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Selection of effective risk mitigation strategies in container shipping operations

Article

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ABSTRACT

Purpose:

Container shipping companies face various risks with different consequences that are required to be mitigated. Limited empirical research has been done on identifying and evaluating risk management strategies in shipping operations with different risk consequences. This paper aims to identify the appropriate risk mitigation strategies and evaluate the relative importance of these strategies.

Design/methodology/approach:

Literature review and interviews were used to identify and validate the appropriate risk mitigation strategies in container shipping operations. A questionnaire with a Likert five-point scale was then conducted to rank the identified risk mitigation strategies in terms of their overall effectiveness. Top six important strategies were selected to evaluate their relative importance under three risk consequences (i.e. financial, reputation, and safety and security incident related loss) through using another questionnaire with paired-comparison. Fuzzy analytic hierarchy process (AHP) was then conducted to analyse the paired-comparison questionnaire.

Findings:

After conducting systematic literature review and interviews, 18 mitigation strategies were identified. The results from the first questionnaire show that among the 18 strategies, the top three are "form alliances with other shipping companies", "use more advanced infrastructures (hardware and software)", and "choose partners very carefully". After conducting fuzzy AHP, the results show that shipping companies emphasize more on reducing the risk consequence of financial loss; and "form alliance with other shipping companies" is the most important risk mitigation strategy.

Originality/value:

This paper evaluates the risk mitigation strategies against three risk consequences. Managers can be benefit from the systematic identification of mitigation strategies, which shipping companies can consider for adoption to reduce the operational risk impact.

Key Words: Container Shipping; Risk Management; Risk Mitigation Strategies; Fuzzy AHP; Survey.

1. Introduction

Risks have always been an important issue in container shipping operations since they may lead to various severe consequences. For example, Chang et al. (2014, 2015, 2016) identified three types of risks in the container shipping industry from a logistics perspective: risks associated with the information flow, physical flow, and payment flow. They also identified three types of risk consequences, including financial loss, reputation loss, and safety and security incident-related loss. Financial loss is the most common risk consequence, for which a monetary value is typically used to measure its severity. Reputation loss is a type of non-financial loss that harms a firm's reputation. Safety and security incident-related loss refers to another type of non-financial loss that results in injure/loss of life to the crew and their families. Tummala and Anumba (2011) found that risk consequences may include loss of or damage to assets, loss of income, interruption of service levels, cost overruns, schedule delays, poor process performance, liabilities incurred, damage repair costs, injuries, or their combinations.

In order to reduce the negative impact from such risks, identifying appropriate and effective risk mitigation strategies for container shipping companies has attracted much attention from both academia and the shipping industry (Wan et al., 2019). The studies in the field, however, have largely focused on one or a few risk mitigation strategies responding to only one type of risk consequence. For example, researchers have addressed empty container handling to reduce operational cost (Lu et al., 2010; Song and Dong, 2011, 2012), the topic of fleet deployment (Ng, 2015; Zhao et al., 2016), delays through timetable designs intended to reduce reputation loss (Qi and Song, 2012; Wang and Meng, 2012a, 2012b; Ng, 2015), and implementation of international regulations to reduce safety and security losses (Lun et al., 2008). Few of them holistically discussed risk mitigation strategies in relation to the three risk consequences mentioned above (financial loss, reputation loss, and safety and security loss). This study attempts to provide a systematic review of risk mitigation strategies in the container shipping industry and an analysis of the effectiveness of the identified strategies. Notably, some of the shipping risks are closely inter-relative, and thus the risk mitigation strategies are not designed for only a specific risk. In particular, this paper aims to address the following research questions:

RQ1: What are the potential strategies that can mitigate risk in container shipping operations?

RQ2: What strategy(ies) is(are) the most important to be addressed?

They are important questions because a shipping company has limited resources to manage risks, and it is therefore crucial for managers to know the priority of risk mitigation strategies when they have a specific goal to avoid all consequences of risk or some specific types of risk consequence. Different companies may have different goals when managing risks (Chang et al., 2016). For example, smaller companies may place a greater emphasis on mitigating financial loss, whereas larger companies may focus on reputation loss. This study adopts the structure of risk consequence proposed by Chang et al. (2014, 2015, 2016), which presents a relatively comprehensive list of consequences relating to the container shipping environment.

The contributions of the article are twofold: Firstly, through comprehensive interviews and a literature review, the strategies for risk mitigation for container shipping operators are identified. This will provide operators with useful information on the available strategies intended to reduce negative impacts from risks. Secondly, the priority of the identified strategies with respect to three risk consequences and their overall priorities are also determined, respectively. Because of scarcity of resources, shipping companies have to invest wisely in various risk mitigation strategies. This study will be useful for them to determine the sequence of investment in risk mitigation.

The rest of the paper is organised as follows. A literature review is conducted to identify current risk mitigation strategies in Section 2. The research methods adopted in this study are presented in Section 3, including the literature review, a set of interviews, two questionnaire surveys, and the fuzzy AHP method. Section 4 presents the results of interviews, whereas Section 5 focuses on the empirical data analysis on their importance. Discussion and conclusions are drawn in Section 6 based on the results of the study.

2. Identification of Risk Mitigation Strategies from the Literature Review

Many risk mitigation strategies have been revealed from previous studies. For example, in order to deal with slight delays, shipping companies could include a time buffer when designing the timetable/ schedule to reduce the impact of an unreliable schedule. The benefits of adding a time buffer include: (1) The shipping schedule will be more flexible, thus offering opportunities to reduce the impact of uncertainties and delays at transport nodes (e.g. ports) and during transport (e.g. on the sea); (2) a more robust shipping network, and (3) minimisation of impact of port time uncertainty on operational costs (Notteboom, 2006; Notteboom and Vernimmen, 2009; Chopra and Meindl, 2010; Qi and Song, 2012; Wang and Meng, 2012a, 2012b; Oppen, 2016). Some studies investigated a slow steaming strategy, which is to reduce the sailing speed to an appropriate speed for significant reduction of fuel consumption costs (Notteboom, 2006; Notteboom and Vernimmen, 2009; Cariou, 2011; Ronen, 2011; Qi and Song, 2012; Mander, 2016). Some researchers suggested using more advanced information communication technology (ICT) infrastructure (Stefansson, 2002; Porter, 2008). In order to improve safety and security, companies can also use some initiatives (e.g. ISPS Code, the

Container Security Initiative, and the Customs-Trade Partnership Against Terrorism) or technologies (e.g. RFID, the SMART box initiative, and container non-intrusive inspection) (Lun et al., 2008; Chang et al., 2014; Nair, 2015), and/or execute regular employee training (Shang and Lu, 2007; Young, 2010; Ganesan, 2010).

In terms of the external risks introduced by their partners (in supply chains), shipping companies can use their influence to reduce the negative impact from partners with bad performance or to improve the positive impact from partners with good performance (Cruz and Marques, 2012). Shipping companies can also build trust with partners (Kwon and Suh, 2005; Sodhi and Son, 2009) and then further enter into long-term contracts with shippers (Notteboom, 2004), share information with partners without co-management (Harrison and Hoek, 2005; Schmidt, 2009), exchange ideas with partners to resolve conflicts or improve service quality (Harrison and Hoek, 2005 ; Sodhi and Son, 2009). They can also form alliances with other shipping companies (Lu et al., 2010; Tan and Thai, 2014; Rau and Spinler, 2016) or acquire and merge with other shipping companies (Notteboom, 2004; Lu et al., 2007). Table 1 summaries the risk mitigation strategies from the existing literature.

[Please insert Table 1 about here]

3. Research Methods

3.1. Identification of Risk Mitigation Strategies

3.1.1 Identification of Risk Mitigation Strategies through Literature Review

To identify the risk mitigation strategies that can be used by container shipping companies, an extensive literature review was conducted in Section 2, followed by face-to-face interviews to validate the findings of the literature review. Literature reviews are often used to identify risk mitigation strategies in academic studies (e.g., Mitchell, 1995; Ellegaard, 2008; Veselko and Bratkovič, 2009). In order to inclusively identify the risk mitigation strategies appropriate for the container shipping, both the literature directly relating to container shipping risk management and the literature in the field of risk management of general supply chain were reviewed since the latter studies may have incorporated strategies that are applicable to container shipping. For example, regular employee training as an important risk mitigation strategy in general supply chain management (e.g. Richardson, 2000; Elkins et al., 2005), can also be used in container shipping operations (Young, 2010; Genesan, 2010). Thus, reviewing the literature related to general supply chain management was used to further confirm the applicability of the strategies identified from the literature related to container shipping operations.

3.1.2 Validation of Risk Mitigation Strategies through Interviews

After the literature review was completed, in order to validate the literature review findings and also to explore any additional risk mitigation strategies in container shipping operations, a set of face-to-face interviews were conducted. In the face-to-face interview, the managers were asked to modify the strategies if they felt any strategies described in Table 1 are inappropriate, to confirm and support the strategies if they thought the strategies are appropriate, or to propose other relevant strategies if they felt there are some strategies that have been used in container shipping operations but yet mentioned in Table 1.

In total, seven managers from two major world leading container shipping companies participated in the interviews, including two vice-presidents, two senior managers in the IT department, and three senior managers in the operations department. Based on the results of the interviews, all mitigation strategies in Table 1 were confirmed to be appropriate by having the consensus from the interviewees. In addition, three additional strategies were proposed as follows.

As an international business, a shipping company has to implement international regulations to mitigate the negative impact of both security and safety issues in the container shipping operations. A senior manager said:

> we have already used ISO 27001 to increase information security… to keep business confidential. … we implement the IMGD Code, an international regulation, which can reduce potential risks in shipping operations when transporting dangerous goods.

In the context of the container shipping supply chain, every entity in the channel is important, and a weak or problematic one will cause a negative impact on container shipping performance or its partners' performance. Choosing appropriate partners is an important issue in shipping operations. A senior manager stated:

> Sometimes we need to handle or face the risk related to the shippers who are bankrupt before they make payment. In order to reduce such risk, we have to do some credit search about the shippers or supply chain partners to avoid doing business with the shippers who have bad credit or unstable finances. Sometimes shipping companies will transfer this risk to forwarders…

In container shipping operations, cultivating the loyalty of supply chain partners can reduce the uncertainty of transportation demand. One manager stated:

> We usually cultivate loyalty with our partners and make a long-term contract with shippers to reduce uncertain transportation demand, and these strategies also help maintain a minimal revenue for us.

Based on the above remarks, we formulated four new mitigation strategies as follows. Firstly, two strategies are refined and separated from the original Strategy 4. They are "improve security measures, such as by implementing security rules and regulations like the ISO 27001 and ISPS Code" and "improve safety measures, such as by implementing safety rules and regulations like the IMDG Code and ISM Code." Secondly, two other strategies are identified based on the interview results: “choose partners very carefully,” and “cultivate the loyalty of supply chain partners.” Therefore, we summarised the risk mitigation strategies used in container shipping in Table 3, where the new strategies identified from the interviews are in Italic (i.e. No. 4, 5, 8, 11).

In Table 3, it is noteworthy that the partners mentioned in Strategy 13 only refer to shippers, whilst those in Strategy 16 are not shippers. The different lies in that shipping companies play different roles in the associated supply chains: in a cargo supply chain (Strategy 13), the role of the shipping company is on the supply side, whereas in the service supply chain (Strategy 16), it is on the service demand side, and its supply chain partners are on the service supply side (e.g. terminal operators provide lifting on/off services to shipping companies).

3.2.Measuring the Effectiveness of Risk Mitigation Strategies

After identifying the strategies, a large scale questionnaire survey, namely “mitigation-strategy survey” was then administered. This survey was conducted through using a five-point Likert scale, where 1 meant “very inefficient” and 5 meant “very efficient”. The respondents were asked to select the level of effectiveness of the strategies based on their work experience.

The population was based on the list from the 2010 ROC National Association of Shipping Agencies in Taiwan, and all 116 container shipping companies in the list were included. Managers from three departments in each company were selected, including the information/documentation department, the physical/operations department, and the financial/accounting department. This is because these three departments cover the main risk management issues that arise in container shipping operations. However, some companies did not have all three of these departments. After recalculating the population size, the final effective simple size was 342. After collecting the replies, the rank of these strategies could then be obtained.

3.3.Evaluating the Relative Importance of Risk Mitigation Strategies

There are a number of methods for multiple criteria decision making, yet there are some limitations for these methods such as some methods need a large scale of questionnaire replies, some of their purpose is not suitable for our research aim, and some of them need high computer language design skills and extensive quantitative data (Qu et al., 2017). As this study is relating to empirical research and has relatively limited number of population to investigate, we decided using Analytic Hierarchy Process (AHP) as the method to evaluate the relative importance of risk mitigation strategies. AHP proposed by Saaty (1988) has been widely used to evaluate the relevant importance of decision criteria/alternatives in various industries including maritime and port (e.g. Ha et al., 2017). The basic concept of the AHP is to assist decision making through a hierarchical structure with different criteria and sub-criteria that are weighed through pairwise comparisons (Wang et al., 2015). Chang et al. (2014) proposed a structure with three risk categories (i.e. financial risk, reputation risk, and safety and security risk), whereas the criteria in our study are adapted from this structure and amended as Reducing financial loss, Reducing reputation loss, and Reducing safety and security incident related loss. Four axioms of the AHP are assumed in its applications, including reciprocal comparison, homogeneity, dependence, and expectations (Satty, 1986). Reciprocal comparison means that when making paired comparisons, both members of the pair must be considered to judge the relative value. Homogeneity means that when the disparity is great, the elements are placed in separate clusters of comparable size giving rise to the idea of levels and their accommodation. Dependence means that the smaller elements depend on the outer parent elements to which they belong, in a large hierarchical cluster. Expectations are beliefs about the rank of alternatives derived from prior knowledge (Satty and Kułakowski, 2016). The data was examined and matched to the four axioms.

While the AHP method can be used in many areas (Saaty, 1988; Ho, 2008), it has been criticised in a number of studies (e.g., Chang, 1996; Bana e Costa & Vansnick, 2008; Wang et al., 2015). Among the critics, the most common is uncertainty in terms of subjective perception (Chan & Kumar, 2007), which may result in inaccurate measurement. Respondents may be confused and hence provide inconsistent answers when being asked to do pair comparisons, or may also result in a lack of data when respondents fail to answer some questions (Wang et al., 2015). In order to overcome the weakness related to uncertainty, Zadeh (1965) proposed the fuzzy set theory, which fuzzifies the respondents' perceived value by considering that human beings cannot always perceive exact values. Based on this, Laarhoven and Pedrycz (1983) proposed a fuzzy AHP method by adapting fuzzy numbers (e.g. triangular/trapezoidal) from the fuzzy set theory into the AHP method. With the advantage of fuzzy set theory, the fuzzy AHP thus overcomes the shortcomings of the AHP and has become a widely accepted method in multiple criterion decision making under uncertainty. In the maritime area, a number of studies have used the fuzzy AHP to carry out their investigations. For example, Ding (2010) addressed the critical factors which affect customer value for shipping companies from a customer perspective. Ka (2011) used the fuzzy AHP to determine selection of location for China's dry ports. Yang and Chung (2013) applied the fuzzy AHP to find preferred ship flag registry locations among Taiwan, Hong Kong, and China. This study therefore also uses the fuzzy AHP method to cope with the subjective perceptions of respondents. To keep the research task at a manageable scale, a set of the most important risk mitigation strategies are selected from the results of the "mitigation-strategy survey" to conduct a further survey evaluation, namely the fuzzy AHP survey. In order to save space, the steps of the fuzzy AHP analyses are described with the analysis data in Section 4.

4. Data Analysis

4.1. Respondents' Profile and Validity and Reliability Test

According to Davis (2005), several common methods are used to enhance the level of validity, including careful identification of the measurement items from the literature and expert interview to validate the identified items. The questions in the mitigation-strategy survey were designed based on the literature review, and were validated through the seven face-to-face interview to ensure a high level of validity.

After collecting the replies from the mitigation-strategy survey, we identified 62 (out of 88 replies) valid, and 26 invalid feedbacks. The valid response rate was 18.13%. The 62 respondents' profile in the survey is presented in Table 2. The results show that approximately 80% of respondents have work experience more than 10 years. The respondents' department include President/vice-president, Information/document, Financial/accounting, and Operation/ shipping department. For the position, there are approximate 80% of respondents who are vice director or above. A reliability test was conducted for the questions on risk mitigation strategies, for which the Cronbach's Alpha was 0.872 (>0.8). It indicated that the designed questions on risk mitigation strategies were reliable.

[Please insert Table 2 about here]

4.2.Ranking of Risk Mitigation Strategies

Table 3 shows the results of the different risk mitigation strategies based on the data from the risk-mitigation survey. Based on the mean score, the top six strategies include "form alliances with other shipping companies" (mean score: 4.02); "use more advanced infrastructures and technologies (hardware and software)" (mean score: 3.92); "choose partners more carefully" (mean score: 3.87); "enter into long-term contracts with shippers" (mean score: 3.85); "collaborate with partners (e.g., port operators, inland transportation operators) through making joint long-term plans" (mean score: 3.85), and "flexible design of the timetable/schedule, e.g., include time buffers" (mean score: 3.81).

The strategy "acquire and merge with other shipping companies" (mean score: 2.95) had the lowest score among all mitigation strategies. Since this strategy has a long-term, significant impact on shipping company operations, it often implies a high degree of uncertainty and may only be adopted in critical situations. On the other hand, it is interesting to observe that the recent popular practice of slow steaming had a relatively low score among these strategies. Slow steaming can reduce fuel consumption and absorb the idle capacity, which is an appropriate strategy for shipping lines when supply exceeds demand. However, it increases transit time and could cause extra inventory costs to shippers. The low score for slow steaming with the highest S.D. indicates that the respondents' opinions were very different. Some of the respondents felt that slow steaming is a realistic strategy to reduce risks within container shipping operations, whilst the others hold an opposite opinion.

When considering the three different "cooperation" levels (strategies 14, 15, and 16), the results show that collaboration level had the highest mean score with 3.85, following by coordination level (mean score: 3.77), and cooperation level has the lowest mean score with 3.65. This indicates that shipping companies will have better risk mitigation effects if the companies have a higher level of "cooperation" relationships with partners.

[Please insert Table 3 about here]

In order to evaluate the priority of these mitigation strategies under the three criteria (i.e. reducing financial loss, reducing reputation loss, and reducing safety and security incident-related loss), the top six strategies were selected for a further step by conducting the fuzzy AHP. The reason of selecting the top six strategies is because the human being brain will be confused when comparing more than seven items (Saaty, 1977). In addition, several studies also suggested that to serve both consistency and redundancy to the AHP method, it is best to keep the number of criteria and alternatives at seven or less (Saaty and Ozdemir, 2003; Russo and Camasnho, 2015). In this study, there are two strategies ranked at the seventh among the 18 ones, we thus selected six instead of seven strategies. As shown in Table 3, the six selected strategies include: "form alliances with other shipping companies" (renamed as Strategy A for the AHP analysis in Section 3.3); "use more advanced infrastructures (hardware and software)" (Strategy B); "choose partners very carefully" (Strategy C); "collaborate with partners (e.g., port operators, inland transportation operators) through making joint long-term plans (collaboration level)" (Strategy D);" "enter into long-term contracts with shippers" (Strategy E), and "flexible design of the timetable/schedule, e.g., include time buffers" (Strategy F).

4.3.Fuzzy AHP Analysis

After building the hierarchy structure, paired comparisons were conducted for the fuzzy AHP survey. The purpose was to evaluate the relative importance of the different criteria and different alternatives in the fuzzy AHP model. The population size for the fuzzy AHP survey was still 342 in this study, (i.e. the same as that for the mitigation-strategy survey); however, the sampling process was different. To increase the return rate, all respondents to the first questionnaire survey were selected. In addition, some key managers from the non-responding list were also selected. Finally, a total of 114 questionnaires were sent out, and 21 replies were received; including 12 valid ones, and 9 invalid ones. The valid return rate was 10.53%. Microsoft Office Excel software was then used to conduct the fuzzy AHP analysis. The results show the consistency ratio (C.R.) of each criterion to be 0.01, which is less than the standard acceptable value (0.1). Therefore, the data met the consistency requirement. After confirming the requirement, the fuzzy AHP was used to measure the weight of the selected strategies. A fuzzy AHP analysis includes the following eight main phases (Buckley, 1985; Ding, 2010;

Ding and Tseng, 2012):

1. Develop a hierarchical structure with three criteria and six alternatives:

In this study, the hierarchy structure included three major levels: goal, criteria, and alternatives. The goal refers to "mitigating risks in shipping operations". Three criteria corresponding to three risk consequences were identified as "reducing financial losses", "reducing reputation loss", and "reducing safety and security incident-related losses". The alternatives included a set of the most important risk mitigation strategies selected from the results of the mitigation-strategy survey. The number of selected strategies is usually less than seven since the brains of human beings cannot compare more than seven items at the same time.

2. Collect pairwise comparison matrix of decision elements:

   Let x_{ij}^{h}, $h = 1, 2, \dots, 12$, be the relative importance given to reducing risk consequence *i* compared to reducing risk consequence *j* by expert *h* at the criteria level; let x_{st}^{h}, $h = 1, 2, \dots, 12$, denote the relative importance given to risk mitigation strategies *s* compared to risk mitigation strategies *t* by expert *h* at the alternative level.

3. Transform relative importance into Triangular Fuzzy Number (TFN);

   TFN combines the minimum value (denoted by *l*), maximum value (denoted by *u*), and mean value (denoted by *m*) of the opinions of all experts. The meaning of TFN used in the fuzzy AHP is presented in Table 4.

[Please insert Table 4 about here]

4. Build Fuzzy positive reciprocal matrix

The TFN was used to build a fuzzy positive reciprocal matrix. Because of limited space, we only display the results of one respondent. There are three criteria at the criteria level; thus the fuzzy positive reciprocal matrix is a 3×3 matrix that can be generated by

$$[\tilde{B}_{ij}^{C}]_{3\times3} = \begin{bmatrix} \tilde{1} & \tilde{B}_{12}^{C} & \cdots & \tilde{B}_{1k}^{C} \\ 1/\tilde{B}_{12}^{C} & \tilde{1} & \cdots & \tilde{B}_{2k}^{c} \\ \vdots & \vdots & \ddots & \vdots \\ 1/\tilde{B}_{1k}^{C} & 1/\tilde{B}_{2k}^{c} & \cdots & \tilde{1} \end{bmatrix} = \begin{bmatrix} (1,1,2) & (1,1,2) & (1,\frac{1}{2},\frac{1}{3}) \\ (1,1,\frac{1}{2}) & (1,1,2) & (\frac{1}{2},\frac{1}{3},\frac{1}{4}) \\ (1,2,3) & (2,3,4) & (1,1,2) \end{bmatrix},$$

Where, $\tilde{B}_{ij}^{C}$ represents the TFN of relative importance of reducing risk consequence *i* over reducing risk consequence *j*, $\tilde{B}_{ij}^{C} \otimes \tilde{B}_{ji}^{C} = 1, \ \forall i,j = 1,2,3,$

Where 1 means reducing financial loss

2 means reducing reputation loss, and

3 means reducing safety and security-related incident loss.

At the alternative level, we use the criterion called "reducing financial loss" as an example, where the fuzzy positive reciprocal matrix is given by

$$[\tilde{B}_{st}^{A}]_{6\times6} = \begin{bmatrix} \tilde{1} & \tilde{B}_{12}^{A} & \cdots & \tilde{B}_{1p}^{A} \\ 1/\tilde{B}_{12}^{A} & \tilde{1} & \cdots & \tilde{B}_{2p}^{A} \\ \vdots & \vdots & \ddots & \vdots \\ 1/\tilde{B}_{1p}^{A} & 1/\tilde{B}_{2p}^{A} & \cdots & \tilde{1} \end{bmatrix} = \begin{bmatrix} (1,1,2) & (1,2,3) & \cdots & (3,4,5) \\ (1,\frac{1}{2},\frac{1}{3}) & (1,1,2) & & (2,3,4) \\ & \vdots & \ddots & \vdots \\ (\frac{1}{3},\frac{1}{4},\frac{1}{5}) & (\frac{1}{2},\frac{1}{3},\frac{1}{4}) & \cdots & (1,1,2) \end{bmatrix},$$

Where $\tilde{B}_{st}^{A}$ represents the TFN of relative importance of risk mitigation strategies *s* over risk mitigation strategies *t*. $\tilde{B}_{st}^{A} \otimes \tilde{B}_{ts}^{A} = 1, \ \forall s,t = 1,2,\ldots 6.$

5. Calculate the fuzzy weights of the fuzzy positive reciprocal matrices.

The method for calculating the fuzzy weights $\widetilde{W}$ can be separated into two steps: (i) Calculate the geometric mean $\tilde{Z}_i$ and $\tilde{Z}_s$ of the fuzzy comparison value of reducing risk consequence i and alternative s; (ii) calculate the fuzzy weight $\widetilde{W}_i$ and $\widetilde{W}_s$ of the reducing risk consequence i and alternative s (Kahraman et al., 2009). At the criteria level, we use the criterion "reducing financial loss" as the example, where the geometric mean of TFN of ith criteria can be given by

$$\tilde{Z}_i^C = \sqrt[k]{\left(\tilde{B}_{i1}^C \otimes \tilde{B}_{i2}^C \otimes \ldots \otimes \tilde{B}_{i3}^C\right)} = \sqrt[3]{(0.33,0.5,1)}, \qquad \forall i = 1, 2, and\ 3$$

and the fuzzy weight of ith criteria is given by

$$\tilde{w}_i^C = \tilde{Z}_i^C \otimes \left(\tilde{Z}_1^C \oplus \tilde{Z}_2^C \oplus \ldots \oplus \tilde{Z}_k^C\right)^{-1} = (0.13, 0.24, 0.65)$$

To simplify the notation, the fuzzy weight can be further denoted by

$$\tilde{w}_i^C = \left(w_{il}^C, w_{im}^C, w_{iu}^C\right)$$

Similarly, the geometric mean of TFN of ith alternative at alternative level can be expressed by

$$\tilde{Z}_s^A = \sqrt[p]{\left(\tilde{B}_{s1}^A \otimes \tilde{B}_{s2}^A \otimes \ldots \otimes \tilde{B}_{sp}^A\right)} = \sqrt[6]{12,144,1440}, \qquad \forall s = 1, 2, \ldots 6$$

The fuzzy weight of ith alternative is given by

$$\tilde{w}_s^A = \tilde{Z}_s^A \otimes \left(\tilde{Z}_1^A \oplus \tilde{Z}_2^A \oplus \ldots \oplus \tilde{Z}_p^A\right)^{-1} = (w_{sl}^A, w_{sm}^A, w_{su}^A) = (0.15,0.35,0.73)$$

6. Defuzzify the fuzzy weights to crisp weights.

After obtaining the fuzzy weights, they are converted into crisp weights using a widely used centroid defuzzification method (Ali et al., 2012).

7. Standardise the crisp weights

To facilitate the comparison of the relative importance between elements at the same level, the obtained crisp weights (in step 6) are standardised by,

$Sw_i^C = \frac{w_i^C}{\sum_{i=1}^{k} w_i^C} =$ for the criteria

and

$Sw_s^A = \frac{w_s^A}{\sum_{s=1}^{p} w_s^A}$ for the risk mitigation strategies.

8. Calculate the integrated weight for each level

After standardising the crisp weights, the integrated weight for each element at each level in the AHP model can be computed by taking into account the weight at the current level and its upper level. More specifically,

(1) the integrated weights of each criterion at the criteria level are given by (note that the weight at its upper level is 1),

$$Iw_i^C = Sw_i^C, \ \forall i = 1,2,3, \text{ and}$$

(2) the integrated weights of each alternative at the alternatives level are given by

$$Iw_s^A = Sw_i^C \times Sw_s^A, \ \forall i = 1,2,\dots,k; \ \forall s = 1,2,\dots p.$$

The weights of the criteria and strategies were calculated by averaging the weight value of the 12 respondents' perceived value. In addition, by combining the criterion priorities and the relevant alternative priorities, we were able to obtain an overall priority ranking of the decision alternatives shown in Table 5.

[Please insert Table 5 about here]

Table 5 shows that the weights of criterion "reducing financial loss" (0.424) and "reducing safety and security incident-related loss" (0.420) are much greater than "reducing reputation loss" (0.156). This indicates that the first two criteria are more important under the goal of mitigating risks in shipping operations. It is easy to understand that almost every company pays a lot of attention to reducing financial loss. However, "reducing safety and security incident-related loss" is also important in container shipping operations due to the dangerous work environment. Compared to retailer operations in which maintaining reputation and brand are of high priority (see Dawar and Parker, 1994), container shipping operations tend to focus more on financial loss reduction and safety and security incident-related loss reduction.

Under the criterion "reducing financial loss", Strategy E: "Enter into long-term contracts with shippers" and Strategy A: "Form alliances with other shipping companies" are the top two strategies for mitigating financial loss in container shipping operations. These two strategies can be used to tackle and reduce the risk caused by transportation demand uncertainty. Moreover, the global importance of Strategy E (0.108) was twice more than the one of Strategy F (0.048).

Under the criterion “reducing reputation loss”, Strategy A: “Form alliances with other shipping companies” was evaluated as the most important strategy. However, the variation of the weights of the six strategies under this criterion was insignificant, indicating their contributions to reducing reputation loss have no vast difference.

Under the criterion “reducing safety and security incident-related loss, Strategy A: “Form alliances with other shipping companies” was calculated as the most important risk mitigation strategy, and its global weight (0.089) doubled that of Strategy F (0.046).

In order to understand the importance of the mitigation strategies over all three criteria, we calculated the overall priority of each strategy, by calculating the sum of the global weights of each strategy under three criteria. The calculations of overall priority of individual strategies are as follows:

Overall priority of Strategy A

$= 0.424 \times 0.189 + 0.156 \times 0.204 + 0.420 \times 0.213$

$= 0.202$

In a similar way the overall priority values of strategies B to F are obtained as 0.165, 0.162, 0.160, 0.197 and 0.112, respectively. Such a result reveals that from the overall perspective, the best risk mitigation strategies is strategies A and E, while the worst is strategy F. Strategies B to D of a priority value around 0.16 present a large distance to both best and worst strategies. It therefore can help ship lines to rationalise and justify their safety resources on different risk mitigation strategies with respect to the priority values.

5. Discussion and Conclusions

Compared to other studies addressing risk management in general manufacturing industries or examining only one or a few risk mitigation strategies in container shipping operation, this study considered risk management in container shipping with three risk consequences. We identified and confirmed 18 typical risk mitigation strategies through a literature review and interviews, in which the interviews contributed four new strategies not mentioned in existing literature.

Through the mitigation-strategy questionnaire survey, we were able to rank the mitigation strategies according to their overall effectiveness. The results show that the top six strategies include "form alliances with other shipping companies", "use more advanced infrastructures (hardware and software)", "choose partners more carefully", "enter into long-term contracts with shippers", "collaborate with partners (e.g., port operators, inland transportation operators) through making joint long-term plans", and "flexible design of the timetable/schedule, e.g., include time buffers"; whereas the strategy "acquire and merge with other shipping companies" had the lowest score among all mitigation strategies.

The six most important strategies were then selected to conduct an AHP survey to compare their relative importance in terms of three different criteria: reducing financial loss, reducing reputation loss, and reducing safety and security incident-related loss. The AHP survey and the AHP analysis yielded the results. Firstly, it was found that container shipping companies tend to place more emphasis on "reducing financial loss", yet they also pay a lot of attention to "reducing safety and security incident-related losses". However, the results showed that in average container shipping companies do not place much emphasis on "reducing reputation loss" compared to the first two criteria. The implication is that the top mitigation strategies probably have a more significant and direct impact on the first two criteria. In Taiwan case, given today's shipping business climate, even large companies pay more attention to mitigating financial loss as evidenced from our findings. It is different with previous studies which were conducted in a better global financial situation. It stimulates a new research question that if the global shipping market situation has impact on the shipping companies' risk mitigation strategies. Secondly, it was also found that "forms alliance with other shipping companies" and "enter into long-term contracts with shippers" are the top two strategies for risk mitigation in shipping operations. It is therefore suggested that container shipping companies pay more attention to making good relationships with their alliance partners or even their competitors to co-mitigate the impacts of the associated risks. Thirdly, it is often the case that a shipping company has restricted recourses to implement all the identified 18 strategies. It is very essential to choose the control strategies with priority. Hence, this study investigated the first 6 strategies to prioritise them for recommendation as well as to demonstrate how the remained strategies can be further evaluated by shipping companies to meet their own needs.

Based on the results of the fuzzy AHP, the six strategies were ranked according to their overall priority as follows: A, E, B, C, D, and F. This ranking has a notable difference (for Strategy E) compared to the result from the mitigation-strategy survey, where the ranking order was A, B, C, D, E, and F. This may be due to the fact that container shipping is a logistics service provider industry, which does not have its own production, and the profit relies totally on the transportation demand from shippers. Therefore, making long-term contracts with shippers can reduce future demand uncertainty and ensure that shipping companies will have a certain volume of promised cargo to transport. It should also be pointed out that the AHP survey compared the selected strategies against three different criteria separately, whereas the mitigation-strategy survey only considered the overall impact of the strategies. The overall priority of Strategy A "form alliances with other shipping companies" exhibited the largest overall priority of 0.202, which infers that it plays the most important role in reducing container shipping operation risks. This was followed by Strategy E: "enter into long-term contracts with shippers", which also had a priority of 0.197. Note that the weights of the middle three strategies (i.e. B, C, and D) were fairly close; the six strategies could thus be divided into three groups. That is, Group 1 comprises Strategy A and Strategy E, which have the highest impact on reducing the container shipping operational risks; Group 2 includes Strategy, B, C, and D that have a medium impact, and Group 3 comprises only Strategy F, which has the lowest impact on mitigating the container shipping operational risks. More specifically, the weight of Strategy A (0.202) in Group 1 is about two times that of the weight of Strategy F (0.112) in Group 3, and the weights of the alternatives in Group 2 are around one and half times that of Strategy F. Comparing the above result with the overall effectiveness ranking from the first survey, they are generally consistent with the exception of Strategy E, which held second place among the six strategies.

Although this research achieved its aims and objectives, there are several limitations in this study: (1) Seven face-to-face interviews involved in this research. This was caused by time constraints and the difficulties in involving senior shipping managers. It would be better if more managers were involved in the interviews. However, the interviews involved managers who work in the three main departments, so it is believed that the interview results had reasonable reliability. (2) We obtained 62 valid questionnaire replies in the mitigation-strategy survey. It is, of course, suggested that more valid questionnaire replies will lead to more accurate results. More valid questionnaire replies can be achieved through sending a second round of the same questionnaire survey. Although we conducted a reliability test to prove the results of this questionnaire to be reliable, it is still suggested that future researchers collect a larger number of responses so as to improve the study's reliability and validity. (3) This work uses the container shipping industry in Taiwan as a case study. It is believed that the results would be more accurate if we could interview and do the questionnaire survey in international container shipping companies outside of Taiwan. Nevertheless, our results could be generalised to many international container shipping company for the following two reasons: (i) The interviewees include the managers of Taiwan's container shipping companies in the UK. Through their point of view, the risk factors and risk mitigation strategies in container shipping operations could be generalised to international container shipping companies. (ii) Although the respondents of the two surveys work in Taiwan, their companies are also regarding as international companies since they have branches of their company in other countries or their agents work for international container shipping companies. (4) The findings based on a single perspective (i.e. importance of the strategies representing the effectiveness in terms of risk consequence reduction) can be further investigated by the incorporation of cost analysis of each strategy so that ship lines can choose the most cost effective strategies. (5) This study analyses the importance of the strategies, but it is also important to evaluate their financial feasibility. It is suggested to conduct a cost-benefit analysis in future similar research.

It is believed that, through this paper, container shipping managers can have more options to deal with risk management, and they understand how to prioritise strategies in respect to different types of risk consequences. In the academic area, this paper can also fill gaps in previous studies related to comparisons of risk mitigation strategies from the perspective of different levels of cooperation.

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