in Table 7. Among the five main risk sources, risk factors associated with management has the highest likelihood (mean value: 4.25), which indicates that the human factor (and the provided working environment in daily operations) is a principal source bringing risks into the container shipping industry in practice. It is followed by the likelihood of risk factors associated with operations (mean value: 3.99), and society (mean value: 3.79). Among all risk factors, the top three in terms of likelihood are “fierce competition” (HS/EE_6: 5.58), “fluctuation of fuel price” (HS/EE_4: 5.13), and “change of exchange rates” (HS/EE_3: 4.98) as they occur most frequently.

In terms of consequence severity, risk factors associated with society are identified to have the greatest influence, with a mean value of 2.31. As an important component of the external environment, it is crucial for managers to pay attention to the related risk factors in order to reduce their negative impacts on the stable operations of MCSCs. Risk factors associated with operations (mean value: 2.30) rank the second, and those associated with management (mean value: 2.25) are in the third place. The top three risk factors among all are “terrorism” (HS/SE_1: 3.23), “piracy /maritime robbery” (HS/SE_2: 3.08), and “financial crisis” (HS/EE_1: 3.02). The financial crisis in 2008 has led to the economic downturn of many countries worldwide, and the container shipping industry has been seriously affected for a long time. Security issues such as terrorism and piracy have been emphasised and received a lot of attention in both industry and academia in recent years. According to Ewence (2011), more than 7 billion dollars could be costed per year for shipping companies and governments to deal with the Somalia piracy only.

Table 7. Statistics of likelihood and severity of all risk factors

Risk factors	**Code**	**Likelihood**			**Severity**		
		Mean	S.D.	Rank	Mean	S.D.	Rank
Risk factors associated with **society**							
Financial crisis	HS/EE_1	3.70	1.71	42	3.02	0.68	3
Change of interest rates	HS/EE_2	4.38	1.34	12	1.86	0.77	61
Change of exchange rates	HS/EE_3	4.98	1.30	3	2.52	0.73	12
Fluctuation of fuel price	HS/EE_4	5.13	1.34	2	2.47	0.59	14
Unattractive markets	HS/EE_5	4.83	1.38	5	2.43	0.60	16
Fierce competition	HS/EE_6	5.58	1.38	1	2.41	0.77	18
Monopoly	HS/EE_7	4.02	1.78	27	2.38	0.83	21
Trade policy instability	HS/PE_1	3.50	1.26	51	2.25	0.64	34
Maritime security initiatives	HS/PE_2	3.75	1.13	41	1.92	0.74	59
Regulations and measures	HS/PE_3	3.83	1.42	39	2.13	0.65	46
Regional political conflicts	HS/PE_4	3.52	1.54	50	2.95	0.81	4
Terrorism	HS/SE_1	2.56	1.36	64	3.23	1.12	1
Piracy /maritime robbery	HS/SE_2	3.04	1.35	58	3.08	1.09	2
Sabotage	HS/SE_3	2.63	1.13	63	2.38	1.00	21
Smuggling	HS/SE_4	4.06	1.31	24	2.00	0.87	56
Spying /espionage	HS/SE_5	2.94	1.61	60	1.94	0.83	57
Epidemic	HS/SE_6	2.98	1.15	59	2.14	0.89	44
Refugees	HS/SE_7	2.73	1.19	62	1.83	0.79	62
Mean of all risk factors in the group		3.79			2.39		
Risk factors associated with **natural environment**							
Unstable navigational condition	NE_1	4.43	1.61	10	2.08	0.76	50
Natural disasters	NE_2	2.92	1.19	61	2.59	1.00	8
Climate change	NE_3	3.19	1.57	57	1.80	0.74	63
Mean of all risk factors in the group		3.51			2.16		

Risk factors associated with **management**							
Lack of skilled workers	Man/HR _1	4.15	1.15	20	2.47	0.77	14
Lack of motivation	Man/HR _2	4.42	1.28	11	2.14	0.75	44
Mental health of seafarers	Man/HR _3	4.55	1.37	7	2.26	0.78	33
Human errors	Man/HR _4	4.37	1.09	13	2.32	0.64	29
Low wages	Man/HR _5	4.50	1.44	9	2.09	0.75	48
Language and cultural diversity	Man/WE_1	4.08	1.55	22	1.80	0.76	63
Lack of cooperation among departments	Man/WE_2	4.30	1.29	16	2.25	0.71	34
Poor safety culture/climate	Man/WE_3	4.22	1.33	19	2.23	0.81	36
Low degree of safety leadership	Man/WE_4	3.88	1.32	35	2.53	0.87	9
Poor ergonomics at workplace	Man/WE_5	4.02	1.19	27	2.41	0.77	18
Mean of all risk factors in the group		4.25			2.25		
Risk factors associated with **infrastructure and technology**							
Lack of intermodal equipment	I & T _1	3.45	1.21	54	2.19	0.66	41
Poor entrance channels of a port	I & T _2	3.88	1.30	35	2.33	0.71	27
Limited storage ability	I & T _3	3.33	1.18	56	2.08	0.72	50
Low technical reliability	I & T _4	3.50	1.10	51	2.22	0.70	38
Undeveloped ground access system of a port	I & T _5	3.53	1.15	49	2.19	0.71	41
Lack of regular maintenance of equipment	I & T _6	3.94	1.09	32	2.38	0.72	21
Insufficient berthing capability	I & T _7	4.07	1.14	23	2.17	0.70	43
Mean of all risk factors in the group		3.67			2.22		
Risk factors associated with **operations**							
Information delay	Op/IF_1	4.31	1.41	15	2.06	0.73	52
Information inaccuracy	Op/IF_2	4.28	1.27	17	2.36	0.76	25
IT vulnerability	Op/IF_3	3.81	1.31	40	2.30	0.85	31
Internet security	Op/IF_4	3.70	1.45	42	2.38	0.86	21
Poor information sharing	Op/IF_5	3.86	1.33	38	1.94	0.66	57
Lack of information standardisation and compatibility	Op/IF_6	3.70	1.28	42	2.06	0.66	52
Payment delay from partners	Op/FF_1	4.25	1.21	18	2.31	0.69	30
Break a contract	Op/FF_2	3.98	1.24	31	2.53	0.69	9
Shippers going into bankruptcy	Op/FF_3	3.50	1.36	51	2.77	0.73	5
Partners with bad credit	Op/FF_4	3.91	1.33	33	2.27	0.74	32
Charter rates rise	Op/FF_5	4.14	1.18	21	2.23	0.61	36
Cash flow problem	Op/FF_6	4.04	1.43	25	2.50	0.83	13
Inaccurate demand forecast	Op/PF_1	4.36	1.24	14	2.22	0.68	38
Transportation of dangerous goods	Op/PF_2	4.53	1.44	8	2.72	0.79	6
Container shortage	Op/PF_3	3.88	1.33	35	2.13	0.63	46
Port strikes	Op/PF_4	3.34	1.17	55	2.53	0.80	9
Port/ terminal congestions	Op/PF_5	4.59	1.37	6	2.33	0.71	27
Lack of flexibility of designed schedules	Op/PF_6	4.02	1.23	27	1.92	0.80	59
Problems with customs clearance	Op/PF_7	3.91	1.29	33	2.02	0.77	55
Electricity failure	Op/PF_8	3.59	1.11	48	2.39	0.81	20
Bottlenecks/restriction on transportation routes	Op/PF_9	3.66	1.29	47	2.34	0.65	26
Improper container terminal operations	Op/PF_10	4.03	1.32	26	2.20	0.74	40
Incorrect container packing	Op/PF_11	3.69	1.33	45	2.42	0.92	17
Transport accidents	Op/PF_12	3.67	1.21	46	2.69	0.85	7
Trade imbalance on container shipping routes	Op/PF_13	4.86	1.32	4	2.03	0.64	54
Improper management of container storage area	Op/PF_14	4.00	1.11	30	2.09	0.73	48
Mean of all risk factors in the group		3.99			2.30		
S.D. = Standard Deviation							

5.3 Risk matrix analysis

Based on the statistics of occurrence likelihood and consequence severity from all respondents, *ARI* value of each risk factor can be calculated using Eq. 3, and then be grouped into different risk levels, as shown in Table 8. The top ten risk factors in terms of the *ARI* values are "fierce competition" (HS/EE_6: 6.98), "fluctuation of fuel price" (HS/EE_4: 6.59), "change of exchange rates" (HS/EE_3: 6.50), "unattractive markets" (HS/EE_5: 6.26), "transportation of dangerous goods" (Op/PF_2: 6.25), "port/terminal congestions" (Op/PF_5: 5.92), "trade imbalance on container shipping routes" (Op/PF_13: 5.89), "mental health of seafarers" (Man/HR _3: 5.81), "financial crisis" (HS/EE_1: 5.72), and "human errors" (Man/HR _4: 5.69). Among them, the top five risk factors are located in the high-moderate level, while the rest belongs to the low-moderate level. The macroeconomic environment plays a crucial role that can influence a container shipping business both directly and indirectly. Some factors partially affect the business decision making, including turbulent shipping markets, and competition (Notteboom, 2004; Vilko et al., 2016). Some will affect the entire economy and all of the participants, such as the financial crisis (Vilko and Hallikas, 2012; Samvedi et al., 2013; Chang et al., 2015). These factors will affect the price and investment, which increases the uncertainties in MCSC operations. Transportation of dangerous goods is regarded as a special risk factor in the container transportation compared to other general supply chains because accidents such as explosions, leakage of hazardous chemical materials, and fire during the transportation of dangerous goods can cause huge damage to cargos, ships, and even the nearby ports. Port/terminal congestions will increase the waiting time of a ship in port areas, thus making it difficult to keep the fixed schedule. Appropriate and effective management of empty containers caused by trade imbalance is also a major issue, which contributes to both financial savings and environment protection (Song and Carter, 2009). Due to the harsh working environment onboard a ship, seafarers usually suffer from mental health problems such as fatigue, stress, and anxiety, which will negatively affect their behaviour and increase the risks at sea. Human error is recognised as one of the main causal factors in up to 80% of accidents across various industries (Stewart and Chase, 2010). It is interesting to note that although the terrorism and piracy are of great significance in terms of severity, they are only ranked at 51st (HS/SE_1: 4.79) and 36th (HS/SE_2: 5.12) in terms of *ARI* values respectively when taking into account their relatively low frequency of occurrence. Although some of the factors were assessed in previous studies to have high risk levels, they were tackled only with reference to the limited investigated scope and thus received relevantly low *ARI*s in this systematic analysis within the context of the whole MCSCs. The facts that 1) there are few studies presenting and comparing the risk factors influencing container shipping chains as a whole, and 2) fewer providing quantitative risk index to reveal their safety prioritisation empirically, reveal the new findings and contributions of this work.

It is notable that almost all risk factors (except for "Spying /espionage" (HS/SE_5:3.88), "Refugees" (HS/SE_7:3.56), and "Climate change" (NE_3:3.98)) fall into the moderate risk level with an *ARI* $\in$ [4, 8), which is in harmony with the experience of domain experts. According to the survey results, the spying/espionage is recognised to be acceptable, which may be partly due to the fact that business espionage is not a common issue in the container shipping industry. The "refugees" is a factor that has been less investigated in previous studies, but it is recognised as a risk factor by more and more experts due to the increasing number of refugee immigrants in European countries in recent years. However, its short-term impact on container shipping, compared to the other high-risk factors has not yet evidenced high loss in recent years. It is also probably due to the limitation of this study by having less responses from EU, which will be further addressed in future by conducting a global survey. Regarding the global climate change, which has been an emerging research topic in recent years, especially in the area of transportation resilience and port operations (e.g. Brown et al., 2012; Wan et al., 2018; Yang et al., 2018). Although there is less direct evidence compared to other risk factors of a moderate risk in terms of negative effect, climate change risk index value (3.98) is the highest in non-moderate risk factors. It well reflects the observation from the survey in which experts are aware of and pay increasing attention to the impact of climate change to container transport logistics (particularly ports), however high uncertainty in terms of the frequency of climate disasters made them conservative when evaluating its likelihood. It looks likely that with more evidence collected from climate change related accidents (e.g. hurricanes in Mexico Gulf in 2016), the risk index of climate change within the context of MCSCs will increase in future.

Table 8. *ARI*s, risk levels, and rankings of all risk factors

Risk sources	**Risk factors**	***ARI***	**Risk level**	**Rank**	
				Local rank	Global rank
Society *ARI*: 5.17	HS/EE_1	5.72	Low-moderate	5	**9**
	HS/EE_2	5.23	Low-moderate	8	32
	HS/EE_3	6.5	High-moderate	3	**3**
	HS/EE_4	6.59	High-moderate	2	**2**
	HS/EE_5	6.26	High-moderate	4	**4**
	HS/EE_6	6.98	High-moderate	1	**1**
	HS/EE_7	5.4	Low-moderate	7	25
	HS/PE_1	4.75	Low-moderate	13	53
	HS/PE_2	4.67	Low-moderate	14	56
	HS/PE_3	4.95	Low-moderate	11	45
	HS/PE_4	5.47	Low-moderate	6	21
	HS/SE_1	4.79	Low-moderate	12	51
	HS/SE_2	5.12	Low-moderate	9	36
	HS/SE_3	4	Low-moderate	16	61
	HS/SE_4	5.06	Low-moderate	10	41
	HS/SE_5	3.88	Low	17	63
	HS/SE_6	4.13	Low-moderate	15	60
	HS/SE_7	3.56	Low	18	64
Natural environment *ARI*: 4.67	NE_1	5.51	Low-moderate	1	20
	NE_2	4.52	Low-moderate	2	58
	NE_3	3.98	Low	3	62
Management *ARI*: 5.50	Man/HR _1	5.62	Low-moderate	3	12
	Man/HR _2	5.56	Low-moderate	5	15
	Man/HR _3	5.81	Low-moderate	1	**8**
	Man/HR _4	5.69	Low-moderate	2	**10**
	Man/HR _5	5.59	Low-moderate	4	13

	Man/WE_1	4.88	Low-moderate	10	48
	Man/WE_2	5.55	Low-moderate	6	17
	Man/WE_3	5.45	Low-moderate	7	22
	Man/WE_4	5.41	Low-moderate	9	24
	Man/WE_5	5.42	Low-moderate	8	23
Infrastructure & technology *ARI*: 4.89	I & T _1	4.64	Low-moderate	6	57
	I & T _2	5.2	Low-moderate	3	34
	I & T _3	4.41	Low-moderate	7	59
	I & T _4	4.72	Low-moderate	4	54
	I & T _5	4.72	Low-moderate	4	54
	I & T _6	5.32	Low-moderate	1	29
	I & T _7	5.24	Low-moderate	2	31
Operations *ARI*: 5.28	Op/IF_1	5.38	Low-moderate	9	26
	Op/IF_2	5.64	Low-moderate	4	11
	Op/IF_3	5.11	Low-moderate	15	37
	Op/IF_4	5.08	Low-moderate	18	40
	Op/IF_5	4.8	Low-moderate	25	50
	Op/IF_6	4.77	Low-moderate	26	52
	Op/FF_1	5.56	Low-moderate	6	15
	Op/FF_2	5.52	Low-moderate	8	19
	Op/FF_3	5.27	Low-moderate	12	30
	Op/FF_4	5.17	Low-moderate	14	35
	Op/FF_5	5.38	Low-moderate	9	26
	Op/FF_6	5.54	Low-moderate	7	18
	Op/PF_1	5.58	Low-moderate	5	14
	Op/PF_2	6.25	High-moderate	1	**5**
	Op/PF_3	5	Low-moderate	19	42
	Op/PF_4	4.88	Low-moderate	24	48
	Op/PF_5	5.92	Low-moderate	2	**6**
	Op/PF_6	4.94	Low-moderate	22	46
	Op/PF_7	4.92	Low-moderate	23	47
	Op/PF_8	4.98	Low-moderate	21	44
	Op/PF_9	5	Low-moderate	19	42
	Op/PF_10	5.23	Low-moderate	13	32
	Op/PF_11	5.11	Low-moderate	15	37
	Op/PF_12	5.36	Low-moderate	11	28
	Op/PF_13	5.89	Low-moderate	3	**7**
	Op/PF_14	5.09	Low-moderate	17	39

The classification of risk levels of all identified risk factors provides helpful insights for maritime stakeholders to rationalise their safety resource allocation and risk prevention. It is particularly meaningful given the increasing development of logistics services (door-to-door) by traditional shipping lines. Also, the full profile of risk factors presented in this research can assist the assessment of safety performance of shipping companies from a multi-dimensional (e.g. societal, environmental, economic, and technical) perspective. Furthermore, this research can be served as an initial screening of all risk factors so that the most significant ones can be picked up for an in-depth assessment in the follow-up studies, and suitable risk control options can be put forward for rational policy making accordingly.

6. Conclusion

Identification of risk factors provides the foundation for supply chain risk analysis and accident prevention. In this paper, a new risk factor classification framework is developed, including five main risk sources namely society, natural environment, management, infrastructure and technology, and operations. The first two are external risk resources, whereas the rest three belong to internal ones. It integrates different classification methods and incorporates them in a logical hierarchy suitable to modelling the risk factors influencing MCSCs. Its development is validated by a Delphi expert group of 10 persons through three round verification processes. Based on that, 64 risk factors are identified through a critical review of previous studies, along with an exploration and validation process using a Delphi expert survey. These risk factors are assessed from the aspects of occurrence likelihood and consequence severity by conducting a questionnaire survey, and they are further categorised into different risk levels and ranked according to their *ARI*s calculated through the risk matrix analysis. The results show that "fierce competition", "fluctuation of fuel price", "change of exchange rates", "unattractive markets", "transportation of dangerous goods", "port/ terminal congestions", "trade imbalance on container shipping routes", "mental health of seafarers", "financial crisis", and "human errors" are among the top ten risk factors influencing the safe and effective operations of an MCSC.

The research results based on empirical data further prove the relevant findings from previous studies but involve new contributions by providing quantitative risk prioritisation information. In Lam and Bai's (2016) research, risks associated with IT system, operational risks, and human resource management risk were identified as the top three risks. In our research, management (which is composed of the management of human resource and working environment) is the main risk source with an *ARI* of 5.50, while risk factors related to operations are ranked the second with an *ARI* of 5.28. In line with the research findings of Notteboom and Vernimmen (2006), Chang et al. (2014) and Moslemi et al. (2016), our research also discloses that the fluctuation of fuel price is an important risk factor in the container shipping operations. It ranks the second of all risk factors with both high likelihood and consequence, which deserves the attention of container shipping companies. However, it is noted that according to the research by Moslemi et al. (2016), although oil price change was identified as one of the most serious risks in container shipping operations for both customers and logistics service companies, it plays a dual role because the increase of oil price could be beneficial to some emerging markets in economic terms. Our research findings also emphases that transportation of dangerous goods is an important risk factor (Chang et al., 2015). It ranks the first among operational risk factors, and rank the fifth among all, belonging to a high-moderate risk level with an *ARI* of 6.25.

The main scientific contributions of this study to the supply chain risk management are concluded as follows. Firstly, a novel multi-dimensional and multi-level framework is proposed for identifying and classifying risk factors in MCSCs. Together with the comprehensive analysis, a panorama picture of risk factors in MCSCs is developed to provide a reference for exploiting research gaps of MCSC risk management in the future studies, especially when a specific aspect is concerned. Secondly, this paper incorporates the well-established ALARP principle into the risk matrix approach, so that the risk factors can be appropriately categorised into different risk levels. Thirdly, this study empirically contributes to the literature and knowledge of supply chain risk management as few studies so far have investigated the risks in MCSCs from a systematic perspective using empirical data. Based on the empirical data collected from a large-scale survey on industrial experts, a bridge between the theoretical and applied research of MCSCs can be built timely, which helps to realise the difference of understanding of risks in the maritime container shipping between academics and practitioners. More importantly, its novelty is also seen via some emerging risk factors that are identified in this research such as refugees, ergonomics-related risks, and improper management of container storage area. This can be a reflection of increasing complexity in global supply chain environment, and thus it calls for knowledge renewal in the risk management of container supply chains, especially for academia, where the experience from industrial practice can be illuminating and has a good reference value.

In terms of the managerial implications, this research provides useful insights for actors from different segments of an MCSC in better understanding the risks in their daily operations from a whole supply chain perspective. The comprehensive analysis of the risk factors from multiple dimensional aspects in MCSCs is beneficial to the shipping industry. For example, the information on the quantitative importance analysis (i.e. *ARI*) of each risk factor will be helpful for the stakeholders to understand which parts deserve more attention in the whole maritime supply chain so as to rationalise their safety resource allocation for accident prevention. The analysis results also provide a reference for maritime safety authorises on effectively developing targeted risk mitigation countermeasures under different risk situations within the context of MCSCs.

Despite showing the above-described contributions, this work still reveals some limitations, which the authors keep working to address, including 1) collection of more responses from international MCSC companies, allocated in different regions in order to improve the generalisation of our findings; 2) incorporation of objective risk data in terms of both likelihood and consequence derived from accident investigation reports and accident databases to further the findings purely based on subjective expressions; and 3) development of cost effective risk control measures to reduce/eliminate the factors of high risks in this work.

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