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CONTAINER SHIPPING RISK MANAGEMENT: A CASE STUDY OF TAIWAN CONTAINER SHIPPING INDUSTRY

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CONTAINER SHIPPING RISK MANAGEMENT: A CASE STUDY OF TAIWAN CONTAINER SHIPPING INDUSTRY

By

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Abstract

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Container Shipping Risk Management: A Case Study of Taiwan Container Shipping Industry

Whilst container shipping has become increasingly important over the past few decades due to its obvious advantages, container shipping companies have faced various risks from different sources in their operations. Systematic academic studies on this topic are few; and in light of this, this study aims to systematically explore and analyse the risks in container shipping operations and to examine the applicable risk mitigation strategies in a logistics perspective, including information flow, physical flow, and payment flow.

This thesis uses Taiwan container shipping industry as a case study, and borrows four steps of risk management as the main method, which includes risk identification, risk analysis, risk mitigation strategies identification, and strategies evaluation. In order to ensure the analysis is inclusive and systematic, risk factors and risk mitigation strategies are identified through a related literature review and are validated through a set of interviews. Risk analysis is conducted through using questionnaires, and then through risk ranking, risk matrix, risk mapping, and P-I graph. Risk mitigation strategies are evaluated through classic AHP and fuzzy AHP analysis.

A number of significant findings have been obtained. Firstly, 35 risk factors are identified and classified into three categories: risks associated with information flow, risks associated with physical flow, and risks associated with payment flow. After collecting and analysing the risk-factor survey, the results indicate that the risk associated with physical flow has the more significant impact on shipping companies' operation. However, one risk factor associated with information flow, “shippers hiding cargo information”, has the most significant impact among the 35 risk factors. Secondly, 20 risk mitigation strategies are identified and classified into three categories: intra-organisational strategies, intra-channel strategies, and inter-channel strategies. After collecting the AHP survey and analysing through classic AHP and fuzzy AHP, the result indicates that “slot exchange, slot charter, joint fleet, ship charter with other container shipping companies” is the most important strategy.

The main contributions of this thesis include: (1) based on the literature review, there have been no research on risk management in the context of container shipping operation from a broad logistics perspective, and this thesis is the first attempt to fill this research gap; (2) this thesis uses Taiwan shipping industry as a case study to apply the framework, which generates useful managerial insights; (3) the conceptual model of risk management developed in this thesis

can be applied to container shipping operations in other countries and regions; (4) compared with several studies using secondary data, this thesis uses empirical data to conduct the risk analysis, and make the results more close to the reality situation in container shipping; (5) in terms of risk analysis, this thesis ranks the total 35 risk factors rather than only identify the most important one, this can be used to be generalised to the whole container shipping companies in Taiwan, or even to the whole world; (6) in terms of risk management, the previous studies usually analyse only the importance of strategies. However, this thesis analyses the results of AHP from three different angles: reducing financial loss, reducing reputation loss, and reducing safety and security incident related loss. This can provide different angles for the managers who are considering different aspects.

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Chia-Hsun

Plymouth, March 2013

Author's Declaration

At no time during the registration for the degree of Doctor of Philosophy has the author been registered for any other University award without prior agreement of the Graduate Committee.

Papers have been published and presented by the author including:

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List of Abbreviations

AHP - Analytic Hierarchy Process

ARS - Average Risk Scale

BAF - Bunker Adjustment Factor

B/L - Bill of Lading

CAF - Currency Adjustment Factor

C.I. - Consistency Index

CIF - Cost, Insurance and Freight

CIO - Chief Information Officer

CKYH - COSCO, "K" LINE, Yang Ming, HANJIN

COA - Centre of Area

COG - Centre of Gravity

C.R. - Consistency Ratio

CSCL - China Shipping Container Lines

CSI - Container Security Initiative

CY - Container Yard

DEA - Data Envelopment Analysis

DG - Dangerous Goods

D/O - Delivery Order

EDI - Electronic Data Interchange

EXW - EX-works

FMEA - Failure Mode and Effect Analysis

FOB - Free On Board

FTA - Fault Tree Analysis

HAZOP - Hazard Operability

ICT - Information Communication Technology

IMDG code - the International Maritime Dangerous Goods code

IMO - International Maritime Organisation

INCOTERMS - International Commercial terms

InfoD - Information Delay

InfoI - Information Inaccuracy

InfoIT - IT Problem

InterCS - inter-channel strategy

IntraCS - intra-channel strategies

IOS - intra-organisational strategies

ISM Code - The International Safety Management Code

ISMS - information security management system

ISPS Code - The International Ship and Port Facility Security Code

ISO27001 - International Organization for Standardization27001

IT - Information Technology

L/C - Letter of Credit

MSC - Mediterranean Shipping Company S.A

NASA - The National Aeronautics and Space Administration

NII - Non-Intrusive Inspection

NPSA - National Patient Safety Agency

OOCL - Orient Overseas Container Line

PayCE - Currency Exchange

PayNP - Non-Payment

PayPD - Payment Delay

P-I graph - Probability-Impact graph

PhCD - Cargo/asset loss or Damage

PhTD - Transportation Delay

RFID - Radio-Frequency Identification

R.I. - Random Index

ROC - Republic of China

RSALC - Risk Scale Average Likelihood and Consequence

S.D. - Standard Deviation

SEM - Structural Equation Modelling

S/O - Shipping Order

SOLAS - International Convention for the Safety of Life at Sea

TEU - Twenty-foot Equivalent Unit

TFN - Triangular Fuzzy Number

THX - Taiwan/Hong Kong/Ho Chi Minh Express Service

Chapter 1 Introduction

This chapter provides a general background of container shipping industry, and risks and risk management in container shipping, followed by the research aims and specific objectives, the research methods, and the outline of the thesis.

1.1 Background

Container shipping

In today's dynamic and time-based competitive business environment, the shipping market has faced many challenges (Chow and Chang, 2011). Shipping is an international business; it has a strong relationship with the prosperity and adversity of global economies. It is reported that about 90% of international trade is transported by ships (Shipping Facts, no date). Container shipping has become increasingly important over the past few decades due to its significant advantage in loading and unloading operations and the ability to achieve intermodalism. Containership carrying capacity and world traffic have both increased in significant growth rates (Chow and Chang, 2011). At present, there are approximately 5,000 full-cellular container ships in the world fleet carrying 52% of the world seaborne trade in terms of value of the cargo (World Shipping Council, 2011[a]; 2011[b]).

According to Stopford (1997, p.512), a container shipping service is "a fleet of ships, with a common ownership or management, which provides a fixed service, at regular intervals, between named ports, and offers transport to any goods in the catchment area served by those ports and ready for transit by their sailing dates. A fixed itinerary, inclusion in a regular service, and the obligation to accept cargo from all comers and to sail, whether filled or not, on the date fixed by a published schedule are what distinguish the liner from the tramp." (This definition is an updated version of the definition given in *A Short History of the World's Shipping Industry* Fayle, 1933, p. 253.)

Because of the fixed service routes and published timetable, consignor can trust that their goods will be delivered to the certain port on the certain time (ICS, 2010). Several characteristics in container shipping are identified as follows (Lin and Chang 2006)-

1. Container shipping needs huge capital investment
2. Container shipping is easily impacted from the global economy
3. Container shipping earns unstable income which is impacted by world fuel price and exchange rate
4. Container shipping is limited by inflexible supply of container ships
5. Container shipping is impacted by the degree of government support
6. Container shipping has fixed freight, which is because of the upward trend in sizes of container ships
7. Container shipping has to bear the cost of empty container transportation
8. Container shipping has to follow International regulations

The above characteristics indicate that container shipping is associated with a wide range of risk sources in a complex international environment. In addition, as container shipping is often a part of the supply chain, it needs to interact with other parties, e.g. consignees, consignors, ports, terminal operators, agencies, inland transportation, hauliers, and forwarders. The complex operations within and between these entities and the long distance of physical process may give rise to various types of risks, which could negatively impact on the performance of container shipping companies. It is therefore important for shipping companies to know what are the associated risks? Which ones are more important and how to mitigate the impacts of these risks on shipping operations?

Risk and risk management

Risks in container shipping business have attracted considerable attention in academia over the past decade. Various types of risk in relation to container shipping have been addressed in previous studies, e.g., technical risk, market risk, business risk, and operational risk (Ewert, 2008). Technical risk generally refers to the loss arising from activities such as ship or equipment design and engineering, manufacturing, technological processes and test procedures. Market risk in shipping industry includes revenue and investment risk (Kavussanos *et al*., 2003), and it refers to unforeseen changes in demand and supply (Rodrigue *et al*., 2011). Business risk relates to the nature of the business and it “deals with such matters as future prices, sales or the cost of inputs” (Yip and Lun, 2009, p.153). The main business risk in container shipping operation is the action of increasing capacity due to the fact that container shipping companies try to take advantage of economies of scale (Yip and Lun, 2009). Operational risk is “the possibility of an event associated with the focal firm that may affect the firm’s internal ability to produce goods and services, quality and timeliness of production, and/or the profitability of the company” (Manuj and Mentzer, 2008a, p.139), and it is essentially arising from the logistics processes.

Within this complex picture of risks in container shipping, this thesis attempts to address one group of these risks - the operational risk. To tackle this issue, it is important for the shipping companies to know what these risks are and how they affect the shipping operations. Unless there is unlimited resource that could be employed to mitigate such risks, shipping companies will always have to prioritise their resources to mitigate those risks that are most imminent and significant. This makes it important to analyse the extent to which each risk affects the performance of a shipping company and to identify the relative importance of each risk factor.

Risk management often includes risk identification, risk analysis and risk mitigation. In the aspect of risk identification and analysis, a number of studies have provided some very valuable insight into the risks faced by container shipping companies in their operations. For example, Talley (1996) states that unlicensed operators (versus licensed operators), and smaller ship size (versus large ship size) may contribute to the increase of risks and severity of cargo damage in container shipping. He also suggests that the risks and severity of damage are greater in incidents of collision and fire/explosion than grounding. Noda (2004) states that terrorist attacks have been a threat to container shipping companies for many years. Fu *et al.* (2010) report that piracy is a significant threat and it has forced several major container liners to alter their service routes. Drewry (2009) has identified several physical risk factors in container shipping, including strikes and transport congestion, theft, piracy, and terrorist attack (the detailed information will be presented in Chapter 2).

There are a number of studies that have addressed risk from a logistics perspective by looking at the single organisation's inbound and/or outbound vulnerabilities, which mainly focused on the physical material flow (Zsidisin and Ellram, 1999; Zsidisin *et al.*, 2000; Svensson, 2000, 2002; Johnson, 2001). The concept of logistics has broadened in the last decade, logistics flows involve not only physical material flow, but also information flow, and financial/ payment flow among multiple parties (Spekman and Davis, 2004; Diniz and Fabbe-Costes, 2007; Ellegaard, 2008; Tummala and Schoenherr, 2011). Each flow "represents a different dimension of risk and each is essential for the supply chain to perform its objectives in an efficient and effective manner" (Spekman and Davis, 2004, p.419). As three logistics flows are closely linked in container shipping operations through terms of sales, terms of payment, and bill of lading, it is necessary to investigate risk management in container shipping from a broad logistics perspective.

However, to the best of our knowledge no research has been published on the identification of risks in relation to all three major logistics flows in container shipping. In other words, no studies so far have approached this issue from a perspective that inclusively examines all the possible risks faced by a container shipping company and comprehensively evaluates the relative importance of each of them. Such a study is indeed important as it could assist the shipping company managers to make efficient yet economical strategic decisions given that the attainable resources are normally limited.

In light of this, the first aim of this thesis is to conduct a comprehensive empirical study on the risks that a container shipping company may face in providing services in shipping supply chains. The purpose is to answer the questions as to what are the risk factors in container shipping operations, and which risk factors are relatively more significant to a shipping company's performance. In this thesis, risks will be identified and analysed in relation to three flows in container shipping operations, i.e., risks associated with information flow, risks associated with physical flow and risks associated with payment flow. Three types of risk consequence are discussed within container shipping operation sector, including financial loss, reputation loss, and safety and security incident related loss.

In the aspect of risk mitigation, some research has focused on risk response attitude which defines the general approach to risk management such as whether or not risks are taken, tolerated, retained, shared, reduced, or avoided, and whether or not risk treatments are implemented or postponed. For example, Miller (1992) proposes that strategic risk management can be divided into five generic responses, which are avoidance, control, cooperation, imitation, and flexibility. Hillson (1999) and Vose (2008) suggest that the risk responses can be divided into four quadrants, namely, avoid, control, transfer, and accept.

Many other studies focused on specific mitigation strategies to manage risks in general supply chains. For example, Giunipero and Eltantawy (2004) present several methods of risk management, e.g. consolidate partnerships, just in time deliveries, small flexible supply base, frequent commitment, and highly-trained supply management professionals. Quite a few studies state that information sharing, aligning incentives, risk sharing with co-operators, and corporate social responsibility can reduce the impact of risk on business (Chopra and Sodhi, 2004; Spckman and Davis, 2004). Chopra and Sodhi (2004) suggest several risk mitigating strategies, e.g. acquire redundant suppliers, pool or aggregate demand, and increase capacity, flexibility, capability and inventory.

The discussions of risk mitigation strategies in container shipping are rather fragmented. The majority of studies did not use the term “risk mitigation”. Instead, the attempts to reduce, control or avoid the risks or uncertainties are often implied, e.g., the liner service schedule design considering uncertainties in shipping and port operations (Notteboom, 2006; Notteboon and Vernimmen, 2009; Qi and Song, 2012; Wang *et al*., 2013), joint ventures between shipping companies and the supply chain partners to share financial responsibilities, to avoid conflicts, and to overcome the instability in container shipping (Heaver *et al*., 2000; Heaver *et al*., 2001; Notteboom, 2004), operational measures to respond to uncertain events and delays in shipping (Notteboom, 2006; Imai *et al*., 2007), handling the piracy problem (Chalk, 2008; Fu *et al*., 2010), improving port operation security (Bichou , 2004; Frittelli, 2005). Moreover, the rapid rising fuel prices and containership overcapacity are the new issues that have emerged in recent years mainly due to the global economic crisis, which have urged container shipping companies to lay up ships or operate more idle ships in the existing routes for slow steaming and cost-saving (Bonney, 2010).

In light of the discussion above, the second aim of this thesis is to conduct an empirical study on risk management in container shipping operations. The purpose is to help container shipping companies better understand the different forms of risk mitigation strategies and their relative importance to different performance criteria. In this thesis, the risk mitigation strategies are proposed and classified into three categories: intra-organisational strategies, intra-channel strategies, and inter-channel strategies. The relative importance of these strategies is then evaluated as part of risk management.

It is worth pointing out at the outset that the focus of this thesis is about the risks faced by container shipping companies in their operations and providing services in maritime supply chains, which is different from supply chain risks in container shipping. A “supply chain risk” is defined as “an event that adversely affects supply chain operations and hence its desired performance measures, such as chain-wide service levels and responsiveness, as well as cost” (Tummala and Schoenherr, 2011, p. 474). In other words, supply chain risks are those that affect the entire supply chain. Studies on maritime supply chain risks normally focus on the risks that impact on the performance of the entire supply chain including all the players and not just one or two players such as shipping company. This thesis only addresses the risks faced by a container shipping company, as a player in a supply chain.

1.2 Research aims and objectives

The aim of the thesis is to conduct a comprehensive empirical study on risk management in container shipping industry through the development of a tailored framework that can be used for identifying risks from the logistics perspective, measuring the risk likelihood and risk consequence, analysing risk scale, and evaluating the importance of risk mitigation strategies and their relationships in container shipping operations. The specific research objectives include:

1. Elaborate the logistics flows (information, physical, payment flows) in container shipping operations
2. Develop a conceptual framework for risk management in the context of container shipping operations, and apply the framework to a case study
3. Identify key risk factors within the three flows in container shipping
4. Identify typical risk mitigation strategies for container shipping companies
5. Perform risk analysis to assess the impact of risk factors and their relationships
6. Evaluate the importance of risk mitigating strategies and their relationships

1.3 Research methods

"A research method is a strategy of inquiry which moves from the underlying philosophical assumptions to research design and data collection" (Myers, 1997). General speaking, a research method should include the source of data collection and the method to analyse the data. These methods can be classified into two categories, namely, qualitative method and quantitative method. In this thesis, both qualitative and quantitative research methods were used.

First of all, this thesis is based on the Taiwan container shipping industry as a case study. Owing to its island geography, Taiwan largely relies on international trade. Most of the materials for manufacturing are imported by ships, and therefore the shipping industry plays an important role in Taiwan's economy. According to official statistics (Ministry of Transportation and Communications, 2011), around 99% of international trade in Taiwan is transported by sea. It is expected, therefore, that a case study of Taiwan will be able to provide some insight into the risk analysis issues in the wider maritime context. Findings obtained therein should be generally applicable to those countries where container shipping also plays an important role in their economies.

The data collection methods include a literature review, a series of interviews, and three questionnaire surveys. Relevant literature review is used as a base to identify risks and risk mitigation strategies. The review of literature includes two major parts: a review of risks and risk mitigation strategies in container shipping operations, and a literature review in general supply chains context to expand the coverage of risks and risk mitigation strategies. A series of interviews with managers in container shipping companies was conducted to validate the risk factors and risk mitigation strategies that are extracted from the existing literature and to explore new risk factors and mitigation strategies that have not been mentioned in the literature. In order to analyse the risk scale, it is necessary to measure the risk likelihood and the risk consequence. A risk-factor questionnaire survey is conducted to collect the primary data on risk likelihood and risk consequence. The level of each risk factor is then analysed through risk scaling and risk mapping. This thesis presents a new formulation - Average Risk Scale (ARS) – to perform the risk map for three risk consequences, namely, finance loss, reputation loss, and safety and security incident related loss. The second questionnaire survey (termed mitigation-strategy survey) is conducted to rank the risk mitigation strategies according to their overall performance to shipping companies. An important set of mitigation strategies is then obtained.

In order to better understand the relationships between the identified important risk mitigation strategies with regard to different criteria such as reducing financial loss, reducing reputation loss, and reducing safety and security incident related loss, the third questionnaire survey with paired comparison was used to collect the relevant primary data. The classic Analytic Hierarchy Process (AHP) and fuzzy AHP methods are then used to analyse the data and quantify the relative importance of those mitigation strategies with respect to different performance criteria. The differences between classic AHP results and fuzzy AHP results are discussed.

1.4 Structure of the thesis

This thesis includes eight chapters. The rest of this thesis is organised as follows.

Chapter 2 presents the risk management in container shipping operations. The risk factors in container shipping operations were firstly identified through the review of relevant literature. The second section introduces risk mitigation strategies in container shipping operations. The last section discusses the research gap.

Chapter 3 presents the conceptual model and the methodology of this thesis. An introduction of Taiwan's container shipping industry was firstly presented. The second section developed the research conceptual model, in which three major logistics flows (information flow, physical flow, and payment flow) in container shipping operations were firstly presented. Several risk models were then introduced from previous studies. The research conceptual model was proposed through organising and refining the previous models. Following that, the risk management steps were introduced in detail, which includes risk identification, risk analysis, risk mitigation strategy making and risk mitigation strategy evaluation. The third section discussed data collection methods, including the methods for risk identification and measurement, and risk mitigation strategy identification and evaluation. Within the risk measurement, risk consequences in container shipping were discussed from three performance perspectives, namely, financial loss, reputation loss, and safety and security incident related loss. The fourth section discussed the data analysis methods, including risk analysis methods and risk mitigation strategies evaluation methods. Within the risk analysis method, a new formulation was developed to perform the risk map, and then three methods were introduced to present the risk scale. In terms of risk mitigation strategy analysis method, the classic Analytic Hierarchy Process (AHP) and the fuzzy AHP were described in detail, respectively.

Chapter 4 is the identification of risks in container shipping operations. Risk identification is regarded as the very first step among risk management. In order to expand the coverage of the risk identification, this chapter firstly reviewed relevant literature on risks in general supply chain from the logistics perspective, and categorised them into risks associated with information flow, risks associated with physical flow, and risks associated with payment flow. After identifying the risk factors from previous literature review, seven interviews have been conducted to validate the risk factors and explore more risk factors that are not mentioned in previous studies.

Chapter 5 measures and analyses these risk factors in container shipping operations. The data were collected through a questionnaire survey, which used a five-point Likert scale. The result of this questionnaire survey provided the respondents' details of the questionnaire, and the risk measurement and analysis, including the level of risk likelihood, risk consequence and risk scale. Through risk scale calculation, the impact of each risk factor was presented by categorising them into four levels (extreme risk, high risk, moderate risk and low risk). After this, three risk maps (financial loss, reputation loss, and safety and security incident related loss) were presented to show the relationships (risk likelihood, risk consequence and risk scale) among risk factors. Several important risk factors were then presented and discussed in the end of this chapter.

Chapter 6 presents the identification and evaluation of risk mitigation strategies in container shipping operations. Similar to risk identification, the risk mitigation strategies were firstly identified through a relevant literature review, and then validated and explored through interviews. The risk mitigation strategies in container shipping were classified into three categories, including intra-organisational strategies, intra-channel strategies, and inter-channel strategies. The second section presents the evaluation of risk mitigation strategies in container shipping operations. The result of the five-point Likert scale survey yielded the ranking of the risk mitigation strategies according to their overall importance. The top seven mitigation strategies were selected to be further investigated through conducting the AHP questionnaire survey in order to evaluate their relative impact on three different performance criteria: reducing financial loss, reducing reputation loss, and reducing safety and security incident related loss. The classic AHP and the fuzzy AHP were used to analyse the data. The results of classic AHP and fuzzy AHP were then discussed and compared.

Chapter 7 is the research discussion and implications. Firstly, the findings of risks and their implications were discussed and linked to existing studies to support or refine their results. Secondly, the findings from the risk mitigation strategy evaluation using classic AHP and fuzzy AHP were discussed and also linked to previous studies. Thirdly, the generalisation of the research methods and the research findings from the Taiwan's case study are discussed.

Chapter 8 is the conclusion of this research. This chapter highlights the main findings, points out the limitation, and suggests the further research directions.

Chapter 2 Risks in container shipping operations

Chapter 2 presents the relevant literatures about risk management in container shipping operations, including the identification of operational risks in Section 2.1 and risk mitigation strategies in container shipping in Section 2.2. The research gap is then identified in Section 2.3.

2.1 Operational risks in container shipping

This thesis firstly clarifies what risk is. Then the relevant studies on operational risks in container shipping will be reviewed and the risk factors will be summarised.

2.1.1 What is risk?

The word “risk” originates from the Italian word *risicare*, which means to dare. (Bernstein, 1996; Khan and Burnes, 2007; Rao and Goldsby, 2009). However, its meaning has changed and expanded over time and appears through different people and different situations (Frosdick, 1997). The study of risk was used to apply mathematics to gamble when it was proposed by Pascal and Fermat (Frosdick, 1997; Khan and Burnes, 2007; Rao and Goldsby, 2009). Their work developed probability theory, which becomes the core concept of risk (Bernstein, 1996). Nowadays, more studies have attempted to understand risk and its responses from human behaviour and psychology-based approaches (Kahenman and Tversky, 1979; Thaler, 1985; Khan and Burnes, 2007).

There are various definitions of risk. We conduct a comprehensive literature review and organise different definitions of risk by chronicle into Table 2.1. The definitions can be categorised into several groups such as "risk is a negative consequence/ outcome" (Rowe, 1980; March and Shapira, 1987; Miller, 1991; Sitkin and Pablo, 1992; Hutchins, 2003; Norrman and Jansson, 2004; Spekman and Davis, 2004), "risk is a measure of the probability of loss" (Lowrance, 1980; The Royal Society, 1992; Yates and Stone, 1992; Chiles and McMackin, 1996; Mitchell, 1999; Hutchins, 2003; Norrman and Jansson, 2004; Spekman and Davis, 2004), and "risk is the outcome of uncertainty" (Sitkin and Pablo, 1992; Deloach, 2000; Rao and Goldsby, 2009).

Table 2.1 The selected definitions of risk

Authors	Definition
Knight (1921)	Risk is defined as the probability of incurring a loss
Markowitz (1952, p.89)	The concepts "yield" and "risk" appear frequently in financial writings. Usually if the term "risk" were replaced by "variance of return," little change in apparent meaning would result
Blume (1971)	Risk, in reality, is a somewhat imbalanced definition given that most risky decisions in business are taken on the basis of generating a potential gain
Rowe (1980)	Risk is the potential for unwanted negative consequences to arise from an event or activity
March and Shapira (1987)	Risk refers to the negative variation in business outcome variables such as revenues, costs, profits, etc.
Lowrance (1980)	Risk is a measure of the probability and severity of adverse effects
Miller (1992)	Risk refers to the variance in outcomes or performance that cannot be forecasted ex-ante
The Royal Society (1992)	Risk is "the chance, in quantitative terms, of a defined hazard occurring. It therefore combines a probabilistic measure of the

	occurrence of the primary event(s) with a measure of the consequences of that/those event(s)"
Sitkin and Pablo (1992)	Risks refers to "the extent to which there is uncertainty about whether potentially significant and/or disappointing outcomes of decisions will be realized"
Yates and Stone (1992)	Risk is an inherently subjective construct that deals with the possibility of loss
Chiles and Mackin (1996)	Risk refers to the possibility of loss
Mitchell (1999)	Risk is defined as a subjectively determined expectation of loss; the greater the probability of this loss, the greater is the risk
Deloach (2000)	Business risk is the level of exposure to uncertainties that the enterprise must understand and effectively manage as it executes its strategies to achieve its business objectives and create value.
Hutchins (2003)	Risk is the probability that an event or action may have negative impact on the organisation
Norrman and Jansson (2004)	Risk is "a quality that reflects both the range of possible outcomes and the distribution of respective probabilities for each of the outcomes"
Spekman and Davis (2004)	Risk is defined as the probability of variance in an expected outcome
Rao and Goldsby (2009)	Risk is exposure to a premise, the outcome of which is uncertain

In this thesis, "risk" is deemed as a negative outcome from uncertainty and it can be measured from the likelihood and the consequence of uncertainty. As this study focuses on operational risks in container shipping, it is necessary to review all the studies related to risks and uncertainties in container shipping operations.

2.1.2 Operational risks in container shipping

This section reviews the operational risks in container shipping. The literature is roughly organised according to the nature of the associated risk including asset risks, schedule unreliability, inappropriate empty container repositioning, fuel price uncertainty, cargo damage, and terrorist attack.

Drewry (2009) identified a list of business process risks and asset risks in container transport and logistics including documentation, booking and invoicing errors, errors in customs regulatory compliance and in security compliance, strikes and transport congestion, theft and cargo loss or damage, piracy, and terrorist attack. Podsada (2001) also reported that each year more than 10,000 containers are lost at sea. In 2007 in Antwerp, just in one incident, about 100 containers with cars fell overboard during the loading operation where the ship was capsized (IMC, 2007). It is easy to understand that asset/cargo losses at sea are quite significant in container shipping operations.

Unreliability of service schedule is also a risk factor in container shipping as it would lead to transportation delay and affect shipping companies' reputation. Notteboom (2006) investigated the sources of schedule unreliability of the East Asia-Europe route and identified several sources that had led to unreliability of service schedule, including waiting time and delays caused by port strikes, unstable weather and sea conditions, port/terminal/transport congestion, and port/terminal productivity being below expectations. He found that port congestion is the most important source that leads to schedule unreliability. A large survey from Drewry (2006a) showed that more than 40% of the vessels deployed on worldwide container shipping services arrived one or more days behind schedule, based on the monitoring of more than 5,410 vessels between April and September 2006. The result also revealed that only 52% of the vessels were on-time, with 21% of the vessels arriving 1 day late, and more than 22% of the vessels arriving 2 or more days late. Vernimmen *et al*. (2007) stated that several common factors impacted on vessel delay include bad weather at sea, congestion or labour strikes at the different ports of call, and knock-on effects of delays suffered at previous ports. They found that the impact of decreasing liner schedule reliability on shipping companies include "the delays in ports add to the duration of the total round-trip time, affecting bottom-line profits through additional fixed delay ship costs and/ or increased operational costs by the need to sail at full service speed to make up for lost time" (Vernimmen *et al*., 2007, p. 210). Qi and Song (2012) pointed out that lack of appropriately designed flexible liner service schedules would lead to service unreliability.

Inappropriate empty container repositioning could incur significant costs to shipping lines (Dong and Song, 2009; Song and Dong, 2011; Dang *et al*., 2013). It is thus considered as a risk in container shipping. Song *et al*. (2005) stated that empty container transportation incurred approximately 15 billion USD for the world containership fleet in 2002. Drewry (2006a, 2006b) reported that empty containers have accounted for at least 20 per cent of global port handling activity ever since 1998.

Notteboom and Vernimmen (2009) used a cost model to simulate the impact of bunker cost changes on the operational costs of liner services and the results showed that oil price rise may force shipping lines to face increasing operational costs and operational risks. Notteboom (2006) reported that at the historic price of 135 USD per ton bunker fuel costs were about half the operating cost of larger containerships; whilst Ronen (2011, p.211) argued that “a large ship may be burning up to 100,000 USD of bunker fuel per day, which may constitute more than 75% of its operating costs”. Rubin and Tal (2008) also reported that shipping a standard 40-foot container from Shanghai to the U.S. eastern seaboard cost 8000 USD in 2008. In 2000, when oil prices were 20 USD per barrel, it cost only 3000 USD to ship the same container.

Talley (1996) based on micro-data of individual vessel accidents that occurred in the U.S. for the time period 1981-89 found that unlicensed operators (versus licensed operators) and smaller ship size (versus large ship size) may contribute to the increase of risk and severity of cargo damage in container shipping. He also suggested that the risks and severity of damage are greater in collision and fire/explosion incidents than in grounding. Vernimmen *et al*. (2007) reported several more serious factors that lead to transportation disruption, such as cargo loss, fire incidents (cf. Hyundai Fortune fire incident in the Gulf of Aden in March 2006), ship collision or ship groundings (cf. the incident with the MSC Napoli off the UK East Coast in early 2007).

Tseng *et al*. (2012) analysed the risks of cargo damage for aquatic products of refrigerated containers based on a questionnaire survey in various maritime communities in Taiwan, including container carriers, ocean freight forwarders, and container terminal operators. They identified a number of risk factors in transporting refrigerated containers and found that “container data setting errors” is the top factor of perceived risk as well as of risk severity.

Noda (2004) stated that terrorist attacks have been a threat to container shipping companies for many years. According to the report of International Maritime Organisation (IMO), by the beginning of February 2011, about 30 ships and 714 hostages have been held by the pirates (IMO, 2011). Fu *et al.* (2010) reported that piracy has been a significant threat and it has forced several major container liners to alter their service routes. They focused on the Far East-Europe container liner shipping service and proposed a simulation-related economic model using history data to explain the impact of piracy.

Yang (2010; 2011) investigated the impact of the container security initiative (CSI) on Taiwan's shipping industry. The CSI is a programme imposed by US after 9/11, which requires that an inbound container or cargo from foreign commercial ports be pre-inspected in order to strengthen the US nation security. They identified several CSI-related risk factors including "cargo cannot make a shipment on time and shut out by customs authority", "cargo handling time delay", "longer lead time of data entering", and "various transmission system". It was reported that "cargo cannot be shipped on time and is shut out by the customs authority" is the top CSI-related factor in terms of risk severity.

Table 2.2 summaries the risk factors in container shipping operations from previous studies.

Table 2.2 The risk factors in container shipping operations

Risk factors	Authors
Port strike	Notteboom (2006); Drewry (2009)
Port congestion (unexpected waiting times before berthing or before starting loading/discharging)	Notteboom (2006); Drewry (2009)
Port/terminal productivity below expectations (loading/discharging)	Notteboom (2006)
Unstable weather	Notteboom (2006)
Inappropriate empty container transportation	Song *et al*. (2005); Notteboom (2006); Dong and Song, 2009;Song and Dong (2011); Dang *et al*., 2013
oil price rising	Notteboom and Vernimmen (2009)
Cargo stolen from unsealed containers	Drewry (2009)
Damage to ship or quay due to improper berth operations	Talley (1996); Vernimmen *et al*. (2007)
Damage to frozen cargo	Tseng *et al*. (2012)
Attack from pirates or terrorists	Noda (2004); Drewry (2009); Fu *et al.* (2010)

2.2 Risk mitigation strategies in container shipping

Similar to the organisation of Section 2.1, we first discuss the definition of risk management in general, and then review the relevant literature about risk mitigation strategies in container shipping.

2.2.1 Risk management

In the competitive business environment, risk is everywhere. The management to mitigate the impact of risks is an important issue to companies. There are also many studies that address risk management in various areas, such as banking (e.g. Sinkey, 1983; Bessis, 2010), finance (e.g. Smith *et al*., 1989; Vaughan, 1997), economics (e.g. Kahneman and Tversky, 1979; Tversky and Kahneman, 1992), gold mining (e.g. Tufano, 1996), medical/health (e.g. Neale, 1998; Aufseeser-Weiss and Ondeck, 2001; NPSA, 2008; Hollman, 2010), technology (e.g. DeLone and McLean, 1992; Elky, 2006), transportation (e.g. Alizadeh and Nomikos, 2009), logistics (e.g. Notteboom, 2006; Husdal and Bråthen, 2010) and supply chain (e.g. Harland *et al*., 2003; Christopher and Peck, 2004; Zsidisin *et al*., 2004; Waters, 2007; Manuj and Mentzer, 2008a, 2008b; Knemeyer *et al*., 2009; Yang, 2010, 2011), etc. The definitions of risk management can therefore be found across the authors and industries. This thesis presents several definitions of risk management from selected studies that related to business management and these are presented in Table 2.3.

Table 2.3 The selected definitions of risk management

Authors	Definition
Dickson (1989)	The identification, analysis and control of those risks which can threaten the assets or earn capacity of an enterprise
The Royal Society (1992, p.3)	Risk management is the making of decisions regarding risks and their subsequent implementations, and flows from risk estimation and risk evaluation
Fone and Young (2000)	Risk management is a general management function that seeks to assess and address risks in the context of the overall aims of the organisation
Norrman and Jansson (2004)	Risk management is the process whereby decisions are made to accept a known or assessed risk and/or the implementation of actions to reduce the consequences or probability of occurrence
Waters (2007, p.75)	Risk management is the process for systematically identifying, analysing and responding to risks throughout an organisation
Syriopoulos (2011)	Risk management for shipping is the process by which various risk exposures are identified, measured and controlled
Yang (2011)	Risk management is a decision-making process which is in view of the outcome of risk assessment

There are four common risk management steps, i.e. risk identification, risk analysis, risk mitigation strategies identification, and risk mitigation strategies evaluation. This reflects some of the above definitions such as Dickson (1989), Norrman and Jansson (2004), and Waters (2007). This thesis will generally follow the four step risk management perspective.

The identification of risk factors in container shipping has been mentioned in Section 2.1. The following section presents the risk mitigation strategies in container shipping industry from the relevant studies.

2.2.2 Risk mitigation strategies in container shipping

A number of risk mitigation strategies in container shipping have been mentioned in the previous studies. The literature is roughly organised according to the nature of the associated risk mitigation strategies including adding buffer time, omit port-of-call, slow steaming, advanced information technology, training, long-term contracts with shipper, collaboration, alliance, cooperation with competitors, merge and acquisition.

In order to reduce the impact from unreliable schedule, Notteboom (2006) suggested that designing service schedules with buffer time to make it more flexible. If a shipping schedule has included a buffer time, it offers opportunities to reduce the impact of uncertainties and delays at ports and at sea. Notteboom and Vernimmen (2009), based on the data from Drewry (2006c), stated that the biggest container shipping company (Maersk Line) has 70% on time service vessels in the world. Whilst the second biggest container shipping company (MSC) has the poorest performance with 41% on time service vessels because of the relatively low time buffers and random skipping of one or more ports of call during a round voyage. They suggested that buffer time in the service schedule should be sufficiently large to cope with unexpected transportation delays. It has been reported that adding certain buffer time in each route can lead to a more robust shipping network (Wang and Meng, 2012a, 2012b). Moreover, appropriately designing the ship schedule with a given fixed round-trip time can also minimize the impact of port time uncertainty on operational costs (Qi and Song, 2012).

Sometimes ships may not be able to arrive at destination ports on time due to various reasons such as temperamental weather, engineering break down or port congestion. Notteboom (2006) suggested five strategies to deal with delay in container shipping operations, include: (1) reshuffling the order of ports of call: more import cargos will be discharged in the first port-of-call, and they will be transported through inland transport to the destinations near ports that will be called at much later than initially planned; (2) cancel one or more port-of-calls to reduce total port time and get the vessel back on schedule; (3) deploy other vessels to take over in combination with delivery to hub; (4) speed up turnaround time at next port(s) of call in the loop to catch up and resume the schedule; and (5) make up time by increasing vessel speed on the intercontinental trunk route. Using a flexible transportation network allows a company to reduce the overall cost in responding to unstable risks. When the transportation delays happen such as port strike or bad weather condition, shipping companies may reduce the berthing time in the port or cut ports-of-call (Kerr, 2011b). Cutting ports-of-call is a common method to catch up the original shipping schedule when the ship has a very serious delay or port strike. Usually, the ship may berth at the next port-of-call to loading and unloading the cargos which should be done at this coming port-of-call. Brouer *et al*. (2013) studied the problem of real-time recovering a disrupted container shipping schedule using several operational measures such as speeding up vessel, cutting ports-of-call, and swapping ports-of-call.

Rising fuel prices and overcapacity are new issues that have emerged in recent years. The fuel consumption of a ship is regarded as a cubic function of the sailing speed (Ronen, 1982; Fagerholt *et al*., 2010; Qi and Song, 2012). Many studies have stated that slowing the sailing speed is an effective risk mitigation strategy to reduce the operational cost caused by the rising fuel price. Notteboom (2006) used the data provided by Sea Span to show that when a vessel sails at the maximum service speed (25.4 knots), the daily fuel consumption will be twice more than a slower sailing speed (18 knots). He also stated that a number of shipping companies slowed down vessel speed on the Trans-Pacific route to 19 knots instead of the normal 22-23 knots because of the port congestion at the US West Coast. Notteboom and Vernimmen (2009) further confirmed that operating vessels at an economic speed would benefit shipping companies to reduce the fuel consumption and an overall operating cost. Ronen (2011) used the published data and calculated the operational costs and fuel costs through a cost model, the result shows that when a vessel is operated at the minimal-cost speed, the shipping company can gain great cost-savings. Cariou (2011) found that under slow steaming, shipping companies can save more than 16% of average fuel oil consumption per ship when the vessel size is more than 5000 Twenty-foot Equivalent Unit (TEU). Qi and Song (2012) stated that the fuel consumption and emissions can be minimised by appropriately designing the containership schedule in situations with port uncertainty, which essentially balance the ship sailing speed over the entire journey. Maloni *et al.* (2013) aimed to quantify the costs and benefits of slow steaming related to container shipping companies and shippers, and the results showed that the most beneficial vessel speed is “extra slow steaming”, which means a 20% reduction in total costs and a 43% reduction in carbon dioxide emissions.

E-commerce has been used in container shipping operations for many years, Marle (2009) states that shippers could save a huge amount of money in bills of lading (B/L) overcharges through new transport management software. Kerr (2011a) emphasizes that the use of an e-invoice system could significantly reduce errors and costs when processing documents. However, only 59% of logistics and freight businesses use e-commerce as standard practice because of the huge investment (Brett, 2011).

Employee training can reduce a lot of risks in a shipping company. Almost every shipping company pays much attention to it. Lloyd’s List even holds an award called ‘Lloyd's List Maritime Excellence Award for Commitment to Training and Education’. Several research studies state that regular training is an important mechanism to reduce the probability of risk in container shipping (Young, 2010, Ganesan, 2010). Training also can reduce the probabilities of information delay and error. Therefore, we choose employees’ skill and risk awareness training as one type of risk mitigating strategies in container shipping.

Container shipping companies have to invest heavily in capital to operate regular, reliable and frequent services. Once the cost consumption networks are set up, the shipping companies need to fill the networks with freight (Notteboom, 2004). To gain a reasonable profit, shipping companies have to ensure high vessel utilisation. However, it is difficult to match capacity supply with trade demand. Establishing a close relationship with major shippers is an important strategy to reduce the risk of vessel underutilisation. Notteboom (2004) stated that container shipping companies need to negotiate long-term contracts with shippers to secure the cargo volume.

In order to provide comprehensive services (such as door-to-door services), some container shipping companies attempt to use trustworthy independent inland operators' services on a contract base (Baird and Lindsay, 1996, Graham, 1998; Carious, 2001; Heaver, 2002; Notteboom, 2004). Apart from inland transportation, Notteboom (2006) also suggested that container shipping companies can use joint ventures with port/terminal operators to reduce the impact of port congestion, which is the main source of schedule unreliability. For example, a shipping line may collaborate with inland distributors through expanding/ subcontracting inland container logistics, and collaborate with terminal operators through a joint venture or dedicated terminal. Such relationships often go beyond information sharing because partners in the supply chain are more closely linked and involve joint long-term planning. For example, Yang Ming Marine Transport Corporation has many supply chain partners including Yes Logistics Corporation (distribution centre), Jing Ming Transport Corporation (inland transportation company), and Kao Ming Container Terminal Corporation (www.yml.com.tw).

There are also some practical strategies across shipping companies including strategic alliances (Ryoo and Thanopoulou, 1999; Midoro and Pitto, 2000; Heaver *et al*., 2000; Slack *et al*., 2002; Song and Panayides, 2002; Notteboom, 2004; Lu *et al*., 2010), exchanging slots (Song and Panayides, 2002;

Notteboom, 2004; Lu *et al*., 2010), merging with (Heaver *et al*., 2000; Song and Panayides, 2002 Notteboom, 2004) or acquiring (Song and Panayides, 2002; Notteboom, 2004) other companies. Strategic alliances are defined as the partnership of two or more organisations to pursue a set of private and common interests through cooperation and sharing of resources (Ariño *et al*., 2001). Midoro and Pitto (2000) stated that container shipping companies can gain several benefits from strategic alliances, including "wider geographical scope", "possibility to perform vessel planning and co-ordination on a global scale", "risk and investment sharing", "economies of scale", "entry in new markets", "increase in frequency of services", and "cost down through combining purchasing power and volumes". There are currently several container shipping alliances, such as CKYH (COSCO, "K" LINE, Yang Ming, HANJIN) Alliance, G6 Alliance (APL/NOL, Mitsui OSK lines, Hyundai, Hapag-Lloyd, NYK line, and OOCL), and P3 Alliance (Maersk Line, Mediterranean Shipping Company, and CMA CGM). Each shipping company in an alliance group often contributes several ships to co-operate on the same routes, and this could reduce the capital investment and risk for these shipping companies. Heaver *et al*. (2001) indicated that the dedicated terminal is an important form of joint venture between shipping liners and container ports/terminals, which has been implemented by many container shipping lines, e.g. Maersk/Sea-Land, P&O Nedlloyd and the other members of the Grand Alliance, and World Alliance.

Several studies stated that the collaboration strategies in container shipping include joint fleet, slot charter, slot purchase, and slot exchange (Cullinane and Khanna, 1999; Song and Panayides, 2002; Shry *et al*., 2003; Notteboom, 2004; Lu *et al*., 2010; Chow and Chang, 2011). Cullinane and Khanna (1999) found that through joint services, the benefit of economies of scale is significant when ship sizes are above 8,000 TEU for both the Europe-Far East and trans-Pacific trade, and for ship sizes between 5,000 and 6,000 TEU on the shorter trans-Atlantic trade. Lu *et al*. (2010) stated that slot exchange allows the companies to use the recognised capacities of the group of container shipping companies not operated by them; and if the exchanged slots are insufficient, more slots can be purchased from its partners in the group.

Merging or acquisition is a common method to make a company rapidly increase market share. In the container shipping industry, there are many cases that a shipping company merges with or acquires other liner companies. Notteboom (2004, p. 90) stated "*the economic rationality for mergers and acquisitions is rooted in the objective to size, growth, economies of scale, market share and market power. Other motives for mergers and acquisitions in liner shipping related to gaining instant access to markets and distribution networks, obtaining access to new technologies or diversifying*". For example, two of Germany's shipping companies plan to merge recently to reduce pressure from tumbling charter rates (Barnard, 2011); the first large merging occurred between P&O Containers and Royal Nedlloyd in 1997, although this merger produced some problems, the benefits of merger still outweighed initial difficulties (Bonney, 2011). In 2005, Maersk Sealand acquired P&O Nedlloyd to become Maersk Line.

Table 2.4 summaries the risk mitigation strategies in container shipping operations from previous studies.

Table 2.4 The risk mitigation strategies in container shipping operations

Risk mitigation strategies	Authors
Add buffer time when designing routes	Notteboom (2006); Notteboom and Vernimmen (2009)
Omit pot-of-call when transportation delay happen	Notteboom (2006); Kerr (2011b)
Implement slow steaming to reduce the oil price rise	Notteboom (2006); Notteboom and Vernimmen (2009); Ronen (2011); Cariou (2011); Qi and Song (2012); Maloni *et al*. (2013)
Use more advanced information technology	Marle (2009); Kerr (2011a)
Train employee regularly	Young (2010); Ganesan (2010)
Enter into long-term contracts with shipper	Notteboom (2004)
Make collaboration with partners	Baird and Lindsay (1996); Graham (1998); Carious (2001); Heaver (2002); Notteboom (2004), (2006)
Make alliance with other container shipping companies	Ryoo and Thanopoulou (1999); Heaver *et al*. (2000); Slack *et al*. (2002); Song and Panayides (2002); Notteboom (2004); Lu *et al*. (2010)
Joint fleet, slot charter, slot purchase, and slot exchange with other container shipping companies	Cullinane and Khanna (1999); Song and Panayides (2002); Shry *et al*. (2003); Notteboom (2004); Lu *et al*. (2010); Chow and Chang (2011)
Merge or acquisition other container shipping companies	Notteboom (2004); Barnard (2011)

2.3 Research Gaps

As mentioned in the Introduction, the role of container shipping is becoming more and more important in global economics. Meanwhile container shipping business is to facing various types of risks, it is therefore necessary to know what the risks are and how to mitigate these risks.

Although the studies reviewed in this Chapter have provided some very valuable insight on risks and risk management in container shipping operations, the research in this area is still rather fragmental. For example, the majority of the existing studies focused on dealing with the risks caused from cargo delivery.

There is a lack of research that explicitly considers the risk management in container shipping from a comprehensive logistics perspective including physical flow, information flow and payment flow.

To the best of our knowledge, no studies so far have approached the risk management issue from a perspective that inclusively examines all the possible operational risks and risk mitigation strategies faced by a container shipping company and comprehensively evaluates the relative importance of each of them. Note that the resource of each container shipping company is limited, every company has to firstly mitigate the most imminent and significant risk factors. This makes it important to analyse the extent to which each risk affects the performance of shipping company and to identify the relative importance of each risk factor. Equally important, although many risk mitigation strategies could be used to reduce the impact of risks, their effectiveness may vary significantly. It is therefore necessary to evaluate the relative importance of different mitigation strategies under a given performance criterion.

Chapter 3 Conceptual model

In this chapter, three main logistics flows in container shipping operations will firstly be presented to build up the research structure in Section 3.1. Section 3.2 discusses the development of risk management model in the context of container shipping operations will be discussed. Section 3.3 presents the risk management steps as the main guideline to structure the research process in this thesis. Section 3.4 is the summary of this chapter.

3. 1 The three flows in container shipping logistics operations

The majority of the literature in Chapter 2 address the risk factors and risk mitigation strategies in physical part. In addition, these previous studies focus on one or two or several risk factors and risk mitigation strategies and this is fragmental and insufficient. In fact, there have been discussed various aspects in container shipping operations from a logistics perspective (See Section 2.3). In order to develop a conceptual model on risk management in container shipping operations, this thesis firstly introduces the three main flows in general supply chains and then discuss how they work in container shipping operations.

There are various classifications of supply chain flows. For example, Mentzer *et al*. (2001) stated that supply chains require coordinated goods flows, services flow, information flow and money flow with and across national boundaries. Ayers (2006) stated that there should be four major flows in a supply chain, including physical flow, information flow, financial flow, and knowledge flow whose purpose is to satisfy end-user requirements with physical products and services from multiple, liked suppliers. He also supported the supply chain definition from American Production and Inventory Control Society, and stat that "physical, information, and financial flows are frequently cited dimensions of the supply chain, the viewpoint, a very common one, of supply chains as only physical distribution is too limited. Information and financial components are as important as physical flow in many supply chains" (Ayers, 2006, p.5). Fawcett *et al*. (2007) stated that information flow, physical flow and financial flow are three major flows in process management. Mangan *et al*. (2008) stated that supply chains includes three key flows, namely, physical flows of materials, flows of information that inform that supply chain, and resources flow which help that supply chain to operate effectively. They, furthermore, think that not all resources are tangible in the supply chain, such as good partner-relationships in supply chains. The most common classification of supply chain flows includes information flow, physical/ cargo flow, and payment/ financial flow (e.g. Premkumar, 2000; Chopra and Meindl, 2007).

3.1.1 Information flow

Information flow in logistics normally refers to the information/knowledge collection and transfers between manufacturers, transportations, retailers and customers. The information includes the data or documents that need to be transferred for cargo processes. Information flow is an important factor in supply chains. Chopra and Meindl (2010, p.60) stated that "information consists of data and analysis concerning facilities, inventory, transportation, costs, prices, and customers throughout the supply chain. Information is potentially the biggest driver of performance in the supply chain because it directly affects each of the other drivers. Information presents management with the opportunity to make supply chains more responsive and more efficient.” Coyle *et al*. (2003) argued that the directions of information flow not only involve the flows from downstream to upstream (in traditional viewpoint), but also include the opposite directions and the flows between supply chain members for replenishing orders. From a customer-oriental perspective (e.g. retailer), Fawcett *et al*. (2007, p.376) stated that the process of supply chain relies heavily on information flows about the product or service life cycle. Information flows can therefore enhance the value-added activities and make the operation more efficiently within a set of supply chain networks. Handfield and Nichols (1999) stated that “little doubt remains about the importance of information and information technology to the ultimate success, and perhaps even the survival, of any supply chain management initiative.”

Several studies have mentioned the processes of information flow within a supply chain, which usually involves cargo flows. For example, Wilson (2007) presented a traditional structure of goods flow and information flow in supply chains in Figure 3.1, in which includes six basic entities, namely, raw material supplier, supplier (Tier 2) for incoming raw material converted into subassemblies, supplier (Tier 1) subassemblies converted into final goods, warehouse, retailer, and customer.

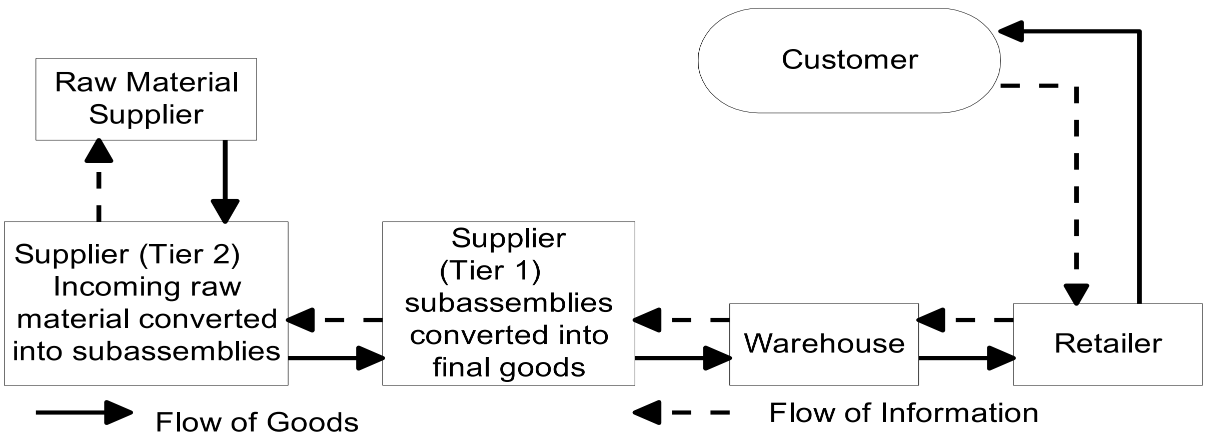


Figure 3.1 Flow of goods and information: the traditional structure

Source: Wilson (2007)

Moreover, Christiaanse *et al*. (1996) proposed a flow chart (Figure 3.2) within the traditional intercontinental air cargo supply chain, which was adapted from Zijp (1995) and involved physical flow of goods and 16 steps of information flow (with the numbers in Figure 3.2). In the flow chart, the information flows connect between almost every entity in this supply chain.

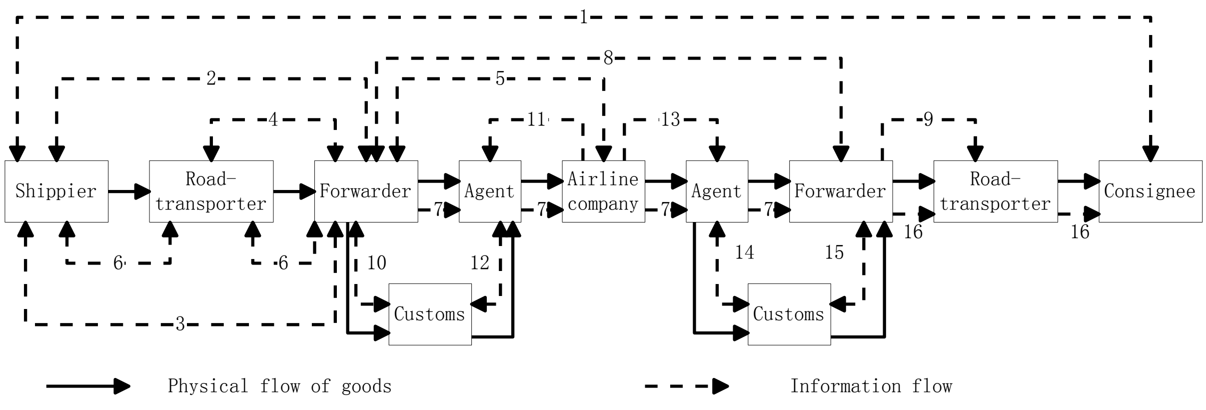


Figure 3.2 Physical flow and information flow in the air cargo supply chain

Source: Christiaanse *et al*. (1996) adapted from Zijp (1995) "Telematics in Air Cargo"

A typical information flow in the container shipping services is developed by the author which is presented in Figure 3.3 based on the flow chart of Christiaanse *et al*. (1996), Lu and Wang (2008) and WanHai Line (no date). Firstly, the Consignee will enquire and negotiate the price of the cargo several times and make a contract with the Consignor. Following that, the Consignee needs to apply for a Letter of Credit (L/C) from the Paying Bank (Bank2) by the Consignee itself or through the Broker2 (who arranges transactions between the consignor and the consignee), and Bank2 will transfer the L/C to the Consignor through the Advising/Notifying Bank (Bank1). At the same time, the Consignee/Broker2 has to apply for import documents from the Government2, and waits for the import documents returning back from the Government2; the Consignor/Broker1 also has to apply for export documents from the Government1, and waits for the export documents returning back from the Government1. The Consignor/Broker1 can directly or indirectly via the forwarder to ask freight price and book container space from the shipping company. After transferring goods information (Shipping Order, S/O) to the Shipping company (or through the Forwarder), the Consignor will receive the documents of Bill of Lading (B/L) from the Shipping company or through the Forwarder. Next step, the Consignor/Broker1 needs to declare export to the Customs1, and the Customs1 will check and discharge the cargos in the Container Yard (CY1). Following that, the Shipping company contacts the CY1 to load the cargo to the container ship. The Consignor/Broker1 will transfer the B/L and shipping documents to the Consignee/Broker2 through the Bank1 and Bank2. After the goods arriving at the port of destination and unloading the goods to the CY2, the shipping company will inform the Consignee/Broker2 that cargos have arrived and ask the Consignee/Broker2 to use the B/L to exchange a Delivery Order (D/O). At the same time, the Consignee/Broker2 needs to declare import to the import customs or entrust the customs agency. Finally, the Consignee can take the D/O to exchange the goods from the CY2.

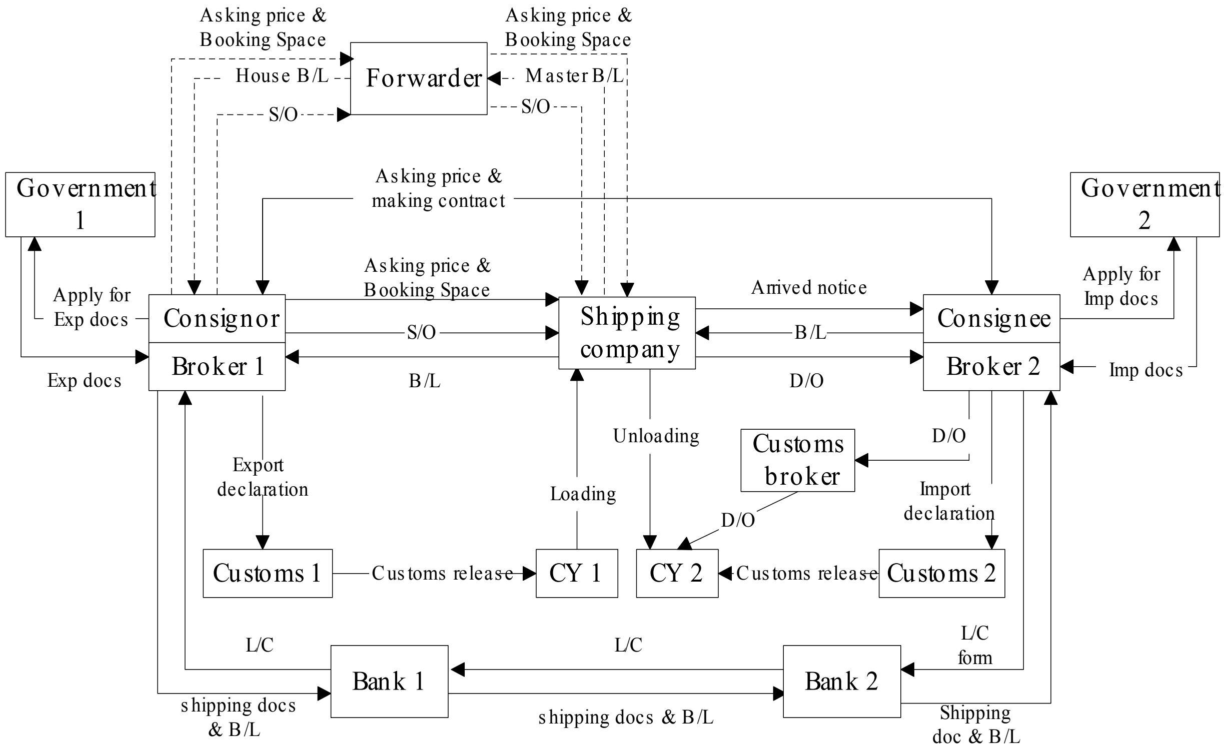


Figure 3.3 Information flows in container shipping services

Source: author

3.1.2 Physical flow

Physical flow generally refers to that goods such as raw materials, finished goods, and return/recycle products are transferred from business sectors to customer sectors in a supply chain. Chopra and Meindl (2010, p.60) stated that "transportation entails moving inventory from point to point in the supply chain". Transportation can take the form of many combinations of modes and routes, each with its own performance characteristics. Coyle *et al*. (2003) stated that products and related services flow has traditionally focused on the logistics section and is still an important element in supply chain management. In a transportation industry, it is essential that cargos can be delivered in a timely, reliable, and damage-free manner are essential. As a type of transportation industry, physical flow is the most important concern in container shipping domain. The flow of cargos is delivered from consigners to consignees through various transportation types such as trailers, trains, airplanes and ships. Cargo delivery on time and safety are the main elements that have to be considered in container shipping operations.

The physical flows in container shipping services refer to the movement of container cargos. Figure 3.4, designed by the author, illustrates the physical flows in a container shipping services, the Consignor transports goods to the inland deport or the Container Yard (CY1) through an Inland Transportation firm 1. Following that, the goods are transferred to the port of loading to wait for loading. In the next step, the goods are loaded on ship and transported to the Port of destination or several transhipment ports by the shipping company. Finally, the goods are unloaded and transported to the consignee by another Inland Transportation firm 2. Cavinato (2004) also stated that physical flow involves transportation, warehousing, checking goods by customs, handling, and other forms of activities.

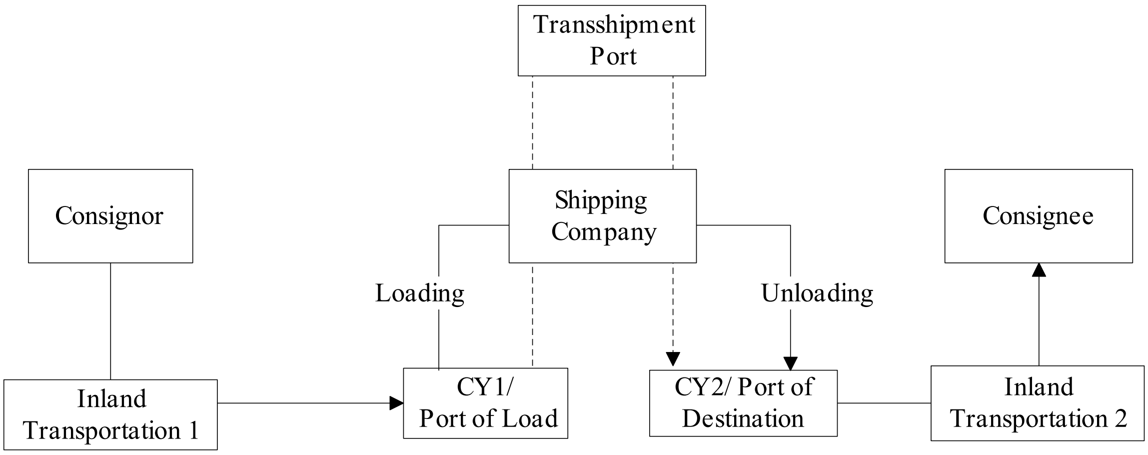


Figure 3.4 Physical flows in container shipping services

Source: author

3.1.3 Payment flow

Payment flow refers to monetary payment from the customer sector to the business sector that provides goods or services. Coyle *et al*. (2003) stated that, payment flow traditionally has been deemed as one-directional in a supply chain or, in other words, payment for goods and services. Fawcett *et al*. (2007) stated that cash flow can be divided into cash entries and cash out. Cash enters a business from three sources, including creditors make loans, investors provide new capital, and operations generate cash; whilst the purpose of cash out is to pay for the goods and services used in operations.

This thesis adapts the payment flow chart from several reports, e.g., Lu and Wang (2008), KLS Logistics (no date), and organises the whole payment flows in a container shipping services showing in Figure 3.5. At first, the consignor and the consignee have to agree the terms of sale (contracts) according to the International Commercial terms (INCOTERMS), which was issued by the International Chamber of Commerce. Each INCOTERM refers to a type of agreement between the consignor and the consignee for the purchase and shipping of goods. There were 13 different terms in 2000 and these were reduced to 11 rules in 2010, each of which helps users deal with different situations involving the physical movement of goods and the payments. For example, EXW (EX-works) is one of the simplest and most basic shipment arrangements in which the consignor has the minimum responsibility. Under EXW terms, goods are made available for collection at the consignor's factory or warehouse and the consignee or its forwarder is responsible for making arrangements for insurance, export clearance, handling of all other paperwork, and the movements of the goods. FOB (Free On Board) is a commonly used terms, in which the consignor or its forwarder takes the responsibility to move the goods to the port or designated point of origin. The consignee or its forwarder will take the responsibility for insurance and transportation after that point. The terms of sale is closely linked to the payment. In most cases, the payment is triggered at the point when the ownership of the goods (or the responsibility of goods movement) is transferred from the consignor to the consignee.

The payment flow between the Consignee and the Consignor involves not only international banks in both countries, but also the Shipping companies' supply chain partners. In Figure 3.5, designed by the author, the payment flow could start at the Bank1 to the Consignor. After the contract made by the Consignor and the Consignee, the Bank2 will check the credit of the consignee, and then the Bank1 will pay the money of goods to the consignor. The consignor will pay the money of freight and commission to the Shipping company in order to book the cargo space through the forwarder. The Consignor can also book the cargo space from the Shipping company without the forwarder if the Consignor has a huge transportation demand. This payment might also be paid be the Consignee if the contract is EXW. Simultaneously, the Consignor needs to pay the money of freight to the Inland Transportation 1 in order to transport the cargo from the factory or warehouse to the port of load. After the cargo arriving port of destination, the consignee needs to pay the money of freight to the Inland Transportation 2 for collecting and transporting the cargos to the consignee.

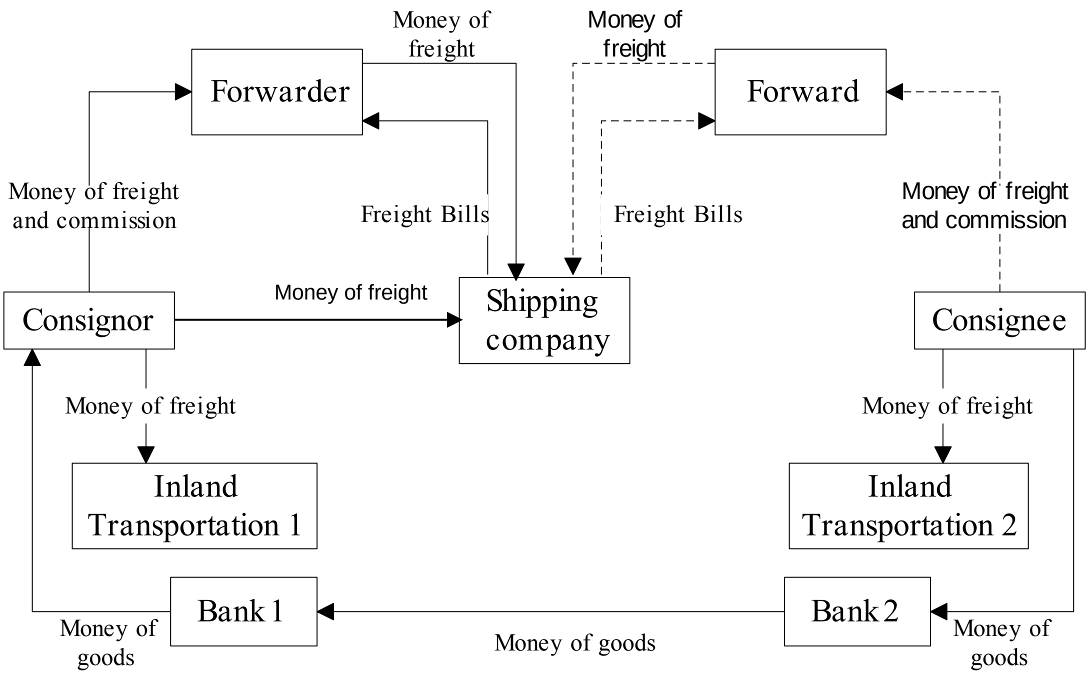


Figure 3.5 Payment flows in container shipping services

Source: author

3.2 Development of risk management model in the context of container shipping operations

Several studies have addressed the risk models in different industrial sectors. Some of them focused on uncertainty identification and mitigation. The following sections will discuss the details from “uncertainty model” to “risk model”.

Davis (1993) proposed that there are three distinct sources of uncertainty that impact on supply chains: suppliers, manufacturing, and customers. He also stated that it is essential to measure all of them to reduce the uncertainty. Mason-Jones and Towill (1998) proposed a model of the causes of uncertainty in the product delivery process (Figure 3.6). Within the product delivery process, four main uncertainty sources are included: the supply side, the manufacturing process, the demand side, and the control systems. In order to reduce uncertainties in supply chains, it is important to understand and tackle the root causes in these four sources, and how they interact with each other. They suggested that lean-thinking principles can be used to deal with the uncertainty in the supply side and or in the manufacturing process; whilst understanding dynamics of the whole system can help to manage the uncertainty happening in control systems and/ or in demand side.

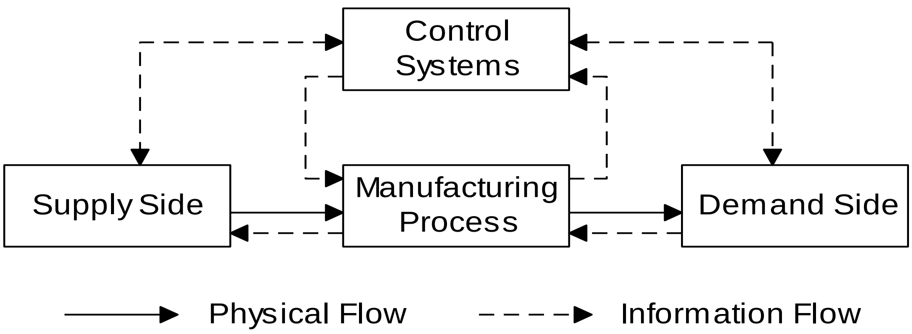


Figure 3.6 Uncertainty model in the product delivery process

Source: Mason-Jones and Towill (1998)

Based on Mason-Jones and Towill's (1998) research, Rodrigues *et al*. (2008) proposed a logistics triad model with five uncertainty sources (including shipper, carrier, customer, control systems and external) and three flows (physical flow, information flow, and relationships) (Figure 3.7). Various strategies are also proposed to tackle the five uncertainty sources. Rodrigues *et al*.'s (2008) model is based on the general transportation uncertainty model, whilst this thesis focuses on the risk of container shipping operations. It is considered as a base model that can be extended to the conceptual model of this thesis.

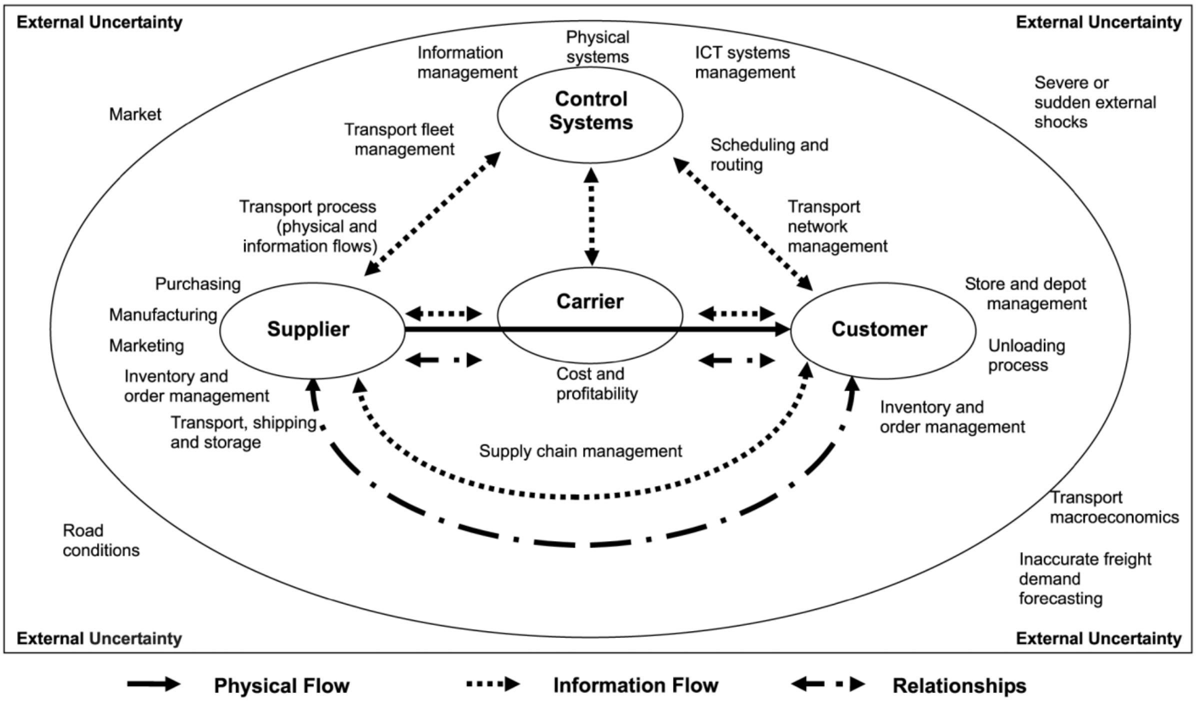


Figure 3.7 Uncertainty logistics triad model

Source: Rodrigues *et al*. (2008)

Regarding uncertainty as risk, Christopher and Peck (2004) presented a model to categorise supply chain risks (Figure 3.8) based on Mason-Jones and Towill's (1998). Three main risk categories are proposed: internal to the firm (includes the process risk and the control risk), external to the firm but internal to the supply chain network (includes demand risk and supply risk), and external to the network (called as environmental risk). Process risk relates to disruption to the internal-organisation processes, which are the arrangements of management activities undertaken by the company. Control risk refers to the risks arising from the application or misapplication of some rules that control the process, such as the risk from order quantities or safety stock policies. Demand risk refers to the risks from the product flow, information flow, and cash flow in the network from the focal company to its downstream entities; whilst supply risk arises in the network from the focal firm to its upstream entities. Environment risk refers to the risks that are external to the network of organisations, and it may have impact on the focal company or on the upstream or downstream entities.

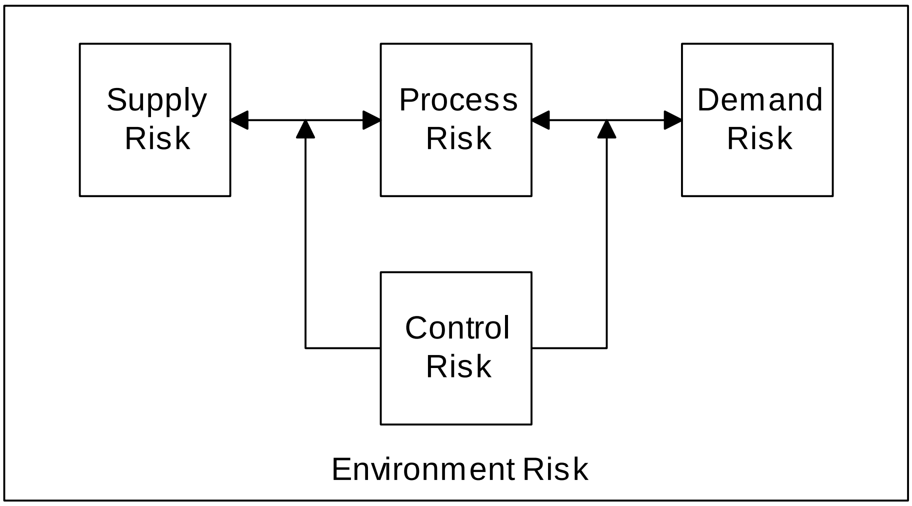


Figure 3.8 Sources of risk in the supply chain

Source: Christopher and Peck (2004)

Jüttner *et al*. (2003) presented a basic supply chain risk management model (Figure 3.9) including risk sources, risk drivers, risk mitigating strategies, and risk consequence. Within this model, the risk sources have the impact on supply chain risk consequence. However, the path of the impact could be impacted by the other two dimensions. The “supply chain risk drivers” has a positive impact on this path; whilst the “supply chain risk mitigating strategies” has a negative impact on this path. The model is designed for general supply chain systems but is rather conceptual. No applications have been reported.

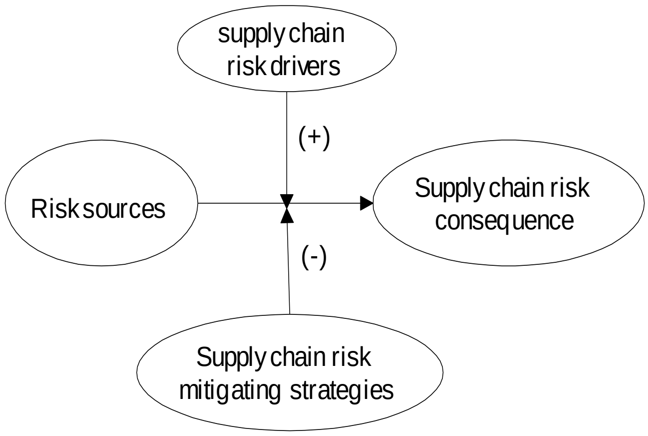


Figure 3.9 Supply chain risk management model

Source: Juttner *et al*. (2003)

Trkman and McCormack (2009) proposed a model for managing supply chain network risk with the emphasis on supplier risks (Figure 3.10). The model is built based on the characteristics and the structure of the supply chain, a supplier's attributes and performance, and two supplier's specific environment uncertainties (endogenous and exogenous). The endogenous uncertainty (market turbulence and technology turbulence) and the exogenous uncertainty (such as interest rates, terrorism, and strikes) of each supplier are key factors to affect the relationships between supplier attribute, supply chain strategy and structure, and supplier risk of non-performance or disruption in a supply chain. Although this model includes various types of uncertainty in supply chains, some of them such as CPI and GDP and even endogenous uncertainty are beyond the scope of this study, because this thesis only focuses on the risks happened during cargo transportation.

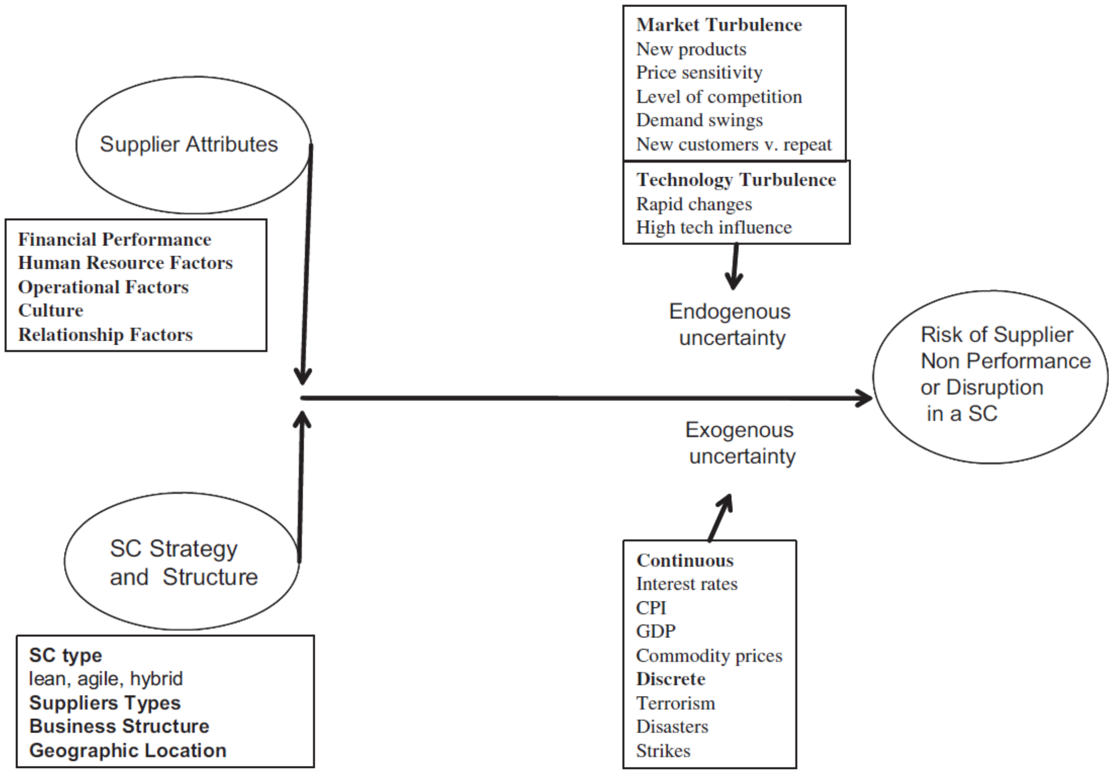


Figure 3.10 A model for managing supply chain network risk

Source: Trkman and McCormack (2009)

Based on the above models (i.e. Figure 3.6, Figure 3.7, Figure 3.8, Figure 3.9, and Figure 3.10), the literature review in Chapter 2, and the emphasis on logistics flows, this thesis proposes a research conceptual model as shown in Figure 3.11. This conceptual model firstly identifies risk and categorises the risks in container shipping operations into three groups, i.e. risks associated with information flow, risks associated with physical flow, and risks associated with payment flow. The literature review related to the risks associated with these three flows will be discussed in Chapter 5 as the literature review is one of the methods for risk identification that has been used in this thesis and therefore should be located at that point in the discussion. Secondly, the risk factors are analysed through risk scale, which is multiplied by risk likelihood and risk consequence (the details of risk likelihood, risk consequence, and risk scale will be discussed in Section 4.2.1.3). Thirdly, risk mitigation strategies are to be identified to improve shipping companies' performance. Finally, the impact from risk mitigation strategies to company performance will be evaluated.

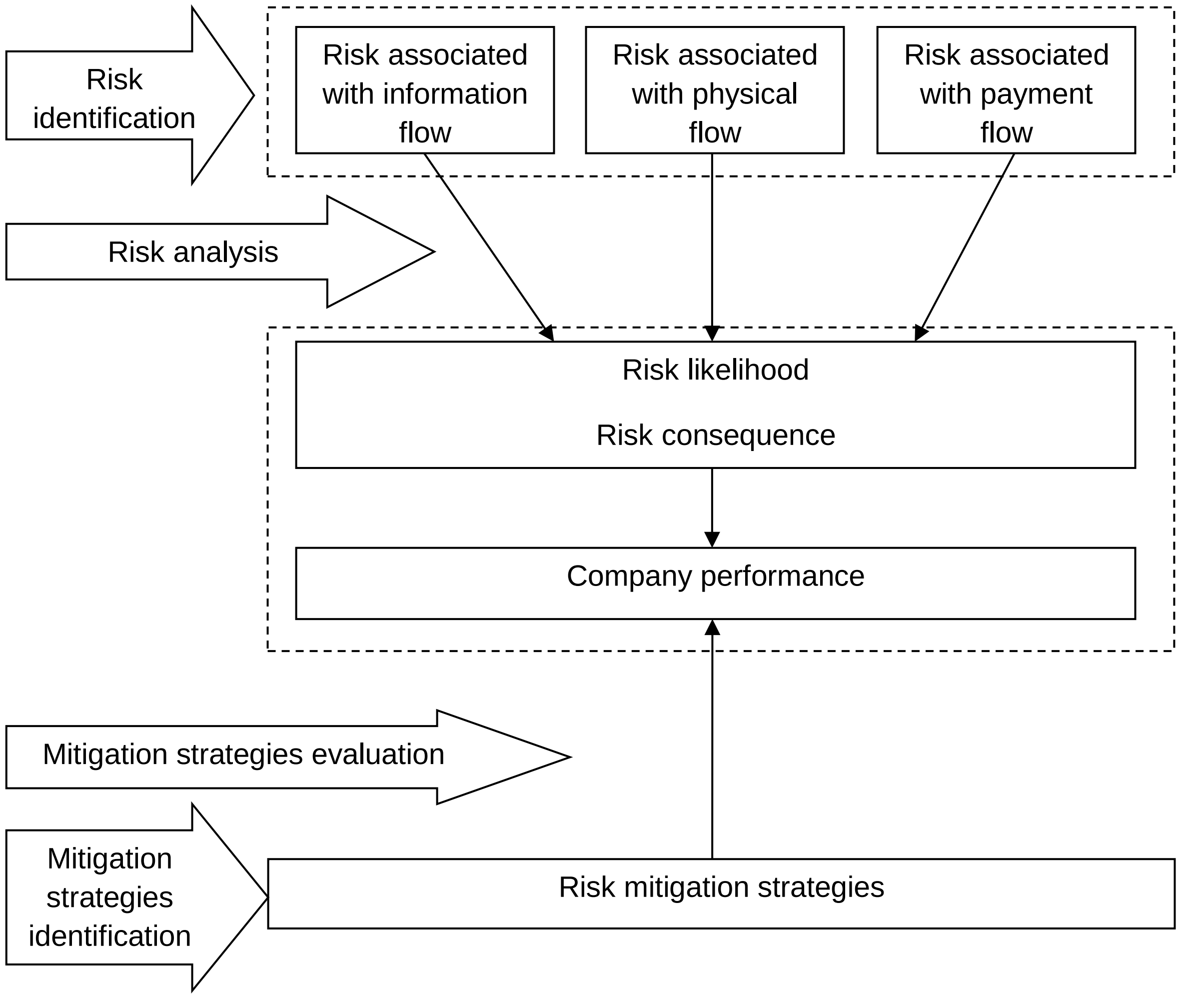


Figure 3.11 Conceptual model

Source: author

The three logistics flows between relevant entities in the container shipping business are illustrated in Figure 3.12, which includes three flows that have been presented in previous sections, and multiple entities such as shipping companies, other transport companies, agency related companies, consigner, consignee, and bank. One objective of this thesis is to identify the risk factors within the three flows in container shipping operations.

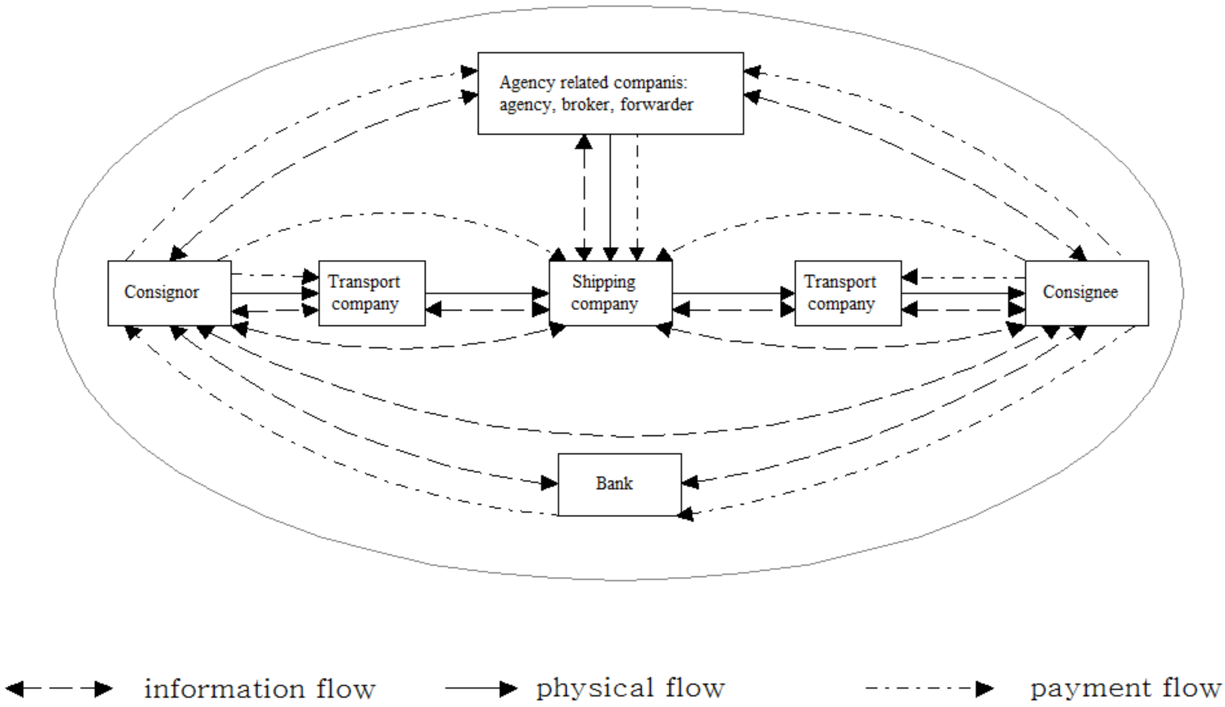


Figure 3.12 The three flows in container shipping operations in the conceptual model

Source: author

3.3 Risk management steps

The process of risk management has been addressed by many researchers. For example, Norrman and Jansson (2004) stated that the risk management processes broadly include understanding the risks, and managing the risks to minimise their impact by addressing probability and impact. These two processes can be further divided into more detailed stages from risk identification via risk analysis to different ways of risk management. Sung (2005) reported five steps of risk management as: (1) Identifying and measuring loss exposure; (2) Identifying and examining alternative techniques for dealing with this exposure; (3) Selecting the most appropriate risk management alternatives consistent with the organisation's risk financing philosophy; (4) Implementing the selected alternatives; and (5) Monitoring and improving the selected alternatives. Several studies use the term "risk assessment" to represent risk management. For example, Christopher *et al*. (2002) stated that "to assess supply chain risk exposures, the company must identify not only direct risks to its operation, but also the potential causes or sources of those risks at every significant link along the supply chain". van Duijne *et al*. (2008) stated three stages of risk assessment including risk identification, risk estimation, and risk evaluation. Blackhurst *et al*. (2008) claimed that the most important step in the process of risk assessment is the selection and definition of the risk categories, which can be weighted, compared and quantified. Zsidisin and Ellram (1999) organised the supply risk management process for a high-tech company and proposed ten sub-processes (Figure 3.13): identify material or service, appoint manager to own the process, initiated risk assessment score card (which includes eight risk factors: design, cost, legal, availability, manufacturability, quality, supply base, and environmental, health and safety impacts), review criteria for each risk factor, collect data for each risk factor, assign risk scores, conduct impact analysis, document analysis and actions, monitoring, and determine to cease assessment.

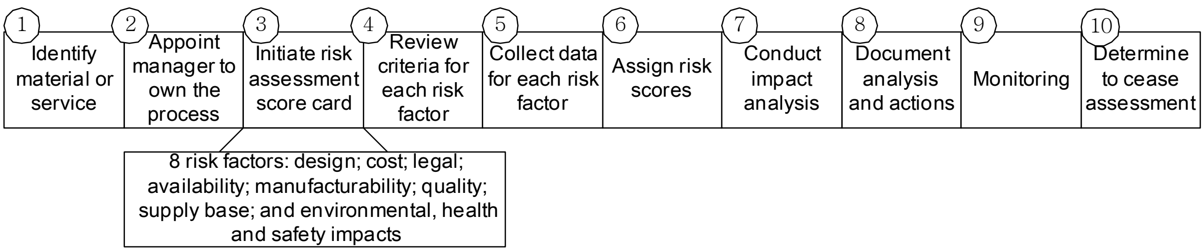


Figure 3.13 Supply risk assessment processes

Source: Zsidisin and Ellram (1999)

Generally speaking, the steps of risk management include risk identification, risk measurement and analysis, and risk mitigation strategies development and evaluation. This thesis will follow the above risk management steps.

3.3.1 Risk identification

Risk identification is the first step in the process of risk management (e.g., Waters, 2007; Tummala and Schoenherr, 2011), and it is an important stage in the risk management process because decision-makers can become aware of the unfavourable factors in the projects by risk identification (Norrman and Jansson, 2004). Risk identification produces a list of risks that impacts on an organisation or even the whole supply chain (Waters, 2007). There are various risk classifications in the literature. For example, Jason-Jones and Towill (1998) stated that risks within supply chains can be divided into internal risks, supply chain risks, and external risks. Shimpi (2001) illustrated that organisational risks consist of financial, political, operational, and legal liability. The Institute of Risk Management (2002) stated that risk categories include strategic risk, operational risk, financial risk, and hazard risk. Waters (2007) identified several risks in a supply chain, such as physical risks, financial risk, information risks, and organisational risks. Manuj and Mentzer (2008a) classified risks into eight categories: supply risks, operational risks, demand risks, security risks, macro risks, policy risks, competitive risks, and resource risks. Vilko and Hallikas (2011) selected five risk categories out of the above eight (by excluding demand risks, competitive risks and resource risks) and added a new risk category called environment risk. In this thesis, we try to identify risks from the three logistics flows in container shipping operations.

3.3.2 Risk measurement and analysis

Risk measurement and analysis is the second step in the risk management process. It provides a quantitative view of the severities of the risks and helps decision-makers know which risks should priority to be managed.

There are various methods for risk measurement and analysis. One common method is to compare the risk factors through their likelihood and consequences (Tummala and Schoenherr, 2011) and put them into a risk matrix/map (Yang, 2010, 2011), which can provide a straightforward ranking according to the risk severity. However, the risk consequence varies (NPSA, 2008): some consequences are more tangible and easy to evaluate, such as financial loss; whereas the others may be intangible and difficult to evaluate (Waters, 2007), such as reputational loss. Damage to maritime safety and security caused by, e.g., piracy attacks, bad weather conditions and dangerous working environment in container shipping operations is indeed a serious risk consequence (Tzannatos, 2003; IMO, 2009). Notably, some of the damages are measurable by monetary terms and some, such as pain and suffering of the crew and their families, may not be measured directly by monetary terms. The following sections introduce the three risk consequences, including financial loss, reputation loss, and safety and security incident related loss.

3.3.2.1 Financial loss

Financial loss is the most common measure phrased in terms of a cost and it can be obtained by actual calculations or estimated from historical data, e.g. a lost load of goods which may have a clear monetary value. Container shipping companies have to tackle many risks that cause financial loss. A number of studies have addressed different financial related loss, e.g., Tzannatos (2003), Elky (2006), Notteboom (2006), Notteboom and Vernimmen (2009), Ronen (2011) and Vilko and Hallikas (2011).

3.3.2.2 Reputational loss

Although financial loss is probably the most concerned consequence in relation to risks, the monetary value is not always appropriate or obtainable, e.g. a delivery may be delayed, which may incur not only penalty but also loss of goodwill. Due to the intangible characteristics of some risk consequence and/or the difficulty to quantify the impact, this type of consequence is not very suitable to be measured in financial terms. Alternative measures may be more appropriate, e.g. reputation loss (Bebbington *et al*., 2008). Many studies have pointed out that the reputation of container shipping companies is an important asset and can be a critical factor for shippers selecting the container shipping companies (e.g., Brooks, 1985; Javidan, 1998; Yang *et al*., 2009).

3.3.2.3 Safety and security incident related loss

Safety and security has been an increasing concern in the maritime domain over the past few decades; and it has been further highlighted recently by the problem of piracy in Somalia. A number of international conventions and legislation, such as SOLAS (International Convention for the Safety of Life at Sea) and IMDG code (the International Maritime Dangerous Goods code), have been adopted by the International Maritime Organization (IMO) in order to reduce the risks and the impact of damage in relation to maritime safety and security incidents. However, maritime safety and security incidents still occur from time to time and in most cases, huge damage could be incurred.

There have been a great number of studies on maritime safety and security in the academic field. It is commonly recognised that maritime safety and maritime security are quite different from each other in their nature and cause. Maritime safety incidents are normally caused by technical failure or human elements whereas maritime security incidents are normally caused by piratical or terrorist attacks. In the thesis, however, these two phenomena are analysed together as a group from the perspective of risk consequence, which is the standpoint of this thesis.

A number of articles focus on maritime safety. For example, Håvold (2005) addressed safety culture in a Norwegian shipping company and classified the risks into 11 factors, including knowledge, management attitude to safety, safety behaviour, attitude to safety rules/instruction, employees satisfaction with safety and quality, concentration of authority, training experience, quality experience, stress experience, actions after an unsafe act, and environmental systems. Hetherington *et al*. (2006) state that human factors issues (including fatigue, stress, health, situation awareness, teamwork, decision-making, communication, automation, and safety culture) are the major one which cause maritime problems. The articles focusing on security in the shipping industry have been increasing recently. For example, Roach (2004) focused on the security management to terrorism threats in a shipping company, such as the principles of co-operation and flag state jurisdiction which provide the legal foundation for ship boarding and enforcement; Thai (2007) investigated the impacts of security improvements in maritime transport using an empirical study of Vietnam; Lun *et al*. (2008) discussed the security enhancement of container transportation through the adoption of technology. Yang (2010, 2011) focused on the risk management of Taiwan's container shipping supply chain security, and the result was reported that "cargo cannot be shipped on time and is shut out by the customs authority" is the top container security initiative related factor in terms of risk severity (see Chapter 2).

3.3.3 Development and evaluation of risk mitigation strategies

Risk mitigation strategies making, monitoring and evaluation is the last step in the risk management processes. Managers need to make the right strategies corresponding to the risks to mitigate their impacts on the companies. In some studies, this step is also called risk management, which is defined as "the process whereby decisions are made to accept a known or assessed risk and/or the implementation of actions to reduce the consequences or probability of occurrence" (Norrman and Jansson, 2004, p.438).

3.4. Chapter summary

This chapter develops a conceptual model based on several existing risk models and the consideration of three flows in container shipping logistics operations. This thesis classifies the risks into three categories, namely, risks associated with information flow, risks associated with physical flow, and risks associated with payment flow. The conceptual model includes three parts, i.e., container shipping operations (which is organised by the three logistics flows), three risk categories (which have negative impact to the container shipping service and include financial loss, reputation loss, and safety and security incident related loss), and several risk mitigation strategies (which have positive impact on the container shipping service). The steps of risk management were also introduced, including risk identification, risk measurement and analysis, and risk mitigation strategies development and evaluation.

Chapter 4 Research methodology

Chapter 4 presents the research methodologies that will be used in this thesis. Section 4.1 introduces Taiwan’s container shipping industry; Section 4.2 presents the data collection methods; Section 4.3 discusses several methods for data analysis, which includes two major parts: risk analysis methods (risk scale ranking, risk matrix, risk map, and P-I graph) and risk mitigation strategy evaluation methods (classic AHP and fuzzy AHP); and Section 4.4 summarises the chapter.

4.1 Case study: Taiwan’s container shipping industry

Owing to its island geography, Taiwan largely relies on international trade. Most of the materials for manufacturing are imported by ships, and therefore the shipping industry plays an important role in Taiwan’s economy. According to official statistics (Ministry of Transportation and Communications, 2011), around 99% of international trade in Taiwan is transported by sea.

Based on the reason above, this thesis uses Taiwan’s container shipping industry as a case study. Case study is defined as “*analyses of persons, events, decisions, periods, projects, policies, institutions, or other systems that are studied holistically by one or more methods. The case that is the subject of the inquiry will be an instance of a class of phenomena that provides an analytical frame — an object — within which the study is conducted and which the case illuminates and explicates*” (Thomas, 2011). This case study will focus on Taiwan’s main container shipping companies and shipping agents (also called freight forwarders), from which the empirical data will be collected. The results will be expanded to general research as the obtained samples are represented. The author first introduces the three largest Taiwan container shipping companies: Evergreen Line, Yang Ming Marine Transport Corp., and Wan Hai Lines, and then discuss the shipping agent industry in Taiwan.

According to Alphaliner database (2012), Evergreen Line is the 4th large container shipping company in the world in 2012. Owning 187 container ships, Evergreen Line services more than 80 countries and covers Asia, America, Europe, Middle-East, Austria, and Africa. A total 735,662 TEU capacity was provided in 2012 (Alphaliner, 2012). Evergreen Group has also invested several sub-companies such as Evergreen International Storage & Transport Corp. and Evergreen Logistics Corp. (www.evergreen-group.com). Evergreen Line also joins a strategic alliance with Yang Ming Marine Transport Corp. and Orient Overseas Container Line (OOCL) to provide Taiwan/Hong Kong/Ho Chi Minh Express Service (THX).

According to Alphaliner (2012) database, Yang Ming Marine Transport Corp. was the 16th container shipping company in the world in 2010 and grew to 15th in 2012. Yang Ming Marine Transport Corp. is the second largest container shipping company in Taiwan, and it owns 82 container ships with total 346,972 TEU carrying capacity in 2012 (Alphaliner, 2012). The service covers Asia, Europe, America, Australia, and Africa with more than 190 branches. Several sub-companies are invested by Yang Ming Group to enhance their service quality such as YES Logistics Corp., Kao Ming Container Terminal Corp., and Jing Ming Transport Corp. Yang Ming Marine Transport Corp. is a member of CKYH Alliance (including COSCO, K-Line, Yang Ming and Hanjin shipping), which is the top container shipping strategic alliance in the world (www.yangming.com).

Wan Hai Lines is the 21st largest container shipping company in the world with a total 75 container ships and 158,048 TEU carrying capacity in 2012 (Alphaliner, 2012). The main business of Wan Hai Lines focuses on Asia, and it has the more routes in Asia countries than the previous two companies. Its service also covers Middle-East, America, Europe, and Africa. Wan Hai Group also invested several sub-companies to provide a quality shipping supply chain service, including Wan Hai Logistics and several related companies. Wan Hai Lines co-operates several service routes with other container shipping companies such as Yang Ming Marine Transport Corp. and Evergreen Line. (web.wanhai.com.tw)

In terms of shipping agents in Taiwan, there are 333 companies registered in Taiwan Shipping Agencies Association in 2011 (unpublished list), in which 155 companies are in Taipei, 41 companies in Keelung, 97 companies in Kaohsiung, 29 companies in Taichung, and 11 companies in Hualien. Shipping agent means "person and establishment who act on behalf of ship owner, captain, operator or ship leaser by the agreements entered between them, and who protect their rights against third parties and establishments, who perform their obligations in the agreement, and get paid for these actions" (www.deepbluemaritime.com/).

Due to the research topic of this thesis which focuses on risk management in the container shipping industry, many companies in the list of Taiwan Shipping Agencies Association are not suitable because this list includes some companies not related to container shipping such as bulk shipping companies.

This thesis has to narrow down the target population to the companies related to container shipping, so that this can match our research objective 2, 3 and 4. This thesis therefore identified 116 container shipping companies and container shipping agents from the list as the target population. The whole identified population will be used as samples in this study. Table 4.1 presents part of the target samples: ten selected container shipping agencies (in the right column) who serve international container shipping companies in Taiwan (in the left column).

Table 4.1 Selected container shipping agents

International container shipping companies	General agent in Taiwan
Maersk Sealand	Maersk Taiwan
CMA/CGM/ANL	CMA CGM (Taiwan) Ltd
CCNI	Wilhelmsen Ships Service Inc.
CSAV	CSAV Group Agencies (Taiwan) Ltd. (Taipei)
Hyundai Merchant Marine	Hyundai Merchant Marine (Taiwan) Co., Ltd.
K LINE	"K"LINE (Taiwan) Ltd.
Hapag-Lloyd	Hapag-Lloyd (Taiwan) Ltd
Korea Marine Transport Co., Ltd	Trans Vantage Shipping Agency Ltd.
MOL	MOL (Taiwan) Co., Ltd.
PIL	Pacific International Lines (Taiwan) Ltd

4.2 Data collection methods

The data collection methods will be presented in relation to the steps of the risk management process. The first sub-section introduces the data collection methods in risk identification, validation and measurement. The second sub-section discusses the data collection methods in risk mitigation strategies identification, validation and analysis.

4.2.1 Data collection methods in risk identification, validation and measurement

4.2.1.1 Identification of risks

Yang (2010) listed several tools that can be used to systematically identify risks, including questionnaire surveys, review of corporate loss history, analysis of corporate financial reports and meeting records, checking of other corporate records and documents, construction of operational flow charts, continuous facility examinations, and consulting form internal and external experts, etc. Waters (2007) also suggested several common methods for identifying risk, including historical data collection/ relative document review, interviews, and group meetings.

The general process for risk identification has the following five steps: (i) define the overall process; (ii) divide this into a series of distinct, related operations; (iii) systematically consider the details of each operation; (iv) identify the risks and their main features; and (v) describe the most significant risks (Waters, 2007). This thesis first reviews the relevant literature to identify all the risk factors that have been directly addressed in container shipping operations (in Chapter 2) and then conduct a more comprehensive literature review in the general supply chain context to identify relevant risks (which will be conducted in Chapter 6). Several studies have also used a literature review to identify the risk factors, e.g., Knemeyer *et al*. (2009), Rao and Glodsby (2009), Yang (2010, 2011), and Jackson *et al*. (2012).

4.2.1.2 Validation of risks

When the risks are unclear and complex, interview perhaps is the most suitable way to collect new information from the people who are most familiar with conditions to clarify the ambiguity (Waters, 2007). Several studies have used interviews to identify and validate risks, e.g. Yang (2011) used interviews to validate and identify risk factors in Taiwan's maritime supply chain security.

Based on the reviews of previous literature, considering the time limitation and the complex degree of data analysis, this thesis uses semi-structured face-to-face interviews with experts to validate the identified risks, and explore other potential risks in container shipping operations. In order to explore more risk factors, the interview includes several open questions such as "what kinds of risk". Moreover, three flow charts (information flow, physical flow, and payment flow) in container shipping operations were also confirmed by the container shipping experts. The semi-structure interview questions are listed in Appendix 1.

Several methods/tools for recording interviews are widely used, such as digital recorder machines and note writing. This thesis uses both methods to collect the interview data. Transcription is produced if the interviewee agrees using the digital recorder machine to record the content of the interview; whilst note writing is taken if the interviewee does not want to be recorded in the interview.

In terms of the sample size of the interview, the author has connected with 12 container shipping companies in Taiwan; however, only seven managers of two companies replied to the author during one month. These two companies are two of the top three container shipping companies in Taiwan, so they are able to reasonably represent the container shipping industry in Taiwan. These seven managers of container shipping companies in Taiwan have been face-to-face interviewed in February 2011. In order to balance the interviews' professional area, the interviewees include two information managers, two vice presidents, and three senior managers. Some of the interviewees did not want to be recorded by the digital recorder machine, as mentioned before, we therefore used note writing to take the important information mentioned by the interviewers instead of transcription. The transcriptions and notes from the interviews are presented in Appendix 2.

After producing the transcriptions and organising the note writing, the results of the interviews were summarised. A table of risk factors was generated by taking into account the interview results. The three flows were also modified accordingly to reflect the face-to-face interview results.

The table of risk factors generated from the literature review, face-to-face interviews and email interview is then organised in a hierarchical structure: risk categories, risk elements, and risk factors. Three risk categories are formed according to three logistics flows, i.e. physical flow, information flow, and payment flow. Each risk category is divided into several risk elements and each risk element is a group of closely related risk factors. Before conducting a large-scale risk-factor survey (to measure their likelihood and consequence), the author conducts another semi-structure email interview to confirm the appropriateness of risk element classification. This email interview can be regarded as a pilot test for the following large-scale questionnaire. The email interview is listed in Appendix 3.

4.2.1.3 Measurement of risks

Risk measurement methods are often used in quantitative way, and most of them are based on two factors: 1) the likelihood of a risky event occurring; and 2) the consequences when the event does occur (Waters, 2007; Cox, 2008; Beretta and Bozzolan, 2008). Waters (2007) stated that likelihood and consequence are just two considerations in many factors when managers do risk analysis.

In this study, a questionnaire survey with five-point Likert scale is used to measure the level of agreement of each question from the respondents. This survey is called risk-factor questionnaire survey. The target sample is selected from the list of ROC National Association of Shipping Agencies, a total 116 container shipping related companies were selected and each company was sent several questionnaire surveys to relevant departments, e.g. president/vice-president, information/document department, operation/shipping department, and financial department in order to cover all three logistics flows. In total, 342 questionnaires were sent out on 14th July 2011.

The questionnaire survey includes five major parts: the level of risks associated with information flow, the level of risks associated with physical flow, the level of risks associated with payment flow, the impact of risk mitigation strategies, and the respondents' profile. In order to measure the level of risk scale, this questionnaire measure both risk likelihood and three risk consequences (financial loss, reputation loss, and safety and security incident related loss) in each question of the three risk parts (i.e. risks associated with information flow, risks associated with physical flow and risks associated with payment flow). The last part of this questionnaire is the respondents' profile. The following sections discuss the risk likelihood, risk consequence, and risk scale that will be used in this thesis. The whole questionnaire is list in the Appendix 4.

Risk likelihood

Risk likelihood is defined as the probability of the risk will occur (Garvey and Lansdowne, 1998). It is often a subjective view of whether the risk will materialise (Waters, 2007). More specifically, the value of likelihood is located between 0 and 1, in which 0 means never happen and 1 means always happen.

However, an accurate numerical percentage is sometimes difficult to identify. Many studies use five abstractive categories to describe the probability of events (e.g. Hallikas *et al*. 2004; NPSA, 2008): very unlikely (or very low; impossible; rare), improbable (or low; unlikely), moderate (or medium; occasional; possible), probable (or high; frequent; likely), and very probable (or very high; almost certain). In this thesis, a questionnaire with Likert five-point scale is used to collect the likelihood of risks occurred in container shipping operations. We follow this format and use 1, 2, 3, 4 and 5 to represent "rare", "unlikely", "possible", "likely", and "almost certain" respectively. Table 4.2 shows the classification for probabilities in this thesis.

Table 4.2 Definition of risk likelihood

Likelihood	Likert scale	Definition
Rare	1	The occurrence is not anticipated May only occur in exceptional circumstances; simple process; no previous incidence of non-compliance
Unlikely	2	Trivial likelihood however could occur Could occur at some time; non-complex process and/or existence of checks and balances
Possible	3	Possibility less than 50 -50 Might occur at some time; complex process with extensive checks and balances; impacting factors outside control of organisation
Likely	4	Possibility more than 50 -50 Will probably occur in most circumstances; complex process with some checks and balances; impacting factors outside control of organisation
Almost certain	5	Almost certain it would occur Can be expected to occur in most circumstances; complex process with minimal checks and balances; impacting factors outside control of organisation

Risk consequence

Risk consequence is regarded as an outcome (losses or gains) of a risk event (Waters, 2007; NPSA, 2008). Jüttner *et al*. (2003, p. 200) also stated that risk consequences are "the focused supply chain outcome variables like costs or quality, i.e. the different forms in which the variance becomes manifest". Norrman and Jansson (2004, p.437) defined risk consequences as "the focused supply chain outcome variables like costs or quality (but also health and safety), i.e. the different forms in which the variance becomes manifest."

The level of risk consequence can be described in different ways. Some scholars use "negligible, minor, moderate, serious, and critical" (Garvey and Lansdowne, 1998; NPSA, 2008); some use "no safety effect, minor, major, hazardous, and catastrophic" (Cox, 2008); "no impact, minor impact, medium impact, serious impact, and catastrophic impact" (Hallikas *et al*., 2004), "low, moderate, and high" (Elky, 2006) and "negligible, marginal, critical, and catastrophic" (Tummala and Schoenherr, 2011) have also been used. This thesis uses "insignificant, minor, moderate, major, and catastrophic" to describe the level of risk consequence. Each of three risk consequences mentioned above is measured at five levels from 1 to 5. The classification for risks impact and their definition are illustrated in Table 4.3.

Table 4.3 Definition of risk consequence

Consequence categories	Likert scale	Definition
Insignificant	1	An event that, if it occurred, would have no effect on the programme.
Minor	2	An event that, if it occurred, would cause only a small cost/schedule increase. Requirements would still be achieved.
Moderate	3	An event that, if it occurred, would cause moderate cost/schedule increase, but important requirements would still be met.
Major	4	An event that, if it occurred, would cause major cost/schedule increase
Catastrophic	5	An event that, if it occurred, would cause programme failure (inability to achieve minimum acceptable requirements)

4.2.2 Data collection methods in risk mitigation strategies identification and analysis

The use of data collection methods in risk mitigation strategies is similar to the case of risks in Section 4.2.1, including relevant literature review and a set of interview. The risk mitigation strategies will firstly be identified, validated, and then ranked, and finally evaluated. The following present the detailed information of this process.

4.2.2.1 Identification of risk mitigation strategies

Similar to Section 4.2.1.1, this thesis first reviews the most relevant literature to identify the risk mitigation strategies in the container shipping sector (in Chapter 2) and then reviews more literature in a broaden supply chain context to identify other relevant risk mitigation strategies (which will be discussed in Chapter 7). Several studies have used the literature review method to identify risk mitigation strategies, e.g., Mitchell (1995), Ellegaard (2008), and Veselko and Bratkovič (2009).

4.2.2.2 Validation of risk mitigation strategies

Similar to the case of risk validation in Section 4.2.1.2, the validation and exploration of risk mitigation strategies are also conducted through semi-structured face-to-face interviews after identifying the risk mitigation strategies from reviewing literature in the general supply chain context. In order to explore more risk mitigation strategies, the interview includes several open questions such as "how do you manage the risks". The interview questions are put together with those used in the validation of risk factors in Appendix 1.

4.2.2.3 Ranking of risk mitigation strategies

The same as Section 4.2.1.3 (measurement of risk), a mitigation-strategy survey with a five-point Likert scale is used to measure the levels of effectiveness of these strategies in container shipping operations. This survey is conducted together with the risk-factor questionnaire survey. However, this survey only focuses on the effectiveness of these strategies rather than the likelihood and the consequence in the risk-factor survey. The terms of measurement used are from “no impact” to “very positive impact”, and the definitions are presented in the Table 4.4.

Table 4.4 Definition of the effectiveness category of risk mitigation strategies

Effectiveness category	Likert scale	Definition
No impact	1	The strategy would impact nothing on the shipping company on risk management
Slight impact	2	The strategy would impact slightly on the shipping company on risk management
Medium impact	3	The strategy would have medium impact on the shipping company on risk management
Good impact	4	The strategy would impact well on the shipping company on risk management
Very positive impact	5	The strategy would have very positive impact on the shipping company on risk management

4.2.2.4 Evaluation of risk mitigation strategies

Risk mitigation strategy evaluation is regarded as the last step of the risk management process. After analysing the risk mitigation strategies in the previous questionnaire survey (called mitigation-strategy survey), several top strategies according to their overall importance will be selected to be further evaluated. The purpose is to examine the relationships of these selected mitigation strategies in more details under different performance criteria. This is done using the Analytical Hierarchical Process (AHP) analysis method based on the primary data collected through a purposely designed questionnaire, called an AHP questionnaire survey.

To apply the AHP method, we firstly need to build up a hierarchical structure to achieve the research goal: mitigating the impacts of risks in container shipping operations. Two different structures could be constructed in our research context for AHP decision analysis, as shown in Figure 4.1 and Figure 4.2 respectively. In Model 1 (Figure 4.1), the top level is the goal of this model, which aims to mitigate the impact of risks on shipping operations. The second level is the criteria level, which represents three consequence criteria, i.e. “Reducing financial loss”, “Reducing reputation loss”, and “Reducing safety and security incident related loss”. The three consequence criteria can be affected by each of three groups of risk mitigation strategies, which are listed at the alternative level 1, and temporarily named as strategy group A, strategy group B, and strategy group C. The alternative level 2 lists more detailed mitigation strategies. In this model, the relative importance of different groups at Alternative level 1 can be evaluated using AHP method; however, it is not possible to make comparison between individual mitigation strategies. It should also be noted that the three groups of risk mitigation strategies and the detailed risk mitigation strategies are identified through literature review and confirmed by the shipping managers from the interviews.

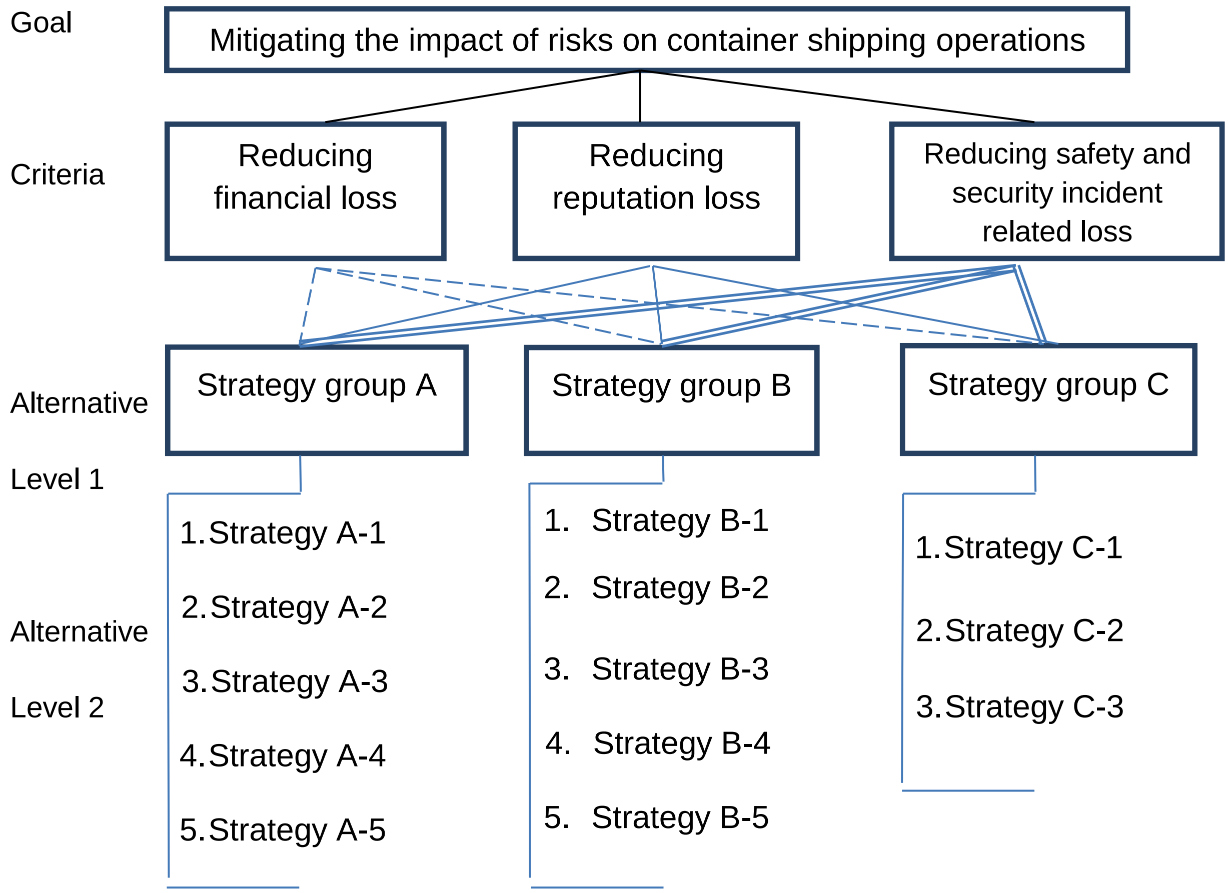


Figure 4.1 Hierarchical Model 1 of mitigation strategies

Source: author

In Model 2 (Figure 4.2), the goal and criteria are the same as those in Model 1. However, there is only one alternative level, at which the mitigation strategies are put at the same level. The advantage of this structure is enable us to evaluate the relative importance of all the mitigation strategies at the alternative level so that shipping companies could prioritise the strategies. However, it is suggested that the number of different items at the same level should not be greater than seven when using AHP method, because the human being brain will be confused when comparing more than seven items (Saaty, 1977a). Therefore, the items at the alternative level in Model 2 have to be limited to seven strategies.

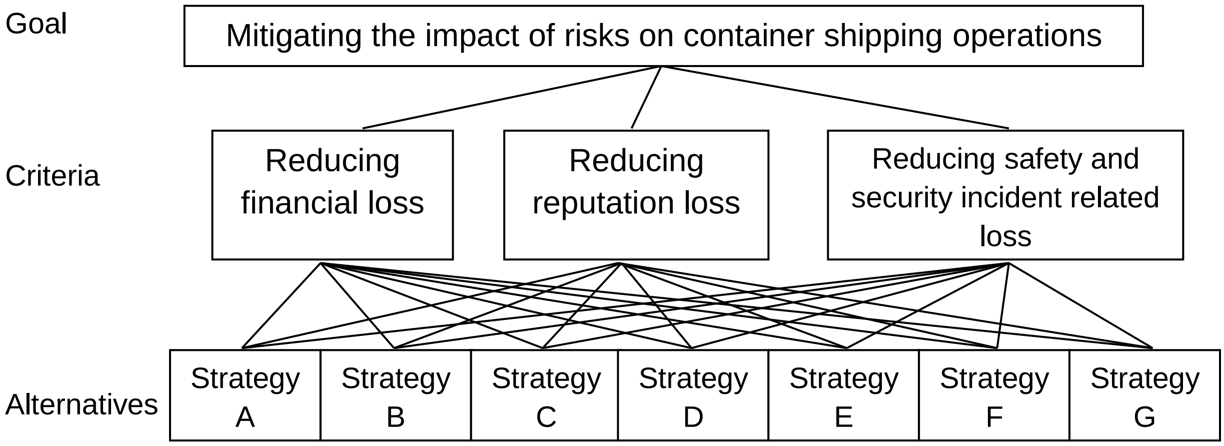


Figure 4.2 Hierarchical Model 2 of mitigation strategies

Source: author

One of the research objectives in this thesis is to understand and evaluate the importance of the risk mitigation strategies as well as the relationships between these strategies. In Model 1, two type of comparison can be evaluated: (i) the comparison between the three risk mitigation strategy groups and (ii) the comparison of the risk mitigation strategies within the group. However, the comparison of the strategy groups is not the main purpose of this thesis, and some important strategies might be hidden in a less important group. Moreover, it cannot compare the strategies across different groups. In Model 2, only seven risk mitigation strategies are chosen to compare, and a full scale of comparison is achievable. With the assumption that the top seven mitigation strategies are selected (e.g. through the mitigation-strategy questionnaire survey, cf. Section 4.2.2.3), it is interesting to examine the relationship of these strategies in more detail. In light of the above, this thesis chooses Model 2 as the hierarchical structure in the AHP analysis method.

To perform the AHP analysis, a questionnaire survey (called AHP survey) is designed to collect primary data from the container shipping industry. The survey consists of three parts, including an introduction (to show the respondents the outline of this questionnaire, and explain the terms and nature of the questions), the main questionnaire *per se* (the questions to compare all items at the same hierarchical level on a pairwise basis), and the respondent's profile. The questions in the main part are constructed in the form of the traditional nine-point pair-comparison scale that will be explained later.

After designing the AHP questionnaire, the author sent the draft of the questionnaire to two experts in November 2011. One is a senior manager in container shipping company, and the other is an expert of AHP method. This is deemed as a pilot test for the AHP questionnaire. The modified questionnaire is given in Appendix 5.

4.3 Data analysis methods

The data analysis methods used in this thesis can be classified into two groups: risk analysis methods and risk mitigation strategies evaluation methods. The risk analysis methods include risk scale analysis (which is the main risk analysis in this thesis) and risk scale presentation. The risk mitigation strategies evaluation methods include the classic AHP method and a fuzzy AHP method.

4.3.1 Risk analysis method

There are several common methods for risk analysis. For example, scenario analysis is used to analyse the possible effects of a series of decisions (Waters, 2007). Hazard Operability (HAZOP) analysis is a structured and systematic technique for predicting the various adverse factors that might arise in a chemical factory (Vaidhyanathan and Venkatasubramanian, 1995). Failure

Mode and Effect Analysis (FMEA) is a procedure in operations management for identifying potential failure modes, and then establishing the impact of each type of failure (Waters, 2007; Tummala and Schoenherr, 2011). Fault Tree Analysis (FTA) is a top down, logic and probabilistic technique used in probabilistic risk assessment and system reliability assessment (NASA, 2002; Tummala and Schoenherr, 2011). Risk scale is a simple method to analyse the impact of risks through multiplying risk likelihood and risk consequence (Waters, 2007; NPSA, 2008). This thesis uses the risk scale method to analyse the importance of the identified risk factors due to its simplicity and the ability to rank different risk factors over a population of respondents.

Before the risk scale analysis, descriptive statistics will be used to present the respondents' profile of the questionnaire. Descriptive statistics is the discipline of quantitatively describing the main features of a collection of data (Mann, 1995). Descriptive statistics can present meaningful information or statistics data after organising the raw data. There are several attributes that are used commonly in descriptive statistics, including frequency, percentage, mean value, standard deviation, minimum value, and maximum value, etc. Moreover, several tools for presenting these attributes include table, bar chart, and pie chart. In this thesis, the frequency, percentage, mean value, and standard deviation are chosen as the major features in descriptive statistics analysis; and table presentation is the main tool to show these features. We use SPSS version 19 to obtain these descriptive statistics.

4.3.1.1 Risk scale analysis

Managers need to know the most serious risk factors before making appropriate strategies to mitigate risks. The level of risk is also termed the risk scale, which is calculated by the following formula (Mitchell, 1995; Norrman and Jansson, 2004; Kleindorfer and Saad, 2005; Cox, 2008; Manuj and Mentzer, 2008a; Vilko and Hallikas, 2011):

$$Risk\ scale = probability\ \times impact\ (or\ frequence \times severity\ or\ likelihood \times consequence\ or\ threat \times vulnerability \times consequence)$$

In this thesis, the risk scale is given by

$$Risk\ scale = risk\ likelihood\ \times risk\ consequence$$

Risk scale is used to identify the relative importance of each risk factor in this thesis. A key step to perform risk analysis is to calculate the risk scale for each risk factor over all respondents, which enables us to draw risk maps to compare the relative importance of each risk factor. In the following we discuss two methods to calculate the risk scale. To simplify the discussion, we introduce the notations below

- M : the total number of risk factors
- N : the total number of respondents
- l_{ri}: the likelihood of risk factor r by the respondent i, $1 \le r \le M$ and $1 \le i \le N$.
- c_{ri} : the consequence of risk factor r by the respondent i, $1 \le r \le M$ and $1 \le i \le N$.

Note that the risk scale is the product of the likelihood and the consequence of a risk factor. Two methods could be used to calculate the risk scale over multiple respondents. The first method is to multiply the average likelihood over all respondents with the average consequence over all respondents for each risk factor. We call this method as Risk Scale Average Likelihood and Consequence (RSALC). The formula is in the following -

$$RSALC_r = \overline{l_r} * \overline{c_r}$$

Where

$$\overline{l_r} = \frac{1}{N}\sum_{i=1}^{N} l_{ri} \text{ and } \quad \overline{c_r} = \frac{1}{N}\sum_{i=1}^{N} c_{ri}$$

The second method is to obtain the risk scale for each individual respondent on each risk factor first, then do the average of those risk scales over all respondents. We call this method as Average Risk Scale (ARS). The formula is in the following -

$$ARS_r = \frac{1}{N}\sum_{i=1}^{N}(l_{ri} * c_{ri})$$

The first method provides three pieces of results for each risk factor, i.e. average likelihood, average consequence, and the risk scale. Therefore it is easy to apply and the results can be directly shown in the risk map in which all three pieces of results are required. However, there is a drawback in this method because the final result of $RSALC_r$ includes components which represent one respondent's likelihood multiplied by another respondent's consequence. This may distort the statistic results.

The second method is more reasonable to calculate the risk scale because it is obtained by multiplying the risk likelihood with the risk consequence from each respondent respectively first, and then averaging over all respondents. This thesis therefore selects the second method – ARS – as the measurement to evaluate the risk scale for each risk factor.

However, the second method only provides the result of risk scale over all respondents. It does not generate the corresponding risk likelihood and risk consequence. We present a method to solve this problem based on the concept of the shortest distance. Consider a two-dimension state space in which the x-axis represents the risk likelihood and the y-axis represents the risk consequence. Each respondent can be represented by a point in the state space. The distance between any two points (x_1, y_1) and (x_2, y_2) is given by $D = \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2}$. Our purpose is to find the best pair of likelihood and consequence, whose product is equal to ARS, while the corresponding point has the shortest total distance with all respondents.

Let $\hat{l}_r$ be the candidate risk likelihood, and $\hat{c}_r$ be the candidate risk consequence. For a given risk factor *r*, the total distance between ($\hat{l}_r$,$\hat{c}_r$) and (l_{ri}, c_{ri}) for $1 \le i \le N$ can be formulated as

$$D_r = \sum_{i=1}^{N} \sqrt{(\hat{l}_r - l_{ri})^2 + (\hat{c}_r - c_{ri})^2} \qquad 1 \le r \le M$$

The objective is to seek the optimal ($\hat{l}_r$,$\hat{c}_r$) for $1 \le r \le M$ by minimizing the following constrained optimisation problem,

$$min \quad D = \sum_{r=1}^{M} D_r = \sum_{r=1}^{M} \sum_{i=1}^{N} \sqrt{(\hat{l}_r - l_{ri})^2 + (\hat{c}_r - c_{ri})^2}$$

Subject to

$$\hat{l}_r * \hat{c}_r = ARS_r$$

The above optimisation problem can be easily solved using existing software tools, e.g. Excel solver. After obtaining the best $(\hat{l}_r, \hat{c}_r)$ for $1 \le r \le M$, we are able to present the risk scale in a further presentation, the risk map.

4.3.1.2 Risk scale presentation: risk matrix, risk map, and P-I graph

Business managers are usually required to evaluate the possible risks according to their estimated impact and expected likelihood of occurrence (Beretta and Bozzolan, 2008). To better understand the risks and their relative importance, the risk scales can be presented in different ways including risk matrix (Yang, 2010; Tseng *et al*., 2012), risk map (Waters, 2007), and P-I graph (Vose, 2008). Risk matrix or a Probability-Impact matrix (P-I table) is a common method that identifies the critical risks in a program and provides an approach to evaluate the potential impacts of a risk (Garvey and Lansdowne, 1998; Vose, 2008). Risk matrix has been used in various areas such as technology (Eleky, 2006), health (NPSA, 2008), and supply chain management (Knemeyer *et al*., 2009). These methods bear some similarity but also have different features. They are briefly introduced below.

Risk matrix

A risk matrix (Table 4.5) is a two-dimension table which consists of several categories of “probability” (“likelihood” or “frequency”) in the horizontal dimension and several categories of “severity” (“impact” or “consequences”) in the vertical dimension (Cox, 2008). Each category of probability is given an estimated numerical value, typically on a scale of 1 to about 5 – individually means rare, unlikely, possible, likely and almost certain. Each category of consequence is also represented by numerical values from 1 to 5 (insignificant, minor, moderate, major, and catastrophic). After that, a score multiplied these two values together reflects the impact of the risk and is shown in the matrix (Waters, 2007).

Table 4.5 Risk matrix

			Likelihood				
			Rare	Unlikely	Possible	Likely	Almost certain
			1	2	3	4	5
Consequence	Catastrophic	5	5	10	15	20	25
	Major	4	4	8	12	16	20
	Moderate	3	3	6	9	12	15
	Minor	2	2	4	6	8	10
	Insignificant	1	1	2	3	4	5

When multiple respondents are involved, the likelihood and the consequence of a specific risk factor can be calculated by averaging over the samples. The corresponding risk factors can be located in the risk matrix (Yang, 2010).

Normally, four levels of risk scale are categorised in the risk matrix, which are defined as follows –

- Low risk: risk scores from 1 to 5, tagging with green colour in the above matrix. This type of risks has minor impacts on companies, and managers could ignore them or accept the impacts.
- Moderate risk: 5.01 – 10, in yellow colour. A certain level of attention should be paid to this type of risks since they have moderate impacts on the companies.
- High risk: 10.01 – 15, in orange colour. Managers should pay more attention on this type of risks to mitigate their impacts on companies.
- Extreme risk: 15.01 – 25, in red colour. This type of risks has serious consequences with high possibilities. It should be managed cautiously by either reducing its occurring probability or its consequence level.

NPSA (2008) described several advantages of using risk matrix as follows -

1. It is a simple yet flexible concept, which can be used in a variety of various research projects.
2. Equal weighting of consequence and likelihood prevents disproportionate effort directed at highly unlikely but high consequence risks.
3. The above four levels (low risk, moderate risk, high risk, and extreme risk) of risk categories may help managers for differentiating risks.

On the other hand, Cox (2008, p.497) pointed out several disadvantages of using risk matrix method –

1. In some cases (e.g. risk likelihood and risk consequence are negatively correlated), risk matrices would ambiguously compare the selected risk factors as they are all in the medium risk.

2. Risk matrices would mistakenly give a higher qualitative rating to a lower quantitative risk. For example, a risk factor with 0.1 risk likelihood and 0.6 consequence would be classified as a medium risk (although its risk scale is 0.1X0.6=0.06), whilst another risk factor with 0.35 risk likelihood and 0.35 risk consequence would be classified as a low risk (even its risk scale is 0.35X0.35=0.12).
3. Effective allocation of resources to risk mitigation strategies cannot only be based on the categories provided by risk matrices, the strategies should also depend crucially on other quantitative information.

An additional disadvantage of risk matrix that we notice is that the risk matrix does not provide an overall picture of multiple risk factors. For example, the relative differences between different risk factors are not obvious, in particular in relation to risk likelihood and risk consequence.

Risk map

Norrman and Jansson (2004) stated that there are various methods to analyse risks, and risk mapping is one of the important tools, i.e. using a structured approach and mapping risk sources to understand their potential consequences. They also suggested that the risk mapping tool can be used after risk analysis, because it is important to "assess and prioritise risks to be able to choose management actions appropriate to the situation" (Norrman and Jansson, 2004, p.438).

A risk map is a two-dimension diagram in which the y-coordinate represents the risk consequence and the x-coordinate represents the risk probability (likelihood), in which the levels of multiple risks and their likelihoods and consequences can be visualised and contrasted in the same diagram (see Figure 4.3, in which one diamond point represents a specific risk factor). Through risk map analysis, managers could have a clearer idea of which risks (extreme risk) require most attention and which risks (low risk) require less attention, and associate them with likelihood and consequence.

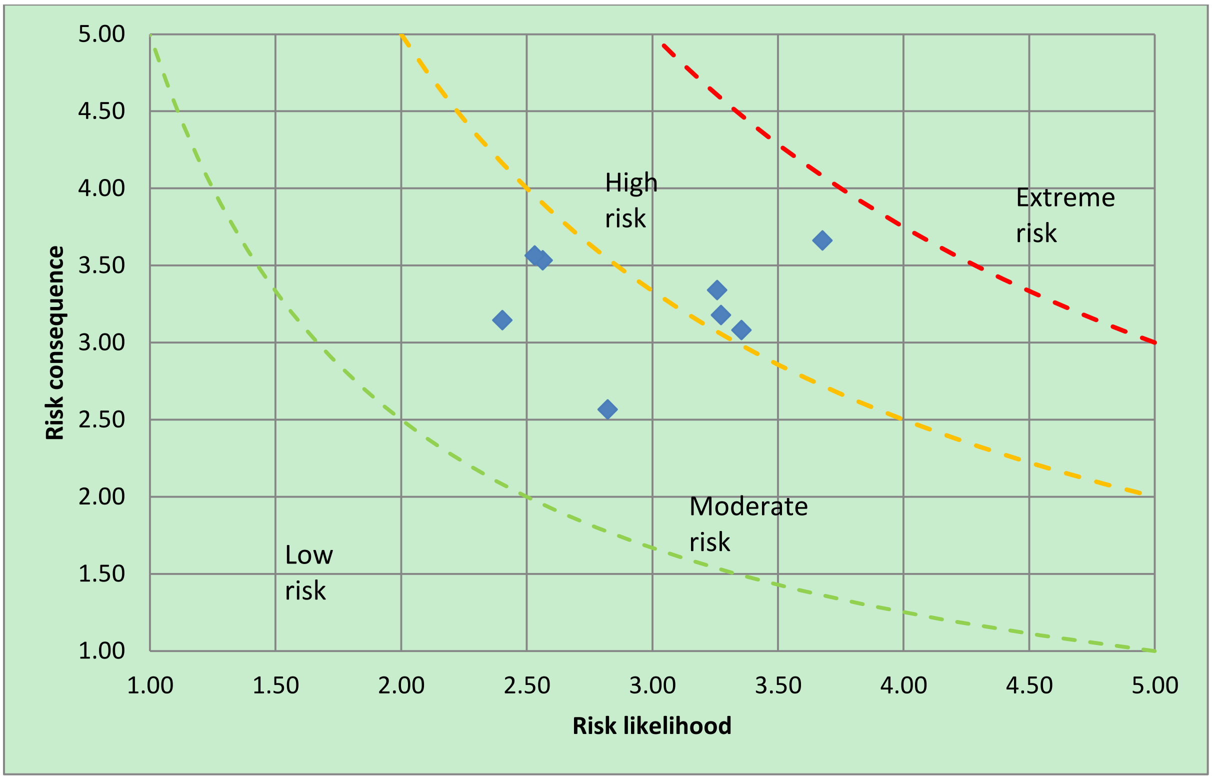


Figure 4.3 An illustrative risk map with multiple risk factors

Similar to the risk matrix, we can also classify the value of risks into four categories from the scores in the risk map as follows –

- Low risk: risk scores from 1 to 5, located in the area under the green dashed line in Figure 3.16.
- Moderate risk: 5.01 – 10, located in the area between the green dashed line and the yellow dashed line.

- High risk: 10.01 – 15, located in the area between the yellow dashed line and the red dashed line.
- Extreme risk: 15.01 – 25, located in the area above the red dashed line.

Compared to the risk matrix, risk map has a higher resolution and provides an overall picture of multiple risk factors to visualise their relative differences in relation to risk likelihood and risk consequence.

<u>P-I graph (risk map with four risk responses)</u>

Hillson (2002) used a probability-impact (P-I) matrix to analyse risk, whilst Vose (2008) introduced a P-I graph (see Figure 3.17) that is very similar to a risk map, in which risk factors are displayed in a two-dimension diagram corresponding to probability (likelihood) and impact (consequence) of risks. The risk levels have also been applied in the P-I graph, which can be categorised into low-level risk, moderate risk, and high-level risk. According to Vose (2008), four risk response options are discussed in a P-I graph, i.e. avoid, control, transfer, and accept; whilst Hillson (2002) categorised the four risk responses as avoid, transfer, mitigate, and accept. Waters (2007) also stated eight risk responses include: (1) ignore or accept the risk, (2) reduce the probability of the risk, (3) reduce or limit the consequences, (4) transfer, share or deflect the risk, (5) make contingency plans, (6) adapt to it, (7) oppose a change, and (8) move to another environment. Some of the responses from Waters (2007) can be categories into the four responses from Hillson (2002) or Vose (2008). The four responses categorised by Hillson (2002) are regarded as follows-

- Avoid: seeking to eliminate the uncertainty by reducing its probability to zero, or by reducing its impact to zero.

- Transfer: identifying another stakeholder who is in better position to manage the risk, and pass the liability and responsibility of action to such a stakeholder.
- Mitigate: reducing the impact of the risk factor in order to make it more acceptable to the organisation, which may be done by reducing the probability and/or the severity.
- Accept: responding either actively by allocating appropriate contingency, or passively doing nothing except monitoring the status of the risk.

Whereas Vose (2008) stated –

- Avoid: managers should avoid this type of risks which has high probability and high impact.
- Control: managers should make some regular plans for controlling this type of risks with high probability and low impact.
- Transfer: managers could reduce the influence to companies through insurance or transferring the risks to other partners.
- Accept: managers do not need to pay much attention on this type of risks with low probability and low impact.

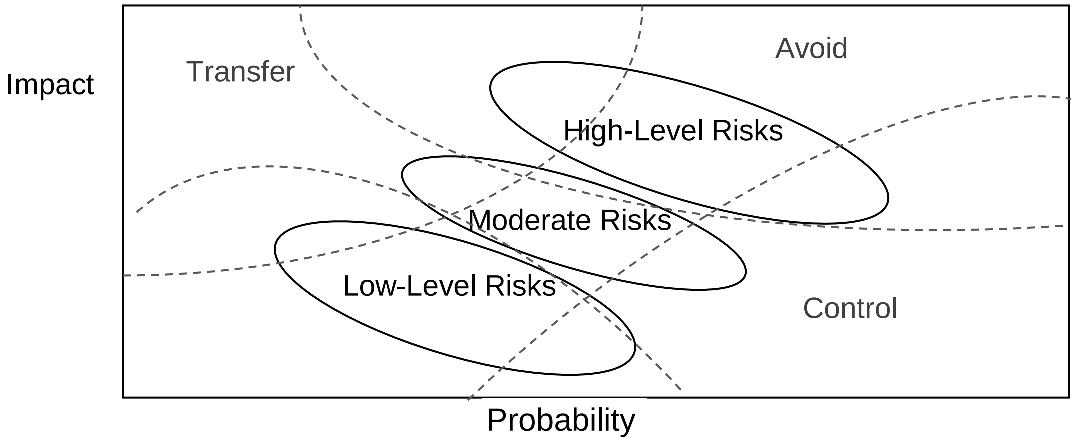


Figure 4.4 P-I graph

Source: Vose (2008)

Because Hillson's (2002) definition of risk responses is more comprehensive and more specific than Vose's (2008) one, this thesis combines Vose's (2008) P-I graph with Hillson's (2002) definition of four risk responses in the later risk scale analysis.

The advantage of using a P-I graph is that it can further present the related risk responses of each risk factor, which can provide a basic risk management thinking for managers. However, as Figure 4.4 shows, the coverage of the four risk responses is sometimes redundant and the central area is ambiguous to distinguish the belonging risk response of the risk factors.

4.3.2 Risk mitigation strategies evaluation methods

In a competitive business environment, managers have to make many decisions in very changeable and difficult situations. A number of methods have been proposed in assisting decision making, including Multiple Criteria/attribute Decision Making, Analytic Hierarchy Process (AHP), Data Envelopment Analysis (DEA), Fuzzy Theory, Data Mining, Artificial Neural Networks, Genetic Algorithms, Simulation-based Methods, Scenario Analysis, Delphi Method, and

Structural Equation Modelling (SEM), etc. (Chang, 2007). However, there are some limitations in each of these methods. For example, SEM needs at least 200 questionnaire replies in order to generate stable results; DEA focuses on measuring organisational performance in relation to the inputs; high computer language design skills and extensive quantitative data are usually required in order to apply Artificial Neural Networks, Genetic Algorithms, and Simulation-based Methods. As this study is an empirical research and has relatively limited number of population and samples (116 companies in total), it is unlikely to achieve over 200 valid replies although three or four participants could be selected from each company. There are several advantages of using AHP method, such as it provides a meaningful integration of systems, it is easy to calculate, and it is reliable and flexible (The details will be discussed in next section). We believe AHP is probably a more appropriate method to evaluate and compare different risk mitigation strategies, therefore, AHP is used in this study. However, there are still some shortcomings of using the classic AHP due to the uncertainty in subjective perception. This thesis therefore also uses Fuzzy AHP as an additional method to overcome such shortcoming. In the remainder of this section, the classic AHP and the Fuzzy AHP will be introduced.

4.3.2.1 Analytic Hierarchy Process (AHP)

This section presents the classic AHP method including an overview of AHP, the axioms of AHP, the process of classic AHP, and software for classic AHP.

<u>Overview of Analytic Hierarchy Process (AHP)</u>

Analytical hierarchy process (AHP) was first proposed by Satty (1988) to identify the best decision in dealing with complex social problems. In order to distinguish it from Fuzzy AHP, the original AHP proposed by Saaty is called classic AHP in this thesis.

The classic AHP method has two main purposes: to provide an overall view of the complex relationships inherent in the situation; and help the decision maker assess whether the issues in each level are of the same order of magnitude, so that he/she can compares such homogeneous element accurately (Saaty, 1990). In other words, it provides the decomposition of a complex problem into a systematic hierarchical level constituting the decision alternatives. These alternatives are compared so as to determine the objectives of the problem (Saaty, 1988). According to Saaty (1988) and Saaty and Vargas (1982), classic AHP can be used in the following areas: 1) Planning; 2) Generating a set of alternatives; 3) Setting priorities; 4) Choosing a best alternative/policy; 5) Allocating resources; 6) Determining requirements; 7) Predicting outcome/ risk assessment; 8) Designing systems; 9) Measuring performance; 10) Insuring the stability of a system; 11) Optimization; 12) Resolving conflict.

In the application of the classic AHP, several principles need to be followed (Saaty, 1986):

1. Decomposition: a problem can be decomposed into some basic elements for structuring the hierarchy through working downward from the focus in the top level to criteria on the focus in the second level.

2. Comparative judgments: a ratio scale is used for pairwise comparison, and then a matrix is created for setting up the result of pairwise comparisons from the elements in the same level.
3. Synthesis of priorities: "Priorities are synthesized from the second level down by multiplying local priorities by the priority of their corresponding criterion in the level above, and adding them for each element in a level according to the criteria it affects" (Saaty, 1986, p. 842).

Some advantages of hierarchies are described as follows:

1. AHP provides a meaningful integration of systems. After analysing the decomposed elements, AHP will integrate these elements into an integrated system. The integrated behaviour or function of a hierarchical organisation accounts for the fact that complicated changes in a large system can result in a single component (Saaty, 1977a).
2. Hierarchical representation of a system can be used to describe how changes in priority at upper levels would affect the priority of elements in lower levels (Saaty, 1988).
3. AHP uses an easy to calculate the observed data and can be used in various test applications (Saaty, 1977b).
4. Greater detail occurs down the hierarchy levels; greater depth in understanding its purpose occurs up the hierarchy levels (Saaty, 1977b, 1988).
5. AHP is efficient and will evolve in natural systems much more rapidly than non-hierarchic systems having the same number of elements (Saaty, 1977a, 1977b, 1988).

6. AHP is reliable and flexible. Local perturbation does not disturb the whole structure (Saaty, 1977a, 1988).

On the other hand, several researchers have raised concerns to the classic AHP method. For example, Belton and Gear (1983) and Dyer (1990) argued that this method has a rank reversal problem; Belton and Gear (1985) and Dyer and Wendell (1985) claimed that classic AHP lacks a strong theoretical support. Nevertheless, Harker and Vargas (1987) stated that “the lacked a strong theory support” can be solved by constructing a network.

Moreover, Millet and Harker (1990) pointed out that the numbers of questions would increase exponentially because of the redundant judgements for checking consistency.

<u>Axioms of AHP</u>

According to Saaty (1994, 1995), four important axioms are assumed when applying the AHP method.

Axiom 1: Reciprocal comparison

When making paired comparisons, both members of the pair need to be considered to judge the relative value. The comparison matrices that we consider are formed by making paired reciprocal comparisons. Decision makers make comparisons and state the strength of their preferences. The intensity of these preferences must satisfy the reciprocal condition, i.e., $a_{ij} = 1/a_{ji}$ for all i, j (If element A is x times more preferred than element B, then B is 1/x times more preferred than A).The violation of Axiom 1 indicates that the questions used to elicit the judgements or paired comparisons are not clearly or correctly stated.

Axiom 2: Homogeneity

Homogeneity is essential for comparing similar things, as the mind tends to make large errors in comparing widely disparate elements. 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. Therefore the preferences are presented by means of a bounded scale for the comparison of elements at the same level. It means that the decision maker never judges one to be infinitely better than another, i.e., $a_{ij} \neq \infty \, for \, all \, i, j \in A$. If Axiom 2 is not satisfied, then the elements being compared are not homogeneous and one may need to form clusters.

Axiom 3: Dependence

Decomposition implies the containment of the small elements by the large clusters or levels. In turn, this means that the smaller elements depend on the outer parent elements to which they belong, which themselves fall in a large cluster of the hierarchy. The process of relating elements in one level of the hierarchy according to the elements of the next higher level expresses the outer dependence of the lower elements on the higher elements. In this way comparison can be made between them and the steps are repeated upward in the hierarchy through each pair of adjacent levels to the top element, the goal. If Axiom 3 is not satisfied, the principle of hierarchical composition would no longer apply because of outer and inner dependence among levels or components which need not form a hierarchy.

Axiom 4: Expectations

For the purpose of making a decision, the hierarchic structure is assumed to be complete. All criteria and alternatives which impact on the given decision problem are represented in the hierarchy. If Axiom 4 is not satisfied, then the decision maker is not using all the criteria and/or all the alternatives available or necessary to meet his reasonable expectations and hence the decision is incomplete.

<u>The process of classic AHP</u>

The procedure of applying the classic AHP can be summarised into the following four main phases (Saaty, 1990) -

1. The structuring of a decision problem;
2. The conduct of measurement and data collection;
3. The computation of normalized weights; and
4. The determination of a synthesis-finding solution to the problem.

Phase1 includes the identification and classification of the decision elements (C_i) into three to four levels of hierarchies (Pun and Hui, 2001), e.g. goal, criteria, sub-criteria, alternative (Figure 4.5). “A hierarchy is an abstraction of the structure of a system to study the functional interactions of its components and their impacts on the entire system” (Saaty, 1988). Each level is composed of several decision elements which can help managers to choose the suitable decisions.

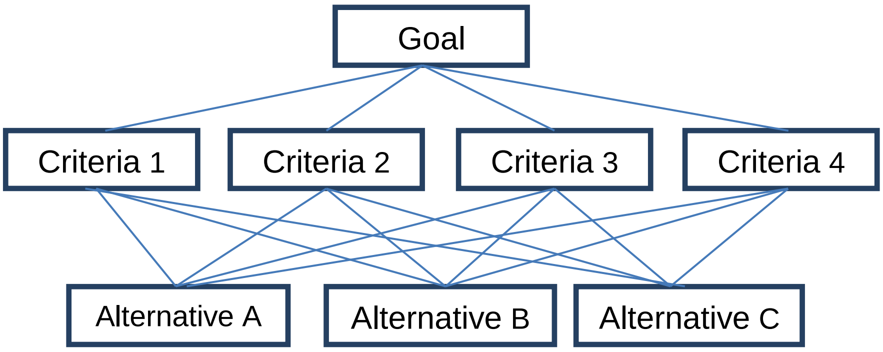


Figure 4.5 An illustrative example of AHP hierarchy

In Phase 2, the relative importance of criteria, sub-criteria, and alternatives in the AHP model will be measured. This is done by performing paired comparisons between all elements at the same level usually through questionnaire survey. In our study, a questionnaire survey (called the AHP survey in this thesis) is sent to industrial experts to assess the relative importance and priority weights of the criteria and risk mitigation strategies in container shipping operations.

The AHP questionnaire survey is composed of several sets of pairwise comparisons, by lifting one and then lifting another and then back to the first and then again the second and so on until each pair of decision elements have been formulated to the relative weight (Saaty, 1988). In Table 4.6, the definition and description of AHP measure scale is illustrated to assign the relative scales and priority weights of the decision criteria and sub-criteria with the nine-point pairwise comparison scale.

Table 4.6 Nine-point pairwise comparison scale (Saaty, 1988)

Measure scale	Definition	Description
1	Equal importance	Two factors contribute equally to the objective
3	Weak importance of one over another	Experience and judgement slightly favour one over another.
5	Essential or strong importance	Experience and judgement strongly favour one over another.
7	Very strong or demonstrated importance	A decision element is favoured very strongly over another. Its dominance demonstrated in practice.
9	Absolutely importance	The evidence favouring one decision element over another is of the highest possible order of affirmation.
2, 4, 6, 8	Intermediate values	When compromise is needed.
Reciprocals of above nonzero	If decision element i has one of the above nonzero numbers assigned to it when compared with decision element j, then j has the reciprocal value when compared with i	A reasonable assumption
Rational	Ratios arising from the scale	If consistency were to be forced by obtaining n numerical values to span the matrix

The following gives an example of AHP questionnaire with the structure of Figure 4.5. Respondents will be asked to evaluate each set of decision elements in a pairwise comparison questionnaire. For the Criteria level, respondents need to answer $\frac{n(n-1)}{2}$, where n represents the number of decision elements at the criteria level. In this example, $\frac{4(4-1)}{2} = 6$ questions are presented to compare the relationship between these 4 criteria. The questions are designed with the nine-point pairwise comparison scale at the criteria level for the example in Figure 4.5 that has been presented in Table 4.7. Respondent can mark the left side of the scale 3 if he/she thinks criterion A is 3 times more important than criterion B (it means Criterion A has a weak importance over Criterion B). For the alternative level, the three alternatives will be compared under four different criteria. A total of 12 questions will be asked at the alternative level in this example.

Table 4.7 Example of AHP questionnaire survey

Criteria	←More important																More important→	Criteria
Criterion A	9	8	7	6	5	4	③	2	1	2	3	4	5	6	7	8	9	Criterion B
Criterion A	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Criterion C
Criterion A	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Criterion D
Criterion B	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Criterion C
Criterion B	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Criterion D
Criterion C	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Criterion D

Note: Regarding the 4 criteria at the second level, in your opinion what is the relative importance of “criterion A”, “criterion B”, “criterion C” and “criterion D” in the overall goal?

Phase 3 includes several detailed steps. The main purpose is to compute the normalized weights and examine the survey consistency. First of all, after comparing all the pair decision elements ($C_1, C_2, \ldots, C_n$), a set of numerical weights ($w_1, w_2, \ldots, w_n$) will be calculated. The data will be organised as a reciprocal matrix A composed of numbers a_{ij} – a value indicating the strength of decision element C_i when compared with decision element C_j (Saaty, 1988). The a_{ij} should use geometric mean approach to combine the pairwise comparison judgement when the respondents are more than two.

The matrix can be illustrated as follow -

$$A = [a_{ij}] = \begin{bmatrix} {}^{w_1}/_{w_1} & {}^{w_1}/_{w_2} & \cdots & {}^{w_1}/_{w_n} \\ {}^{w_2}/_{w_1} & {}^{w_2}/_{w_2} & \cdots & {}^{w_2}/_{w_n} \\ \vdots & \vdots & \ddots & \vdots \\ {}^{w_n}/_{w_1} & {}^{w_n}/_{w_2} & \cdots & {}^{w_n}/_{w_n} \end{bmatrix} = \begin{bmatrix} {}^{w_1}/_{w_1} & {}^{w_1}/_{w_2} & \cdots & {}^{w_1}/_{w_n} \\ {}^{1}/_{{}^{w_1}/_{w_2}} & {}^{w_2}/_{w_2} & \cdots & {}^{w_2}/_{w_n} \\ \vdots & \vdots & \ddots & \vdots \\ {}^{1}/_{{}^{w_1}/_{w_n}} & {}^{1}/_{{}^{w_2}/_{w_n}} & \cdots & {}^{w_n}/_{w_n} \end{bmatrix}$$

Where

$$w_i/w_j = a_{ij} \quad (for\ i, j = 1, 2, \ldots, n)$$

The equation above can be transferred as

$$w_i = a_{ij} w_j \quad (for\ i, j = 1, 2, \ldots, n)$$

Where Saaty (1988) suggested an alternative presentation form from the more realistic relations as

$$w_i = \frac{1}{n} \sum_{j=1}^{n} a_{ij} w_j \quad (for\ i, j = 1, 2, \ldots, n)$$

and consequently

$$\sum_{j=1}^{n} a_{ij} w_j = n w_i \quad (for\ i, j = 1, 2, \ldots, n)$$

which is equivalent to (where w is a column vector consisting of w_j)

$$A \cdot w = n \cdot w$$

The above equation with matrix presenting can be fully expressed as

$$A \cdot w = \begin{bmatrix} 1 & a_{12} & \cdots & a_{1n} \\ a_{21} & 1 & \cdots & a_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ a_{n1} & a_{n2} & \cdots & 1 \end{bmatrix} \cdot \begin{bmatrix} w_1 \\ w_2 \\ \vdots \\ w_n \end{bmatrix} = n \cdot \begin{bmatrix} w_1 \\ w_2 \\ \vdots \\ w_n \end{bmatrix}$$

In this thesis, C_i and C_j can be regarded as both risk criteria and risk mitigation strategies, a_{ij} represents the weight pair-compared between decision elements C_i and C_j. For instance, the managers regard "Using different communication channels in the supply chain increases the time of information transmission" (C_1) as five times more important as "Supply chain partners do not transmit essential information on time" (C_2), then the a_{12} equals 5.

However, w is an unknown vector to the evaluator and is not possible to accurately produce the weights in matrix A. In order to solve this problem, the eigenvector method is proposed through estimating the consistency of the judgement. The eigenvector method can be formulated as $\hat{A} \cdot \hat{w} = \lambda_{max} \cdot \hat{w}$, where $\hat{w}$ is the eigenvector and λ_{max} is the maximum eigenvalue of the matrix A. According to Saaty (1988, p.21), "λ_{max} is used in estimating the consistency as reflected in the proportionality of preferences. The closer λ_{max} is to n (the number of decision elements in the matrix) the more consistent is the result". In a perfectly consistent matrix, the maximum eigenvalue λ_{max} is equal to n. For a positive reciprocal matrix, λ_{max} is always greater than n. The maximum eigenvalue λ_{max} can be derived from above equation as follow –

$$\lambda_{max} = (\sum_{j=1}^{n} a_{ij} w_j)/w_i$$

After obtaining the maximum eigenvalue λ_{max}, consistency index (C.I.) can be calculated to examine whether the respondent has a consistent scaling system to complete the AHP questionnaire. The consistency index C.I. is defined as follow –

$$C.I. = \frac{\lambda_{max} - n}{n - 1}$$

According to Saaty (1980), a questionnaire survey is acceptable when the C.I. is smaller than 0.1. However, the value of C.I. is difficult to be smaller than 0.1 when the number of decision elements (ranks) increase. Therefore, Saaty (1988) proposed the random index (R.I.) (Table 4.8) to adjust the value of C.I. under different ranks and produced a new value, which is called consistency ratio (C.R.), to examine the consistency of the whole questionnaire. C.R. is the ratio of C.I to the average R.I. for the same order matrix and it is acceptable for the consistency degree of the hierarchy structure when C.R. is smaller than 0.1. The equation of C.R. is presented as follow –

$$C.R. = \frac{C.I.}{R.I.}$$

Table 4.8 Random index table

N	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
R.I.	0	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49	1.51	1.48	1.56	1.57	1.59

*N is the number of ranks

Phase 4 is about "The determination of a synthesis-finding solution to the problem". If the hierarchy structure fits the requirement of consistency test, the evaluator can calculate the weight of each decision element and rank the priority. The priorities are pulled together through the principle of hierarchic composition to provide the overall assessment (global priority) of the alternative. The resulting priorities of each level represent the intensity of the respondents' judgements as to the relative importance of the element represented in the hierarchy considering the importance of and trade-off among criteria, and the global priorities represent the preference among alternatives and so they are used in making final decisions.

The above four phase procedure can be further expanded to the following eleven step procedure (Saaty, 1988) -

1. State the problem
2. Put the problem in broad context – embed it if necessary in a larger system including other actors, their objectives, and outcomes.
3. Identify the criteria that influence the behaviour of the problem.
4. Structure a hierarchy of the criteria, sub-criteria, properties of alternatives, and the alternatives themselves.
5. In a many-party problem, the levels may relate to the environment, actors, actor objectives, actor policies, and outcomes, from which one derives the composite outcome.
6. To remove ambiguity carefully define every element in the hierarchy.
7. Prioritise the primary criteria with respect to their impact on the overall objective called the focus.
8. State the question for pairwise comparisons clearly above each matrix. Pay attention to the orientation of each question, e.g. costs go down, benefits go up.
9. Prioritise the sub-criteria with respect to their criteria.
10. Enter pairwise comparison judgments and force their reciprocals.

11. Calculate priorities by adding the elements of each column and dividing each entry by the total of the column. Average over the rows of the resulting matrix and then get the priority vector.

Software for classic AHP

There are quite a few software tools that support the application of AHP, including Export Choice, HIPEW 3, REMBRANDT, and Microsoft Office Excel. Expert Choice is a well-established computer programme, which make it very easy and natural to go through the entire AHP process, including building the hierarchy. Criterium is a newer product, which allows users to use a spreadsheet oriented approach. It can be effective as well. Both of these computer programmes have been noted to be quite easy to use, even for large AHP models (Olson, 1996).

HIPRE 3 is another computer programme with different aspects of pairwise comparisons. HIPRE 3 incorporates the idea of interval pairwise comparisons. With this approach, decision makers are not asked for a precise ratio of the relative value of one element over another, but rather are asked for a range of relative advantages. If the system is able to prove that the final score of the leading alternative could be no worse than the best of all other alternatives, it concludes with a recommendation. The benefit of this approach is that ranges of preference might be more accurate representations of decision maker preferences than some precise value. The problem is that the analysis may take considerable time if the first two alternatives are very close in value (Olson, 1996).

REMBRANDT is a piece of software which uses geometric means rather than eigenvalues to calculate weights. It uses a logarithmic scale rather than the 1-9 verbal scale in standard AHP, and aggregates scores by weighted products rather than by arithmetic means. REMBRANDT also provides the option of assessing relative advantage by standardised scoring rather than by pairwise comparisons. This package provides computer support to those who have questioned some of the approaches incorporated into AHP (Olson, 1996).

Microsoft Office Excel can also be used to support the AHP, and this thesis uses it as the software tool to solve the AHP problem. The reason of choosing Excel includes it is free and easy to operate. The steps of using Excel in our thesis can be described as follows. We firstly enter the data into a sheet by individual respondents respectively. The data include the weight of the three criteria and the seven strategies under the three criteria respectively, this produces one reciprocal matrix at criterion level and three reciprocal matrices at strategy level. Secondly, the weights of the criteria and strategies will be calculated by geometric mean. The standard weights of the criteria will be calculated by using the criterion's weight divided by the sum of the criteria's weights. Thirdly, an eigenvalue λ_{max} and a consistency ratio (C.R.) test are then implemented to exam the consistency of the respondent's opinions. The C.R. value must be smaller than 0.1, which means the opinions of each respondent are consistent. Fourthly, integrate all the respondents' opinion on the standard weights of the three criteria and the seven strategies through using arithmetic mean. Finally, calculate the global weight of each strategy and overall priority of each strategy.

4.3.2.2 Fuzzy set theory and fuzzy AHP

There are several shortcomings of the classic AHP. For example, respondents usually cannot present objective thinking and judgment when measuring the weight of criteria in a high-level hierarchy (Millet and Harker, 1990). Sometimes respondents cannot give a crisp number when answering multiple criteria questions (Belton and Gear, 1983, 1985). In order to remedy these shortcomings, Fuzzy AHP has been developed since 1983 (van Laarhoven and Pedrycz, 1983), which combines the advantages of Fuzzy set theory (fuzzy objective judgement) and AHP (easily analyse the nature of the question), as discussed below:

Fuzzy set theory

Fuzzy set theory is used to deal with the problem with ambiguity, vagueness, or blur. For example, people may say "this person is very tall". But how tall can a person be called a tall person? We might say that a person higher than 190 cm can definitely be called a tall person, and a person shorter than 160 cm can be called a short person. The major problem is "how to tell a person is tall if the person's height is between 160 and 190 cm?" The fuzzy set theory is therefore regarded as a class of objects that do not have precisely defined criteria of membership (Zadeh, 1965).

The process of fuzzy theory can be illustrated as Figure 4.6. A crisp number inputs into a fuzzy controller and then outputs another crisp number for the further analysis. There are four main elements in the fuzzy controller (Passino and Yurkovich, 1998, p.10): "(1) the rule-base holds the knowledge, in the form of a set of rules, of how best to control the system; (2) the inference mechanism evaluates which control rules are relevant at the current time and then decides what the input to the plant should be; (3) the fuzzification interface simply modifies the inputs so that they can be interpreted and compared to the rules in the rule-base; and (4) the defuzzification interface converts the conclusions reached by the inference mechanism into the inputs to the plant".

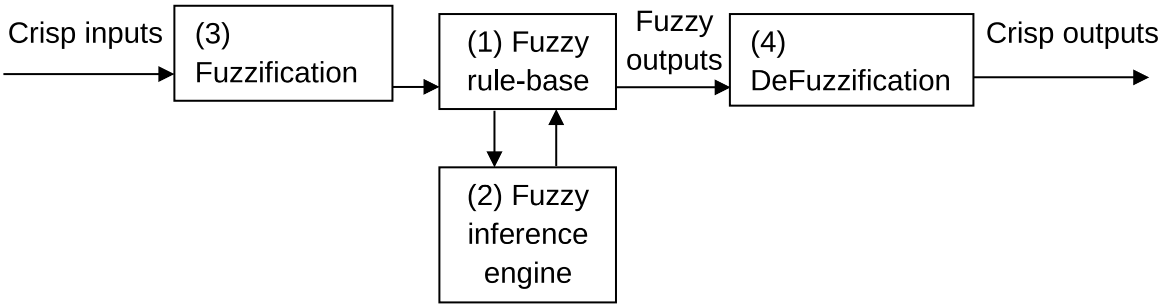


Figure 4.6 The fuzzy controller

Source: Saade and Diab (2004)

The first stage of fuzzy theory is fuzzification defined by Huang (1997, p.16) as "a mapping from an observed input space to fuzzy sets in a certain input universe of discourse", which means it makes a crisp number become a fuzzy set number. A set is characterised by a membership function, which assigns to each object a grade of membership ranging between zero and one. A tilde "~" is placed above a symbol if the symbol represents a fuzzy set.

A membership function is usually presented by a set of triangular fuzzy numbers (TFN) $\tilde{A}$= (l, m, u). The TFN membership function (called $\mu_{\tilde{A}}(x)$ in this thesis) is defined as follows

$$\mu_{\tilde{A}}(x) = \begin{cases} 0, & x \leq l \\ \dfrac{x-l}{m-l}, & l \leq x \leq m \\ \dfrac{u-x}{u-m}, & m \leq x \leq u \\ 0, & x \geq u \end{cases}$$

Where

l: the minima value of TFN

m: the mean value of TFN

u: the maxima value of TFN

The membership function of TFN is illustrated in Figure 4.7.

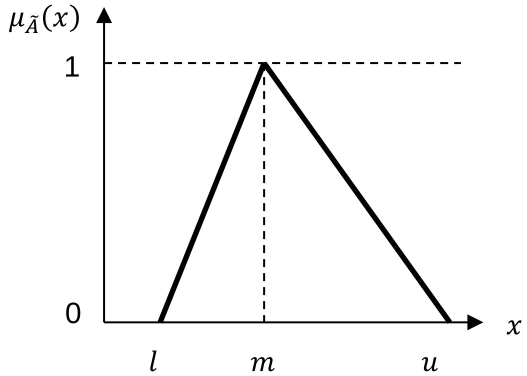


Figure 4.7 Membership function of TFN

The defuzzification stage can produce a crisp number from a fuzzy number. Three common defuzzificaiton methods are introduced as followings:

(1) Centre of Gravity/Area (COG/COA) (Liu, 2007; Ross, 2009):

Centre of Gravity (or called Centre of Area) method is the most prevalent and physically appealing defuzzification method (Sugeno, 1985; Lee, 1990;

Ross, 2009). This method generates the centre of gravity of the probability distribution of a control action. The formula is presented as follows

$$DF = \frac{\int \mu_{\tilde{A}}(x) \ \cdot x dx}{\int \mu_{\tilde{A}}(x) \, dx}$$

(2) Mean of Maximum method (Ross, 2009):

The Mean of Maximum method produces a control action which represents the mean value of all local control actions whose membership functions reach the maximum. In the case of a discrete universe, the control action will be presented as

$$DF = \sum \frac{x}{n}$$

(3) Middle of Maxima (Liu, 2007; Ross, 2009):

Middle of Maxima takes the average of the greatest and smallest value of the largest degree of membership. The formula is presented as follows

$$DF = \frac{l + u}{2}$$

As the Centre of Gravity method is the most reasonable and common defuzzification methods (e.g. Huang, 1997), this thesis uses Centre of Gravity method as the tool for defuzzification.

The two basic algebraic operations, addition and multiplication, used to deal with the fuzzy numbers are introduced as follows. Let $A_1 = (l_1, m_1, u_1)$ and $A_2 = (l_2, m_2, u_2)$ as two fuzzy set number. The algebraic operations of A_1 and A_2 can be expressed as:

- Fuzzy addition ⊕

$$A_1 \oplus A_2 = (l_1 + l_2, m_1 + m_2, u_1 + u_2)$$

- Fuzzy multiplication ⊗

$$A_1 \otimes A_2 = (l_1 l_2, m_1 m_2, u_1 u_2)$$

Fuzzy AHP

Fuzzy AHP is a systematic method to solve the multi-criteria decision making problem by combining the concepts of fuzzy set theory with the classic AHP method. Buckley (1985, p. 233) proposed a Fuzzy Hierarchy Analysis, which "the experts are allowed to use fuzzy ratio in place of exact ratios".

The Fuzzy AHP can be organised in eight steps (Buckley, 1985; Ding, 2010; Ding and Tseng, 2012). These are described one by one as follows:

Step 1: Develop a hierarchical structure with k criteria and p alternatives (the same as classic AHP Phase 1);

Step 2: Collect pairwise comparison matrix of decision elements

Let x_{ij}^h, $h = 1, 2, \ldots, n$, be the relative importance given to criterion i compared to criterion j by expert h at the criteria level; whilst let x_{st}^h, $h = 1, 2, \ldots, n$, denote the relative importance given to alternative s compared to alternative t by expert h at the alternative level.

Step 3: Transform relative importance into Triangular Fuzzy Number (TFN)

TFN combines the min value, max value, and mean value of the opinions of all experts. The meaning of TFN using in Fuzzy AHP is presented in Table 4.9, and the illustration of membership function of triangular fuzzy numbers used in Fuzzy AHP is presented in Figure 4.8.

Table 4.9 TFN of Fuzzy AHP

Meaning	Triangular fuzzy number
Equally Preferred	$\tilde{1}$ = (1,1,2)
Equally to Moderately Preferred	$\tilde{2}$ = (1,2,3)
Moderately Preferred	$\tilde{3}$ = (2,3,4)
Moderately to Strongly Preferred	$\tilde{4}$ = (3,4,5)
Strongly Preferred	$\tilde{5}$ = (4,5,6)
Strongly to Very Strongly Preferred	$\tilde{6}$ = (5,6,7)
Very Strongly Preferred	$\tilde{7}$ = (6,7,8)
Very Strongly to Extremely Preferred	$\tilde{8}$ = (7,8,9)
Extremely Preferred	$\tilde{9}$ = (8,9,9)

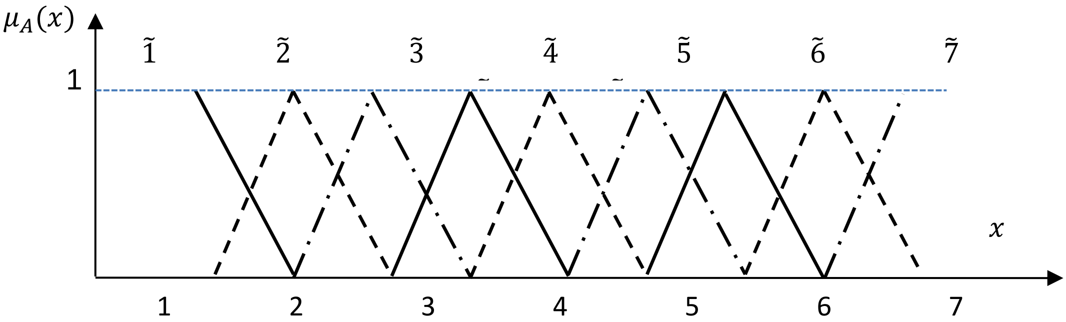


Figure 4.8 Membership function of TFN used in Fuzzy AHP

Step 4: Build Fuzzy positive reciprocal matrix

The TFN is used to build fuzzy positive reciprocal matrix. At the criteria level, the fuzzy positive reciprocal matrix can be generated by

$$[\tilde{B}_{ij}^{C}]_{k\times k} = \begin{bmatrix} \tilde{1} & \tilde{B}_{12}^{C} & \cdots & \tilde{B}_{1k}^{C} \\ 1/\tilde{B}_{12}^{C} & \tilde{1} & \cdots & \tilde{B}_{2k}^{c} \\ \vdots & \vdots & \ddots & \vdots \\ 1/\tilde{B}_{1k}^{C} & 1/\tilde{B}_{2k}^{c} & \cdots & \tilde{1} \end{bmatrix},$$

where $\tilde{B}_{ij}^{C} \otimes \tilde{B}_{ji}^{C} = 1, \ \forall i, j = 1, 2, \dots k.$

At alternative level, the fuzzy positive reciprocal matrix is given by

$$[\tilde{B}_{st}^{A}]_{p \times p} = \begin{bmatrix} \tilde{1} & \tilde{B}_{12}^{A} & \cdots & \tilde{B}_{1p}^{A} \\ 1/\tilde{B}_{12}^{A} & \tilde{1} & \cdots & \tilde{B}_{2p}^{A} \\ \vdots & \vdots & \ddots & \vdots \\ 1/\tilde{B}_{1p}^{A} & 1/\tilde{B}_{2p}^{A} & \cdots & \tilde{1} \end{bmatrix},$$

where $\tilde{B}_{st}^{A} \otimes \tilde{B}_{ts}^{A} = 1, \ \forall s, t = 1, 2, \dots p.$

Step 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 fuzzy comparison value of criteria i and alternative s; (ii) calculate the fuzzy weight $\widetilde{W}_i$ and $\widetilde{W}_s$ of the criterion i and alternative s (Kahraman *et al*., 2009). At the criteria level, the geometric mean value of TFN of ith criteria can be given by

$$\tilde{Z}_i^C = \sqrt[k]{\left(\tilde{B}_{i1}^{C} \otimes \tilde{B}_{i2}^{C} \otimes \dots \otimes \tilde{B}_{ik}^{C}\right)}, \qquad \forall i = 1, 2, \dots k$$

and the fuzzy weight of ith criteria is given by

$$\widetilde{w}_i^C = \tilde{Z}_i^C \otimes \left(\tilde{Z}_1^C \oplus \tilde{Z}_2^C \oplus \dots \oplus \tilde{Z}_k^C\right)^{-1}$$

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

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

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

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

The fuzzy weight of ith alternative is given by

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

Step 6: Defuzzify the Fuzzy weights to crisp weights

After obtaining the fuzzy weights, they will be converted into crisp weights using the defuzzification methods. Various difuzzification methods have been used in different studies such as $DF = \frac{l+2m+u}{4}$ (Durán and Aguilo, 2008), $DF = \frac{l+4m+u}{6}$ (Ding, 2010), and $DF = \frac{((u-l)+(m-l))}{3} + l$ (Ali *et al*., 2012), where Ali *et al*. (2012) is the Centre of Gravity/Area that have been introduced in previous section.

Step 7: Standardise the crisp weights

To facilitate the comparison of the relative importance between elements at the same level, these crisp weights should be standardised. For example, at the criteria level, the standardised crisp weights are given by,

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

At the alternative level, the standardised crisp weights are given by

$$Sw_s^A = \frac{w_s^A}{\sum_{s=1}^{p} w_s^A}$$

Step 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 is given by (note that the weight at its upper level is 1),

$Iw_i^C = Sw_i^C, \ \forall i = 1,2,\ldots,k$; and

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

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

Software for Fuzzy AHP

There are relatively few previous studies addressing the software tools for Fuzzy AHP. Matlab and Microsoft Excel are the two common computer programmes that can be used to support the application of the Fuzzy AHP.

Matlab can be used to deal with the time-consuming calculations of fuzzy AHP. Firstly, the user has to input the selected criteria and strategies into Matlab. The software keeps a database with a series of attributes that the user can select to conduct the comparison analysis. Next, the user has to key in the pair-wise comparisons matrix for the decision elements. Secondly, the software solves and obtains an eigenvector, eigenvalue and C.R. that produce the priority weight for each decision element. (Durán and Aguilo, 2008).

Microsoft Excel is another piece of software for fuzzy AHP method. The benefits of using Excel are because it is free and easy to operate. The procedure to implement the Fuzzy AHP in Excel includes the following four steps:

1. Enter all the data from respondents into Excel sheets and transfer the data into TFN.
2. The information including the weight of each criterion, the λ_{max}, the CI and the CR, are then calculated and presented.
3. Defuzzify the fuzzy weights and normalise the crisp weights. Fourthly, a new Excel sheet is created to integrate the respondents' opinion by using arithmetic mean.
4. Calculate the global weight of each strategy and overall priority of each strategy.

4.4 Chapter summary

This chapter firstly introduces the case study, Taiwan's container shipping industry, and the population for data collection.

Secondly, the data collection methods are discussed, which include two main parts: (1) data collection methods in risk factor identification, validation and measurement, and (2) data collection methods in risk mitigation strategies identification and evaluation. In the first part, the risk factors are identified through literature review; risk validation and exploration are done through semi-structured face-to-face interviews with industrial experts; the measurement of risk factors is conducted through a risk-factor questionnaire survey. In the second part, the risk mitigation strategy identification, validation, and exploration are done in a similar way to the risk factors, i.e. through literature review and semi-structured interviews. In order to rank the identified risk mitigation strategies, a mitigation-strategy questionnaire survey is conducted. This enables the author to selected several most important risk mitigation strategies, which are then further evaluated through a AHP questionnaire survey to examine their relative importance in relation to different performance criteria.

Thirdly, the data analysis methods are discussed, which also include two main parts: (1) risk analysis methods and (2) risk mitigation strategies evaluation methods. In the first part, the methods including risk scale analysis, risk matrix, risk map, and P-I graph (risk map with risk responses) are introduced. In order to estimate the risk likelihood and risk consequence over a population of respondents more accurately, we propose the Average Risk Scale (ARS) method. The Average Risk Scale (ARS) method firstly calculates the risk scale for each individual respondent, then averages over all respondents to obtain the average risk scale for each risk factor, finally determines the likelihood and consequence based on the shortest distance rule. In the second part, the risk mitigation strategies evaluation methods are discussed. This thesis will use classic AHP and Fuzzy AHP to evaluate the relationships between several most important risk mitigation strategies.

Finally, the methods mentioned above can be summarised into Table 4.10, which include the four main risk management steps, and the related approaches and purposes of these approaches.

Table 4.10 Summaries of the research methods

Steps	Approaches	Purposes
Risk identification	Literature review	To identify the existing risk factors in container shipping operations and in general supply chains.
	Interviews	To validate that the risk factors from the literature review are appropriate in container shipping operations, and explore more risk factors that are not mentioned in previous studies.
Risk analysis	Risk-factor survey	To collect the data about the likelihood and three different consequences of the risk factors
	Risk ranking	To rank the importance of the risk factors from three different consequences
	Risk matrix	To classify the level of these risk factors
	Risk map	To show the detailed relationship and to classify the level of these risk factors
	P-I graph	To identify the risk response of each risk factor
Risk mitigation strategies identification	Literature review	To identify the existing risk mitigation strategies in container shipping operations and in general supply chains.
	Interviews	To validate that the risk mitigation strategies from the literature review are appropriate in container shipping operations, and explore more risk mitigation strategies that are not mentioned in previous studies.
Risk mitigation strategies evaluation	Mitigation-strategies survey	To collect the data about the importance of the risk mitigation strategies
	Risk mitigation strategies ranking	To rank the importance of the risk mitigation strategies from mitigation-strategies survey, and to select the top 7 strategies to conduct the following AHP survey
	AHP survey	To collect the data about the relationship between the three criteria, and the seven strategies under the three criteria
	Classic AHP	To evaluate the relationship of the seven strategies under the three criteria, and the importance of the seven strategies after integrating the three criteria
	Fuzzy AHP	To overcome the uncertainty in subjective perception by using classic AHP

Chapter 5 Identification of risks in container shipping operations

Chapter 5 focuses on the first step of risk management, i.e. risk identification and validation. Section 5.1 identifies risks through a systematic review of relevant literature on risks associated with the three logistics flows. Section 5.2 validates the identified risks and explores new risks through interviews, which include a set of face-to-face interviews and a set of email interviews. Section 5.3 is the summary of this chapter.

5.1 Risk identification through review of the relevant literature

Risk identification is deemed as the first step of risk management (Norrman and Jansson, 2004; Sung, 2005; Waters, 2007; van Duijne *et al*., 2008; Tummala and Schoenherr, 2011). In order to make the risk identification comprehensively, apart from the existing studies on risks in container shipping (see in Chapter 2), the risks in general supply chains are also included to be the background of risk identification. The following sections discuss risk identification from the three logistics flows that have been introduced in Section 3.1, i.e., information flow, physical flow, and payment flow.

5.1.1Risks associated with information flow

From the initial literature review in Chapter 2, the risk factors associated with information flow may be categorised into three elements: information delay, information inaccuracy, and IT (information technology) problem. The following discussion concentrates on risks associated with information flow in general supply chains.

The speed of information transfer between supply chain partners is a key element for a successful business, and it depends on different channels. Many information channels for transferring data have been widely used including face-to-face meetings, telephone calls, email, fax, and Electronic Data Interchange (EDI), etc. Using different communication channels in a supply chain may increase time in information transmission due to un-uniform data. Delay in information transfer can increase information risks in the global supply chain business as it may affect the subsequent information transmissions. According to Ramayah and Omar (2010), information delay and inaccurate information mean poor information quality. They also pointed out that lack of advanced IT may be a cause for poor information quality. Angulo *et al.* (2004, p.102) stated that information delay is an important risk element in information flow; they defined it as “the wait time that shared information experiences before it is used by an internal supply chain functions”. Metters (1997, p. 99) explained that “lack of inter-company communication combined with large time-lags between receipt and transmission of information are the root cause of information delay”. He suggested that using EDI to transfer information can reduce the impact from information delay; however, not every company can afford the huge investment of EDI. It increases the time of information transmission when supply chain partners use different communication channels for exchanging information.

With regard to the element of information inaccuracy, DeLone and McLean (1992) pointed out that it may lead to wrong decision making. Several studies suggested that lack of information security may affect information accuracy as it can lead the transferring data to being tampered or leaked (e.g. Sharma and Gupta, 2002; Finch, 2004; Qi and Zhang, 2008). Angulo *et al.* (2004) stated that using inaccurate information may lead to costly investment and work inefficiencies and it might be caused by customer's poor inventory integrity. Forrester (1961) and Lee *et al.* (1997) found that information asymmetry or lack of communication can lead to inaccurate or distorted information flow in a supply chain. Fawcett *et al*. (2007) stated that supply chain managers often get inadequate information when making decisions. Although technology can reduce the possibility of information missing or error, most managers still think that inaccurate information is a significant barrier to decision making. Inadequate information usually leads to bad decisions, and inaccurate information might lead to disasters. Lack of common terminology or communication standards is also a challenge to supply chains. Husdal and Bråthen (2010) identified several risks relating to information flow in the context of Norwegian freight transport; these risks are disregard of rules and regulations, wrong or erroneous lading permits, wrong or erroneous documents (e.g. customs declaration), and wrong or erroneous information from or to other players in the supply chain.

A number of studies have addressed the importance of the element of IT problem. Lack of necessary IT and IT problems are also considered as important elements in information risk as they may disrupt the process of information transmission (e.g. Lyytinen and Hirschheim, 1987; Sharma and Gupta, 2002; Tummala and Schoenherr, 2011). Tummala and Schoenherr (2011) suggested that lack of necessary IT or IT problems should be considered as an important risk element associated with information flow as they may disrupt the process of information transmission. They stated that the triggers that may cause system risks include information infrastructure breakdowns, lack of effective system integration or extensive system networking, and lack of compatibility in IT platforms among supply chain partners. Swabey (2009) and Qi and Zhang (2008) stated that IT infrastructure breakdown is a risk factor. Millman (2007) pointed out that human error is the biggest risk to an organisation's network security.

All the above identified risk factors and their categorisations are summarised in Table 5.1.

Table 5.1 The risk elements and factors associated with information flow

Risk element	Risk factors	Authors
Information delay	Using different communication channels in the supply chain and consequently increasing the time of information transmission. (e.g. telephone, Email, EDI)	Metters (1997)
	Supply chain partners not transmitting essential information on time	Angulo *et al.* (2004); Yang (2010), (2011)
	Processing documents being detained by government departments (e.g. customs)	Husdal and Bråthen (2010); Yang, (2010)
	Shipping company not transmitting essential information on time	Angulo *et al.* (2004)
Information Inaccuracy	Lack of information security during the information flow	Sharma and Gupta (2002); Finch (2004); Qi and Zhang (2008)
	Information asymmetry/incompleteness	Forrester (1961); Lee *et al.* (1997); Angulo *et al.* (2004); Husdal and Bråthen (2010)
	Lack of information standardisation and compatibility	Tummala and Schoenherr (2011)
IT Problem	IT infrastructure breakdown or crash	Qi and Zhang (2008); Swabey (2009); Tummala and Schoenherr (2011)
	Unsuitable human operation on IT infrastructure	Millman (2007)
	Unsuitable human operation on application software	Millman (2007)

Source: author

5.1.2 Risks associated with physical flow

There are a significant number of studies that focus on risks associated with physical flow in container shipping or general supply chains. A number of risk factors have been identified in Chapter 2. These include: port strike, port congestion (unexpected waiting times before berthing or before starting loading/discharging), port/terminal productivity below expectations (loading/discharging), unstable weather, inappropriate empty container transportation, oil price rising, cargo stolen from unsealed containers, damage to ship or quay due to improper berth operations, damage to frozen cargo, and attack from pirates or terrorists. They may be categorised into two broad elements: transportation delay and cargo/asset loss or damage. Almost all studies mentioned in the Introduction (e.g. Talley, 1996; Noda, 2004; Drewry, 2009; Fu *et al*., 2010) in this thesis fall into these two domains. In addition to that, the following papers need to be mentioned.

Although delivering cargo on time is a basic requirement for a logistics company, delay in delivery is sometimes unavoidable. Schary (1970) stated that “time” is an important risk which may impact on physical distribution in cargo transportation. Transportation delay is therefore considered as one significant risk factor in physical flow. Transportation delay may have adverse impacts on both shippers and transportation companies. The shippers may lose profit if they cannot receive the cargo on time. The delay may also impact on the reputation of the transportation company. Vernimmen *et al*. (2007) reported, based on a large-scale survey, that over 40% of the vessels deployed on worldwide liner services arrive one or more than one day behind schedule. They found several risk factors that may cause transportation delay including bad weather at sea, congestion or labour strikes at the different ports of call, and knock-on effects of delays suffered at previous ports. Notteboom (2006) stated that transportation delay may incur extra logistics costs to the shippers and damage the container companies’ reputation. Husdal and Bråthen (2010) identified several risk factors; those are relevant to this context include unstable weather and road conditions, lack of fuel supply, and strikes and other work-related issues. Tummala and Schoenherr (2011) classified several risk factors into transportation delay including port capacity and congestion, port strikes, and delay at ports due to port capacity. Chopra and Meindl (2010) stated that transportation delay may also be caused by the limited availability of transportation or infrastructure capacity

In relation to cargo/company asset loss or damage, Husdal and Bråthen (2010) suggested that accidents, engine/vehicle breakdowns, theft, and errors in loading (e.g., mixing hazardous and non-hazardous goods may cause explosion accidents) may affect supply chains. Dangerous Goods (DG) transportation is a special risk factor in the transportation industry supply chains compared to other general supply chains because a DG explosion may cause huge damage to the cargo, the ship and even the nearby port. Tummala and Schoenherr (2011) stated that terrorism and wars may lead to disruption risk.

Table 5.2 summarises the risk factors associated with physical flow, which have been mentioned in Chapter 2 (related to container shipping operations) and above (related to general supply chain operations).

Table 5.2 The risk elements and factors associated with physical flow

Risk element	Risk factors	Authors
Transportation delay	Port strike	Notteboom (2006); Drewry (2009); Husdal and Bråthen (2010); Tummala and Schoenherr (2011)
	Port congestion (unexpected waiting times before berthing or before starting loading/discharging)	Notteboom (2006); Drewry (2009); Tummala and Schoenherr (2011)
	Port/terminal productivity being below expectations (loading/discharging)	Notteboom (2006); Tummala and Schoenherr (2011)
	Unstable weather	Notteboom (2006); Husdal and Bråthen (2010)
	Inappropriate empty container transportation	Song *et al*. (2005); Drewry (2006); Song and Dong (2011)
	Lack of flexibility of fleet size and designed schedules	Song *et al*. (2005); Qi and Song (2012)
	oil price rise	Notteboom and Vernimmen (2009); Husdal and Bråthen (2010)
Cargo/asset loss or damage	Damage to containers or cargo due to terminal operators' improper loading/ unloading operations	Husdal and Bråthen (2010)
	Cargo being stolen from unsealed containers	Drewry (2009); Husdal and Bråthen (2010)
	Damage caused by transporting dangerous goods	Talley (1996); Husdal and Bråthen (2010)
	Damage to ship or quay due to improper berth operations	Talley (1996); Husdal and Bråthen (2010)
	Attack from pirates or terrorists	Drewry (2009); Fu *et al.* (2010); Tummala and Schoenherr (2011)

Source: author

5.1.3 Risks associated with payment flow

There has been no specific literature on risks associated with payment flow in container shipping operations. However, in the general supply chain context, a number of risk factors associated with payment flow have been identified in previous studies. They may be categorised into three elements: currency exchange, payment delay, and non-payment.

Tummala and Schoenherr (2011) pointed out that an international business may lose profit if the fees are paid in a weak currency. They also suggested that unrealised contracts with partners may lead to payment delay, and shippers going into bankruptcy or having partners with bad credit may lead to non-payment. Husdal and Bråthen (2010) stated that bankruptcy or other financial difficulties faced by one player in a supply chain may cause risks to the other players in the supply chain. Seyoum (2009) pointed out that if a consignee delays or does not make the payment, it would have a direct impact on the consignor's financial performance. Seyoum (2009, p.240) also stated that payment delay may not have any impact on the buyers, but it "often creates liquidity problems for many exporting firms". Chen (2008) stated that a break of trade caused by one company usually causes big losses to the others in the supply chain. Notably there are several payment methods in international trade, e.g., Open Account, Letter of Credit (L/C), and Cash-in-Advance (U.S. Department of Commerce, 2008). Each payment method imposes different level of risks to different parties. For example, an open account imposes the highest risk to the sellers. In container shipping business, different international contracts of sale have been used, e.g., Free On Board (FOB), and Cost, Insurance and Freight (CIF). Under FOB, the shipping companies may not receive payment if the buyers have gone bankrupt.

The risk factors associated with payment flow discussed above are summarised in Table 5.3.

Table 5.3 The risk element and factors associated with payment flow

Risk element	Risk factors	Authors
Currency exchange	Change of currency exchange rate during payment process	Tummala and Schoenherr (2011)
Payment delay	Payment delay from partners or shippers	Seyoum (2009)
	Unrealised contract with partners	Tummala and Schoenherr (2011)
Non-payment	Shippers going into bankruptcy	Husdal and Bråthen (2010); Tummala and Schoenherr (2011)
	Shippers breaking the contract or reducing the container volume	Chen (2008)
	Having partners with bad credit	Tummala and Schoenherr (2011)

Source: authors

5.2 Validation and further exploration of risk factors though Interviews

The risk validation and exploration procedure in this study includes two major parts: (i) the results of the seven semi-structured face-to-face interviews and (ii) the results of six email interviews. Within the result of face-to-face interview, this thesis firstly presents the risk factors confirmation, and then the risk factors exploration. In the results of six email interviews, the overall categorisation of risk factors in container shipping operations is confirmed by the six interviewees and this set of email interviews can be deemed as the pilot test for the risk-factor questionnaire survey to be conducted in next Chapter.

5.2.1 Results from face-to-face interview

The interviewees were invited from two Taiwan's container shipping companies. In order to obtain a balanced view from different professional areas, the invited interviewees consisted of two information managers, two vice presidents, and three senior operation managers. The series of face-to-face interviews were conducted between February and March 2011. The semi-structured face-to-face interview questions can be referred to Appendix 1, and the transcriptions are presented in Appendix 2.

During the interview survey, all the risk factors identified in the literature review were confirmed. In addition, a number of risk factors that have not been addressed in previous studies were suggested by the interviewees. Details are presented below.

Using different communication channels is suggested as a risk factor associated with information flow. Using different communication channels produces un-standardised data, which may lead to inaccurate data input or engaging extra human resource and extra time to organise the data. An information manager mentioned:

> *"EDI is the most popular IT system used in shipping companies ... However, there are still some supply chain partners who cannot afford the investment of EDI, and they transmit the required information through other information channels such as email or telephone. The information transmitted through these different information channels is neither organised nor standardised. The dis-integrated information transmission may cause information delay and inaccuracy."*

Another added risk factors is "shippers requesting extra service information". Container shipping companies usually pay more attention to large shippers.

However, the influential negotiation power of large shippers sometimes creates risks associated with information flow to container shipping companies. For example, a large shipper may use its negotiation power in making unreasonable requests to the shipping company. As a manager explained:

> *"… large shippers often request for extra service, such as organising holistic logistic information which includes inland transportation shifts and customs clearance date.… Large shippers may even request for forecasting inland transportation timetable for several months in the future."*

Shippers hiding cargo information is also considered as a risk factor. Some shippers used the wrong cargo information to reduce the transportation fee or insurance payment, including declaring cheaper cargo category and declaring lighter cargo weight. A shipping manager mentioned:

> *"We have paid some penalties and our ship has once been detained because the documents for customs clearance were inconsistent with the shipper and the process was delayed. The reason is that our customer [the shipper] did not inform us that the contents of the cargos had been changed, or even the cargo information was hidden by the shipper."*

It has also emerged during the interviews that asset and cargo damage is a serious risk faced by shipping companies. As a manager explained:

> *"The majority of the cargos in freezer container transportation are fruit, high technology products, and chemistry material. These types of cargos need to be kept in certain and stable temperature.… Sometimes the electricity failure in ports or on ships damages the high value cargos, and makes fruit decayed or high technology products overheated. … The risk of dangerous goods transportation could damage not only cargos, but also ships, which is more serious than cargo damage or transportation delay. Sometimes we lose the whole ship, cargos, and reparations because of the dangerous goods explosion."*

Cargo stolen could be classed into risks associated with physical flow. In order to avoid the cargo stolen, the container seal is a common method used in shipping companies and Customs. However, cargo is still stolen and it generates financial and reputation loss to shipping companies. “Cargo stolen from unsealed containers” is confirmed as a risk factor associated with physical flow. A senior manager mentioned:

> *“… the thieves will drive trucks to some occult places and change the containers if the containers have no seal security during re-export transportation. Even [the containers] have container seal security, they (the criminals) will cut off the top of containers and steal the goods without breaking the container seal. Sometimes, they (the criminals) have other trucks and containers which are exactly the same as the original one. They use the fake containers to replace the valued ones…”*

As an international business, a container shipping company will receive different currencies for the transportation fee. The unstable currency exchange rate is regarded as a huge risk within risks associated with payment flow. A shipping manager mentioned:

> *“The transportation fees we get are usually calculated by USD. However, some shippers will still pay the bills by local currency, such as euro or JPY. We need to afford the risk from the unstable currency exchange rate,… sometimes it will make us lose the profit. … We can also transfer some impacts of currency exchange risk [to shippers] by doing Currency Adjustment Factor (CAF), but it could only be used in a huge fluctuation of currency exchange rate.”*

“Shippers go into bankruptcy”, “shippers break the contract and reduce the container volume”, and “have partners with bad credit” are confirmed as three risk factors by the interviewees. A shipping senior manager mentioned:

> *“Sometimes we need to handle or accept the risks from the shippers who bankrupt before making the payment. We need to do some survey about the shippers or supply chain partners. Avoid doing the business with the shippers who have bad credit or unstable finance [is very important to us]…”*

In addition, “Shippers abandoning cargos when cargos have already reached the port of destination” is also defined as a risk factor by the interviewees. A senior manager stated -

... shippers may abandon cargos if the value of the cargos become lower during the transportation, we therefore cannot receive the transportation fee if the contract is under FOB (Free on Board).

This thesis re-organises the possible risks within container shipping operations from the previous studies and interviews into Table 5.4, and uses yellow highlight to mark the new risk factors that explore from the face-to-face interviews. Six new risk factors have been added based on the results of the face-to-face interviews. They are “shippers requesting extra service information” (InfoI_4) and “shippers hiding cargo information (non-declare)” (Info_5) in the category of “risks associated with information flow”; “container shortage (e.g. shippers use containers as storage, container revamp, unexpected demand)” (PhTD_6) and “damage to frozen cargo/ reefer containers due to electricity failure” (PhCD_5) in the category of “risks associated with physical flow”; and “financial crisis in the loan countries” and “shippers abandoning cargos when cargos have already reached the port of destination” (PayNP_2) in the category of “risks associated with payment flow”, respectively. Eventually, a total of 34 risk factors have been identified in container shipping operations after face-to-face interviews.

These risks are roughly categorised into risks associated with information flow (information delay, information inaccuracy, IT problem), risks associated with physical flow (transportation delay, and cargo/asset damage), and risks associated with payment flow (curacy exchange, payment delay, and non-payment).

Table 5.4 Risks within container shipping operations (refined after face-to-face interview)

Risks associated with information flow
Information Delay (InfoD)
1. Using different communication channels in the supply chain increases the time of information transmission. (e.g. telephone, Email, EDI)
2. Supply chain partners do not transmit essential information on time
3. Processing documents are detained by the government departments (e.g. customs)
4. Shipping company cannot transmit essential information on time
Information Inaccuracy (InfoI)
1. Lack of information security during the information flow
2. Information asymmetry/incompleteness
3. Lack of information standardisation and compatibility
4. Shippers request extra service information
5. Shippers hide cargo information (non-declare)
IT Problem (InfoIT)
1. IT infrastructure breakdown or crash
2. Unsuitable human operation on IT infrastructure
3. Unsuitable human operation on application software
Risks associated with physical flow
Transportation Delay (PhTD)
1. Port strike
2. Port congestion (unexpected waiting times before berthing or before starting loading/discharging)
3. Port/terminal productivity below expectations (loading/discharging)
4. Unstable weather
5. Inappropriate empty mile transportation
6. Container shortage (e.g. Shippers use containers as storage, container revamp, unexpected demand)
7. Lack of flexibility of fleet size and designed schedules
8. Oil price rise
Cargo/asset loss or Damage (PhCD)
1. Damage to containers or cargos due to terminal operators' improper loading/unloading operations
2. Cargo being stolen from unsealed containers
3. Damage caused by transporting dangerous goods
4. Damage to ship or quay due to improper berth operations
5. Damage to frozen cargos/ reefer containers due to electricity failure
6. Attack from pirates or terrorists
Risks associated with payment flow
Currency Exchange (PayCE)
1. Currency exchange during payment process
2. Financial crisis in the loan countries
Payment Delay (PayPD)
1. Payment delay from partners or shippers
2. Unrealised contract with partners
Non-Payment (PayNP)

1.	Shippers go into bankruptcy
2.	Shippers abandon cargos if the value of the cargos become lower during the transportation
3.	Shippers breaking the contract and reduce the container volume
4.	Having partners with bad credit

4.2.2 Result from email interview

Table 4.4 provides an overall structural organisation of risk factors, risk elements and risk categories in container shipping operations. To confirm the categorisation in Table 5.4, we conducted small scale email interviews with open and closed questions to further explore the appropriateness of the identified risk factors within three main constructs, i.e. risks associated with information flow, risks associated with physical flow and risks associated with payment flow.

The samples were selected from the managers of Taiwan's container shipping companies in the UK. The reason that we chose the managers who work in the UK is to confirm and complement the results from the face-to-face interviews that were conducted in Taiwan. In addition, including the view from international managers, the results of the risk factors in container shipping operations could be generalised to international container shipping companies.

In total, six email interviews were sent out on 6th May 2011. The email interview questions can be referred to Appendix 3. The respondents' profile includes working position and working years, as shown in Table 5.5. All of the interviewees have more than 17 years working experience, and some of them are in the high level of working positions. It is believed that these six interviewees have had sufficient professional experience to judge the appropriateness of the risk categorisation.

Table 5.5 Respondent's profile in the email interviews

Working position	Managing Director	CIO	Chief Accountant	Navigation-superintendent	Senior consultant operations	Senior commissioner
Working years	27	30	Over 20	17	35	20

CIO means Chief Information Officer

The results of the email interviews are summarised in Table 5.6, which shows that most of the experts agree the categories of risk element. The elements in the category of "risks associated with information flow" are confirmed as "information delay", "information inaccuracy", and "IT problem"; the elements in the category of "risks associated with physical flow" are confirmed as "transportation delay" and "cargo/asset loss or damage"; and the elements in the category of "risks associated with payment flow" are confirmed as "currency exchange", "payment delay", and "non-payment". However, there are quite a few interesting comments from the email interviews that are worth mentioning below.

Commenting on the category of "risks associated with information flow", the cost of information/ information system (such EDI) could be deemed as a source of risks associated with information flow, which is consistent with the above face-to-face interview results. Illegal information exchange is commented as a risk element within the category of "risks associated with information flow". For example, it is not allowed for carriers to exchange tonnage supply or capacity of the trade lane in shipping business. It is also not allowed for carriers to exchange information for freight rates or surcharges in the EU. One manager suggests that risks associated with information flow could be categorised into information processing risk, information transmission risk, and information storing risk. However, we believe that these three elements have been included in the elements of “information delay”, “information inaccuracy”, and “IT problem”.

With regard to the category of “risks associated with physical flow”, a manager argues that “a delay in transportation does not always mean an increase in risk”. This may be true in some special contexts (e.g. in order to avoid further congestion at ports). However, other respondents agree that transportation delay is an element within the category of “risks associated with physical flow”, and our research needs to consider a complete perspective, we therefore maintain “transportation delay” as an element within the category of “risks associated with physical flow”. One respondent regarded unstable international fuel price as a source of risks associated with physical flow. This may be explained by the fact that shipping companies sometimes implement slow steaming or use low quality but cheap types of fuels to reduce the operational cost when fuel prices are high. These strategies might lead to transportation delay or asset damage. Moreover, one risk factor was added after the email interviews, “cargos detained by customs”, which implies that the physical flow is suspended at some points, and it could be regarded as a type of transportation delay.

In terms of the category of “risks associated with payment flow”, a manager also mentioned a risk factor (i.e. shippers give up the cargos when the cargos have already been transported to ports of destination) that was mentioned in face-to-face interview. In such case, the shipping company cannot get freight fee, and needs to absorb some extra fee such as terminal charge, storage, demurrage, etc. This is in agreement with the result from the face-to-face interviews and can be considered as an important factor in the risk element of "non-payment".

Table 5.6 Summary of data on resources acquired

<table>
<tr><th>Dimensions</th><th>Element</th><th>Agree</th><th>Dis-agree</th><th>Comments from respondents</th></tr>
<tr><td rowspan="3">Risks associated with information flow</td><td>Information Delay</td><td>5</td><td>1</td><td rowspan="3">• Cost of information (EDI)
• Illegal information exchanges
• More wide range of IR, i.e. information processing risk, information transmission risk, and information storing risk</td></tr>
<tr><td>Information Inaccuracy</td><td>6</td><td>0</td></tr>
<tr><td>IT Problem</td><td>6</td><td>0</td></tr>
<tr><td rowspan="2">Risks associated with physical flow</td><td>Transportation Delay</td><td>5</td><td>1</td><td rowspan="2">• A delay in transportation does not always mean an increase in risk
• Cost fuel, environmental regulation
• Restriction by law or regulations
• Cargos are detained by customs</td></tr>
<tr><td>Cargo/asset loss or Damage</td><td>6</td><td>0</td></tr>
<tr><td rowspan="3">Risks associated with payment flow</td><td>Currency Exchange</td><td>5</td><td>1</td><td rowspan="3">• Bad debts, credit, extra cost for special cargoes
• Shippers abandon cargos when cargos have already reached the port of destination. The shipping company cannot get freight fee, and needs to absorb some extra fee such as terminal charge, storage, demurrage, etc.</td></tr>
<tr><td>Payment Delay</td><td>5</td><td>1</td></tr>
<tr><td>Non-Payment</td><td>6</td><td>0</td></tr>
</table>

Based on the literature review (specific to container shipping and general supply chain operations), the face-to-face interviews and the email interviews, this thesis has identified a total of 35 risk factors under three categories of risks associated with information flow, physical flow and payment flow. This is summarised in Table 5.7, and the yellow highlight refers to the new risk factor that explore from the email interviews. One new risk factor is explored from the email interviews, namely, "cargos being detained by customs" (PhTD_8), which is deemed as a risk factor in the category of "risk associated with physical flow". To facilitate the narrative, the risk factors are coded with short names. This table will be used as a base risk classification when designing the risk-factor questionnaire in next chapter.

Table 5.7 Classification of risks within container shipping operations

Risk associated with information flow	
Information Delay (InfoD)	
1. Using different communication channels in the supply chain and consequently increasing the time of information transmission. (e.g. telephone, Email, EDI)	**InfoD_1**
2. Supply chain partners not transmitting essential information on time	**InfoD_2**
3. Processing documents being detained by government departments (e.g. customs)	**InfoD_3**
4. Shipping company not transmitting essential information on time	**InfoD_4**
Information Inaccuracy (InfoI)	
1. Lack of information security during the information flow	**InfoI_1**
2. Information asymmetry/incompleteness	**InfoI_2**
3. Lack of information standardisation and compatibility	**InfoI_3**
4. Shippers requesting extra service information	**InfoI_4**
5. Shippers hiding cargo information (non-declare)	**InfoI_5**
IT Problem (InfoIT)	
1. IT infrastructure breakdown or crash	**InfoIT_1**
2. Unsuitable human operation on IT infrastructure	**InfoIT_2**
3. Unsuitable human operation on application software	**InfoIT_3**
Risk associated with physical flow	
Transportation Delay (PhTD)	
1. Port strikes	**PhTD_1**
2. Port congestion (unexpected waiting times before berthing or before starting loading/discharging)	**PhTD_2**
3. Port/terminal productivity being below expectations (loading/discharging)	**PhTD_3**
4. Unstable weather	**PhTD_4**
5. Inappropriate empty container transportation	**PhTD_5**
6. Container shortage (e.g. Shippers use containers as storage, container revamp, unexpected demand)	**PhTD_6**
7. Lack of flexibility of fleet size and designed schedules	**PhTD_7**
8. Cargos being detained by customs	**PhTD_8**
9. Oil price rise	**PhTD_9**
Asset/cargo loss or damage (PhCD)	
1. Damage to containers or cargo due to terminal operators' improper loading/unloading operations	**PhCD_1**
2. Cargo being stolen from unsealed containers	**PhCD_2**
3. Damage caused by transporting dangerous goods	**PhCD_3**
4. Damage to ship or quay due to improper berth operations	**PhCD_4**
5. Damage to frozen cargo/ reefer containers due to electricity failure	**PhCD_5**
6. Attack from pirates or terrorists	**PhCD_6**
Risk associated with payment flow	

Currency Exchange (PayCE)	
1. Change of currency exchange rate during payment process	**PayCE_1**
2. Financial crisis in the loan countries	**PayCE_2**
Payment Delay (PayPD)	
1. Payment delay from partners or shippers	**PayPD_1**
2. Unrealised contract with partners	**PayPD_2**
Non-Payment (PayNP)	
1. Shippers going into bankruptcy	**PayNP_1**
2. Shippers abandoning cargos when cargos have already reached the port of destination	**PayNP_2**
3. Shippers breaking the contract or reducing the container volume	**PayNP_3**
4. Having partners with bad credit	**PayNP_4**

Source: author

5.3 Chapter summary

In order to identify the risks as complete as possible, this chapter reviews more literature in the broad supply chain context from three logistics flows perspective. Based on the initial literature review in Chapter 2 and more general literature review in this Chapter, a hierarchical risk classification is presented, which consists of risk categories, risk elements, and risk factors. The category of “risks associated with information flow” includes three risk elements, namely, information delay, information inaccuracy, and IT problem. The element of “information delay” includes four risk factors, the element of “information inaccuracy” includes three risk factors, and the element of “IT problem” includes three risk factors. The category of “risks associated with physical flow” includes two risk elements, namely, transportation delay and cargo/asset loss or damage. The element of “transportation delay” includes seven risk factors, and the element of “cargo/asset loss or damage” includes five risk factors. The category of “risks associated with payment flow” includes three elements, namely, currency exchange, payment delay, and non-payment. The element of “currency exchange” includes one risk factor, the element of “payment delay” includes two risk factors, and the element of “non-payment” includes three risk factors. Eventually, a total of 35 risk factors are identified through literature review and a set of face-to-face interview and a set of email interview.

Chapter 6 Measurement and analysis of risks in container shipping operations

Chapter 5 focuses on the second step of risk management, i.e. risk measurement and analysis. A risk-factor questionnaire survey is conducted to collect the primary data on risk likelihood and risk consequence, which are then analysed using several methods. Section 6.1 reports the respondents' profile in the risk-factor survey; Section 6.2 presents the results of validity and reliability test; Section 6.3 presents the results of risk measurement from the survey, including the results of risk likelihood and the risk consequences under three different criteria. Section 6.4 performs risk analysis, including risk scale, three risk matrices (i.e. financial loss risk matrix, reputation loss risk matrix, and safety and security incident related loss risk matrix), three risk maps, and four risk management responses in association with the three risk maps. Section 6.5 is the summary of this chapter.

6.1 Respondents' profile in the risk-factor survey

The target sample is selected from the list of ROC National Association of Shipping Agencies. A total 116 container shipping related companies were selected and each company was sent several questionnaire surveys to relevant departments, e.g. President/vice-President, information/document department, operation/shipping department, and financial department, etc. In total, 342 questionnaires were sent out on 14th July 2011 and received 88 replies in two months, including 62 valid ones and 26 invalid ones as the respondents did not answer all the questions of this survey, within a month. The valid return rate is 18.13% (Table 6.1).

Table 6.1 Questionnaires reply detail

Questionnaire distributed	Questionnaire returned	Invalid replies	Valid replies	Valid reply rate
342	88	26	62	18.13%

The 62 respondents' profile in the survey is presented in Table 6.2. Approximately 75% of respondents have already worked within the shipping industry for more than 16 years. This indicates that most of the respondents have very long professional working experience in container shipping operations and therefore the results of this questionnaire have a high reliability.

From a working department aspect, most respondents are working in operation/ shipping department (48.4%), followed by the financial/accounting department (19.4%), the information/ document department (12.9%) and president/ vice-president (11.3%). Although in this survey the author have tried to distribute similar numbers of questionnaires among information, financial and operation departments, the response rates from different departments appeared to be quite different. The unbalanced samples might cause a bias in the results of risk identification and risk mitigation strategies choice. Nevertheless, each department did have a representative size of samples and the inclusion of President and vice-President may reduce such bias.

In terms of the professional role, the largest type of respondents' role is manager/ assistant manager (35.5%), and the second one is director/ vice director (29%). There are 48.4% of the respondents who hold a position at or above the manager level, and have the power to make decisions within shipping companies. From the company's main business aspect, more than 60% of respondents are working in container shipping agency, and approximately 30% of respondents are working in container shipping company. In the ownership type section, more than 70% of respondents work in local container shipping companies. From the company size aspect, 35.5% of respondents work in small companies (fewer than 50 employees), and around 45% of respondents work in companies which have more than 200 employees.

Table 6.2 respondents' profile

		number	%
How many years have you worked in the shipping industry?	1 - 5 years	9	14.5
	6 - 10 years	4	6.5
	11 - 15 years	3	4.8
	16 - 20 years	12	19.4
	21 - 25 years	17	27.4
	Over 25 years	17	27.4
What is your department in your company?	President/ vice-president	7	11.3
	Information/ document	8	12.9
	Financial/ accounting	12	19.4
	Operation/ shipping	30	48.4
	Other	5	8.1
What is your professional role in your company?	Vice president or above	8	12.9
	Manager/Assistant manager	22	35.5
	Director/Vice Director	18	29.0
	Clerk	10	16.1
	Sales representative	3	4.8
	Others	1	1.6
What is your company's main business?	Container shipping company	19	30.6
	Container shipping agency	38	61.3
	Others	5	8.1
What is your company's ownership type?	Local firm	44	71.0
	Foreign-owned firm	10	16.1
	Foreign-local firm	7	11.3
	Others	1	1.6
How many employees are in your company?	1 - 50 people	22	35.5
	51 - 100 people	11	17.7
	101~200 people	1	1.6
	201~500 people	15	24.2
	over 500 people	13	21.0

6.2 Validity and reliability test for risk-factor survey

A validity test is to examine whether "a measurement scale is valid, if it does what it is supposed to do and measures what it is supposed to measure" (Davis, 2000, p.177). In order to obtain a high level of validity test, Davis (2000, pp.177-178) proposed a set of processes for improving validity, including the following four steps:

1. Conduct an exhaustive search of the literature for all possible items to be included in the scale
2. Solicit expert opinions on the inclusion of items
3. Pre-test the scale on a set of respondents similar to the population to be studied.
4. Modify as necessary.

The questions of this thesis are identified from previous literature addressed in container shipping operations and general supply chains, and have been validated through a set of face-to-face interviews and a set of email interviews from container shipping managers. Moreover, in order to make an inclusive risk picture for designing the questions, the face-to-face interviewees include 2 vice-presidents, 2 senior managers in the IT department, and 3 senior managers in the operations department; whilst the email interviewees include a managing director, a Chief information officer, a Chief Accountant, a Navigation superintendent a senior consultant operations, and a senior commissioner. Therefore, this survey is believed to have a high level of validity.

Reliability refers to “the consistency and stability of a score from a measurement scale” (Davis, 2000, p.179). After collecting data, the author conducted a reliability test for the whole survey and the results are shown in Table 6.3. A total of 140 questions were tested, including risk likelihood (35 questions), risk consequence on financial loss (35 questions), risk consequence on reputation loss (35 questions), and risk consequence on safety and security incident related loss (35 questions). The Cronbach’s Alpha is 0.991, whilst the Cronbach’s Alpha based on standardised items is also 0.991. According to Camines and Zeller (1979) and Bryman and Cramer (1997), the Cronbach’s Alpha should more than 0.80 to achieve a high level of reliability test. Therefore, this survey achieves a high level of reliability.

Table 6.3 Reliability test for the whole survey

Cronbach's Alpha	Cronbach's Alpha Based on Standardised Items	Number of question
0.991	0.991	140

In addition to the reliability test for the whole survey, the author further conducted a reliability test for the questions of risk likelihood and the results are shown in Table 6.4. The Cronbach’s Alpha is 0.969 (>0.8), whilst the Cronbach’s Alpha based on standardised items is also 0.970 (>0.8), which illustrates that the questions of risk likelihood are reliable.

Table 6.4 Reliability test for risk likelihood

Cronbach's Alpha	Cronbach's Alpha Based on Standardised Items	Number of question
0.969	0.970	35

The author also a conducted reliability test for the questions of risk consequence on financial loss and the results are shown in Table 6.5. The

Cronbach's Alpha is 0.976 (>0.8), whilst the Cronbach's Alpha based on standardised items is also 0.975 (>0.8), which illustrates that the questions of risk consequence on financial loss are reliable.

Table 6.5 Reliability test for risk consequence on financial loss

Cronbach's Alpha	Cronbach's Alpha Based on Standardised Items	Number of question
0.976	0.977	35

The author also conducted a reliability test for the questions of risk consequence on reputation loss and the results are shown in Table 6.6. The Cronbach's Alpha is 0.975 (>0.8), whilst the Cronbach's Alpha based on standardised items is also 0.975 (>0.8), which illustrates that the questions of risk consequence on reputation loss are reliable.

Table 6.6 Reliability test for risk consequence on reputation loss

Cronbach's Alpha	Cronbach's Alpha Based on Standardised Items	Number of question
0.975	0.975	35

Finally, the author conducted a reliability test for the questions of risk consequence on safety and security incident related loss and the results are shown in Table 6.7. The Cronbach's Alpha is 0.968 (>0.8), whilst the Cronbach's Alpha based on standardised items is also 0.969 (>0.8), which illustrates that the questions of risk consequence on safety and security incident related loss are reliable.

Table 6.7 Reliability test for risk consequence on safety and security incident related loss

Cronbach's Alpha	Cronbach's Alpha Based on Standardised Items	Number of question
0.968	0.969	35

6.3 Risk measurement

This section presents the result of the risk-factor questionnaire survey (see Appendix 4), including the level of risk likelihood and the level of risk consequences from three aspects (i.e. financial loss, reputation loss, and safety and security incident related loss as identified in Section 3.2.3.2).

6.3.1 Results in relation to risk likelihood

Table 6.8 shows the risk likelihood in container shipping operations from the risk-factor survey. Although the survey used a five point scale to measure the likelihood, no risk factor falls into scale 1, 4, and 5 after averaging the respondents' opinions. We therefore further classify the risk likelihoods into three levels: (1) high likelihood (red colour, the mean value of a risk factor is greater than 3): this risk factor is more likely happened compared with others; (2) moderate likelihood (orange colour, the mean value of a risk factor is between 2.8 and 2.99): this risk factor has somewhat high likelihood of happening; and (3) low likelihood (no colour marked): this risk factor is unlikely to happen compared with others. Moreover, the least occurring risk factor will be marked as blue colour.

Among the three risk categories, the category of the risks associated with physical flow has the highest likelihood (mean value is 2.88); whilst the other two categories, i.e. the risks associated with information flow and the risks associated with payment flow, have similar likelihood (mean value: 2.71). Among all risk factors in all three categories, the top three risks in terms of likelihood are “oil price rise”, “unstable weather” and “port congestion”, and all of them belong to the category of risks associated with physical flow. This reveals that the risks associated with physical flow are more likely to happen.

There are three risk elements within the category of risks associated with information flow, i.e. “Information delay”, “information inaccuracy”, and “IT problem”. The results show that the first two elements have the same mean value (2.77), which is greater than the third risk element – “IT problem” (with mean value: 2.55). This indicates that in general “Information delay” and “information inaccuracy” are more likely to happen in container shipping operations compared to “IT problem”. Each risk element consists of a set of risk factors. Among all risk factors in the category of risks associated with information flow, the top three risk factors are “shippers hiding cargo information (non-declare)” (InfoI_5: 3.26), “shippers requesting extra service information” (InfoI_4: 2.84) and “using different communication channels in the supply chain and consequently increasing the time of information transmission. (e.g. telephone, Email, EDI)” (InfoD_1: 2.82). Especially InfoI_5 has a significantly higher likelihood than the other risk factors, which reveals that shipping companies need to pay more attention to the information of the cargos, e.g. through confirming and checking the cargo content more frequently to reduce the occurring of such risk. The least likely risk factor is “lack of information security during the information flow” (InfoI_1: 2.40). However, its Standard Deviation (S.D.) is the greatest one within the category of risks associated with information flow. This indicates that some shipping companies may regard it as a risk factor that is likely to occur. In fact, our interviews confirmed that some shipping companies do place a heavy emphasis upon information security in order to reduce its likelihood, e.g. several shipping companies have applied the new international regulation – ISO27001 – to protect confidential business information so that it is not exposed within the competitive marketplace.

There are two risk elements within the category of risk associated with physical flow, i.e. “transportation delay” and “cargo/asset loss or damage”. The results show that the former element has a higher mean value of the likelihood (2.96) than the latter one (with mean value: 2.76). This indicates that in general “transportation delay” is more likely to happen in container shipping operations. Managers should pay more attention on reducing the occurrence of transport delay to mitigate the impact from this risk element. Among all risk factors in the category of risks associated with physical flow, the top three risk factors associated with physical flow include “oil price rise” (PhTD_9: 3.68), “unstable weather” (PhTD _4: 3.35) and “port congestion (unexpected waiting times before berthing or before starting loading/discharging)” (PhTD _2: 3.27). All of these three risks belong to the element of “transportation delay”, this shows that this element is more likely to happen than the element of “cargo/asset loss or damage” in container shipping operations. The least likely occurring risk factor is “Damage to ship or quay due to improper berth operations” (PhCD_4: 2.53), which has a big gap with PhTD_9 (mean value: 3.68) (i.e. the most frequently happening risk factor in this risk category), and the difference of the mean values is 1.12. Piracy at sea has received a lot of attention in recent years with more and more newspapers and research reporting or addressing this issue (e.g.

Kaye, 2011; Nkwocha, 2011). From our result, it appears that its likelihood does not stand out (PhCD_6: 2.66); it actually ranks 12th among all risk factors associated with physical flow. However, its S.D. is the greatest one (S.D. = 1.12) in the category of risks associated with physical flow, which indicates that some respondents (e.g. shipping agencies or some shipping companies) may less care about the pirate problem whereas other companies (e.g. shipping companies) may consider that it can happen quite often (e.g. if they have their ships sailing in some pirate-prone routes). This thesis therefore speculates that some responding companies may not have the routes through pirate sea areas.

There are three risk elements within the category of risks associated with payment flow, i.e. “currency exchange”, “payment delay” and “non-payment”. The results show that the first element has the largest mean value (2.79), whilst the second element has a mean value 2.74, and the third element has a mean value 2.65. There is a more notable difference of likelihood between the first two risk elements (“currency exchange” and “payment delay”) and the third element (“non-payment”). Among all risk factors in the category of risks associated with payment flow, the top three risk factors are “change of currency exchange rate during payment process” (PayCE_1: 3.08), “payment delay from partners or shippers’ (PayPD_1: 2.82) and “shippers breaking the contract or reducing the container volume” (PayNP_3: 2.73). The least likely risk factor is “financial crisis in the loan countries” (PayCE_2: 2.49). It is worth noting that after the financial crisis in 2008, many currencies become fluctuated more, including some global general currency such as the American dollar. According to Wang (2011), China Shipping Container Lines (CSCL) is facing a big risk caused by foreign exchange. This may explain why “change of currency exchange rate during payment process” is ranked as the top one.

Table 6.8 Risk likelihood

Risks associated with information flow	Mean	S.D.	Rank	
Information Delay (InfoD)			A	D
1. Using different communication channels in the supply chain and consequently increasing the time of information transmission. (e.g. telephone, Email, EDI)	2.82	1.12		3
2. Supply chain partners not transmitting essential information on time	2.76	0.94		5
3. Processing documents being detained by the government departments (e.g. customs)	2.81	1.01		4
4. Shipping company not transmitting essential information on time	2.68	0.92		7
Mean value of InfoD	2.77			
Information Inaccuracy (InfoI)				
1. Lack of information security during the information flow	2.40	1.23		12
2. Information asymmetry/incompleteness	2.61	1.03		8
3. Lack of information standardisation and compatibility	2.73	1.01		6
4. Shippers requesting extra service information	2.84	0.98		2
5. Shippers hiding cargo information (non-declare)	3.26	1.07		1
Mean value of InfoI	2.77			
IT Problem (InfoIT)				
1. IT infrastructure breakdown or crash	2.56	0.86		9
2. Unsuitable human operation on IT infrastructure	2.53	0.86		11
3. Unsuitable human operation on application software	2.56	0.78		9
Mean value of InfoIT	2.55			
Mean value of risks associated with information flow	2.71			
Risks associated with physical flow				
Transportation Delay (PhTD)				
1. Port strike	2.56	0.99		14
2. Port congestion (unexpected waiting times before berthing or before starting loading/discharging)	3.27	0.94	3	3
3. Port/terminal productivity being below expectations (loading/discharging)	2.82	0.97		6
4. Unstable weather	3.35	0.85	2	2
5. inappropriate empty container transportation	2.77	1.00		8
6. Container shortage (e.g. Shippers use containers as storage, container revamp, unexpected demand)	2.82	0.84		6
7. Lack of flexibility of fleet size and designed schedules	2.73	0.87		10
8. Cargos are detained by customs	2.63	0.91		13
9. Oil price rise	3.68	1.00	1	1
Mean value of PhTD	2.96			
Cargo/asset loss or damage (PhCD)				
1. Damage to containers or cargos due to terminal operators' improper loading/unloading operations	3.03	1.02		4
2. Cargo being stolen from unsealed containers	2.77	1.05		8

3. Damage caused by transporting dangerous goods	2.90	0.90		5
4. Damage to ship or quay due to improper berth operations	2.53	0.95		15
5. Damage to frozen cargos/ reefer containers due to electricity failure	2.68	0.92		11
6. Attack from pirates or terrorists	2.66	1.12		12
Mean value of PhCD	2.76			
Mean value of risks associated with physical flow	2.88			
Risks associated with payment flow				
Currency Exchange (PayCE)				
1. Change of currency exchange rate during payment process	3.08	1.08		1
2. Financial crisis in the loan countries	2.49	1.07		8
Mean value of PayCE	2.79			
Payment Delay (PayPD)				
1. Payment delay from partners or shippers	2.82	0.97		2
2. Unrealised contract with partners	2.66	0.97		5
Mean value of PayPD	2.74			
Non Payment (PayNP)				
1. Shippers going into bankruptcy	2.61	1.06		6
2. Shippers abandoning cargos when cargos have already reached the port of destination	2.68	0.88		4
3. Shippers breaking the contract or reducing the container volume	2.73	0.96		3
4. Having partners with bad credit	2.58	0.88		7
Mean value of PayNP	2.65			
Mean value of risks associated with payment flow	2.71			

*S.D. = Standard Deviation
*red colour means the mean value is more than 3
*orange colour means the mean value is between 2.8 and 2.99
*blue colour means the mean value is the smallest one
*Rank A means the overall risks rank (only shows the top three ones)
*Rank D means the risk rank within the dimension risks, i.e. risks associated with information flow, risks associated with physical flow, and risks associated with payment flow

6.3.2 Results in relation to financial loss consequence

Table 6.9 shows that the risk consequences from the financial loss perspective from the risk-factor survey. Among three risk categories, the category of risks associated with physical flow has the greatest mean, which is 3.22 and is regarded as the most serious risk category in terms of financial consequence. The category of risks associated with payment flow (mean value: 2.95) ranks the second and the category of risks associated with information flow (mean value: 2.87) is the third one. However, all three categories of risks deserve a lot of attention if managers aim to reduce the financial loss consequence as their mean values are all reasonably high (e.g. greater than 2.8). Among all risk factors in all three categories, the top three risk factors in terms of financial consequence are PhTD_9, PhCD_4, and PhTD_1. All these three risk factors belong to the category of risks associated with physical flow, which means that the main risks that impact on the financial loss are among the risks associated with physical flow.

Among three risk elements within the category of the risks associated with information flow, "IT problem" (mean value: 2.90) has the most serious financial consequence; whilst "information inaccuracy" (mean value: 2.89) ranks the second, and "information delay" (mean value: 2.82) is the least serious one yet it still plays an important role in financial loss consequence. Among all the risk factors within the category of the risks associated with information flow, the top three risk factors in terms of financial loss consequence are "shippers hide cargo information" (InfoI_5: 3.34), "shipping company cannot transmit essential information on time" (InfoD_4: 3.18), and "lack of information security during the information flow" (InfoI_1: 3.15). This indicates that shipping companies may suffer serious financial loss if shippers hide cargo information. Shipping companies also need to make some strategies for transmitting the information on time by itself, such as regular employee training. The third risk factor, "lack of information security", has the greatest S.D. (1.23) in the category of risks associated with information flow, and this means that some companies consider it being rather serious (e.g. may be more serious than the second one, i.e. "shipping company cannot transmit essential information on time"). Although "using different communication channels in the supply chain increases the time of information transmission" it has the least impact upon financial loss (InfoD_1:

2.56), and does not have a huge gap with other risk factors associated with information flow. Therefore, it may still need to be considered in container shipping operations.

Among two risk elements within the category of the risks associated with physical flow, "cargo/asset loss or damage" (mean value: 3.39) has a greater impact on financial loss consequence than "transportation delay" (mean value: 3.10). All mean values of risk factors within the risk element, "cargo/asset loss or damage", are greater than 3, which illustrates the important severity of "cargo/asset loss or damage" from the financial loss consequence aspect. Among all the risk factors within the category of the risks associated with physical flow, the top three risk factors in terms of financial loss consequence include "oil price rise" (PhTD_6: 3.66), "damage to ship or quay due to improper berth operations" (PhCD_4: 3.56), and "port strike" (PhTD_1: 3.53). Undoubtedly, unstable oil price has become an important issue from 2007. Many studies indicated that the dramatic fluctuation of oil price makes many shipping companies suffer huge financial crises (e.g. Michaelowa and Krause, 2000; Goulielmos and Psifia, 2006). There were some reports on the accidents caused by improper berth operations, e.g. a containership capsized when loading in Antwerp on 8th March 2007, which caused about 100 containers and cars to fall overboard (IMC, 2007). Port strikes also lead to serious financial loss to container shipping companies. The well-known example is the strike in the U.S. in 2002 that cost America's economy 1 to 2 billion dollars per day (Park *et al*., 2008). Although the risk factor, "attack from pirates or terrorists", is not in the top three, its mean value is noticeably high (PhCD_6: 3.50). This may be supported by Ewence's (2011) report, which stated that it could cost shipping companies and the governments $7bn to $ 12bn per year to deal with the Somalia piracy. Moreover, except “inappropriate empty container transportation” (PhTD_5: 2.79), other risk factors’ mean values in the element of “transportation delay” are all greater than 2.8. However, the mean value of PhTD_5 is very close to 2.8. In addition, the gaps of these mean values are marginal (difference of the maximum and minimum mean = 0.2), which means the risks associated with payment flow have similar effect in terms of the financial loss consequence.

Among three risk elements within the category of the risks associated with payment flow, “payment delay” (mean value: 3.00) has the most serious financial loss consequence; however, “currency exchange” (mean value: 2.96) and “non-payment” (mean value: 2.91) also have quite close severity in financial loss consequence. Among all the risk factors within the category of risks associated with payment flow, the top three top risk factors in terms of financial loss consequence are “change of currency exchange rate during payment process” (PayCE_1: 3.02), “payment delay from partners or shippers” (PayPD_1: 3.02), and “shippers going into bankruptcy” (PayNP_1: 3.02). It is interesting that all of the mean values of these three risks are the same and the S.D. are close, which shows that these three risk factors have similar levels of impact upon the financial loss within shipping operations.

Table 6.9 Risk consequence - financial loss

Risks associated with information flow	Mean	S.D.	Rank	
Information Delay (InfoD)			A	D
1. Using different communication channels in the supply chain and consequently increasing the time of information transmission. (e.g. telephone, Email, EDI)	2.56	1.10		12
2. Supply chain partners not transmitting essential information on time	2.68	1.05		9
3. Processing documents being detained by government departments (e.g. customs)	2.84	1.13		5
4. Shipping company not transmitting essential information on time	3.18	1.13		2
Mean value of InfoD	2.82			
Information Inaccuracy (InfoI)				
1. Lack of information security during the information flow	3.15	1.23		3
2. Information asymmetry/incompleteness	2.71	1.11		8
3. Lack of information standardisation and compatibility	2.58	0.98		11
4. Shippers requesting extra service information	2.66	1.14		10
5. Shippers hiding cargo information (non-declare)	3.34	1.17		1
Mean value of InfoI	2.89			
IT Problem (InfoIT)				
1. IT infrastructure breakdown or crash	3.03	1.02		4
2. Unsuitable human operation on IT infrastructure	2.82	1.00		7
3. Unsuitable human operation on application software	2.84	0.93		5
Mean value of InfoIT	2.90			
Mean value of risks associated with information flow	2.87			
Risks associated with physical flow				
Transportation Delay (PhTD)				
1. Port strikes	3.53	1.22	3	3
2. Port congestion (unexpected waiting times before berthing or before starting loading/discharging)	3.18	0.97		8
3. Port/terminal productivity being below expectations (loading/discharging)	3.03	0.96		11
4. Unstable weather	3.08	0.98		10
5. Inappropriate empty container transportation	2.79	1.03		15
6. Container shortage (e.g. Shippers use containers as storage, container revamp, unexpected demand)	2.90	0.97		13
7. Lack of flexibility of fleet size and designed schedules	2.95	1.03		12
8. Cargos being detained by customs	2.81	1.01		14
9. Oil price rise	3.66	0.92	1	1
Mean value of PhTD	3.10			
Cargo/asset loss or damage (PhCD)				
1. Damage to containers or cargo due to terminal operators' improper loading/unloading operations	3.15	1.02		9
2. Cargo being stolen from unsealed containers	3.24	1.18		7
3. Damage caused by transporting dangerous goods	3.43	1.01		6
4. Damage to ship or quay due to improper berth operations	3.56	1.17	2	2
5. Damage to frozen cargo/ reefer containers due to electricity failure	3.48	1.08		5
6. Attack from pirates or terrorists	3.50	1.33		4

Mean value of PhCD	3.39			
Mean value of risks associated with physical flow	3.22			
Risks associated with payment flow				
Currency Exchange (PayCE)				
1. Change of currency exchange rate during payment process	3.02	1.12		1
2. Financial crisis in the loan countries	2.90	1.22		6
Mean value of PayCE	2.96			
Payment Delay (PayPD)				
1. Payment delay from partners or shippers	3.02	1.12		1
2. Unrealised contract with partners	2.97	1.14		4
Mean value of PayPD	3.00			
Non Payment (PayNP)				
1. Shippers going into bankruptcy	3.02	1.14		1
2. Shippers abandoning cargos when cargos have already reached the port of destination	2.97	1.06		4
3. Shippers breaking the contract or reducing the container volume	2.84	1.03		7
4. Having partners with bad credit	2.82	1.05		8
Mean value of PayNP	2.91			
Mean value of risks associated with payment flow	2.95			

*S.D. = Standard Deviation
*red colour means the mean value is more than 3
*orange colour means the mean value is between 2.8 and 2.99
*blue colour means the mean value is the smallest one
*Rank A means the overall risks rank (only shows the top three ones)
*Rank D means the risk rank within the dimension risks, i.e. risks associated with information flow, risks associated with physical flow, and risks associated with payment flow

6.3.3 Results in relation to reputation loss consequence

Table 6.10 shows the risk consequences in relation to the reputation loss from the risk-factor survey. Among three risk categories, the category of risks associated with information flow (with mean value: 2.70) and the category of risks associated with physical flow (with mean value: 2.71) in the reputation loss consequence are similar yet not as important as in the financial loss consequence (with mean values 2.87 and 3.22 respectively in Table 5.4); whilst the category of risks associated with payment flow (with mean value: 2.42) is the least serious one that impacts on reputation loss, which is also significantly less than on the financial loss (with mean value 2.95 in Table 5.4). Among all the risk factors in all three categories, the top three risk factors in terms of reputation loss consequence are PhCD_3, InfoI_5, and PhCD_4. Compared to other risk consequences, the mean value of these risks in reputation loss are smaller. These are the only three risk factors with mean value greater than 3 and the greatest mean value is solely 3.08. This result indicates that these risk factors may be the main ones that lead to reputation loss. On the other side, it is noted that the mean value of InfoD_1, i.e. “Using different communication channels in the supply chain and consequently increasing the time of information transmission”, is the least serious one (InfoD_1: 2.24) in reputation loss consequence.

Among three risk elements within the category of the risks associated with information flow, “IT problem” (mean value: 2.76) and “information inaccuracy” (mean value: 2.73) are the first and second risk elements that causes reputation loss, whilst “information delay” (mean value: 2.62) is the least serious one. However, all three risk elements’ mean values are not greater than 2.8, which indicate that these three risk elements may not hugely impact on the reputation loss. Among all the risk factor within the category of the risks associated with information flow, the top three risk factors in reputation loss consequence include “shippers hiding cargo information (non-declare)” (InfoI_5: 3.03), “shipping company not transmitting essential information on time” (InfoD_4: 2.92), “processing documents being detained by the government departments (e.g. customs)” (InfoD_3: 2.89), and “IT infrastructure breakdown or crash” (InfoIT_1: 2.89). Although InfoD_3 and InfoIT_1 have the same mean value, the S.D. of InfoIT_1 (S.D. = 1.22) is greater than InfoD_3 (S.D. = 1.10). This result illustrates that some companies may regard “processing documents are detained by the government departments” is more important than “IT infrastructure breakdown or crash", but other companies may think in the opposite way, whereas overall their impact on reputation loss is similar.

Among the two risk elements within the category of risks associated with physical flow, "cargo/asset loss or damage" (mean value: 2.96) is more serious than "transportation delay" (mean value: 2.58). Moreover, all of the mean values of transportation delay are smaller than 2.8. This means that the risk element of "cargo/asset loss or damage" causes more reputation loss compared to the other one and more attention should be paid to reducing its impact. Among all the risk factors within the category of the risks associated with physical flow, the top three ones are "damage caused by transporting dangerous goods" (PhCD_3: 3.08), "damage to ship or quay due to improper berth operations" (PhCD_4: 3.00), and "damage to frozen cargos/ reefer containers due to electricity failure" (PhCD_5: 2.97). It is easy to understand that the above three risk factors would lead to the companies' reputation loss. The least serious risk factor is "oil price rise" (with mean value: 2.31).

Among three risk elements within the category of risks associated with payment flow aspect, all of the mean values are not more than 2.5. This indicates that the category of risks associated with payment flow is relatively less important on the reputation loss consequence to shipping companies. However, the S.D. of the two risk factors in currency exchange is relatively large, which means the currency exchange risks may still need to be considered in shipping operations.

Table 6.10 Risk consequence - reputation loss

Risks associated with information flow	Mean	S.D.	Rank	
<u>Information Delay</u> (InfoD)			A	D
1. Using different communication channels in the supply chain and consequently increasing the time of information transmission. (e.g. telephone, Email, EDI)	2.24	1.07		12
2. Supply chain partners not transmitting essential information on time	2.44	1.07		11
3. Processing documents being detained by government departments (e.g. customs)	2.89	1.10		3
4. Shipping company not transmitting essential information on time	2.92	1.22		2
Mean value of InfoD	2.62			
<u>Information Inaccuracy</u> (InfoI)				
1. Lack of information security during the information flow	2.82	1.19		5
2. Information asymmetry/incompleteness	2.66	1.14		8
3. Lack of information standardisation and compatibility	2.48	1.00		10
4. Shippers requesting extra service information	2.65	1.12		9
5. Shippers hiding cargo information (non-declare)	3.03	1.12	2	1
Mean value of InfoI	2.73			
<u>IT Problem</u> (InfoIT)				
1. IT infrastructure breakdown or crash	2.89	1.22		3
2. Unsuitable human operation on IT infrastructure	2.69	1.14		6
3. Unsuitable human operation on application software	2.69	1.05		6
Mean value of InfoIT	2.76			
Mean value of risks associated with information flow	2.70			
Risks associated with physical flow				
<u>Transportation Delay</u> (PhTD)				
1. Port strikes	2.79	1.36		6
2. Port congestion (unexpected waiting times before berthing or before starting loading/discharging)	2.73	1.15		8
3. Port/terminal productivity being below expectations (loading/discharging)	2.69	1.06		10
4. Unstable weather	2.44	1.15		13
5. Inappropriate empty container transportation	2.42	1.18		14
6. Container shortage (e.g. Shippers use containers as storage, container revamp, unexpected demand)	2.55	1.11		11
7. Lack of flexibility of fleet size and designed schedules	2.76	1.04		7
8. Cargos being detained by customs	2.53	1.16		12
9. Oil price rise	2.31	1.18		15
Mean value of PhTD	2.58			
<u>Cargo/asset loss or damage</u> (PhCD)				
1. Damage to containers or cargo due to terminal operators' improper loading/unloading operations	2.82	1.09		5
2. Cargo being stolen from unsealed containers	2.85	0.92		4
3. Damage caused by transporting dangerous goods	3.08	1.11	1	1
4. Damage to ship or quay due to improper berth operations	3.00	1.10	3	2
5. Damage to frozen cargo/ reefer containers due to electricity failure	2.97	1.06		3
6. Attack from pirates or terrorists	2.73	1.27		8
Mean value of PhCD	2.91			

Mean value of risks associated with physical flow	2.71			
Risks associated with payment flow				
Currency Exchange (PayCE)				
1. Change of currency exchange rate during payment process	2.37	1.24		6
2. Financial crisis in the loan countries	2.41	1.33		5
Mean value of PayCE	2.39			
Payment Delay (PayPD)				
1. Payment delay from partners or shippers	2.45	1.20		3
2. Unrealised contract with partners	2.55	1.21		1
Mean value of PayPD	2.50			
Non Payment (PayNP)				
1. Shippers going into bankruptcy	2.37	1.22		6
2. Shippers abandoning cargos when cargos have already reached the port of destination	2.34	1.14		8
3. Shippers breaking the contract or reducing the container volume	2.42	1.22		4
4. Having partners with bad credit	2.48	1.18		2
Mean value of PayNP	2.40			
Mean value of risks associated with payment flow	2.42			

*S.D. = Standard Deviation
*red colour means the mean value is more than 3
*orange colour means the mean value is between 2.8 and 2.99
*blue colour means the mean value is the smallest one
*Rank A means the overall risks rank (only shows the top three ones)
*Rank D means the risk rank within the dimension risks, i.e. risks associated with information flow, risks associated with physical flow, and risks associated with payment flow

6.3.4 Results in relation to safety and security incident related loss consequence

Table 6.11 shows the risk consequence in relation to the safety and security incident related loss from the risk-factor survey. The category of risks associated with physical flow (mean value: 2.93) and the category of risks associated with information flow (mean value: 2.91) are the first and second important risk categories, and both of their mean values are greater than 2.9; this indicates that both of them may lead to serious safety and security incident related loss in container shipping operations. The category of risks associated with payment flow has the least serious impact (mean value: 2.29). Among all risk factors in all three categories, the top three risk factors are “attack from pirates or terrorists” (PhCD_6: 3.95), “damage to ship or quay due to improper berth operations”

(PhCD_4: 3.84), and “damage caused by transporting dangerous goods” (PhCD_3: 3.74). All of these three risk factors belong to the category of risks associated with physical flow, which means that the main risks that impact on the safety and security loss are among the risks associated with physical flow. It is noted that the least serious risk factor is “shippers breaking the contract or reducing the container volume” (mean value: 2.21), which may be explained by the fact that this risk factor is not directly related to the safety and security.

Among three risk elements within the category of risks associated with information flow, “IT problem” (mean value: 3.13) has the most serious impact on safety and security incident related loss; whilst “information inaccuracy” (mean value: 3.09) is quite close to the former one. Both these two risk elements have mean values greater than 3, which reveal that the consequences of these two elements are quite serious in terms of safety and security. The least serious element is “information delay” with a mean value 2.53, which is significantly lower than the other two risk elements. Among all the risk factors within the category of the risks associated with information flow, the top three risk factors in terms of safety and security incident related loss consequence are “shippers hiding cargo information (non-declare)” (InfoI_5: 3.56), “lack of information security during the information flow” (InfoI_1: 3.31), and “IT infrastructure breakdown or crash” (InfoIT_1: 3.23). The importance of InfoI_5 is supported by Mele’s (2011) report: the potential threat of cargo fraud is more damaging than the cargo theft. Additionally, all the mean values of the risk factors in the element of “IT problem” are greater than 3, which show IT problems could have serious effect on safety and security. Moreover, the S.D. of “information asymmetry/incompleteness” (1.30) and “shippers request extra service information" (1.31) are quite large; this result indicates that although these two risk factors are not in the top three risk factors within the category of risks associated with information flow in terms of the safety and security incident related loss consequence, some companies may still consider them.

Among the two risk elements within the category of risks associated with physical flow, "cargo/asset loss or damage" (with mean value: 3.61) plays a much more important role than the other one, i.e. "transportation delay" (mean value: 2.48), in terms of safety and security incident related loss consequence. This may be explained by the fact that "cargo/ asset loss or damage" is directly linked to safety and security performance, whereas "transportation delay" is not. Among all the risk factors within the category of risks associated with physical flow , the top three risk factors are "attack from pirates or terrorists" (PhCD_6: 3.95), "damage to ship or quay due to improper berth operations" (PhCD_4: 3.84), and "damage caused by transporting dangerous goods" (PhCD_3: 3.74). The piracy issue has been emphasised in recent years, and its damage to employee safety and the security of ships is countless (Kaye, 2011; Nkwocha, 2011). The ships that transport dangerous goods also need much attention because of its serious damage to employees. For example, according to AP's (2011) report, an explosion accident happened on a ship and it killed three crew members on 8th September 2011 because an unknown substance leaked into water. Additionally, all the mean values of the risk factors in the element of "cargo/asset loss or damage" are greater than 3 (similar to the case of financial loss consequence in Table 5.4) and all these six risk factors are also the top six risk factors within the category of risks associated with physical flow in terms of safety and security incident related loss consequence. Moreover, "unstable weather" (PhTD_4: 2.95) and "port strike" (PhTD_1: 2.85) also have serious impacts on safety and security incident related loss consequence. On the other hand, the least serious risk factor is "container shortage (e.g. Shippers use containers as storage, container revamp, unexpected demand)" (PhTD _6: 2.23).

Among three risk elements within the category of risks associated with payment flow, all the mean values of three risk elements are close to 2.3. This result shows that the risks associated with payment flow have quite small impact on safety and security incident related loss consequence in container shipping operations. Among all the risk factors within the category of risks associated with payment flow, the top three risk factors in terms of safety and security incident related loss consequence are "shippers going into bankruptcy" (PayNP_1: 2.40), "having partners with bad credit" (PayNP_4: 2.34), and "financial crisis in the loan countries" (PayCE_2: 2.27). Except PayNP_1, all the mean values of risk factors within the category of risks associated with payment flow are smaller than 2.4. Therefore, it is suggested that shipping managers may pay more attention to other types of risk category (i.e. risks associated with information flow and risks associated with physical flow) than to risks associated with payment flow when reducing the safety and security incident related loss is concerned.

Table 6.11 Risk consequence - safety and security incident related loss

Risks associated with information flow	Mean	S.D.	Rank	
Information Delay (InfoD)			A	D
1. Using different communication channels in the supply chain and consequently increasing the time of information transmission. (e.g. telephone, Email, EDI)	2.40	1.14		12
2. Supply chain partners not transmitting essential information on time	2.45	1.22		11
3. Processing documents being detained by government departments (e.g. customs)	2.65	1.26		9
4. Shipping company not transmitting essential information on time	2.60	1.23		10
Mean value of InfoD	2.53			
Information Inaccuracy (InfoI)				
1. Lack of information security during the information flow	3.31	1.29		2
2. Information asymmetry/incompleteness	2.95	1.30		6
3. Lack of information standardisation and compatibility	2.82	1.06		7
4. Shippers requesting extra service information	2.79	1.31		8
5. Shippers hiding cargo information (non-declare)	3.56	1.29		1
Mean value of InfoI	3.09			
IT Problem (InfoIT)				
1. IT infrastructure breakdown or crash	3.23	0.97		3
2. Unsuitable human operation on IT infrastructure	3.10	1.14		4
3. Unsuitable human operation on application software	3.06	1.07		5
Mean value of InfoIT	3.13			
Mean value of risks associated with information flow	2.91			
Risks associated with physical flow				
Transportation Delay (PhTD)				
1. Port strikes	2.85	1.29		8
2. Port congestion (unexpected waiting times before berthing or before starting loading/discharging)	2.42	1.08		9
3. Port/terminal productivity being below expectations (loading/discharging)	2.40	1.08		10
4. Unstable weather	2.95	1.08		7
5. Inappropriate empty container transportation	2.37	1.16		12
6. Container shortage (e.g. Shippers use containers as storage, container revamp, unexpected demand)	2.23	1.14		15
7. Lack of flexibility of fleet size and designed schedules	2.39	1.26		11
8. Cargos being detained by customs	2.35	1.10		13
9. Oil price rise	2.35	1.24		13
Mean value of PhTD	2.48			
Cargo/asset loss or damage (PhCD)				
1. Damage to containers or cargo due to terminal operators' improper loading/unloading operations	3.11	1.03		6
2. Cargo being stolen from unsealed containers	3.27	1.10		5
3. Damage caused by transporting dangerous goods	3.74	1.17	3	3
4. Damage to ship or quay due to improper berth operations	3.84	1.22	2	2
5. Damage to frozen cargo/ reefer containers due to electricity failure	3.72	1.11		4
6. Attack from pirates or terrorists	3.95	1.22	1	1

Mean value of PhCD	3.61			
Mean value of risks associated with physical flow	2.93			
Risks associated with payment flow				
<u>Currency Exchange</u> (PayCE)				
1. Change of currency exchange rate during payment process	2.27	1.28		4
2. Financial crisis in the loan countries	2.32	1.33		3
Mean value of PayCE	2.30			
<u>Payment Delay</u> (PayPD)				
1. Payment delay from partners or shippers	2.26	1.09		6
2. Unrealised contract with partners	2.26	1.10		6
Mean value of PayPD	2.26			
<u>Non Payment</u> (PayNP)				
1. Shippers going into bankruptcy	2.40	1.29		1
2. Shippers abandoning cargos when cargos have already reached the port of destination	2.27	1.20		4
3. Shippers breaking the contract or reducing the container volume	2.21	1.12		8
4. Having partners with bad credit	2.34	1.23		2
Mean value of PayNP	2.31			
Mean value of risks associated with payment flow	2.29			

*S.D. = Standard Deviation
*red colour means the mean value is more than 3
*orange colour means the mean value is between 2.8 and 2.99
*blue colour means the mean value is the smallest one
*Rank A means the overall risks rank (only shows the top three ones)
*Rank D means the risk rank within the dimension risks, i.e. risks associated with information flow, risks associated with physical flow, and risks associated with payment flow

6.4 Risk analysis

In this section, the results of risk scale, three risk matrices and maps corresponding to three different risk consequences (i.e. financial loss, reputation loss, and safety and security incident related loss), and risk maps with four risk management responses (i.e. avoid, transfer, mitigate, and accept) will be presented respectively.

6.4.1 Risk scale

Instead of multiplying the mean value of risk likelihood with the mean value of risk consequence to calculate the risk scale, in this thesis the risk scale is measured by multiplying risk likelihood and risk consequence for each individual respondent, and then averaging over all respondents. This thesis uses Average Risk Scale (ARS) (which has been developed in Section 4.3.1.1) to calculate the relevant risk likelihood and risk consequence of each risk factor and then to locate these risk factors to the risk map.

Three types of risk scale – financial loss risk scale, reputation loss risk scale, and safety and security incident related loss risk scale – have been calculated and the mean values are also calculated and ranked respectively (Table 6.12). Although we have introduced four levels of risk scale: extreme risk (risk scale: 15.01 – 25), high risk (risk scale: 10.01 – 15), moderate risk (risk scale: 5.01 – 10), and Low risk (risk scale: 1 to 5), all the risk scales fall between 6.5 and 14. This thesis therefore classifies the risk scale into the following three categories: high risk (the mean value of risk scale is bigger than 10, in red colour), moderate risk (the mean value of risk scale is between 8.01 and 9.99, in yellow colour), and low risk (the rest risk factors, with no colour). In addition, the least risk scale of the risk factor is marked in blue colour.

Averaging over all risk factors in terms of their impact on financial loss, reputation loss and safety and security incident related loss, the results, as shown in Table 6.12, reveal that financial loss is the most affected criterion (the average is 9.05) and reputation loss is the least affected criterion (the average is 7.92) with the safety and security incident related loss (the average is 8.21) being in the middle.

From the financial loss risk scale perspective, the category of risks associated with physical flow (mean value: 9.80) is the main risk category which leads to financial loss; the category of risks associated with information flow is the least one with a mean value 8.33. Among all the risk factors, the top three risk factors are "oil price rise" (PhTD_9: 14.00), "shippers hiding cargo information (non-declare)" (InfoI_5: 11.44), and "port congestion (unexpected waiting times before berthing or before starting loading/discharging)" (PhTD_2: 10.81). It is easy to understand that the fluctuated oil price has become one of the most serious risk factors in financial loss due to the rapid increasing oil price in recent years (e.g. up to $147.27 in July, 2008) (www.cnyes.com). Shippers sometime will hide cargo information to smuggle some illegal goods or to avoid the expensive freight of dangerous goods and high valued cargos. This leads to the severity of the risk factor InfoI_5 sometimes is greater than PhTD_9. The third risk factor, port congestions (PhTD_2), has been identified as a very important risk from Notteboom's research (2006). Moreover, there are several risk factors, whose risk scales, although lower than the top three, are also quite high (greater than 10), e.g. "unstable weather" (PhTD_4: 10.63), "damage caused by transporting dangerous goods" (PhCD_3: 10.26), "damage to containers or cargos due to terminal operators' improper loading/unloading operations" (PhCD_1: 10.21), and "change of currency exchange rate during payment process" (PayCE_1: 10.18). The results suggest that shipping managers also need to pay attention to these risk factors. On the other hand, "lack of information standardisation and compatibility" (InfoI_3: 7.66) has the least impact on shipping companies' financial loss. Shipping managers could accept this risk and pay more attention to other more serious risks. In terms of financial loss, among three risk categories, the category of risks associated with physical flow is the most significant one (the mean is 9.80), and the category of risks associated with information flow is the least significant one (the mean value is 8.33).

In terms of the reputation risk scale, the category of risks associated with physical flow is again the most significant one, but the impact is not as high as that in the financial risk scale (the mean here is 8.29). The category of risks associated with payment flow (the mean being 7.28) has the least impact on shipping companies' reputation loss. Among all the risk factors, the top three risk factors are "shippers hiding cargo information (non-declare)" (InfoI_5: 10.61), "damage caused by transporting dangerous goods" (PhCD_3: 9.52), and "port congestion (unexpected waiting times before berthing or before starting loading/discharging)" (PhTD_2: 9.39); the least one is "using different communication channels in the supply chain and consequently increasing the time of information transmission. (e.g. telephone, Email, EDI)" (InfoD_1: 6.66), which has a big gap from the top three factors.

In the section of the safety and security incident related loss risk scales, the category of risks associated with physical flow is still in first place (the average risk scale is 8.81) and the category of risks associated with payment flow is still the least one (the average risk scale is 6.88). Among all the risk factors, the top three risk factors include "shippers hiding cargo information" (InfoI_5: 12.08), "damage caused by transporting dangerous goods" (PhCD_3: 11.42), and "attack from pirates or terrorists" (PhCD_6: 11.03). There are another two risk factors with risk scale being greater than 10, i.e. "unstable weather" (PhTD_4: 10.21) and "damage to frozen cargos/ reefer containers due to electricity failure" (PhCD_5: 10.06). It is noted that the risk factor "financial crisis in the loan countries" (PayCE_2: 5.79) has the least impact on the safety and security incident related loss.

Notably, among all the risk factors, "shippers hiding cargo information (non-declare)" (InfoI_5) is ranked as the first with respect to two types of consequence - reputation and safety and security incident related loss, and as the second with respect to the financial loss consequence. This suggests that this factor is the most serious risk factor in container shipping operations. It may be worth mentioning that in relation to InfoI_5, a shipping manager during the interview survey stated:

> *"We have paid some penalties and our ship has once been detained because the documents for customs clearance were inconsistent with the shipper and the process was delayed. The reason is that our customer [the shipper] did not inform us that the contents of the cargos had been changed*."

"Oil price rise" (PhTD_9) is another important risk factor especially in respect of financial loss. According to Ronen (2011), fuel price rise could substantially increase the operational cost of a large ship as more than 75% of the operating cost is used for bunker fuel. "Damage caused by transporting dangerous goods" (PhCD_3) and "unstable weather" (PhTD_4) are also notable factors as they have significant impact on employees' safety.

Change of currency exchange rate duing payment process (PayCE_1) is the only risk associated with payment flow factor, the scale of which is larger than 10 in respect of financial loss consequence. An unstable currency exchange rate may explain its importance. During the interview survey, a shipping manager explained -

"The transportation fees we get are usually calculated by USD. However, some shippers will still pay the bills by local currency, such as Euro or JPY. We need to afford the risk from the unstable currency exchange rate,… sometimes it will make us lose the profit."

Table 6.12 Risk scale

Risk	Financial loss risk scale			Reputation loss risk scale			Safety and security incident related loss risk scale		
	RS	S.D.	Rank	RS	S.D.	Rank	RS	S.D.	Rank
InfoD_1	7.81	5.42	32	6.66	4.96	35	7.40	5.52	21
InfoD_2	7.87	4.91	30	7.13	4.90	30	7.21	5.06	23
InfoD_3	8.34	5.36	23	8.48	5.28	6	7.79	5.17	19
InfoD_4	8.97	5.27	15	8.18	5.16	10	7.21	4.76	23
InfoI_1	8.34	6.05	23	7.65	5.98	21	8.77	6.24	10
InfoI_2	7.85	5.48	31	7.76	5.60	19	8.40	5.69	12
InfoI_3	7.66	5.12	35	7.40	5.15	25	8.16	4.89	16
InfoI_4	8.13	5.20	26	8.15	5.52	11	8.35	5.35	13
InfoI_5	11.44	6.13	2	10.61	6.39	1	12.08	6.38	1
InfoIT_1	8.15	4.81	25	7.87	5.51	17	8.44	4.21	11
InfoIT_2	7.73	5.16	33	7.48	5.47	23	8.19	4.76	14
InfoIT_3	7.71	4.57	34	7.35	4.82	27	8.13	4.32	17
Mean of risks associated with information flow	8.33			7.89			8.35		
PhTD_1	9.65	5.98	10	7.79	5.99	18	7.85	5.46	18
PhTD_2	10.81	5.24	3	9.39	5.72	3	8.19	4.79	14
PhTD_3	9.00	5.01	14	8.00	5.17	14	7.18	4.89	26
PhTD_4	10.63	5.05	4	8.48	5.36	6	10.21	4.95	4
PhTD_5	8.47	5.63	22	7.39	6.04	26	7.27	5.76	22
PhTD_6	8.77	5.05	16	7.68	5.08	20	6.71	4.94	30
PhTD_7	8.58	5.26	20	7.98	4.96	15	7.19	5.82	25
PhTD_8	7.89	4.75	29	7.18	5.27	29	6.65	4.79	33
PhTD_9	14.00	6.31	1	8.73	5.77	5	9.03	6.16	9
PhCD_1	10.21	5.93	6	9.29	6.31	4	9.77	5.31	7
PhCD_2	9.65	5.85	10	8.48	4.92	6	9.55	5.31	8
PhCD_3	10.26	4.86	5	9.52	5.69	2	11.42	5.87	2
PhCD_4	9.37	5.18	12	8.11	5.45	12	9.97	5.35	6
PhCD_5	9.85	5.34	8	8.29	5.08	9	10.06	5.48	5
PhCD_6	9.84	5.84	9	8.03	6.22	13	11.03	6.01	3
Mean of risks associated with physical flow	9.80			8.29			8.81		
PayCE_1	10.18	6.44	7	7.95	6.38	16	7.69	6.42	20
PayCE_2	8.10	5.98	27	7.10	6.57	31	6.89	6.58	28
PayPD_1	9.21	5.65	13	7.44	5.40	24	6.82	4.76	29
PayPD_2	8.68	5.81	17	7.55	5.90	22	6.69	5.12	31
PayNP_1	8.66	6.01	18	6.95	5.99	33	7.13	6.22	27
PayNP_2	8.63	5.53	19	6.92	5.45	34	6.66	5.23	32
PayNP_3	8.48	5.73	21	7.31	5.97	28	6.58	5.33	34
PayNP_4	7.94	5.12	28	7.03	5.34	32	6.58	5.22	34

Mean of risks associated with payment flow	8.73		7.28		6.88	
Total average	9.05		7.92		8.21	

*red colour means the mean value of risk scale is more than 10
*orange colour means the mean value of risk scale is between 8.01 and 9.99
*blue colour means the mean value of risk scale is the smallest one

6.4.2 Risk matrix

Based on the classification of risk matrix that has been mentioned in Chapter 4, the results of the risk likelihood and consequence on the risk-factor survey will be classified into four levels: low risk (green colour), moderate risk (yellow colour), high risk (orange colour), and extreme risk (red colour). The following sections present the risk matrix corresponding to three different consequences.

6.4.2.1 Risk matrix in relation to financial loss

In the financial loss risk matrix (Table 6.13), a total eighteen risk factors are in the moderate risk level. Six of them with the "possible" likelihood (3) and "moderate" consequence (3) are InfoI5, PhTD_2, PhTD_4, PhTD_9, PhCD_1, and PayCE_1; whilst twelve of them locate in the cell with "unlikely" likelihood (2) and "moderate" consequence (3). Among the above 18 risk factors, three risk factors are associated with information flow, seven risk factors are associated with physical flow, and two risk factors are associated with payment flow. The rest risk factors are located in the low risk cell with "unlikely" likelihood (2) and "minor" consequence (2). It is found that the majority of risk factors at the moderate risk level belong to the category of risks associated with physical flow. This means managers should pay more attention on risks associated with physical flow as far as the financial loss criterion is concerned.

Table 6.13 Financial loss risk matrix

			Consequence				
			Insignificant	Minor	Moderate	Major	Catastrophic
			1	2	3	4	5
Likelihood	Almost certain	5					
	Likely	4					
	Possible	3			InofI_5 PhTD_2,4,9 PhCD_1 PayCE_1		
	Unlikely	2		InfoD_1-3 InfoI_2-4 InfoIT_2,3 PhTD_5-8 PayCE_2 PayPD_2 PayNP_2-4	InfoD_4 InfoI_1 InfoIT_1 PhTD_1,3 PhCD_2-6 PayPD_1 PayNP_1		
	Rare	1					

*red colour means the extreme risk level
*orange colour means the high risk level
*yellow colour means the moderate risk level
*green colour means the low risk level

6.4.2.2 Risk matrix in relation to reputation loss risk

In the reputation loss risk matrix (Table 6.14), eight risk factors are in the moderate risk level. Only one risk factor (InfoI_5) locates in the "possible" likelihood (3) and "moderate" consequence (3); two risk factors locate in "unlikely" likelihood (2) and "moderate" consequence (3) (PhCD_3 and PhCD_4), and five risk factors locate in "possible" likelihood (3) and "minor" consequence (2) (PhTD_2, PhTD_4, PhTD_9, PhCD_1, and PayCE_1). Six of the eight risk factors belong to the category of risks associated with physical flow. The rest factors are located in the low risk level with "unlikely" likelihood (2) and "minor" consequence (2). From the results above, the most serious risk factor that harms companies' reputation is InfoI_5, whilst some risk factors within the category of risks associated with physical flow also could harm companies' reputation. Moreover, compared to the financial loss risk matrix, only eight risk factors are in the "considerable" level, this might mean that only a few risk factors could affect companies' reputation.

Table 6.14 Reputation loss risk matrix

			Consequence				
			Insignificant	Minor	Moderate	Major	Catastrophic
			1	2	3	4	5
Likelihood	Almost certain	5					
	Likely	4					
	Possible	3		PhTD_2,4,9 PhCD_1 PayCE_1	InfoI_5		
	Unlikely	2		InfoD_1-4 InfoI_1-4 InfoIT_1-3 PhTD_1,3,5-8 PhCD_2,5,6 PayCE_2 PayPD_1,2 PayNP_1-4	PhCD_3,4		
	Rare	1					

*red colour means the extreme risk level
*orange colour means the high risk level
*yellow colour means the moderate risk level
*green colour means the low risk level

6.4.2.3 Risk matrix in relation to safety and security incident related loss

In the reputation loss risk matrix (Table 6.15), a total fifteen risk factors are in the moderate risk level. Two of them have "possible" likelihood (3) and "moderate" consequence (3) (InfoI5 and PhCD_1); nine of them locate in "unlikely" likelihood (2) and "moderate" consequence (3) (InfoI_1, InfoIT 1-3, and PhCD_2-6), and four of them locate in "possible" likelihood (3) and "minor" consequence (2) (PhTD_2, PhTD_4, PhTD_9, and PayCE_1). Within the moderate risk level, both the category of risks associated with information flow (five risk factors) and the category of risks associated with physical flow (nine risk factors) are important.

The rest of the factors are located in the low risk level with "possible" likelihood (2) and "moderate" consequence (2). From the results above, managers have to pay a lot of attention on risks associated with information flow and risks associated with physical flow to reduce the negative impact on safety and security incident related loss.

Table 6.15 Safety and security incident related loss risk matrix

			Consequence				
			Insignificant	Minor	Moderate	Major	Catastrophic
			1	2	3	4	5
Likelihood	Almost certain	5					
	Likely	4					
	Possible	3		PhTD_2,4,9 PayCE_1	InfoI_5 PhCD_1		
	Unlikely	2		InfoD_1-4 InfoI_2-4 PhTD_1,3,5-8 PayCE_2 PayPD_1,2 PayNP_1-4	InfoI_1 InfoIT_1-3 PhCD_2-6		
	Rare	1					

*red colour means the extreme risk level
*orange colour means the high risk level
*yellow colour means the moderate risk level
*green colour means the low risk level

6.4.3 Risk map

Although the three risk matrices in the above Section have presented the level of each risk factor, the detailed relationships between the risk factors are not presented clearly. The similar scales of risk factors were just put into the same cell. Therefore, three risk maps are produced to show the relative position of each risk corresponding to three risk consequences.

In order to produce the risk map, a risk factor's likelihood and consequence over all respondents should be derived. In this thesis, the Average Risk Scale (ARS) method is used as proposed in Chapter 3. Based on the risk scales, this thesis divides the risk map into four regions: low risk region (corresponding to risk scale <5), moderate risk region (5< risk scale <10), high risk region (10< risk scale <15), and extremely high risk region (risk scale>15) (as discussed and presented in Figure 4.16).

6.4.3.1 Risk map in relation to financial loss

As shown in the financial loss risk map (Figure 6.1), the majority of the risk factors (28 out of 35) fall within the moderate risk region and none of the risk factors falls within the low risk region or the extremely high risk region. A total seven risk factors fall within the high risk region including “oil price rise” (PhTD_9), “shippers hiding cargo information (non-declare)” (InfoI_5), ‘port congestion” (PhTD_2), “unstable weather” (PhTD_4), “port/terminal productivity being below expectations” (PhTD_3), “damage to containers or cargos due to terminal operators’ improper loading/ unloading operations” (PhCD_1), and “change of currency exchange rate during payment process” (PayCE_1). This result is very different compared to the result from the risk matrix (Table 6.13), which shows no risk factor is located within the high risk region, and the majority of the risk factors fall in the low risk region. This is due to the fact that the risk matrix is not very accurate (Cox, 2008). Notably, PhCD_5 and PhCD_6, although they are in the moderate risk region, are very close to the boundary of the high risk region. Since the majority of risk factors located in the high risk region belong to the physical flow risk category, the category of risks associated with physical flow is regarded as the major one which causes the most serious financial impact to the businesses. The risk factors within the moderate risk region are much more centralised, so every risk factor needs to be considered rather equally. Most of these risk factors belong to the category of risks associated with physical flow; this is in agreement with the findings presented in the earlier sections, which state that the category of risks associated with physical flow is more significant than the other two risk categories in respect of financial loss. It is also worth mentioning that the risk factor PhTD_9 (oil price rise) has the highest risk scale and is quite close to the extreme risk region.

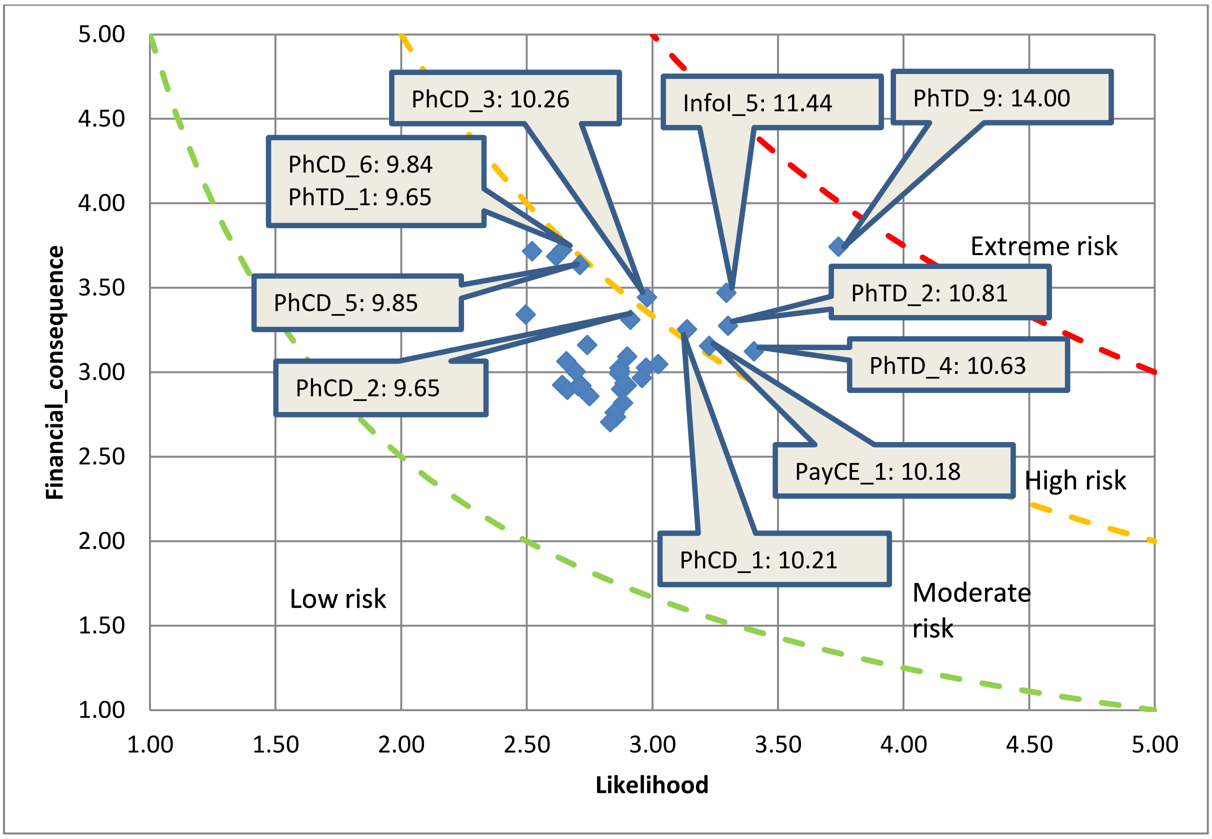


Figure 6.1 Financial loss risk map

6.4.3.2 Risk map in relation to reputation loss

As shown in the reputation loss risk map (Figure 6.2), except for “shippers hiding cargo information” (Infol_5) that falls within the high risk region, all other risk factors are in the moderate risk region. It is recommended that shipping companies need to pay more attention to the risk factor Infol_5 in order to reduce the damage to companies' reputation.

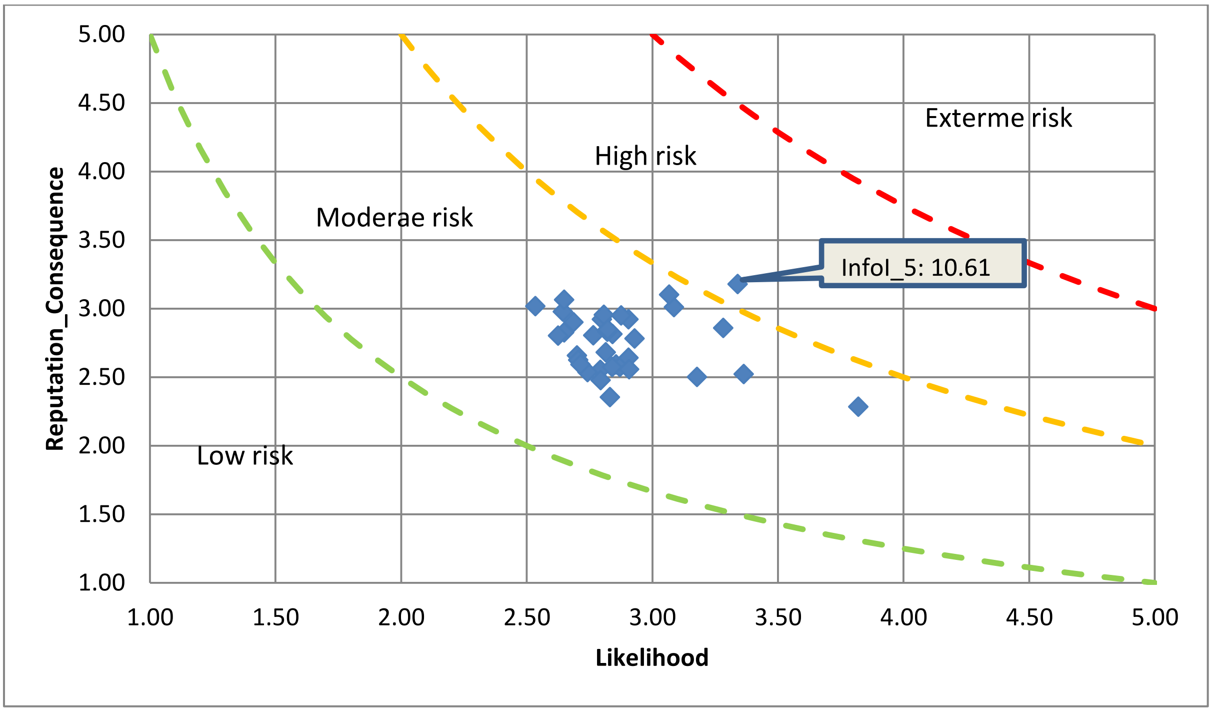


Figure 6.2 Reputation loss risk map

6.4.3.3 Risk map in relation to safety and security incident related loss

In the safety and security incident related loss risk map (Figure 6.3), five risk factors fall within the high risk region, including "shippers hiding cargo information (non-declare)" (Infol_5), "damage caused by transporting dangerous goods" (PhCD_3), "attack from pirates or terrorists" (PhCD_6), "damage to frozen cargos/ reefer containers due to electricity failure" (PhCD_5), and "unstable weather" (PhTD_4). The case of cargo information hidden by shippers has been discussed in previous interview result. Sometimes it can cause a disaster to shipping companies such as putting dangerous goods into containers without providing appropriate information that may result in explosion during the transportation process. Moreover, two risk factors within the moderate risk region are close to the high risk region boundary; they are “damage to ship or quay due to improper berth operations” (PhCD_4) and “damage to containers or cargos due to terminal operators’ improper loading/ unloading operations” (PhCD_1). Except for InfoI_5, all the other top seven risk factors in respect of safety and security incident related loss belong to the category of risks associated with physical flow; this suggests that the risks associated with physical flow has the most serious impact on safety and security incident related loss in container shipping operations. To mitigate the impact of the risk factor InfoI_5, shipping managers could try to reduce its likelihood via strategies such as checking the processing document more carefully. For the risk factors with high consequence and low likelihood, PhCD_6 and PhCD_4, using insurance is a possible option to mitigate their impact. It is also suggested (IFW, 2011) that shipping companies may charge more fees for protecting the cargos going through highly risky routes.

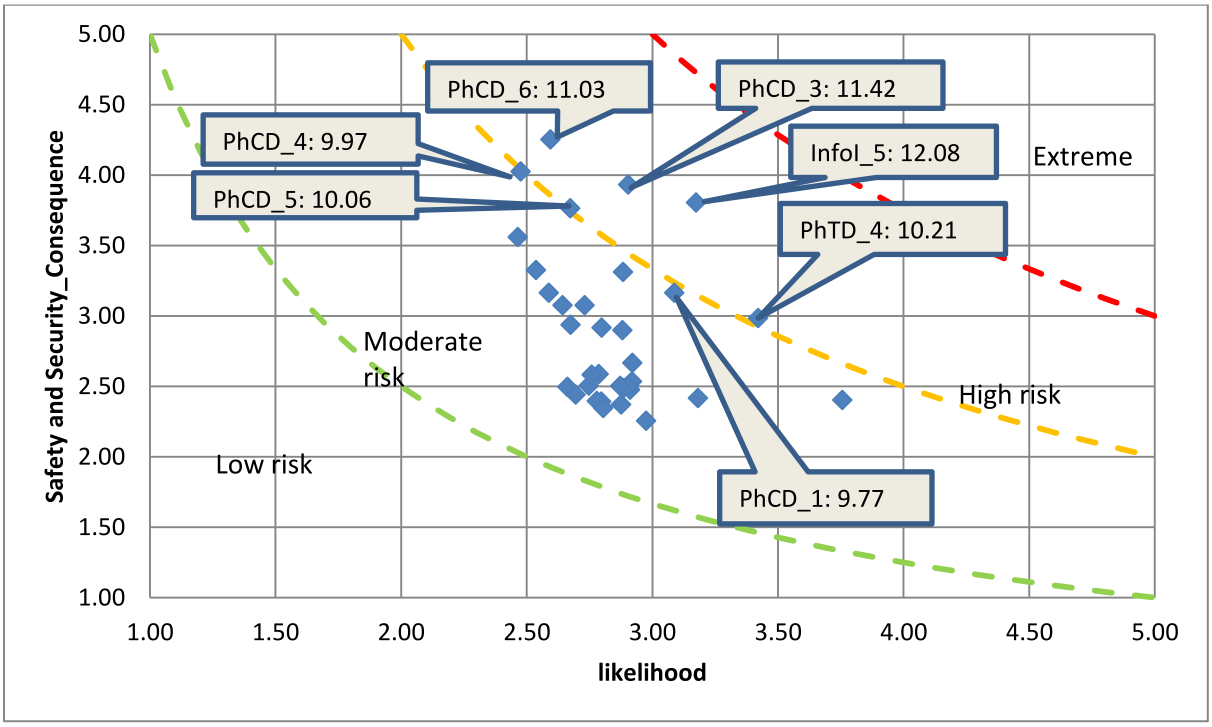


Figure 6.3 Safety and security incident related loss risk map

6.4.4 P-I graph (Risk map with risk responses)

Based on the risk responses discussed in Chapter 4, four risk responses could be used to tackle different risk factors including avoid response (in the upper right corner), mitigate response (in the lower right corner), transfer response (in the upper left corner) and accept response (in the lower left corner). This can refer to Figure 4.17 in Chapter 4.

6.4.4.1 Risk map with risk responses in relation to financial loss

Figure 6.4 shows the result of risk map with risk responses in relation to financial loss. In order to classify the risk factors into four groups corresponding to four responses, the coordinates of each risk factor (risk likelihood and risk consequence) is used to divide the space into four areas: avoid response, transfer response, mitigate response, and accept response. Two risk factors, “shippers hiding cargo information (non-declare)” (InfoI_5: 3.30, 3.47) and “oil price rise” (PhTD_9: 3.74, 3.74), are located clearly in the “avoid response” area. According to Hillson’s (2002) definition of avoid response (see Section 4.3.1.2): seeking to eliminate the uncertainty by reducing its likelihood to zero, or by reducing its consequence to zero, managers should try to avoid these risks’ occurrence. However, sometimes it is difficult to avoid these risk factors but it may be possible to reduce their likelihoods or consequences. For example, a company can implement measures to check the cargo declaration from shippers more strictly to reduce the likelihood of InforI_5 to zero or to an acceptable level, so that it would have a lower risk scale although it may still have a high risk consequence. The other risk factor, i.e., PhTD_9, is difficult to reduce its likelihood, but it can be mitigated through reducing the risk consequence by hedging, adjusting the Bunker Adjustment Factor (BAF), signing a long-term contract with oil supplier to stabilise oil price, or adopting the strategies that have been mentioned in Section 2.7.3, e.g., slow steaming, form an alliance with other shipping companies or slot-exchange, slot charter, joint fleet, ship-charter with other container shipping companies.

Five risk factors are located clearly in the “transfer response” area, including “lack of information security during the information flow” (InfoI_1: 2.50, 3.34), “port strikes” (PhTD_1: 2.62, 3.68), “damage to ship or quay due to improper berth operations” (PhCD_4: 2.52, 3.72), “damage to frozen cargo/ reefer containers due to electricity failure” (PhCD_5: 2.71, 3.63), and “attack from pirates or terrorists” (PhCD_6: 2.64, 3.72). According to Hillson’s (2002) definition of transfer: “identifying another stakeholder better able to manage the risk, to whom the liability and responsibility for action can be passed” (see

Section 4.3.1.2), managers should try to transfer the risk impact of this type of risk factors into other partners who can better deal with it. For example, in order to deal with PhTD_1, shipping companies can load/unload the cargos to the next port-of-call and transport the cargos by their partners (e.g. inland transportation) to the destination more efficiently to reduce the impact of port strikes.

The rest of the risk factors are located in the central region in Figure 6.4, which is close to all four areas. This implies that there is no obvious response action corresponding to them.

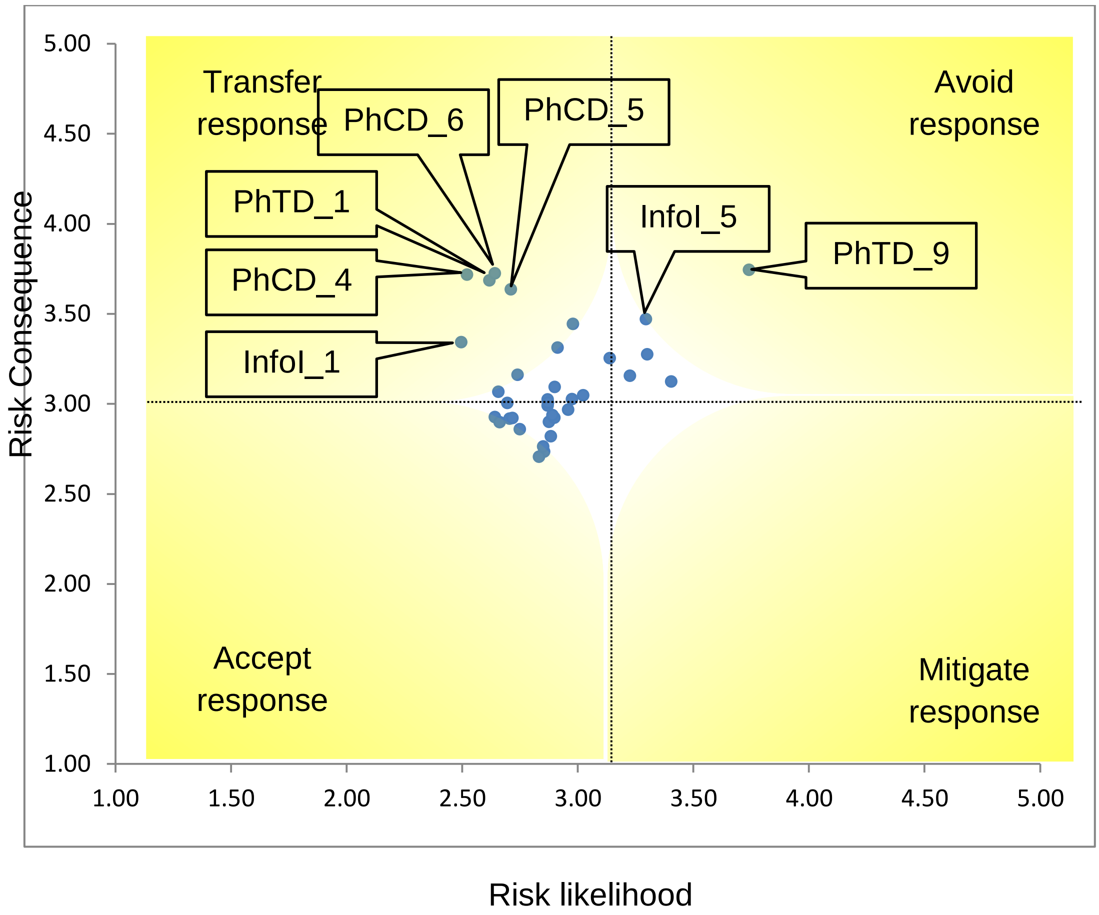


Figure 6.4 Financial loss risk map with four responses

6.4.4.2 Result of risk map with risk responses in relation to reputation loss

Figure 6.5 shows the results of risk map with risk responses in relation to reputation loss. It can be observed that only one risk factor is clearly located in the “avoid response” area, which is “shippers hiding cargo information (non-declare)” (InfoI_5: 3.34, 3.18). This result indicates that InfoI_5 should have a priority to be avoided in order to reduce reputation loss. Some strategies mentioned in the above sub-section may be applied to avoid InfoI_5. Additional strategies could also be adopted, e.g. reward/assist partners who comply with shipping lines’ initiatives, and shorten/ withdraw the contract with partners who have bad performance.

Three risk factors are clearly located in the “mitigate response” area, including “unstable weather” (PhTD_4: 3.36, 2.52), “oil price rise” (PhTD_9: 3.82, 2.28), and “change of currency exchange rate during payment process” (PayCE_1: 3.18, 2.50). According to Hillson’s (2002) definition of mitigate: “reducing the size of the risk in order to make it more acceptable to the project or organisation, by reducing the likelihood and/or the consequence” (see Section 4.3.1.2), managers could reduce the likelihood and consequence of PhTD_4 through using more advanced information technology; reducing PhTD_9 through the strategies mentioned in Chapter 2, such as slow steaming to reduce the oil consumption.

There are no risk factors that are obviously located in the “transfer response” area. Most of the risk factors are located in the “accept response” area close to the central region in Figure 5.5. According to Hillson’s (2002) definition of accept response (see Section 4.3.1.2): recognising that residual risks must be taken, and responding either actively by allocating appropriate contingency, or passively doing nothing except monitoring the status of the risk.

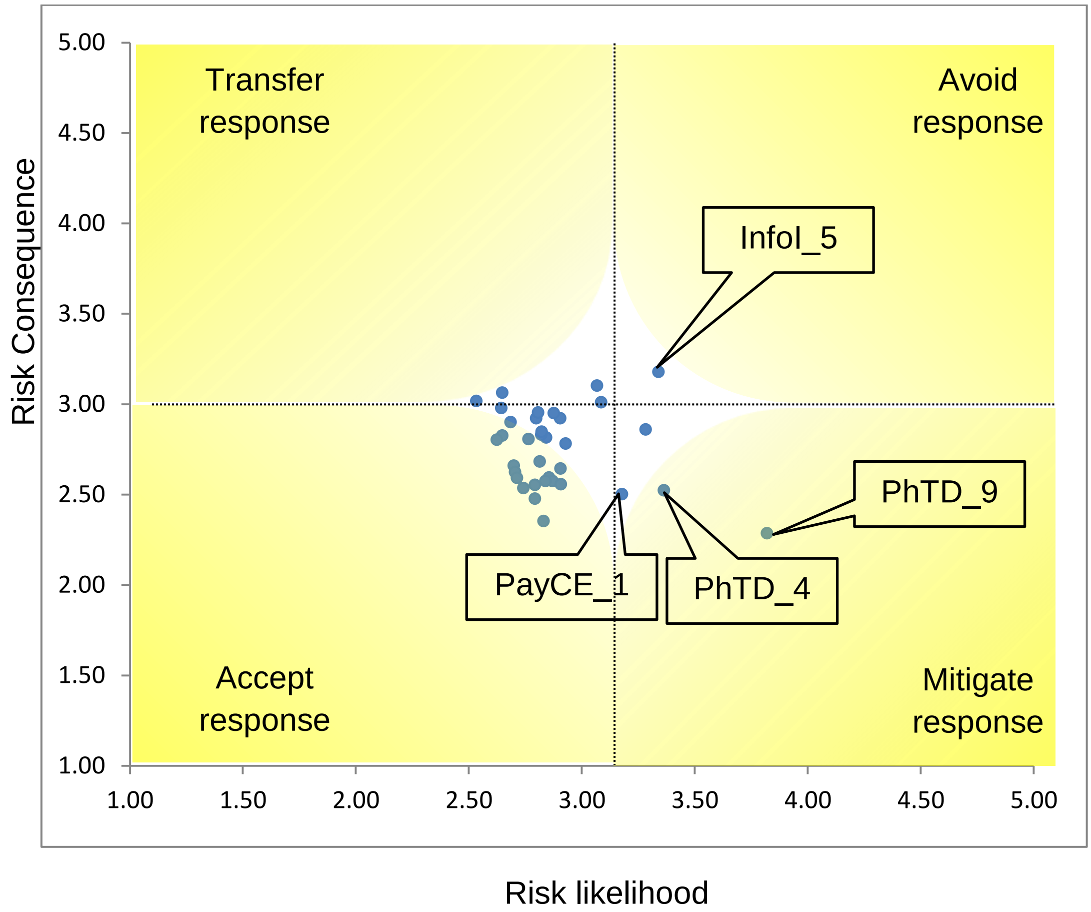


Figure 6.5 Reputation loss risk map with four responses

6.4.4.3 Result of risk map with risk responses in relation to safety and security incident related loss

Figure 6.6 shows the results of the risk map with risk responses in relation to safety and security incident related loss. It can be seen that one risk factor, "shippers hiding cargo information (non-declare)" (Infol_5: 3.17, 3.81), is clearly located in the "avoid response" area, which suggests that the shipping companies should give priority to avoid this risk factor in order to reduce the safety and security incident related loss. The strategies mentioned in previous sections could be adopted to reduce its likelihood.

Three risk factors are clearly located in the “mitigate response” area, including “port congestion (unexpected waiting times before berthing or before starting loading/discharging)” (PhTD_2: 3.34, 2.45), “oil price rise” (PhTD_9: 3.76, 2.40), and “change of currency exchange rate during payment process” (PayCE_1: 3.18, 2.42). Their risk consequences could be reduced through some systematic regulations/strategies such as reducing port time or cutting port-of-calls when delay occurs for the port congestion or hedge for the oil price rise and even for currency exchange in the payment process.

There are six risk factors clearly located in the “transfer response” zone, including “lack of information security within the information flow” (InfoI_1: 2.46, 3.56), “IT infrastructure breakdown or crash” (InfoIT_1: 2.54, 3.33), “damage caused by transporting dangerous goods” (PhCD_3: 2.90, 3.93), “damage to ship or quay due to improper berth operations” (PhCD_4: 2.48, 4.02), “damage to frozen cargo/ reefer containers due to electricity failure” (PhCD_5: 2.67, 3.76), and “attack from pirates or terrorists” (PhCD_6: 2.59, 4.25). Four of the above six risk factors belong to the risk element of cargo/asset loss and damage, shipping companies may use some strategies to transfer these risk factors to other parties such as purchasing insurances or outsourcing. Shipping companies may also consider charging more fees (IFW, 2011) or using armed guards on ships (Nkwocha and Badger, 2011) to protect cargos on the routes which have high possibility of piracy attack.

The rest of risk factors are located either in the central region or in the "accept response" zone.

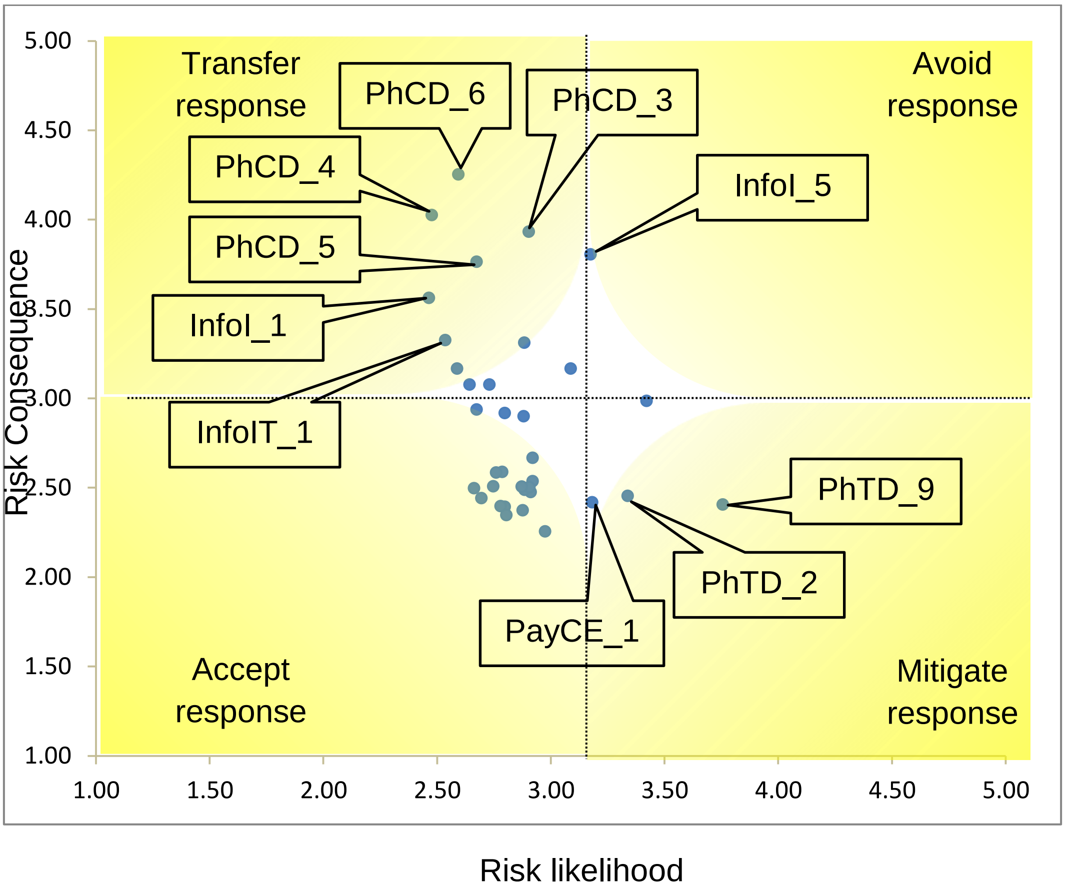


Figure 6.6 Safety and security incident related loss risk map with four responses

6.5 Chapter summary

This chapter presents the main findings of the risk-factor survey, including risk likelihood, three risk consequences, risk scales, risk matrices, risk maps and four risk responses.

In terms of risk likelihood, "oil price rise" (PhTD_9) has the highest risk likelihood among the 35 risk factors, and the second and third ones are "unstable weather" (PhTD_4) and "port congestion (unexpected waiting times before berthing or before starting loading/ discharging)" (PhTD_2). All these three risk factors belong to the category of risks associated with physical flow, and also belong to the risk element of "transportation delay".

In terms of the financial loss consequence, the top three risk factors are PhTD_9, "damage caused by transporting dangerous goods" (PhCD_3) and "port strikes" (PhTD_1). All these three risk factors belong to the category of risks associated with physical flow. Seven factors are larger than 10 (which represents high risk in this thesis) in risk scale, including PhTD_9, "shippers hiding cargo information (non-declare)" (InfoI_5), PhTD_2, PhTD_4, "damage to frozen cargo/ reefer containers due to electricity failure" PhCD_5, "attack from pirates or terrorists" PhCD_6, and "change of currency exchange rate during payment process" PayCE_1. Only two factors (InfoI_5 and PayCE_1) do not belong to the category of risks associated with physical flow. The result of the risk matrix shows that these risk factors are in the moderate risk level. The risk map analysis presents relatively clearer and more detailed information in the relationships between individual risk factors. Overall, the category of risks associated with physical flow has more serious impact on the financial loss than the other two categories. However, the category of risks associated with payment flow and the category of risks associated with information flow also play quite important roles in financial loss. This result reveals that although the priority should be given to the risks associated with physical flow, container shipping companies also need to pay some attention on managing the risks associated with payment flow and the risks associated with information flow in order to reduce the financial loss. From the four risk responses perspective, InfoI_5 and PhTD_9 should be given a priority to be avoided. InfoI_5 is suggested to reduce its likelihood through more strictly checking the cargo declaration from shippers; whilst PhTD_9 is suggested to reduce its consequence through hedge, BAF, signing a long-term contract with oil suppliers to keep buying the same price of oil, slow steaming, forming alliances with other shipping companies, or slot-exchange, slot charter, joint fleet, ship-charter with other container shipping companies. Five risk factors are located in the "transfer response" area, including InfoI_1, PhTD_1, "damage to ship or quay due to improper berth operations" (PhCD_4), PhCD_5, and PhCD_6. These risk factors could be tackled by transferring the risk impact to other stakeholders who are in better position to deal with them.

In terms of the reputation loss consequence, the top three factors are PhCD_3, InfoI_5, and PhCD_4. According to the calculated risk scale, InfoI_5 is the only risk factor whose risk scale is greater than 10. It is located in the high risk level in the risk map whilst it is in moderate risk level in risk matrix. On average, the category of risks associated with physical flow scale still plays the most important role. From the four risk responses perspective, only InfoI_5 is clearly located in the "avoid response" area, and it can be avoided by using the similar strategies to those in the financial loss situation, or taking additional strategies such as reward/assist partners who comply with shipping lines' initiatives or shorten/withdraw the contract with partners who have bad performance. Three risk factors are located in the "mitigate response" area, including PhTD_4, PhTD_9, and PayCE_1. This thesis suggests mitigating their risk impact through several strategies that have been mentioned in the previous paragraph.

With regard to the consequence of the maritime safety and security incident related loss, the top three risk factors are PhCD_6, PhCD_4 and PhCD_3.

According to the obtained risk scale, five factors' risk scales are larger than 10, including InforI_5, PhCD_3, PhCD_6, PhTD_4, and PhCD_5. These five risk factors are identified as at the moderate risk level in the risk matrix analysis whilst they are classified into the high risk level in the risk map. On the other hand, although the category of risks associated with physical flow as a whole is the most significant one among the three categories of operational risks, InforI_5 in risks associated with information flow is the most serious one among all the risk factors. From the four risk response perspective, only InfoI_5 is clearly located in the "avoid response" area; three risk factors are notably located in the "mitigate response" area, including PhTD_2, PhTD_9, and PayCE_1; and six risk factors are clearly located in the "transfer response" area, including InfoI_1, InfoIT_1, PhCD_3, PhCD_4, PhCD_5, and PhCD_6. The strategies for most of the risk factors above have been mentioned in the previous sections.

Chapter 7 Identification and evaluation of risk mitigation strategies

This chapter focuses on the last step of risk management, i.e. identification, validation and evaluation of risk mitigation strategies. In Section 7.1, the risk mitigation strategies are identified through reviewing more relevant literature in a broad supply chain context. Section 7.2 is the validation of the identified risk mitigation strategies and the exploration of new risk mitigation strategies through a set of face-to-face interviews and a set of email interviews. Section 7.3 is the evaluation of risk mitigation strategies, which firstly conducts the validity and reliability test; and then ranks these risk mitigation strategies through the mitigation-strategy survey; and then the top seven strategies are selected to be further evaluated and compared in relation to different performance criteria through the Analytic Hierarchy Process (AHP) survey; finally, the classic AHP and the Fuzzy AHP methods are applied to analyse the relative effectiveness of these mitigation strategies. Section 7.4 is the summary of this chapter.

7.1 Identification of risk mitigation strategies from existing literature

Section 2.2 has discussed the risk mitigation strategies in container shipping operations. However, the direct relevant literature is rather limited and fragmented. This thesis therefore extends the literature to general supply chains so that a more comprehensive set of risk mitigation strategies could be identified.

Risk mitigation is an important part of business decisions as modern business operations are unavoidably subject to various tangible and intangible risks. A number of risk mitigation strategies have been addressed in previous studies, but they do not have a systematic structure. This thesis borrows the classification from Barratt (2004): entities in supply chains could be categorised into two categories: inter-organisational and intra-organisational. He divided the scope of collaboration into vertical and horizontal ones. In this thesis, container shipping is taken as a focal company in the context of supply chain and classify risk mitigation strategies into three categories: intra-organisational strategies (internal), intra-channel strategies (vertical), and inter-channel strategies (horizontal). Each category includes several risk mitigation strategies.

7.1.1 Intra-organisational strategies

Intra-organisational strategies refer to the approaches that are mainly taken by the focal firm. Many intra-organisation strategies have been proposed in the literature to reduce the impact of risks. The following sections discuss the details of these strategies, including buffer time, advanced equipment, security, and employee training.

Including buffer time when designing timetable/schedule is considered as a risk mitigation strategy in the transportation-related industry. Chopra and Meindl (2010) stated that managers should consider the risks in transportation when designing transportation networks. They also suggested that designing route schedules with a buffer time is a way to mitigate the transportation delay caused by congestion or other uncertainties. As container shipping is a transportation-related industry and provides a regular service, including buffer time when designing timetable/schedule should be considered as a risk mitigation strategy.

Using advanced equipment is deemed as one risk mitigation strategy (Porter 1998a). Porter (1998b, p.80) pointed out that "companies can be highly productive in any industry… if they employ sophisticated methods and use advanced technology". This strategy also covers using advanced information communication technology (ICT), which is suggested as a risk mitigation strategy in several studies (e.g. Baldwin and Sabourin, 2001; Stefansson, 2002). Baldwin and Sabourin (2001) stated that ICT revolution provides more timely information for a company to adjust its operations and to meet the changes of customer demand. Stefansson (2002) also reported that electronic data interchange (EDI) is the most common ICT used in large companies, as it provides quicker data transmission and shorter lead time. This can be linked back to the literature covered in Chapter 2, in which Kerr (2011a) and Marle (2009) stated that the use of new information exchange system can reduce errors and costs when processing documents in container shipping. Therefore, this strategy covers both hardware and software and can be named as "use more advanced infrastructures (hardware and software)".

Improving the level of security is also an important strategy for companies to avoid or reduce risks (Dhillon and Backhouse, 2000; Blakley *et al*., 2002; Lun *et al*., 2008). Dhillon and Backhouse (2000) stated that a security system is an important management strategy to keep information and cargo safe. Lun *et al*. (2008) focused on container transportation security and stated that using technology to enhance security in a container transport chain is an important strategy. The technology they suggested includes radio-frequency identification (RFID), smart box initiative and container non-intrusive inspection (NII).

Several studies mentioned that organising regular employee training is an effective strategy that mitigates the impact of risk (Richardson, 2000; Gunasekaran and Ngai, 2004; Elkins *et al*., 2005). A regular employee training programme could significantly reduce human-caused risks in a firm especially when employees face a complex IT system (Gunasekaran and Ngai, 2004) or work in a dangerous environment (Richardson, 2000). This point can be linked back to Chapter 2, in which Ganesan (2010) and Young (2010) stated that regular training is an important mechanism to reduce the probability of risk in container shipping operations.

7.1.2 Intra-channel strategies

Intra-channel strategies refer to the activities/ approaches that involve multiple channel members in the same supply chain. In supply chain management, channel members often form a kind of partnership. The following sections discuss the strategies within intra-channel level, including reduce supplier base, reward good partners, withdraw contracts with bad partners, trust partners, enter a long-term contract with suppliers, and cooperate, coordinate and collaborate with partners.

Avoiding too many suppliers is deemed as a strategy to mitigate risks in a supply chain. Harland (1996) claimed that the supplier base reduction is an important strategy to improve the relationships between suppliers and the focal company. Morgan (1987) also reported a case study about Rank Xerox reducing its partners from 5000 to 300 in 6 years to reduce the cost consumption. Moreover, this strategy can also reduce the probability of cooperation with bad-performance suppliers.

In a supply chain, the cooperative partnership between channel members is often accompanied with other types of relationships such as channel power (Assael, 1969; Lusch, 1976; Reve and Stern, 1979; Frazier and Summer, 1984). Stern (1965, p.655) defined the channel power as "the ability of one member of a marketing channel for a given product (or brand) to stipulate marketing policies to other channel members". Cox (1997) stated that a successful company should have power from channel relationships with its customers, employees and suppliers. He also reported that the main reason that demand-pull and Just-in-Time system could be established by Toyota was it had a strong power of channel relationship with its suppliers. French and Raven (1959) defined five possible sources of channel power including reward, legitimate, referent, expert, and coercive. Channel power can be a strong weapon when a company negotiates with its supply chain partners. Geyskens and Steenkamp (2000) reported that channel power could be divided into rewards, assistance, and punishment. A shipping company could avoid entering into contracts with partners with poor performance or reward or assist the partners that follow the shipping company's suggestions (Cruz and Marques, 2012).

Trusting partners is another strategy that can be deemed as a risk mitigation strategy. Many studies have confirmed that "trust" is an important element affecting channel relationships (e.g. Anderson and Narus, 1990; Barratt, 2004; Sodhi and Son, 2009), and "trust" should be established on a long-term partnership (Dwyer *et al*., 1987; Claro, 2004; Kwon and Suh, 2005). A long-time relationship with supply chain partners and a degree of trust can strengthen the partner relationship between the company and their customers (Chopra and Meindl, 2010).

Harrison and van Hoek (2005) classified partnership into three types: cooperation, coordination, and collaboration. Merriam-Webster Online defines cooperation as “to act together or in compliance for mutual benefit” and defines coordination as “the harmonious functioning of parts for effective results” (www.merriam-webster.com/). Schrage (1990, pp.32-33) stated “collaboration is the process of shared creation: two or more individuals with complementary skills interacting to create a shared understanding that none had previously possessed or could have come to on their own. Collaboration creates a shared meaning about a process, a product, or an event.” Harrison and van Hoek (2005) compared the differences between these three types of partnership: cooperation has fewer suppliers with single functional area; coordination has more information linkages with multiple functional areas; and collaboration is more likely in supply chain integration and/or joint planning. This can be linked back to Chapter 2, in which Heaver *et al*. (2001) stated that the dedicated terminal is an important form of joint venture between container shipping companies and container ports/terminals.

The above partnership is highly related to the level of information exchange between the focal company and its partners. Information sharing has been evidenced as an important strategy to benefit supply chain members in various situations (Ellram and Cooper, 1990; Stank *et al*., 1996; Elkins *et al*., 2005;

Kwon and Suh, 2005). The most basic level of information sharing is that channel members share part of information without involving explicit cooperative activities. For example, Schmidt (2009) evaluated the impact of demand information sharing among channel members in a manufacturer-distributor-retailer supply chain, in which each member makes their own decisions. A more advanced level of information sharing is not only exchanges data/ ideas with partners but also cooperatively resolve problems or conflicts caused by incompatible goals between channel members (e.g. Stank *et al*., 1999; Lambert and Cooper, 2000; Lee and Whang, 2000; Barratt, 2004; Elkins *et al*., 2005; Sodhi and Son, 2009). In a harsh economic environment a closer partnership between channel members than the basic information/ideas exchange is often necessary to maintain the efficiency of supply chain systems and reduce risks (Fawcett and Magnan, 2002; Sabath and Fontanella, 2002).

7.1.3 Inter-channel strategies

A company would have more opportunity to achieve effective performance if it develops strategic alliances with other companies doing the similar business, and possibly even with some of its competitors (Harrison and van Hoek, 2005). In this thesis, the relationship of cooperation with competitors is regarded as happening in the "inter-channel" level because competitors often exist in parallel and belong to different supply chains. Therefore, inter-channel strategies refer to the approaches that require the involvement of multiple entities that have parallel relationships, e.g. belonging to different supply chains. The following sections discuss several common inter-channel strategies such as alliance, merge, and acquire.

Strategic alliance has been proposed for many years, and it is an important strategy for many contemporary companies (Harrigan, 1988; Parkhe, 1993; Eisenhardt and Schoonhoven, 1996). This type of cooperative relationship can help companies to effectively use resources/ equipment and share risks (Hamel *et al*, 1989; Ohmae, 1989). In a transportation-related industry such as air companies and shipping companies, inter-competitor alliance is a common strategy to expand the service coverage and improve the performance. The shipping alliance has been discussed in Chapter 2. In the air alliance aspect, Park and Cho (1997) found that two air companies with similar size in an inter-competitor alliance can threaten the positions of small companies in the same market. They also stated that yesterday's competitors can be the most powerful partner to improve their performance if these two companies are in the inter-competitor alliance.

Acquisition is deemed as a quick and effective way to increase profit, expand business, and improve competitive position (Bastien *et al*., 1996). Merger is viewed as the same way, and Porter (1980, p.50) stated that "a merger can instantaneously propel a weak competitor into prominence, or strengthen an already formidable one". The merger and acquisition are also very common in container shipping industries, which have been mentioned by Notteboom (2004) that this strategy can quickly increase the company's growth rate, economies of scale, market share and market power (see Chapter 2).

Based on the above literature review and the strategies that have been mentioned in Chapter 2, Table 7.1 summarises the risk mitigation strategies.

Table 7.1 Risk mitigation strategies based on literature review

Intra-organisation strategies level	Authors
1. Include buffer times when designing the timetable/schedule	Notteboom (2006); Notteboom and Vernimmen (2009); Chopra and Meindl (2010)
2. Omit port-of-calls to keep original schedule when the ship has already been delayed	Notteboom (2006); Kerr (2011b)
3. Slow steaming and increase ships in the existed routes	Notteboom (2006); Notteboom and Vernimmen (2009); Ronen (2011)
4. Use more advanced infrastructure (hardware and software)	Porter (1998a), (1998b); Baldwin and Sabourin (2001); Stefansson (2002); Marle (2009); Kerr (2011a)
5. Improve the safety and security	Dhillon and Backhouse (2000); Blakley *et al*. (2002); Lun *et al*. (2008)
6. Execute regular employee training (e.g. every year or half of year)	Richardson (2000); Gunasekaran and Ngai (2004); Elkins *et al*. (2005); Young (2010); Ganesan (2010)
Intra-channel strategies level	
1. Avoid too many partners	Morgan (1987); Harland (1996)
2. Shorten/ withdraw the contract with partners who have bad performance	Geyskens and Steenkamp (2000)
3. Reward / assist partners who comply with shipping lines' initiatives	French and Raven (1959); Geyskens and Steenkamp (2000)
4. Trust your partners	Dwyer *et al*. (1987); Anderson and Narus (1990); Barratt (2004); Claro (2004); Kwon and Suh (2005); Sodhi and Son (2009)
5. Enter into long-term contracts with shipper	Notteboom (2004)
6. Information sharing with your partners without co-management (cooperation level)	Harrison and van Hoek (2005); Schmidt (2009)
7. Exchange ideas with partners to solve conflict or improve service quality (coordination level)	Stank *et al*. (1999); Lambert and Cooper (2000); Lee and Whang (2000); Fawcett and Magnan (2002); Sabath and Fontanella (2002); Barratt (2004); Sodhi and Son (2009); Harrison and van Hoek (2005)
8. Collaboration with your partners	Harrison and van Hoek (2005); Notteboom (2004), (2006)
Inter-channel strategies level	
1. Slot-exchange, slot charter, joint fleet, ship-charter with other container shipping companies	Cullinane and Khanna (1999); Song and Panayides (2002); Shry *et al*. (2003); Notteboom (2004); Lu *et al*. (2010); Chow and Chang (2011)
2. Form alliance with other shipping companies	Harrigan (1988); Hamel *et al*. (1989); Ohmae (1989); Parkhe (1993); Eisenhardt and Schoonhoven (1996);

	Park and Cho (1997); Ryoo and Thanopoulou (1999); Heaver *et al*. (2000); Slack *et al*. (2002); Song and Panayides (2002); Notteboom (2004); Harrison and van Hoek (2005); Lu *et al*. (2010)
3. Acquire and merge with other shipping companies	Porter (1980); Bastien *et al*. (1996); Notteboom (2004); Barnard (2011)

Source: author

In the first group in Table 7.1, intra-organization mitigation strategies 1, 2 and 3 are about shipping network design and ship operation management. They are rather specific compared to other strategies. The reason to include those specific strategies is that they have been used by shipping lines widely in recent years and would offer more detailed and applicable results than focusing general strategies only.

7.2 Validation and further exploration of risk mitigation strategies through interviews

The process to validate and further explore risk mitigation strategies is similar to the validation and exploration procedure of risk factors in Section 5.2; it consists of two major steps: (i) a set of semi-structured face-to-face interviews and (ii) a set of email interviews.

7.2.1 Result from face-to-face interviews

The face-to-face interview questions (in Appendix 1) for risk mitigation strategies validation and exploration were conducted together with the face-to-face interview for risk factors validation and exploration in Section 5.2. The managers were asked to modify the strategies if they thought the strategies described in Table 7.1 are inappropriate; to confirm and support the strategies if they think the strategies were appropriate; and to propose other relevant strategies if they thought there were some strategies that had been used in container shipping operations but not mentioned in Table 7.1.

Based on the results of seven face-to-face interviews, all mitigation strategies in Table 6.1 are confirmed to be appropriate by most interviewees. In addition, several additional strategies are proposed by some interviewees. The following discusses those new strategies from the interviews.

When vessels are in the situation of transportation delay, shipping companies have several strategies to catch up the original service schedule. A senior manager stated that:

> *In order to reduce the impact of delay on the ensuring part of the journey, three strategies are commonly used in our company for pursuing original schedules: (1) When the delay is not too serious, the ship will normally cancel the buffering time to pursue the original schedule if it is possible; (2) If the delay is more serious, and the buffering time if not enough for the ship to pursue the original schedule, the ship will normally increase her navigating speed; however, this strategy will also increase the fuel consumption; and (3) When the delay is very serious, in order to pursue the original schedule, some ships may skip over one or more ports on her route. The cargos that are therefore discharged to other ports will be transported to their destination ports. This strategy, however, will significantly increase the operational costs and may have considerable impact on the reliability of the company.*

A regular employee training is deemed as an important strategy to avoid or reduce the impacts from the pre-known risk factors. Two interviewees, both are information managers, mentioned that:

> *we hold regular employee training sessions to train the relevant staff to avoid or at least reduce the effect of risks associated with information flow from failures caused by human errors when using IT systems.*

An IT system is usually deemed as a professional and difficult skill to the employees working in a non-information department. However, almost every employee in container shipping has to use it to some extent; some specific knowledge is difficult to master for new employees. Regular employee training can reduce human mistakes and also improve the level of knowledge of employees up to standard.

Using advanced equipment is another risk mitigation strategy in container shipping operations. A senior manager mentioned –

> *using advanced equipment such as dead-reckoning equipment or gyro sextant will definitely improve the safety when ships are sailing, they can also reduce the mistakes caused by human error.*

As an international business, a shipping company needs to implement international regulations to mitigate risks in the container shipping operations. A senior manager said:

> *we have already used ISO 27001 to increase information security. ISO 27001 is a regulation that is used to keep business confidential. … we implement IMGD Code, an international regulations, which can help reduce potential risks in shipping operations when transporting the 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 negative impact on the container shipping performance or its partners' performance. Choosing appropriate partners is deemed as an important issue in shipping operations. A senior manager mentioned:

> *Sometimes we need to handle or accept the risks from the shippers who bankrupt before making the payment. In order to reduce this type of risk, we need to do some survey about the shippers or supply chain partners. Avoid doing business with the shippers who have bad credit or unstable*

finance. Sometimes shipping companies will transfer the risk to forwarders…

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

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

Based on the above discussions, this thesis formulates new mitigation strategies discussed as follows. Firstly, the strategies, “improve security measures, such as by implementing security rules and regulations such as 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”, can be classified into the category of “intra-organisational strategies” because they can be executed within a shipping company. Secondly, the strategies, “enter a long-term contract with shippers”, “choose partners very carefully”, and “cultivate loyalty of supply chain partners”, can be classified into intra-channel strategies because they are related to collaboration with supply chain partners. Therefore, after the analysis of the face-to-face interviews, Table 7.2 summarises the risk mitigation strategies used in container shipping.

Table 7.2 Risk mitigation strategies based on literature review and face-to-face interviews

Intra-organisation strategies	**Code**
1. Be flexible when designing the timetable/schedule, e.g., include buffer times	IOS_1
2. When the ship has already been delayed, omit port-of-calls to keep original schedule	IOS_2
3. Implement slow steaming and increase the number of ships on existing routes	IOS_3
4. Use more advanced infrastructures (hardware and software)	IOS_4
5. Improve safety measures, such as by implementing safety rules and regulations like the IMDG Code and ISM Code	IOS_5
6. Improve security measures, such as by implementing security rules and regulations like the ISO 27001 and ISPS Code	IOS_6
7. Execute regular employee training (e.g. every year or half of year)	IOS_7
Intra-channel strategies	
1. Avoid having too many partners	IntraCS_1
2. Choose partners very carefully	IntraCS_2
3. Shorten/withdraw contract with the partner that perform badly	IntraCS_3
4. Build trust with partners	IntraCS_4
5. Cultivate loyalty of supply chain partners	IntraCS_5
6. Reward /assist partners that comply with shipping lines' initiatives	IntraCS_6
7. Enter a long-term contract with shippers	IntraCS_7
8. Share information with partners without co-management (cooperation level)	IntraCS_8
9. Exchange ideas with partners to solve conflicts or improve service quality (coordination level)	IntraCS_9
10. Collaboration with partners (e.g., terminal operational company, inland transportation) through making a joint long-term plan (collaboration level)	IntraCS_10
Inter-channel strategies	
1. Slot-exchange, slot charter, joint fleet, ship-charter with other container shipping companies	InterCS_1
2. Form alliance with other shipping companies	InterCS_2
3. Acquire and merge with other shipping companies	InterCS_3

Source: author

In the category of intra-channel strategies, it is worth to point out that the partners of IntraCS_7 only refer to shippers, whilst IntraCS_10 considers partners who are not shippers. The reason for distinguishing the partners between these two strategies is because shipping companies play different roles in the associated supply chains: in the cargo supply chain (IntraCS_7), the role of the shipping company is on the supply side and that of the shipper is on the demand side; whereas in the service supply chain (IntraCS_10), the role of shipping company 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).

7.2.2 Result from email interviews

A set of email interviews were used to further explore the appropriateness of the identified risk mitigation strategies within the three levels of strategies. The samples of the email interviews are the same as that in Section 5.2.2. The results indicate that most of respondents agreed the risk mitigation strategies and the categories that this thesis identified. However, there were some arguments that were raised by one interviewee, which are discussed as follows.

One manager did not totally agree one strategy that the author identified (Implement slow steaming and increase the number of ships on existing routes, IOS_3), he mentioned: "*Deploying more ships in a service doesn't necessarily improve reliability or mitigates risk; there will always be circumstances that cannot be planned for (weather, geo-politics etc.)"*. However, this strategy has already been mentioned in many studies, e.g. Notteboom (2006), Notteboom and Vernimmen (2009), and Ronen (2011) (see Chapter 2). We therefore decided to keep this strategy as a risk mitigation strategy in container shipping operations, and would like to assess its effectiveness using a large scale questionnaire survey later on.

After the email interviews, the results of risk mitigation strategies in container shipping operations remain the same as that in Table 7.2.

7.3 Evaluation of risk mitigation strategies

In Table 7.2, there are 20 risk mitigation strategies. In this Section, this thesis aims to: (i) firstly conduct validity and reliability test for mitigation-strategies survey; (ii) secondly rank these twenty risk mitigation strategies through a large scale of questionnaire survey (called risk-mitigation survey that was described in Section 4.2.2.3); (iii) thirdly select the top seven strategies for a further investigation, in order to evaluate their relationships (relative importance with respect to different performance criteria) through another questionnaire survey (called AHP survey that was described in Section 4.2.2.4 and presented in Appendix 4) and the AHP analysis methods (described in Section 4.3.2).

7.3.1 Validity and reliability test for mitigation-strategies survey

The questions of this survey are also identified from previous literature addressed in container shipping operations and general supply chains, and have been validated through a set of face-to-face interviews (includes 2 vice-presidents, 2 senior managers in the IT department, and 3 senior managers in the operations department) and a set of email interviews (includes a managing director, a Chief information officer, a Chief Accountant, a Navigation superintendent a senior consultant operations, and a senior commissioner). Therefore, it is believed that this survey has a high level of validity.

The author conducted a reliability test for the questions on risk mitigation strategies and the results are shown in Table 7.3. A total of 20 questions were tested, and the Cronbach's Alpha is 0.872 (>0.8), whilst the Cronbach's Alpha based on standardised items is also 0.874 (>0.8), which illustrates that the questions of risk mitigation strategies are reliable.

Table 7.3 Reliability test for risk mitigation strategies

Cronbach's Alpha	Cronbach's Alpha Based on Standardised Items	Number of question
0.872	0.874	20

7.3.2 Ranking of risk mitigation strategies

Table 7.4 shows the mean, the standard deviation (S.D.) and the ranking of different risk mitigation strategies based on the data from the risk-mitigation survey. The results show that on average three categories have very close levels of overall effectiveness (Average of IOS: 3.72; Average of IntraCS: 3.68; Average of InterCS: 3.72), and each category appears to include highly ranked mitigation strategies. Moreover, based on the results in Table 6.4 and taking into account the scale of further data collection (to keep it at a manageable level), we will select the top seven mitigation strategies for the AHP analysis. This gives rise to a cut-off score of 3.82: the mitigation strategies with an average score of no less than 3.82 are included in the set of the most important strategies. Next, we provide some interpretation and discussion on the results in Table 7.4.

Two intra-organisational strategies (IOS), "use more advanced infrastructures (hardware and software)" (IOS_4: 3.92) and "when the ship has already been delayed, omit port-of-calls to keep the original schedule" (IOS_2: 3.82), have a mean no less than 3.82. IOS_2 is deemed an operation level of strategy, whilst IOS_4 tends to be more general level. That means both operation level and general level strategies are important when dealing with the IOS. On the other side, it is interesting to observe that the recent popular practice – slow steaming – has the lowest scores within the IOS group. Slow steaming can reduce fuel consumption and absorb idle ships, which is an appropriate strategy for shipping lines when supply exceeds demand. However, it increases the transit time and may incur extra inventory costs to shippers (Kloch, 2013). The low score of slow steaming indicates that not all of the respondents think that slow steaming is a better strategy to reduce risks within container shipping operations compared with other strategies within IOS.

Three intra-channel strategies have average scores greater than 3.82, including "choose partners more carefully" (IntraCS_2: 3.87), "collaboration with partners (e.g., terminal operational company, inland transportation) through making a joint long-term plan (collaboration level)" (IntraCS_10: 3.85), and "enter a long-term contract with shippers" (IntraCS_7: 3.85). On the other hand, the strategy "avoid having too many partners" has the lowest score 3.29 in this group. This may reflect the fact that container shipping is a global business and each shipping company has to build an extensive network with many partners vertically and horizontally. Moreover, within three different levels of "cooperation" – cooperation level (IntraCS_8: 3.65), coordination level (IntraCS_9: 3.77), and collaboration level (IntraCS_10: 3.85) – the results show that shipping companies will have better risk mitigation effects if the companies have a higher level of "cooperation" relationship with partners. In addition, the different supply chains within IntraCS – cargo supply chain (IntraCS_7: 3.85) and service supply chain (IntraCS_10: 3.85) – have the same emphases taken from the shipping managers. The result shows that shipping companies need to emphasise both these supply chains.

There are two strategies having average scores greater than 3.82 within the inter-channel strategy group: “slot exchange, slot charter, joint fleet, ship charter with other container shipping companies” (InterCS_1: 4.18) and “form alliance with other shipping companies” (InterCS_2: 4.02). The strategy “acquire and merge with other shipping companies” (InterCS_3: 2.95) has the lowest score among all mitigation strategies. As this strategy has a long-term and fundamental impact on shipping companies’ operations, it often implies a high degree of uncertainty and may be adopted in critical situations. This explains why it is less popular than other mitigation strategies.

The results in Table 7.4 only provide overall effectiveness of those mitigation strategies. As we mentioned earlier on, there are different criteria to measure the risk consequence in container shipping such as financial loss, reputation loss, and safety and security incident related loss. It is therefore interesting to further investigate the relative importance of those mitigation strategies against different criteria individually and aggregately. This can be done by performing the AHP analysis. However, the AHP has a limitation in terms of the number of alternatives. If all strategies are included, the number of survey questions becomes too large to conduct practically. Therefore, among all strategies, we select the top seven risk mitigation strategies to keep the AHP analysis and data collection at a manageable scale. These risk mitigation strategies include: “slot exchange, slot charter, joint fleet, ship charter with other container shipping companies" (InterCS_2), "form alliance with other shipping companies" (InterCS_1), "use more advanced infrastructures (hardware and software)" (IOS_4), "choose partners very carefully" (IntraCS_2), "collaboration with partners (e.g., terminal operational company, inland transportation) through making a joint long-term plan (collaboration level)" (IntraCS_10), "enter a long-term contract with shippers" (IntraCS_7), and "when the ship has already been delayed, omit port-of-calls to keep original schedule" (IOS_2). These mean values of the selected strategies are highlighted in Table 7.4.

Table 7.4 Risk mitigation strategies

Strategy	Mean	S.D.	Rank	
Intra-organisational strategies (IOS)			A	D
1. Be flexible when designing the timetable/schedule, e.g., include buffer times	3.81	0.76		3
2. When the ship has already been delayed, omit port-of-calls to keep original schedule	3.82	0.80	7	2
3. Implement slow steaming and increase the number of ships on existing routes	3.52	0.82		7
4. Use more advanced infrastructures (hardware and software)	3.92	0.66	3	1
5. Improve safety measures, such as by implementing safety rules and regulations like the IMDG Code and ISM Code	3.71	0.76		3
6. Improve security measures, such as by implementing security rules and regulations like the ISO 27001 and ISPS Code	3.58	0.78		6
7. Execute Regular employee training (e.g. once a year or twice a year)	3.66	0.77		5
Mean of intra-organisational strategies	3.72			
Intra-channel strategies (IntraCS)				
1. Avoid having too many partners	3.29	0.71		10
2. Choose partners very carefully	3.87	0.66	4	1
3. Shorten/withdraw contract with the partner that perform badly	3.52	0.72		9
4. Build trust with partners	3.65	0.77		6
5. Cultivate loyalty of supply chain partners	3.77	0.80		4
6. Reward /assist partners that comply with shipping lines' initiatives	3.58	0.69		8
7. Enter a long-term contract with shippers	3.85	0.76	5	2
8. Share information with partners without co-management (cooperation level)	3.65	0.66		6

9. Exchange ideas with partners to solve conflicts or improve service quality (coordination level)	3.77	0.66		4
10. Collaboration with partners (e.g., terminal operational company, inland transportation) through making a joint long-term plan (collaboration level)	3.85	0.67	5	2
Mean of intra-channel strategies	3.68			
Inter-channel strategies (InterCS)				
1. Slot-exchange, slot charter, joint fleet, ship-charter with other container shipping companies	4.18	0.67	1	1
2. Form alliance with other shipping companies	4.02	0.67	2	2
3. Acquire and merge with other shipping companies	2.95	0.76		3
Mean of inter-channel strategies	3.72			

*S.D. = Standard Deviation
*red colour means the mean value is more than 4
*orange colour means the mean value is between 3.80 and 3.99
*blue colour means the mean value is the smallest one
*Rank A means the overall risk mitigation strategies rank (only shows the top three ones)
*Rank D means the rank within the level of risk mitigation strategies

After selecting the seven mitigation strategies, we consulted with six industrial experts in container shipping. One expert suggested that the range of the seventh strategy, “when the ship has already been delayed, omit port-of-calls to keep original schedule”, was too narrow as a mitigation strategy compared to others. Therefore, we replaced it with the next one in the ranking table, “be flexible when designing the timetable/schedule, e.g., include buffer times”, which has an average score 3.81.

7.3.3 Classic AHP analysis

Similar to the risk-factor survey and the mitigation-strategy survey, the target sample was also from the list of National Association of Shipping Agencies in Taiwan. However, in order to increase the valid response rate, the respondents who replied the risk-factor and mitigation-strategy questionnaire survey were selected to do the AHP questionnaire survey (in Appendix 5). Moreover, several important individuals who did not reply us were also included within the AHP survey. In total, 114 questionnaires were sent out in December 2011 and we then got 21 replies in one month; include 12 valid and 9 invalid as the consistency ratio (C.R.) is over the standard acceptable value (0.1), within a month. The valid return rate is 10.53% (Table 7.5).

Table 7.5 The reply rate of AHP survey

Questionnaire	Return	Invalid reply	Valid reply	Valid reply rate
114	21	9	12	10.53%

This thesis uses the Microsoft Office Excel software to calculate the results of the 12 AHP questionnaires. The steps of using classic AHP have been discussed in Section 4.3.2.1. Firstly, the results show that the consistency ratio (C.R.) of each criterion is 0.01, which is less than the standard acceptable value (0.1). Therefore, the data meet the consistency requirement. Secondly, we are able to calculate the weights/ priorities of each criterion and each alternative. By combining the criterion priorities and the relevant alternative priorities, we are able to obtain an overall priority ranking of the decision alternatives, which can be presented as a priority matrix as shown in Table 7.6 (Al-Harbi, 2001, p.25).

Table 7.6 The standardised weights, the global weights, and the rank

Criteria	Weights of criteria (a)	Strategies	Weights of strategies (b)	Global weights (a)*(b)
Reduce financial loss	0.412 [2]	A	0.189 [2]	0.078
		B	0.143 [3]	0.059
		C	0.107 [6]	0.044
		D	0.116 [5]	0.048
		E	0.131 [4]	0.054
		F	0.219 [1]	0.090
		G	0.095 [7]	0.039
Reduce reputation loss	0.159 [3]	A	0.141 [4]	0.022
		B	0.164 [1]	0.026
		C	0.141 [5]	0.022
		D	0.161 [2]	0.026
		E	0.146 [3]	0.023
		F	0.138 [6]	0.022
		G	0.108 [7]	0.017
Reduce safety and security incident related loss	0.429 [1]	A	0.177 [1]	0.076
		B	0.159 [2]	0.068
		C	0.150 [3]	0.064
		D	0.147 [4]	0.063
		E	0.143 [5]	0.061
		F	0.129 [6]	0.055
		G	0.094 [7]	0.040

A: Slot-exchange, slot charter, joint fleet, ship-charter with other container shipping
B: Form alliance with other shipping companies
C: Use more advanced infrastructure (hardware and software)
D: Choose partners more carefully
E: Cooperate with your partners (e.g. terminal operational company, inland transportation)
F: Make a long-term contract with shippers
G: Design a flexible shipping schedule
[n]: n is the rank of the strategy under each criterion

From Table 7.6, it can be seen that the weights of criterion “reduce financial loss” (0.412) and “reduce safety and security incident related loss” (0.429) are much greater than “reduce reputation loss” (0.159). This indicates that the first two criteria are more important under the goal of mitigating risks in the shipping operations. It is easy to understand that almost every company pays a lot of attention to reducing financial loss. However, “reduce safety and security incident related loss” is also important in container shipping operations due to its dangerous working environment. Compared to retailer operations in which maintaining reputation and brand are highly emphasised (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 “reduce financial loss”, Strategy F “enter a long-term contract with shippers” and Strategy A “slot exchange, slot charter, joint fleet, ship charter with other container shipping” are the top two for mitigating financial loss in container shipping operations. These two strategies can tackle and reduce the risk caused by the uncertainty in transportation demand. Moreover, the global weight of Strategy F (0.090) is about twice the weight of the lowest one, Strategy G (0.039).

Under the criterion “reduce reputation loss”, Strategy B “Form alliance with other shipping companies” is the most important strategy. However, compared with the criterion “reduce financial loss”, the weights of the seven strategies under this criterion are less notable. This indicates that their contribution to reducing reputation loss does not have significant differences.

Under the criterion “reduce safety and security incident related loss, Strategy A “slot exchange, slot charter, joint fleet, ship charter with other container shipping” is the most important risk mitigation strategy, and its global weight (0.076) is more than twice that of Strategy G (0.040).

In order to understand the importance of the mitigation strategies over all three criteria, we calculate the overall priority of each strategy, which is the sum of the global weights of each strategy under three criteria. The calculations of overall priority of individual strategies are presented in the following:

Overall priority of Strategy A
= 0.412 (0.189) + 0.159 (0.141) + 0.429 (0.177)
=0.178 (6.1)

Overall priority of Strategy B
= 0.412 (0.143) + 0.159 (0.164) + 0.429 (0.159)
=0.156 (6.2)

Overall priority of Strategy C
= 0.412 (0.107) + 0.159 (0.141) + 0.429 (0.150)
=0.136
(6.3)

Overall priority of Strategy D
= 0.412 (0.116) + 0.159 (0.161) + 0.429 (0.147)
=0.135 (6.4)

Overall priority of Strategy E
= 0.412 (0.131) + 0.159 (0.146) + 0.429 (0.143)
=0.135 (6.5)

Overall priority of Strategy F
= 0.412 (0.219) + 0.159 (0.138) + 0.429 (0.129)
=0.163 (6.6)

Overall priority of Strategy G
= 0.412 (0.095) + 0.159 (0.108) + 0.429 (0.094)
=0.096 (6.7)

Based on the results in (6.1)~(6.7), the seven strategies are ranked according to their overall priorities as follows: A, F, B, C, D, E, and G. This ranking is notably different (for the Strategy F) compared to the result from the mitigation-strategy survey where the ranking order is A, B, C, D, E, F, and G. This may be due to fact that container shipping is a logistics service provider industry, which does not have its own production, and the profit totally relies on the transportation demand from shippers. Therefore, making a long-term contract with shippers can reduce the future demand uncertainty and ensure shipping companies have a certain volume of promised cargo to transport. It should be also 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 “slot-exchange, slot charter, joint fleet, ship-charter with other container shipping” has the largest overall priority 0.178, which plays the most important role in reducing container shipping operation risks. The second one is Strategy F “make a long-term contract with shippers”, which also has 0.156 of the overall priority. Note that the weights of the middle three strategies (i.e. C, D, and E) are fairly close, therefore the seven strategies can be divided into three groups. That is, group 1 contains Strategy A, Strategy F and Strategy B, which has the highest impact on reducing the container shipping operational risks; group 2 includes Strategy, C, D and E that have the medium impact; and group 3 contains Strategy G, which has the lowest impact on mitigating the container shipping operational risks. More specifically, the weight of Strategy A (0.178) in group 1 is almost two times of the weight of the Strategy G (0.096) in group 3; and the weights of the alternatives in group 2 are around one and half times of that of Strategy G.

Comparing the above result with the overall effectiveness ranking from the first survey, they are generally consistent except Strategy F, which becomes second among the seven strategies.

7.3.4 Fuzzy AHP analysis

There are several steps for analysing the relative importance of seven strategies using the Fuzzy AHP (Ali *et al*., 2012), the details of the data analysis are described in the following (also refer to Section 4.3.2.2 in this thesis for the Fuzzy AHP steps):

Step 1 Build fuzzy positive reciprocal matrix

This thesis uses the data of the relative importance from 12 valid questionnaires and then, based on the method suggested by Durán and Aguilo (2008) and Ali *et al*. (2012), transforms these crisp data into triangular fuzzy numbers by $\tilde{1} = (1,1,2)$; $\tilde{\imath} = (i-1, i, i+1)$; $\tilde{9} = (8, 9, 9)$. In order to save space, the author only presents the results of the fuzzy AHP for one selected respondent's opinion, and all of the results are presented in Appendix 6. The result of the fuzzy positive reciprocal matrix at the criteria layer is shown as Table 7.7; the result for the seven alternatives under financial loss is shown in Table 7.8; the result for the seven alternatives under reputation loss is shown in Table 7.9; and result for the seven alternatives under safety and security incident related loss is shown in Table 7.10. The consistency ratios of the criteria level and the three alternative levels are in the acceptable level (i.e. the C.R. is less than 0.1).

Table 7.7 The fuzzy positive reciprocal matrix of three criteria

	Reduce financial loss	Reduce reputation loss	Reduce safety and security incident related loss
Reduce financial loss	(1, 1, 2)	(5, 6, 7)	(2, 3, 4)
Reduce reputation loss	(0.143, 0.167, 0.2)	(1, 1, 2)	(0.25, 0.333, 0.5)
Reduce safety and security incident related loss	(0.25, 0.333, 0.5)	(2, 3, 4)	(1, 1, 2)
C.R. = 0.015771			

Table 7.8 The fuzzy positive reciprocal matrix of seven strategies under reduce financial loss

		A	B	C	D	E	F	G
Reduce financial loss	A	(1, 1, 2)	(2, 3, 4)	(2, 3, 4)	(2, 3, 4)	(2, 3, 4)	(1, 2, 3)	(1, 2, 3)
	B	(0.25, 0.333, 0.5)	(1, 1, 2)	(0.333, 0.5, 1)	(0.167, 0.2, 0.25)	(0.167, 0.2, 0.25)	(0.143, 0.167, 0.2)	(0.143, 0.167, 0.2)
	C	(0.25, 0.333, 0.5)	(1, 2, 3)	(1, 1, 2)	(1, 1, 2)	(1, 1, 2)	(0.167, 0.2, 0.25)	(0.143, 0.167, 0.2)
	D	(0.25, 0.333, 0.5)	(4, 5, 6)	(0.5, 1, 1)	(1, 1, 2)	(1, 1, 2)	(0.143, 0.167, 0.2)	(0.167, 0.2, 0.25)
	E	(0.25, 0.333, 0.5)	(4, 5, 6)	(0.5, 1, 1)	(0.5, 1, 1)	(1, 1, 2)	(0.167, 0.2, 0.25)	(0.167, 0.2, 0.25)
	F	(0.333, 0.5, 1)	(5, 6, 7)	(4, 5, 6)	(5, 6, 7)	(4, 5, 6)	(1, 1, 2)	(1, 1, 2)
	G	(0.333, 0.5, 1)	(5, 6, 7)	(5, 6, 7)	(4, 5, 6)	(4, 5, 6)	(0.5, 1, 1)	(1, 1, 2)
C.R.=0.082091								

Table 7.9 The fuzzy positive reciprocal matrix of seven strategies under reduce reputation loss

		A	B	C	D	E	F	G
Reduce reputation loss	A	(1, 1, 2)	(1, 1, 2)	(1, 1, 2)	(1, 2, 3)	(1, 2, 3)	(1, 1, 2)	(1, 1, 2)
	B	(0.5, 1, 1)	(1, 1, 2)	(1, 1, 2)	(1, 1, 2)	(1, 1, 2)	(0.25, 0.333, 0.5)	(1, 1, 2)
	C	(0.5, 1, 1)	(0.5, 1, 1)	(1, 1, 2)	(1, 1, 2)	(1, 1, 2)	(0.25, 0.333, 0.5)	(0.167, 0.2, 0.25)
	D	(0.333, 0.5, 1)	(0.5, 1, 1)	(0.5, 1, 1)	(1, 1, 2)	(1, 1, 2)	(0.167, 0.2, 0.25)	(0.25, 0.333, 0.5)
	E	(0.333, 0.5, 1)	(0.5, 1, 1)	(0.5, 1, 1)	(0.5, 1, 1)	(1, 1, 2)	(0.25, 0.333, 0.5)	(0.25, 0.333, 0.5)
	F	(0.5, 1, 1)	(2, 3, 4)	(2, 3, 4)	(4, 5, 6)	(2, 3, 4)	(1, 1, 2)	(1, 1, 2)
	G	(0.5, 1, 1)	(0.5, 1, 1)	(4, 5, 6)	(2, 3, 4)	(2, 3, 4)	(0.5, 1, 1)	(1, 1, 2)
C.R.=0.043089								

Table 7.10 The fuzzy positive reciprocal matrix of seven alternatives under reduce safety and security incident related loss

Reduce safety and security incident related loss		A	B	C	D	E	F	G
	A	(1, 1, 2)	(2, 3, 4)	(2, 3, 4)	(1, 2, 3)	(2, 3, 4)	(1, 1, 2)	(1, 1, 2)
	B	(0.25, 0.333, 0.5)	(1, 1, 2)	(1, 1, 2)	(1, 1, 2)	(1, 2, 3)	(0.333, 0.5, 1)	(1, 1, 2)
	C	(0.25, 0.333, 0.5)	(0.5, 1, 1)	(1, 1, 2)	(1, 1, 2)	(1, 1, 2)	(0.25, 0.333, 0.5)	(0.167, 0.2, 0.25)
	D	(0.333, 0.5, 1)	(0.5, 1, 1)	(0.5, 1, 1)	(1, 1, 2)	(1, 1, 2)	(0.167, 0.2, 0.25)	(0.167, 0.2, 0.25)
	E	(0.25, 0.333, 0.5)	(0.333, 0.5, 1)	(0.5, 1, 1)	(0.5, 1, 1)	(1, 1, 2)	(0.25, 0.333, 0.5)	(0.167, 0.2, 0.25)
	F	(0.5, 1, 1)	(1, 2, 3)	(2, 3, 4)	(4, 5, 6)	(2, 3, 4)	(1, 1, 2)	(1, 1, 2)
	G	(0.5, 1, 1)	(0.5, 1, 1)	(4, 5, 6)	(4, 5, 6)	(4, 5, 6)	(0.5, 1, 1)	(1, 1, 2)
C.R.=0.037491								

Step 2 Calculate the fuzzy weights of fuzzy positive reciprocal matrix

Using Step 5 of the fuzzy AHP approach, the geometric mean of triangular fuzzy number ($\tilde{Z}_i^C$) and the fuzzy weights ($\widetilde{W}_i^C$) of three criteria can be obtained as shown in Table 7.11; the geometric mean of triangular fuzzy number ($\tilde{Z}_i^{FA}$) and the fuzzy weights ($\widetilde{W}_i^{FA}$) of seven alternatives under financial loss are shown in Table 7.12; the geometric mean of triangular fuzzy number ($\tilde{Z}_i^{RA}$) and the fuzzy weights ($\widetilde{W}_i^{RA}$) of seven alternatives under reputation loss are shown in Table 7.13; and the geometric mean of triangular fuzzy number ($\tilde{Z}_i^{SA}$) and the fuzzy weights ($\widetilde{W}_i^{SA}$) of seven alternatives under safety and security incident related loss are shown in Table 7.14.

Table 7.11 The geometric mean of TFN and the fuzzy weights of three criteria

	i =Financial loss	$i =$ Reputation loss	$i =$ Safety and security incident related loss
$\tilde{Z}_i^C$	(2.154, 2.621, 3.826)	(0.329, 0.382, 0.585)	(0.794, 1, 1.587)
$\widetilde{W}_i^C$	(0.359, 0.655, 1.167)	(0.055, 0.095, 0.178)	(0.132, 0.25, 0.484)

Table 7.12 The geometric mean of TFN and the fuzzy weights of seven strategies under reduce financial loss

	i =A	$i =$ B	$i =$ C	$i =$ D	$i =$ E	$i =$ F	$i =$ G
$\tilde{Z}_i^{FA}$	(1.486, 2.284, 3.337)	(0.241, 0.293, 0.425)	(0.481, 0.581, 0.93)	(0.531, 0.662, 0.93)	(0.492, 0.679, 0.869)	(2.012, 2.393, 3.546)	(1.822, 2.393, 3.212)
$\widetilde{W}_i^{FA}$	(0.112, 0.246, 0.472)	(0.018, 0.032, 0.06)	(0.036, 0.063, 0.132)	(0.04, 0.071, 0.132)	(0.037, 0.073, 0.123)	(0.152, 0.258, 0.502)	(0.138, 0.258, 0.455)

Table 7.13 The geometric mean of TFN and the fuzzy weights of seven strategies under reduce reputation loss

	i =A	$i =$ B	$i =$ C	$i =$ D	$i =$ E	$i =$ F	$i =$ G
$\tilde{Z}_i^{FA}$	(1, 1.219, 2.246)	(0.743, 0.855, 1.486)	(0.521, 0.679, 1)	(0.445, 0.615, 0.906)	(0.427, 0.662, 0.906)	(1.486, 2.015, 2.852)	(1.104, 1.723, 2.119)
$\widetilde{W}_i^{FA}$	(0.087, 0.157, 0.392)	(0.065, 0.11, 0.259)	(0.045, 0.087, 0.175)	(0.039, 0.079, 0.158)	(0.037, 0.085, 0.158)	(0.129, 0.259, 0.498)	(0.096, 0.222, 0.37)

Table 7.14 The geometric mean of TFN and the fuzzy weights of seven strategies under reduce safety and security incident related loss

	i =A	$i =$ B	$i =$ C	$i =$ D	$i =$ E	$i =$ F	$i =$ G
$\tilde{Z}_i^{FA}$	(1.346, 1.768, 2.852)	(0.701, 0.855, 1.575)	(0.472, 0.581, 0.906)	(0.42, 0.572, 0.82)	(0.365, 0.526, 0.743)	(1.346, 1.902, 2.737)	(1.346, 1.993, 2.38)
$\widetilde{W}_i^{FA}$	(0.112, 0.216, 0.476)	(0.058, 0.104, 0.263)	(0.039, 0.071, 0.151)	(0.035, 0.07, 0.137)	(0.03, 0.064, 0.124)	(0.112, 0.232, 0.457)	(0.112, 0.243, 0.397)

Step 3 Defuzzify the fuzzy weights and normalise the crisp weights

Using Step 6 of the fuzzy AHP approach, the fuzzy weights can be defuzzified by the Centre of Gravity method to obtain the crisp weights (e.g. Sugeno, 1985; Lee, 1990; Ail *et al*., 2012). Then using Step 7 of the fuzzy AHP approach, the standardised weights can be obtained. The results of the three criteria and the seven strategies under the three criteria are shown in Table 7.15, Table 7.16, Table 7.17, and Table 7.18 respectively.

Table 7.15 The defuzzified and standardized weights of three criteria

	Financial loss	Reputation loss	Safety and security incident related loss
Defuzzified weights	0.727	0.11	0.289
Standardised weights	0.646	0.097	0.257

Table 7.16 The defuzzified and standardized weights of seven strategies under reduce financial loss

	A	B	C	D	E	F	G
Defuzzified weights	0.277	0.037	0.077	0.081	0.078	0.304	0.283
Standardised weights	0.244	0.032	0.068	0.071	0.068	0.267	0.249

Table 7.17 The defuzzified and standardized weights of seven strategies under reduce reputation loss

	A	B	C	D	E	F	G
Defuzzified weights	0.212	0.145	0.102	0.092	0.093	0.296	0.229
Standardised weights	0.181	0.124	0.088	0.079	0.08	0.253	0.196

Table 7.18 The defuzzified and standardized weights of seven strategies under reduce safety and security incident related loss

	A	B	C	D	E	F	G
Defuzzified weights	0.268	0.142	0.087	0.081	0.073	0.267	0.251
Standardised weights	0.229	0.121	0.075	0.069	0.062	0.229	0.215

Step 4 Calculate the global weights

After calculating the results from the 12 respondents individually, the final results were aggregated and averaged over all respondents' opinions (include the standardised weights of the criteria level and seven strategies under the three criteria) by using the arithmetic mean. Finally, global weights can be obtained by multiplying the standardised weights of the three criteria and the standardised weights of the seven strategies.

Table 6.19 shows the results of standardised weights and global weights by using the fuzzy AHP method. Compared with the classic AHP (see Table 6.5), the weights of criteria have a slight change. The weight of "reduce financial loss" becomes the first place among the three criteria and it increases to 0.428 (it was 0.412 in classic AHP). Whilst the weight of "reduce reputation loss" is still the least weight criterion and it decreases slightly to 0.157 (it was 0.159 in classic AHP). The weight of "reduce safety and security incident related loss" becomes the second important criterion and it decreases to 0.415 (it was 0.429 in the classic AHP). This reveals that the shipping companies tend to focus more on reducing financial loss and reducing safety and security incident related loss , and they seem to pay much less attention to reducing the reputation loss compared to reducing the financial loss or the safety and security incident related loss. We believe this result from the fuzzy AHP is probably more reasonable than that from the classic AHP since the ultimate goal of shipping companies is to reduce costs and earn profits.

Under the criterion “reduce financial loss”, Strategy F “make a long-term contract with shippers” is notably more important than others. Under the criterion “reduce reputation loss”, although Strategy B “form alliance with other shipping companies” takes first place, strategies A~F are all very close. Under the criterion “reduce safety and security incident related loss”, the top one is Strategy A “slot-exchange, slot charter, joint fleet, ship-charter with other container shipping”.

The top seven global weights are Strategy FF (the Strategy F under reducing financial loss) “make a long-term contract with shippers”, Strategy FA (the Strategy A under reducing financial loss) “slot-exchange, slot charter, joint fleet, ship-charter with other container shipping”, Strategy SA (the Strategy A under reducing safety and security incident related loss), Strategy SB (the Strategy B under reducing safety and security incident related loss) “form alliance with other shipping companies”, Strategy SC (the Strategy C under reducing safety and security incident related loss) “use more advanced infrastructure (hardware and software)”, Strategy FB (the Strategy B under reducing financial loss), and Strategy SD (the Strategy D under reducing safety and security incident related loss) “choose partners more carefully”. The weights of these seven critical strategies are all above 6%, and the sum of these seven weights account for 51.00% (about 1/2). The results suggest that managers could pay more attention to making long-term contracts with shippers in order to effectively reduce financial loss, whereas this strategy may be not so effective in reducing the other two types of loss (rank 6 in both the criterion of "reduce reputation loss" and "reduce safety and security incident related loss").

On the other hand, the bottom three strategies with the least weights are Strategy RG "design a flexible shipping schedule", Strategy RF "make a long-term contract with shippers", and Strategy RE "Cooperate with your partners (e.g. terminal operational company, inland transportation)". The sum of the three weights is only 0.059%. Moreover, all the strategies belonging to the criterion of "reduce reputation loss" are ranked as the bottom seven places among the 21 strategies in Table 7.19 according to their global weights.

Table 7.19 The standardised weights, the global weights, and the rank

Criteria	Weights of criteria (a)	Strategies	Weights of strategies (b)	Global weights (a)*(b)
Reduce financial loss	0.428 [1]	A	0.192 [2]	0.085
		B	0.142 [3]	0.063
		C	0.114 [6]	0.051
		D	0.118 [5]	0.048
		E	0.131 [4]	0.051
		F	0.212 [1]	0.088
		G	0.092 [7]	0.042
Reduce reputation loss	0.157 [3]	A	0.159 [2]	0.025
		B	0.167 [1]	0.025
		C	0.145 [4]	0.023
		D	0.157 [3]	0.024
		E	0.138 [5]	0.022
		F	0.133 [6]	0.022
		G	0.100 [7]	0.015
Reduce safety and security incident related loss	0.415 [2]	A	0.192 [1]	0.078
		B	0.167 [2]	0.070
		C	0.149 [3]	0.065
		D	0.143 [4]	0.061
		E	0.134 [5]	0.056
		F	0.125 [6]	0.049
		G	0.090 [7]	0.035

A: Slot-exchange, slot charter, joint fleet, ship-charter with other container shipping
B: Form alliance with other shipping companies
C: Use more advanced infrastructure (hardware and software)
D: Choose partners more carefully
E: Cooperate with your partners (e.g. terminal operational company, inland transportation)

F: Make a long-term contract with shippers
G: Design a flexible shipping schedule

Overall priority of Strategy A
= 0.428 (0.192) + 0.157 (0.159) + 0.415 (0.192)
=0.189 (6.8)

Overall priority of Strategy B
= 0.428 (0.142) + 0.157 (0.167) + 0.415 (0.167)
=0.158 (6.9)

Overall priority of Strategy C
= 0.428 (0.114) + 0.157 (0.145) + 0.415 (0.149)
=0.138 (6.10)

Overall priority of Strategy D
= 0.428 (0.118) + 0.157 (0.157) + 0.415 (0.143)
=0.134 (6.11)

Overall priority of Strategy E
= 0.428 (0.131) + 0.157 (0.138) + 0.415 (0.134)
=0.130 (6.12)

Overall priority of Strategy F
= 0.428 (0.212) + 0.157 (0.133) + 0.415 (0.125)
=0.159 (6.13)

Overall priority of Strategy G
= 0.428 (0.092) + 0.157 (0.100) + 0.415 (0.090)
=0.092 (6.14)

Based on the results in (6.8)~(6.14), the seven strategies are ranked according to their overall priorities as follows: A, F, B, C, D, E, and G. This result is the same with the result of classic AHP. However, the overall priorities are slightly different from that of the classic AHP. The fuzzy AHP has a relatively wider range of the overall priorities, i.e. [0.092, 0.189], than that of the classic AHP, i.e. [0.096, 0.178]. This implies that the fuzzy AHP can differentiate the relative importance of the strategies more clearly.

As mentioned in Section 4.3, there are different methods to defuzzify the fuzzy weights (e.g. Durán and Aguilo, 2008; Ding, 2010; Ding and Tseng, 2012; Ali *et* *al*., 2012), in which Ali *et al*. (2012) used the Centre of Gravity method. Table 7.20 presents the results of different fuzzy AHP together with results of the classic AHP in to make a comparison. It can be seen that the rankings of the seven strategies remain the same under all methods, although the overall priorities vary slightly. The ranges of the overall priorities under the fuzzy AHP methods are wider than the classic AHP, which implies that the fuzzy AHP methods have more power to differentiate the relative importance of different strategies.

Table 7.20 The comparison of classic AHP and three different fuzzy AHP

Strategy	Classic AHP		Duran and Aguilo (2008)		Ding (2010); Ding and Tseng (2012)		Ali *et al*. (2012)	
A	0.178	1	0.186	1	0.184	1	0.189	1
B	0.156	3	0.158	3	0.157	3	0.158	3
C	0.136	4	0.138	4	0.138	4	0.138	4
D	0.135	5	0.134	5	0.134	5	0.134	5
E	0.135	6	0.131	6	0.132	6	0.130	6
F	0.163	2	0.160	2	0.161	2	0.159	2
G	0.096	7	0.093	7	0.094	7	0.092	7

A: Slot-exchange, slot charter, joint fleet, ship-charter with other container shipping
B: Form alliance with other shipping companies
C: Use more advanced infrastructure (hardware and software)
D: Choose partners more carefully
E: Cooperate with your partners (e.g. terminal operational company, inland transportation)
F: Make a long-term contract with shippers
G: Design a flexible shipping schedule

7.4 Chapter summary

This chapter can be summarised into two parts: the risk mitigation strategies identification, and the risk mitigation strategies evaluation. The former includes the results from a more general literature review and from seven interviews; the latter includes the results from two questionnaire surveys, the results from the risk mitigation strategies ranking, and the results from the classic AHP analysis and the fuzzy AHP analysis.

From relevant literature review, this study has identified a total of 17 risk mitigation strategies: 6 strategies belong to the intra-organisation level, 8 strategies belong to the intra-channel level, and 3 strategies belong to the inter-channel level. Moreover, based on the results from the interviews, this thesis formulates a few new mitigation strategies, e.g., "implement international regulations (e.g. ISO 27001, IMO regulations)" can be classified into intra-organisational strategies owing to they can be executed within a shipping company; "choose partners more carefully", and "cultivate loyalty of supply chain partners" can be classified into intra-channel strategies owing to they are related to collaboration with supply chain partners. Finally, after interviews, a total of 20 risk mitigation strategies are identified.

After the identification of these risk mitigation strategies, a risk mitigation-strategy survey is used to rank the importance of these strategies. The results from the mitigation-strategy survey can be summarised as follows:

(1) The mean values of three categories (intra-organisational strategies, intra-channel strategies, and inter-channel strategies) are at similar levels of overall effectiveness (mean value of IOS: 3.72; mean value of IntraCS: 3.68; mean value of InterCS: 3.72), and each category appears to include highly ranked mitigation strategies.

(2) The top two intra-organisational strategies are "use more advanced infrastructures (hardware and software)" (IOS_4: 3.92) and "when the ship has already been delayed, omit port-of-calls to keep the original schedule" (IOS_2: 3.82), and both have a mean at no less than 3.8. It is interesting to observe that the recent popular practice – slow steaming –

has the lowest scores within the IOS group. Slow steaming, as Traill (2010) stated, increases the transit time and may incur extra inventory costs to shippers; which can be also supported by the interviewee's opinion: "*Deploying more ships in a service doesn't necessarily improve reliability or mitigates risk; there will always be circumstances that cannot be planned for (weather, geo-politics etc.)"* (see Section 7.2.2).

(3) Three intra-channel strategies have average scores at greater than 3.8, including "choose partners more carefully" (IntraCS_2: 3.87), "collaboration with partners (e.g., terminal operational company, inland transportation) through making a joint long-term plan (collaboration level)" (IntraCS_10: 3.85), and "enter a long-term contract with shippers" (IntraCS_7: 3.85). On the other hand, the strategy "avoid having too many partners" has the lowest score 3.29 in this group.

(4) Two strategies with average scores greater than 3.8 within the inter-channel strategy group are "slot exchange, slot charter, joint fleet, ship charter with other container shipping companies" (InterCS_1: 4.18) and "form alliance with other shipping companies" (InterCS_2: 4.02). The strategy "acquire and merge with other shipping companies" (InterCS_3: 2.95) has the lowest score among all mitigation strategies.

The top seven strategies are selected to do further investigation using the AHP methods. They are: A: Slot-exchange, slot charter, joint fleet, ship-charter with other container shipping; B: Form alliance with other shipping companies; C: Use more advanced infrastructure (hardware and software); D: Choose partners more carefully; E: Cooperate with your partners (e.g. terminal operational company, inland transportation); F: Make a long-term contract with shippers; and

G: Design a flexible shipping schedule. The purpose is to further evaluate their relative importance against three different criteria. The AHP questionnaire survey was conducted to collect the primary data and the data were first analysed using the classic AHP. The main results can be summarised into several points as follows:

(1) The weights of criterion "reduce financial loss" (0.412) and "reduce safety and security incident related loss" (0.429) are much greater than that of "reduce reputation loss" (0.159). This indicates that the first two criteria are more important under the goal of mitigating risks in the shipping operations.
(2) Under the criterion "reduce financial loss", Strategies F "make a long-term contract with shippers" is the top one for mitigating financial loss in the container shipping operations. Under the criterion "reduce reputation loss", Strategy B "form alliance with other shipping companies" is the most important strategy. Under the criterion "reduce safety and security incident related loss", Strategy A "slot exchange, slot charter, joint fleet, ship charter with other container shipping" is the most important risk mitigation strategy.
(3) The seven strategies are ranked according to their overall priorities as follows: A, F, B, C, D, E, and G, which is generally in agreement with the results of the mitigation-strategy survey. However, the strategy F became the second important strategy in the results of the AHP survey.

The fuzzy AHP method was also applied to evaluate the relative importance of the selected seven mitigation strategies, the results are summarised below:

(1) The rank of the three criteria has changed to: “reduce financial loss” (0.428) is the most important criterion to container shipping risk mitigation management; “reduce safety and security incident related loss” (0.415) becomes the second important criterion; whilst “reduce reputation loss” (0.157) is still the slight one on container shipping operations. The first two criteria still dominate the third criterion.

(2) The seven strategies are ranked according to their overall priorities as follows: A, F, B, C, D, E, and G. This result is the same as that of the classic AHP. However, the overall priorities are slightly different from that of the classic AHP. The fuzzy AHP has a relatively wider range of the overall priorities than that of the classic AHP. This implies that the fuzzy AHP can differentiate the relative importance of the strategies more clearly.

(3) Several defuzzification methods were used in the fuzzy AHP analysis. The results showed that the rankings of the seven strategies remain the same.

Chapter 8 Discussion

This chapter presents the discussion of the main findings in this thesis. Section 8.1 discusses the findings from the risk analysis; Section 8.2 discusses the findings from the risk mitigation strategy evaluation; and Section 8.3 discusses the generalisation of the research methodology adopted in this thesis.

8.1 Findings from risk analysis

One aim of this thesis is to provide an inclusive view on the risks in container shipping operations taking a logistics perspective. This section focuses on the discussion of the practical and theoretical implications of the findings from risk analysis, including risk identification and validation, and risk assessment.

8.1.1 Risk identification and validation

The majority of the discussion in this section address the theoretical implications. With regards to the risk identification, the author took the logistics perspective which is composed of three main flows, namely, information flow, physical flow, and payment flow. The processes of these three flows in container shipping operations were elaborated based on relevant literature. This part achieves research objective 1: Elaborate the logistics flows (information, physical, payment flows) in container shipping operations (see Chapter 1). The conceptual framework is formulated through employing the four risk management steps, including identification (and validation) of risk, measurement and analysis of risk, identification (and validation) of risk mitigation strategy, and evaluation of risk mitigation strategy. The conceptual model is then applied to the container shipping industry in Taiwan. This part achieves research objective

2: Develop a conceptual framework for risk management in the context of container shipping operations, and apply the framework to a case study (see Chapter 1).

Based on the review of relevant literature (including the risks in container shipping operations and the risks in general supply chains), a total of 28 risk factors have been identified and classified into three categories, namely, risks associated with information flow, risks associated with physical flow, and risks associated with payment flow. Each category includes several risk elements, and each element includes several risk factors.

The risk validation and further risk exploration were conducted by a set of face-to-face interviews and a set of email interviews. After the series of interviews, the identified risk factors are validated and regarded as appropriate in the container shipping operations context. Several new risk factors were also identified during the interviews, including "Shippers request extra service information (InfoI_4)", "Shippers hide cargo information (non-declare) (InfoI_5)", "Container shortage (e.g. Shippers use containers as storage, container revamp, unexpected demand) (PhTD_6)", "Cargos being detained by customs (PhTD_8)", "Damage to frozen cargos/ reefer containers due to electricity failure (PhCD_5)", "Financial crisis in the loan countries (PayCE_2)", "Shippers abandoning cargos when cargos have already reached the port of destination (PayNP_2)". The reason that these risk factors have not been seen in the existing literature may be because these risk factors are quite unique in container shipping operations and have not yet commonly happened in other general industries, such as PhTD_6, PhTD_8, PhCD_5, and PayNP_2.

Among these seven new risk factors, it is worth mentioning that the risk factor PhCD_5 has been mentioned in existing literature (Tseng *et al*., 2012). However, the paper Tseng *et al*. (2012) published later than this thesis's data collection, which was conducted in 2011. Although the insight of Tseng *et al*. (2012) has been mentioned in Chapter 2, this thesis still categorises PhCD_5 into the new risk factor from face-to-face interview.

Several studies found that information asymmetry is an important issue in some supply chains such as retailing or manufacturing (e.g. Forrester, 1961; Lee *et al*., 1997). However, it is found in this thesis that in the maritime context, information asymmetry among the players in the market is not that important: it ranked 31st for causing financial loss, 19th for reputation loss, and 12th for safety and security incident related loss. As an interviewee put it in one of the interviews with the shipping companies:

> *"We do not really care about information asymmetry. According to 80/20 rule, compared to the cargo flow that starts from small shippers through brokers or forwarders to our company, the large shippers who can offer large scale cargo directly to us without brokers or forwards are the ones that we really concern."*

One interviewee stated that the risks associated with information flow may not be as serious as the risks associated with physical flow. He said: "*information flow could impact on physical flow, but it cannot replace physical flow*". His point was supported latter through the results of risk-factor survey.

Radio-frequency identification (RFID) has become a popular technology in almost every industry, especially in retailing. This technology can significantly improve the security of these retailers that the commodities will not be stolen.

RFID has been used in container transportation but is still in the period of pilot test. One interviewee mentioned that:

> *"There are two types of RFID, passive tag and active tag. The passive tag is not really useful for us as it only works in a close area and has only several gates connecting outside world, so that the reader can set up in the gates and read the information on the passive tag. For us, the containers are transported in an open area, which means all over the world, and this should use the active tag to actively send the cargo information to us if the cargo has been stolen. However, the active tag is quite expensive and we have around 80,000 to 100,000 containers transporting in the world. If our containers are all equipped with the RFID with active tag, this will be a big issue, and we have to consider it very carefully. Now, we still use the normal seal and electronic seal and the e-seal is usually used in transit containers and expensive cargo containers."*

Through a combination of comprehensive literature review, a set of face-to-face interviews, and a set of email interviews, this thesis has identified and validated a total of 35 risk factors in container shipping operations within three logistics flows. This achieves the research objective 3: Identify key risk factors within three flows in container shipping (see Chapter 1), and answers the research question 1 (i.e. what are the risk factors in container shipping operations? see Chapter 1).

8.1.2 Risk analysis

After identifying and validating the risk factors, the second step of risk management is analysing the identified risks. This thesis has used empirical data to measure and analyse the risks faced by container shipping companies from a logistics perspective in relation to three different types of risk consequence: financial loss, reputation loss and safety and security incident related loss.

Moreover, in order to answer research question 2 (i.e. which risk factors are relatively more significant to a shipping company's performance? see Chapter 1), the importance of each factor has been measured by multiplying the risk likelihood and the risk consequence, which are collected through the risk-factor questionnaire survey. Several findings are worth highlighting and discussed in relation to existing literature from a theoretical implications perspective.

Firstly, with regards to the risk likelihood, the top three risk factors are "oil price rise (PhTD_9)", "unstable weather (PhTD_4)", and "port congestion (unexpected waiting times before berthing or before starting loading/discharging) (PhTD_3)". It is worth mentioning that all these three risk factors belong to the element of "transportation delay" in the category of "risks associated with physical flow". These three risk factors are often beyond the control of container shipping companies, which means that it is difficult to reduce their impacts through likelihood reduction.

Secondly, this research further "refines" the findings of some previous studies by placing the risk factors addressed therein in a full "risk picture" which was developed systematically. For example, this research confirms that empty container transportation is a risk element; but the findings show that it is not that important compared to the other risk factors: it ranked 22nd for causing financial loss, 26th for reputation loss, and 22nd for safety and security incident related loss out of 35 risk factors. This may be explained by the fact that although empty container repositioning could incur a significant amount of costs, the shipping industry has long been aware of the trade imbalance and has already been prepared to accept such risk. Notteboom (2006) found that "port/terminal congestion" is the main source of schedule unreliability, followed by "port/terminal productivity below expectations" and "unexpected waiting times due to weather or on route mechanical problems". Schedule reliability is an important aspect in container shipping reputation performance, transportation delay would undoubtedly harm shipping companies' reputation. To put these factors onto the full "risk picture" developed in this research, it is obvious that "port congestion" and "unstable weather" are important, but "port/terminal productivity being below expectations" is not that important when it is compared to other risk factors as it ranked 14th in respect of reputation loss.

Thirdly, the results from thesis also support some previous findings; e.g., findings from Fu *et al*. (2010), Ewence (2011), Kaye (2011), and Nkwocha (2011). This thesis confirms that pirate or terrorist attacks are an important risk element in causing financial loss and safety and security incident related loss; as shown in the two risk maps, it also has very serious risk consequences among the 35 risk factors, especially in the safety and security incident related loss risk map. Kaye (2011) and Nkwocha (2011) also stated that the damage to employee safety and the security of ships is important (see Section 5.2.4). This risk factor is slighter than "shipper hiding cargo information (InfoI_5)" (rank 1st) and "damage caused by transporting dangerous goods (PhCD_3)" (rank 2nd), because the characteristics of these two risk factors are similar and their likelihood are both higher than piracy even if the risk consequence of piracy is the most serious one under safety and security incident related loss. Under the financial loss risk scale, the findings on piracy can support the findings of Fu *et al*. (2010) who stated that piracy has forced several major container shipping companies to alter their service routes (see Section 2.1.2). However, it costs a huge investment building service routes, and it is also expensive altering existing service routes. This problem has been suggested that shipping companies may charge more fees for protecting the cargo going through highly risky routes (IFW, 2011) or using armed guards on ships to protect cargos on the routes which have high possibility of piracy attack (Nkwocha and Badger, 2011) (see Section 5.3.3).

Fourthly, the research findings also support the findings from Notteboon and Vernimmen (2009) and Ronen (2011). It is confirmed that oil price rise is an important risk factor, especially for financial loss where it has the largest impact. In the financial loss risk map, it shows that the oil price rise has the highest likelihood and consequence; but the consequences are not that important in the reputation loss risk map and safety and security incident related loss risk map. It is suggested to reduce the impact from the rising oil price through hedging, adjusting the Bunker Adjustment Factor (BAF), signing a long-term contract with an oil supplier to stabilise oil price (see Section 5.3.3), or adopting the strategies that have been mentioned in Section 2.7.3, e.g., slow steaming, form alliance with other shipping companies or slot-exchange, slot charter, joint fleet, ship-charter with other container shipping companies.

Finally, the findings also confirm that port congestion is an important risk factor (Notteboom, 2006). It is found that it is the third important risk factor regarding both financial loss and reputation loss, and it appears in the high risk zone in the financial loss risk map. This research also shows that the damage to frozen cargo/ reefer containers has important risk consequence (Tseng *et al*. 2012) in the financial loss risk map and safety and security incident related loss risk map.

There are also some discussions of the finding from the practical implication perspective. Firstly, the risk associated with physical flow is the most important risk category among the three categories. It is recommended that the managers, if the available resources are rather limited, could perhaps give priority to risks associated with physical flow in designing risk control policies. This finding is indeed consistent with some of the previous studies in this field as mentioned in Chapter 2 and from the interviewees that have mentioned in previous Chapters.

Secondly, "shipper hiding cargo information (InfoI_5)" is the most serious risk factor among the 35 risk factors under the reputation loss risk scale and the safety and security incident related loss risk scale, and it is in second place under the financial loss risk scale. This reflects the shippers' opportunistic behaviour, which, as revealed in the interviews, has been widely recognised in the transportation industry. This also reflects the concern of International Maritime Organisation (IMO), e.g. IMO (2011, p.10), "container cargo weight misdeclaration remains 'habitual' and discovered cases form just the tip of an iceberg". IMO also proposed a regulation regarding container cargo weight, and suggested that if a shipper fails to comply with the verified weight certificate of gross weight of containers, regarding containers shall be refused for loading. The impact of InfoI_5 under the safety and security incident related loss consequence can also be supported by Penton Business Media's (2011) report: the potential threat of cargo fraud is more damaging than cargo theft. One interviewees also stated that:

> *"We charge expensive freight and insurance for transporting expensive cargo and/ or dangerous goods. Some shippers hide the cargo information in order to save the money. This action may produce serious consequence,*

such as explosion if the cargo is dangerous goods, or cargo damage if the cargo is frangible."

8.2 Findings from risk mitigation strategy evaluation

The other aim of this thesis is to provide a systematic view of the risk mitigation strategies in container shipping operations. This section discusses the finding from risks mitigation strategy evaluation, including the risk mitigation strategies identification and validation, ranking, and evaluation. The theoretical and practical implications are discussed together in this section as the majority of these findings impact on both theoretical and practical sectors.

8.2.1 Risk mitigation strategies identification and validation

This thesis firstly identified the risk mitigation strategies in container shipping operations through reviewing relevant literature (including the container shipping sector and from a general supply chains aspect), a total of 17 risk mitigation strategies were identified and categorised into three levels, i.e. inter-organisational strategies, intra-channel strategies, and inter-channel strategies. Each level includes several risk mitigation strategies.

Several new risk mitigation strategies were further identified through a set of face-to-face interviews and a set of email interviews. They are "improve safety measures, such as by implementing safety rules and regulations like the IMDG Code and ISM Code (IOS_5)", "improve security measures, such as by implementing security rules and regulations like the ISO 27001 and ISPS Code (IOS_6)", "choose partners very carefully (IntraCS_2)", and "cultivate loyalty of supply chain partners (IntraCS_5)". The first two strategies, IOS_5 and IOS_6, come from one simple strategy "improve the safety and security" from reviewing the relevant literature. The reason that separates “improve the safety and security” into two strategies is although “safety” and “security” are sometime similar, they still have different meaning. “Safety”, in this thesis, means the risk that harm to human life; whilst “security” may also harm to human life, yet it also includes information security, which harms to companies but not to human life. A manager said:

> *“we have already used ISO 27001 to increase information security. ISO 27001 is an information security management system (ISMS) standard process that records every single employee to keep business confidential. … From the safety perspective, we implement IMGD Code, an international regulations, which can help reduce potential risks in shipping operations when transporting dangerous goods. This types of risk [dangerous goods transportation] has more serious impact than the previous one [information security risk], because it may harm to human life safety. In our company, we pay more attention on implementing safety rules and regulations.”*

Through literature review, face-to-face interviews, and email interviews, this thesis have identified and validated a total of 20 risk mitigation strategies in container shipping operations, which are categorised into three levels. Therefore, the research objective 4 (i.e. Identify typical risk mitigation strategies for container shipping companies see Chapter 1) has been achieved.

8.2.2 Risk mitigation strategies ranking

Through the mitigation-strategy survey, the author is able to rank the risk mitigation strategies according to their overall effectiveness. The results show that on average three categories have very similar levels of overall effectiveness, and each category appears to include highly ranked mitigation strategies. It is recommended that managers should consider these three levels of strategies when making decisions on risk management as these three levels comprehensively cover all the different operational environments (i.e. internal, vertical, and horizontal).

At the intra-organisational strategies (ISO) level, the strategy, "implement slow steaming and increase the number of ships on existing routes (IOS_3)", is a popular practice recently, but it has the lowest scores within the IOS group in this survey. Note that slow steaming can reduce fuel consumption and absorb idle ships, which is an appropriate strategy for shipping lines when supply exceeds demand. However, it increases the transit time and may incur extra inventory costs to shippers (Traill, 2010). The low score of slow steaming indicates that not all of the respondents think that slow steaming is a better strategy to reduce risks in container shipping operations compared with other strategies within IOS (see Section 6.2.1). This is partially reflected by one email interview, in which a manager stated that: "*Deploying more ships in a service doesn't necessarily improve reliability or mitigates risk; there will always be circumstances that cannot be planned for (weather, geo-politics etc.)*" (see Section 6.2.2).

The inter-channel strategies (InterCS) level has the first and second important strategies among the 20 strategies. They are "slot-exchange, slot charter, joint fleet, ship-charter with other container shipping companies (InterCS_1)" and "form alliance with other shipping companies (InterCS_2)". This may be because of the global economic depression, which has driven down cargo volume significantly since the financial crisis in 2008, and consequently reshaped the shipping industry through inter-channel collaboration and consolidation. Several studies also supported the importance of InterCS_1 and InterCS_2, such as Cullinane and Khanna (1999); Ryoo and Thanopoulou (1999); Heaver *et al*.

(2000); Slack *et al*. (2002); Song and Panayides (2002); Shry *et al*. (2003); Notteboom (2004); Lu *et al*. (2010); Chow and Chang (2011) (see Section 2.2.2).

The Inter-channel strategies level also has the least important strategy to mitigate the risks among the 20 strategies, which is “acquire and merge with other container shipping companies (InterCS_3)”. InterCS_3 might be an important strategy in 1990s and the early 2000s, and it also brought several benefits to the container shipping companies such as rapid increase in market share, economies of scale, or gaining instant access to markets and distribution networks, obtaining access to new technologies (see Section 2.2.2). The last biggest acquisition and merger in container shipping occurred in 2005, in which Maersk Sealand acquired P&O Nedlloyd to become Maersk Line. However, it should be noted that there are many risks associated with acquisition and merger with other shipping companies, e.g. huge capital investment. In the AHP survey sample the author selected, the majority of the respondents were working in shipping agents, who did not have enough money to merge and/or acquire other companies. Therefore, it is understandable that InterCS_3 was regarded as the least important strategy among the 20 strategies to mitigate risks in container shipping operations.

8.2.3 Risk mitigation strategies evaluation

Seven most important risk mitigation strategies are then selected to compare their relative importance in terms of three different criteria: reducing financial loss, reducing reputation loss, and reducing safety and security damage. This is done through the Analytic Hierarchy Process (AHP) questionnaire survey and the AHP analysis.

The classic AHP analysis yields some interesting findings. Firstly, two criteria, "reducing safety and security damage" and "reducing financial loss", are significantly more important than the criterion "reducing reputation loss". The implication is that those top mitigation strategies probably have more significant and direct impact on the first two criteria. Compared with some general industries such as retailer or manufacturer operations in which reputation and brand are highly emphasised (Dawar and Parker, 1994), container shipping operations appear to focus more on financial loss reduction and safety and security incident related loss reduction (See Section 6.3.2). Secondly, the rank of the top seven strategies is A (Slot-exchange, slot charter, joint fleet, ship-charter with other container shipping), F (Make a long-term contract with shippers), B (Form alliance with other shipping companies), C (Use more advanced infrastructure (hardware and software)), D (Choose partners more carefully), E (Cooperate with your partners (e.g. terminal operational company, inland transportation)), and G (Design a flexible shipping schedule). The rank of the Strategy F is very different as it ranks second in the AHP survey while it ranks sixth in the mitigation-strategy survey. This may be due to fact that container shipping is a logistics service provider industry, which does not have its own production, and the profit totally relies on the transportation demand from shippers. Therefore, making a long-term contract with shippers can reduce the future demand uncertainty and ensure shipping companies have a certain volume of promised cargo to transport. Moreover, it should 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. Thirdly, the least important one is Strategy G, "design a flexible shipping schedule". In the AHP survey sample the author selected, the majority of the respondents were working in shipping agents, who did not have the right to adjust the shipping schedule. This may explain why this strategy became the least important one among the seven selected strategy.

The fuzzy AHP analysis generally confirms the findings from the classic AHP method and also produces some new findings. Firstly, "reducing financial loss" overtakes "reducing safety and security damage" and becomes the most important criterion among three criteria. However, they are quite close. On the other hand, "reducing reputation loss" is still the least important criterion. Secondly, the ranking of the seven strategies according to their overall priorities remains the same as that under the classic AHP method. However, the overall priorities are slightly different from that of the classic AHP. The fuzzy AHP has a relatively wider range of the overall priorities than that of the classic AHP. This might be because the fuzzy AHP uses the interval value measurement instead of the exact value, which provides more flexible decision space to handle the uncertainty in subjective opinions

After evaluating the risk mitigation strategies through the surveys, the classic AHP analysis, and the fuzzy AHP analysis, the final research objective: "evaluate the importance of risk mitigating strategies and their relationships" has been achieved.

8.3 Generalisation of the research methods

The majority of the discussions in the research methods address the theoretical implications. This thesis is perhaps the first research that identifies and analyses the risks faced by a container shipping company in their operations from the three main logistics flows (i.e. information flow, physical flow, and payment flow). It is reasonable to believe that approaching from the perspective of these three flows would cover all the elements in shipping companies' operations and thus the possible risks associated with these operation elements would be inclusively identified given that a sound research method will be used. With this whole risk picture (the three logistics flows), it is recommended that the following research can consider the risk identification and analysis in any industry from the logistics perspective.

In this thesis, some of the risk factors and risk mitigation strategies are identified from general supply chains rather than from the studies on container shipping operations. In order to validate whether these risk factors and risk mitigation strategies are appropriate in a container shipping context, this thesis uses expert interviews (including a set of face-to-face interviews and a set of email interviews) after identifying these risk factors and risk mitigation strategies from general supply chains. This may not be an innovation, but there are still numerous studies that did not validate whether the factors or elements from different industries are appropriate in their focus area. It is recommended that similar research in other industries should add one more step to confirm the appropriateness of the identified factors or elements.

The conceptual model (see Section 3.2.2) developed in this thesis combines the four common steps of risk management (i.e. risk identification, risk analysis, risk mitigation strategies identification, and risk mitigation strategies evaluation) and the inclusive risk picture in logistics operations (i.e. risks associated with information flow, risks associated with physical flow, and risks associated with payment flow). In addition, the flows of the three main logistics flows in container shipping supply chains are included in this model. Therefore, this model provides an abstract concept on tackling risks occurred in container shipping operations for container shipping managers.

Compared to the risk matrix method that has been used in the majority of existing studies, the risk map method provides more detailed relationships between the risk factors. In order to calculate the location of each risk factor in the risk map, this thesis developed a new risk analysis method (i.e. Average Risk Scale (ARS)), which firstly multiplies the risk likelihood and risk consequence of each respondent and then calculates the mean value of the risk scale over all respondents (see Section 3.4.1.1). From the mean value of the risk scale, a shortest distance-based method is used to derive the corresponding risk likelihood and risk consequence. it can be argued that the derived risk likelihood and risk consequence are more accurate than the ones simply averaging over the respondents (which is termed as RSALC in Section 3.4.1.1 and was used in Yang 2011). It is recommended that the ARS method is more appropriate than the RSALC method when calculating the risk scale, risk likelihood, and risk consequence over a population in the risk map.

Although this thesis uses Taiwan's container shipping as a case study, the findings of the risk factors and risk mitigation strategies could be extended to almost every international container shipping company. Two reasons can be used to support this. The first reason is that 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 (see Section 4.2). The second reason is that although the respondents of the three surveys this thesis focused are working in Taiwan, these focus companies are also regarded as international companies as they (the container shipping companies) have branches in other countries or they (the container shipping agents) work for international container shipping companies (see Section 3.1).

Chapter 9 Summary and Conclusion

This chapter concludes the highlights of this thesis. Section 9.1 summarises the research background. Section 9.2 summarises the key points from reviewing literature related to container shipping companies. Section 9.3 summarises the research methodology. Section 9.4 summaries the main findings of this thesis. Section 9.5 discusses the significance of the research. 9.6 discusses the research limitations, and Section 9.7 suggests the further research.

9.1 Summary of research background

Shipping industry plays an important role in international trade, and it is reported that about 90% of international trade is transported by ships (Shipping Facts, no date). Container shipping becomes more importation due to its efficient loading and unloading operations and the ability to achieve intermodalism with other transportation modes. At present, container ships carry around 52% of world seaborne trade in terms of value of the cargo (World Shipping Council, 2011a, 2011b).

The complex operations within and between a container shipping company and its partners, and the long distance of physical process may give risk to various types of risks, such as technical risk, market risk, business risk, and operational risk (Ewert, 2008). This thesis focuses on the operational risk in container shipping.

9.2 Summary of literature review

Several risk factors in container shipping operations have been discussed in Chapter 2. For example, schedule unreliability (Notteboom, 2006; Drewry, 2009) would lead to transportation delay and affect shipping companies' reputation. This includes four detailed risk factors such as port strike, port congestion (unexpected waiting times before berthing or before starting loading/discharging), port/terminal productivity below expectations (loading/discharging), and unstable weather. Inappropriate empty container transportation (Song *et al*., 2005; Notteboom, 2006; Song and Dong, 2011) could incur significant costs to container shipping companies. Oil price rising (Notteboom and Vernimmen, 2009) would force container shipping companies to face the increasing operational costs and operational risks. Asset stolen or damage (Talley, 1996; Vernimmen *et al*., 2007; Drewry, 2009; Tseng *et al*., 2012) would directly harm container shipping companies. This includes cargo stolen from unsealed containers, damage to ship or quay due to improper berth operations, and damage to frozen cargo. Attack from pirates or terrorists (Noda, 2004; Drewry, 2009; Fu *et al*., 2010) have been a threat to container shipping companies for many years, this would not only harm container shipping companies, but also safety and security of human being. Therefore, a total of 10 risk factors were identified from the literature related to container shipping sector.

A number of risk mitigation strategies have also been discussed in Chapter 2. In order to reduce the impact from unreliable schedule, several risk mitigation strategies are suggested from previous studies, such as add buffer time when designing routes (Notteboom, 2006; Notteboom and Vernimmen, 2009) and omit pot-of-call when transportation delay happens (Notteboom, 2006; Kerr, 2011b). Implement slow steaming to reduce the oil price rise (Notteboom, 2006; Notteboom and Vernimmen, 2009; Cariou, 2011; Ronen, 2011; Qi and Song, 2012) has become an important strategy against the rising oil price. Use more advanced information technology (Marle, 2009; Kerr, 2011a) such as e-commercial could save huge amont of money in bill of lading overcharges through new transport management software. Train employee regularly (Young, 2010; Ganesan, 2010) could reduce a lot of risks in operational error or the probabilities of information delay and error. Enter into long-term contracts with shipper (Notteboom, 2004) can reduce the risk of vessel underutilisation and secure the cargo volume. Make collaboration with partners (Baird and Lindsay, 1996, Graham, 1998; Carious, 2001; Heaver, 2002; Notteboom, 2004, 2006) could let container shipping companies provide comprehensive and reliable services. Several practical strategies crossing shipping companies include strategic alliances (Ryoo and Thanopoulou, 1999; Midoro and Pitto, 2000; Heaver *et al*., 2000; Slack *et al*., 2002; Song and Panayides, 2002; Notteboom, 2004; Lu *et al*., 2010), exchanging slots (Song and Panayides, 2002; Notteboom, 2004; Lu *et al*., 2010), merging with (Heaver *et al*., 2000; Song and Panayides, 2002 Notteboom, 2004) or acquiring (Song and Panayides, 2002; Notteboom, 2004) other companies. Therefore, a total of 10 risk mitigation strategies were identified from the literature related to container shipping sector.

However, the above literature only focus on one or two or several risk factors/ risk mitigation strategies and this is fragmental and insufficient. In order to cover more aspects of risk factors and risk mitigation strategies, a further identification in risk factors and risk mitigation strategies from general supply chain is discussed in Chapter 5 and Chapter 7.

9.3 Summary of research methodology

This thesis aims to conduct a comprehensive empirical study on risk management in container shipping industry through the development of a tailored framework that can be used for identifying risks from the logistics perspective, measuring the risk likelihood and risk consequence, analysing risk scale, and evaluating the importance of risk mitigation strategies and their relationships in container shipping operations.

Four main steps of risk management have been adopted and conducted to achieve the aim. They are (1) risk identification and validation through reviewing relevant literature (see Chapter 5), and conducting a set of face-to-face interviews and a set of email interviews; (2) risk analysis through risk-factor questionnaire survey (with five-point Likert scale to measure how important are these risk factors in risk likelihood and three risk consequences, i.e. financial loss, reputation loss, and safety and security incident related loss), and a series of analysis methods such as risk scale (Average Risk Scale (ARS)), risk matrix, risk mapping, and P-I graph; (3) risk mitigation strategies risk identification and validation through literature review (see Chapter 7), a set of face-to-face interviews and a set of email interviews; and (4) risk mitigation strategies evaluation through a mitigation-strategy survey (with five-point Likert scale to measure how important are these risk mitigation strategies) and an Analytic Hierarchy Process (AHP) survey (with nine-point pairwise comparison scale to measure the relationship between different selected risk mitigation strategies), and a series of analysis methods such as risk mitigation strategies ranking, classic AHP analysis and fuzzy AHP analysis.

This thesis uses reviewing relevant literature to identify risk factors and risk mitigation strategies in container shipping operations based on the point of several studies, e.g. Knemeyer *et al*. (2009), Rao and Glodsby (2009), Yang (2010, 2011), and Jackson *et al*. (2012). Risk scale method is commonly used in risk analysis as its easy calculation, and it can also be applied into a five-point Likert scale. In terms of the method for risk mitigation strategies evaluation, although many methods have been used in decision making area, most of them have some limitations that are difficult to overcome in this thesis. However, AHP does not have such difficulties to be overcome. Moreover, there are several advantages of using AHP method, such as it provides a meaningful integration of systems, it is easy to calculate, and it is reliable and flexible (see Section 4.3.2). Therefore, it is believed that above methods used in this thesis are reasonable.

9.4 Summaries of main findings

The main research questions in this thesis are: what are the risk factors and risk mitigation strategies in container shipping operations? which risk factors and risk mitigation strategies are relatively more significant to a shipping company's performance? This thesis firstly elaborates the three main logistics flows (i.e. information, physical, payment) in container shipping operations. These three logistics flows are the main structure of this thesis as they are used to develop the conceptual model and conduct the first step of risk management, risk identification, in container shipping operations.

Secondly, the author identifies a comprehensive list of risk factors in container shipping operations. The risks are classified, according to three logistics flows, into three categories, including the risks associated with information flow, the risks associated with physical flow, and the risks associated with payment flow. Each category consists of several elements, i.e. the information flow category consists of information delay, information inaccuracy, and IT problems; the physical flow category consists of transportation delay and cargo/asset damage; and the payment flow category consists of currency exchange, payment delay, and non-payment. Each risk element covers a number of risk factors. In total, thirty five risk factors are identified in this thesis.

Thirdly, we identify the typical risk mitigation strategies for container shipping operations. The mitigation strategies are classified into three major categories: inter-organisational strategies, intra-channel strategies, and inter-channel strategies. These different categories represent different levels of relationship between the shipping company and its supply chain partners in terms of risk management. A total 20 risk mitigation strategies are identified in this thesis.

Fourthly, several findings from risk analysis are worth mentioning. (1) In order to determine the appropriate position of each risk factor in the risk maps, we develop a method, Average Risk Scale (ARS), to calculate the likelihood and consequence of each risk factor averaging over all respondents, which is more accurate than the simple risk scale averaging method. (2) In terms of the risk likelihood, the top three risk factors are “oil price rise” (PhTD_9), “unstable weather” (PhTD_4) and “port congestion (unexpected waiting times before berthing or before starting loading/ discharging)” (PhTD_2). All of them belong to the category of risks associated with physical flow, and also belong to the risk element of “transportation delay”. (3) In terms of the risk scale from the financial loss perspective, seven factors’ risk scales are larger than 10 (which represents high risk in this thesis), including PhTD_9, “shippers hiding cargo information (non-declare)” (InfoI_5), PhTD_2, PhTD_4, “damage to frozen cargo/ reefer containers due to electricity failure” (PhCD_5), “attack from pirates or terrorists” (PhCD_6), and “change of currency exchange rate during payment process” (PayCE_1). Among these seven factors, only two factors (InfoI_5 and PayCE_1) do not belong to the category of risks associated with physical flow. (4) In terms of the risk scale from the reputation loss perspective, InfoI_5 is the only risk factor whose risk scale is greater than 10. (5) In terms of the risk scale from the safety and security incident related loss perspective, five factors’ risk scales are larger than 10, including InforI_5, “damage caused by transporting dangerous goods” (PhCD_3), PhCD_6, PhTD_4, and PhCD_5. (6) It is worth mentioning that InfoI_5 is the most serious risk factor among all risk factors according to three types of risk scale (e.g. financial loss: rank 2, reputation loss: rank 1, safety and security incident related loss: rank 1).

Fifthly, we evaluate the importance of risk mitigating strategies and their relationships. It was found that the mean values of three categories (i.e. intra-organisation strategies, intra-channel strategies, and inter-channel strategies) are at similar levels according to their overall effectiveness, and each category appears to include highly ranked mitigation strategies.

In order to conduct the further AHP survey, top seven strategies (coded as A, B, C, D, E, F, G) are selected, including “use more advanced infrastructures (hardware and software)" (IOS_4: 3.92), "when the ship has already been delayed, omit port-of-calls to keep the original schedule" (IOS_2: 3.82), "choose partners more carefully" (IntraCS_2: 3.87), "collaboration with partners (e.g., terminal operational company, inland transportation) through making a joint long-term plan (collaboration level)" (IntraCS_10: 3.85), "enter a long-term contract with shippers" (IntraCS_7: 3.85), "slot exchange, slot charter, joint fleet, ship charter with other container shipping companies" (InterCS_1: 4.18) and "form alliance with other shipping companies" (InterCS_2: 4.02). The purpose of conducting the AHP survey is to further evaluate the seven selected strategies' relative importance against three different criteria (i.e. reducing financial loss, reducing reputation loss, and reducing safety and security incident related loss). Several findings from the classic AHP analysis are summarised below: (i) The weights of criterion "reduce financial loss" (0.412) and "reduce safety and security incident related loss" (0.429) are much greater than that of "reduce reputation loss" (0.159); (ii) Under the criterion "reduce financial loss", Strategies F "make a long-term contract with shippers" is the top one for mitigating financial loss in the container shipping operations. Under the criterion "reduce reputation loss", Strategy B "form alliance with other shipping companies" is the most important strategy. Under the criterion "reduce safety and security incident related loss", Strategy A "slot exchange, slot charter, joint fleet, ship charter with other container shipping" is the most important risk mitigation strategy; (iii) The seven strategies are ranked according to their overall priorities as follows: A, F, B, C, D, E, and G, which is generally in agreement with the results of the mitigation-strategy survey; however, the strategy F became the second important strategy in the results of the AHP survey.

The author further uses the fuzzy AHP analysis to refine the results of classic AHP analysis. The findings from fuzzy AHP analysis can be summarised as: (i) The rank of the three criteria has changed to: “reduce financial loss” (0.428) is the most important criterion to container shipping risk mitigation management; “reduce safety and security incident related loss” (0.415) becomes the second important criterion; whilst “reduce reputation loss” (0.157) is still the slight one on container shipping operations. The first two criteria still dominate the third criterion; (ii) The seven strategies are ranked according to their overall priorities as follows: A, F, B, C, D, E, and G. This result is the same as that of the classic AHP. However, the overall priorities are slightly different from that of the classic AHP. The fuzzy AHP has a relatively wider range of the overall priorities than that of the classic AHP. This implies that the fuzzy AHP can differentiate the relative importance of the strategies more clearly; (iii) Several defuzzification methods were used in the fuzzy AHP analysis. The results showed that the rankings of the seven strategies remain the same regardless of the defuzzification methods.

9.5 Significance of the research

The significance of this thesis can be concluded in the following several points: Firstly, many studies have done the risk management in container shipping area; however, the risk factors or the strategies they focused are one or two or several parts, and this is fragmental. The aim of this thesis is to cover as many risk factors and risk mitigation strategies as possible, from logistics perspective (i.e. information flow, physical flow, and payment flow), in order to provide an inclusive risk picture in container shipping operations. Based on the literature review, this has never been done before.

Secondly, compared with several studies using secondary data for simulation or other methods, this thesis uses empirical data to conduct risk analysis and risk mitigations strategies evaluation. This provides the latest information that can reflect current situation in Taiwan's container shipping industry rather than using historical data to conduct risk management.

Thirdly, in terms of risk analysis, this thesis ranked a group of risk factors rather than identified the most important risk factor. The reason of doing this is because the situations of the respondents' companies are different. One risk factor might be the most important one in some companies but not in other companies. Through ranking the risk factors, this thesis provides a group of important risk factors that can be general to the whole container shipping companies in Taiwan, or even be generalised to the container shipping companies in the whole world.

Fourthly, in terms of risk management, compared with previous studies usually only analyse the importance of strategies, this thesis analyses the results of AHP from three different angles: the financial, reputation, and safety and security incident related loss. This can provide more comprehensive results for the managers who consider different consequence.

9.6 Research limitation

Although the research has achieved its aims and objectives, there are several limitations in this study. Firstly, we could not conduct more face-to-face interviews with experts who work as shipping agents because of the time limit and the difficulty to get them involved. It is believed that there would be some degree of difference between the experts who work in shipping companies (who own container ships, e.g. Evergreen Line, Yang Ming Marine Transport Corp., and Wan Hai Lines) and the experts in shipping agents (who do not own containerships but serve for container shipping, e.g. Maersk Taiwan, CMA CGM (Taiwan) Ltd, and Hapag-Lloyd (Taiwan) Ltd). However, because of the limited connection with the people who work in shipping agents, the author can only conduct the interviews with the people who work in container shipping companies.

Secondly, we have obtained 62 valid questionnaire replies in the risk-factor survey and mitigation-strategy survey. It is, of course, true that the more valid questionnaire replies the author gets the more accurate results this thesis can obtain. More valid questionnaire replies could have been achieved through sending the second round of the same questionnaire survey. However, because of the cost consideration and the time limit, the author did not conduct the second round questionnaire survey.

Thirdly, this thesis uses Taiwan as a case study. It is believed that the results would be more accurate if the author had interviewed and done the questionnaire survey in international container shipping companies outside of Taiwan. However, our results could be generalised to many international container shipping companies due to the following two reasons: (1) 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. (2) Although the respondents of the three surveys we focused are working in Taiwan, their companies are also regarded as international companies as they (container shipping companies) have branches in other countries or they (container shipping agents) work for international container shipping companies.

9.7 Further research

Many previous studies have brought some valuable insight into the issue of risk management through interviews and/or questionnaire survey. However, what have not been well addressed is that the interviewees or the respondents involved are normally treated as an homogenous group; the factors such as their work experience, age, and position that may have some impact on their perception of risks have not been considered. In the future, we will address this issue and it is expected that such study will shed some light on the issue of risk perception of employees in shipping companies.

Supply chain risk management has been a popular topic recently. In today's competitive business environment, a company cannot make a successful business by itself, the supply chain partners have become more and more important particularly for the international business. Supply chain risk management has been defined as "the management of external risks and supply chain risks through a coordinated approach among supply chain members to reduce supply chain vulnerability as a whole" (Christopher *et al.*, 2002). In the container shipping supply chain, shipping companies are closely linked to other channel members such as shippers, port authorities, freight forwarders, and inland transport companies. Risk management in container shipping operations may impact on the performance of other supply chain members. However, there has been rather limited research on supply chain risk management in container shipping. Further research is required in this direction.

As mentioned in Chapter 1, many types of risks exist in container shipping business such as technical risk, market risk, business risk and operations risk. This study only focuses on risk management in container shipping operations. It would be interesting to consider multiple types of risks in a single framework so that a more complete assessment could be made.

Appendix 1 Face-to-Face Interview Questions

專家訪談問卷 Face-to-face Interview Questions

<u>**第一部份: 定義海運中的資訊流，物流，及現金流**</u>

<u>Part 1: Identification of the three logistics flows in container shipping</u>

1. 下圖為我參考教科書及一些網路資訊，整理過後的資訊流程圖，如有錯誤，請依您的看法進行修改 (虛線是指不一定會有的行程)
   Figure 1 is the information flow that I organised from some text books and the internet. Could you please modify it if there is anything wrong within this flow chart? (The dotted lines represent that the flows are not necessary to happen)

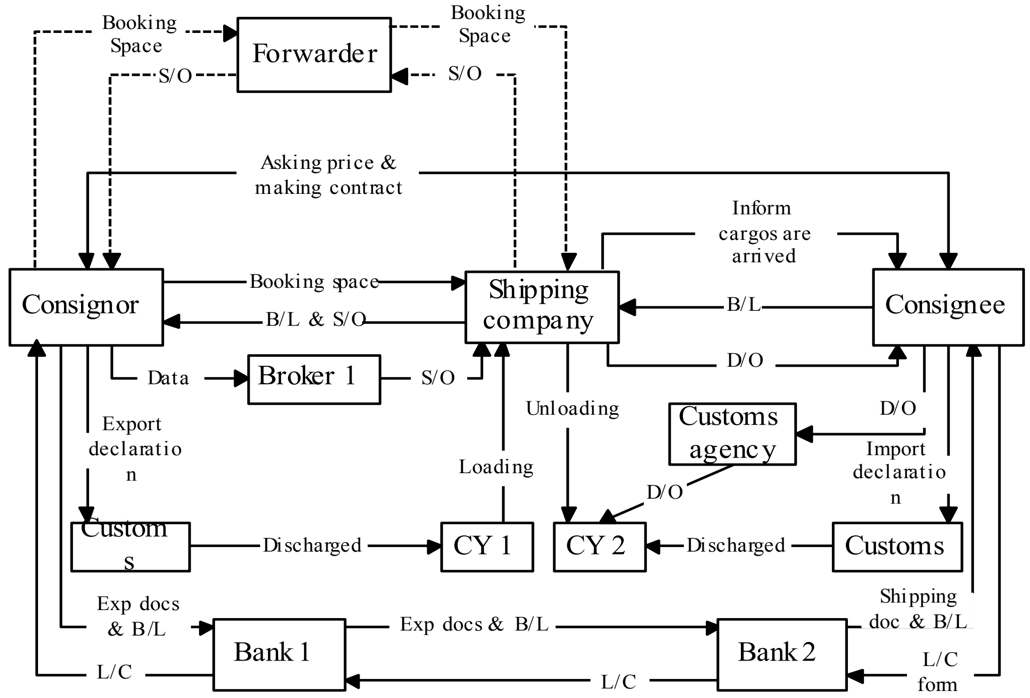


Figure 1

S/O: Shipping order

B/L: Bill of loading

L/C: Letter of credit

D/O: Delivery Order

CY: Container yard

2. 下圖為我參考教科書及一些網路資訊，整理過後的實體運輸流程圖，如有錯誤，請依您的看法進行修改 (虛線是指不一定會有的行程)
Figure 2 is the transportation/physical flow that I organised from some text books and the internet. Could you please modify it if there is anything wrong within this flow chart? (The dotted lines represent that the flows are not necessary to happen)

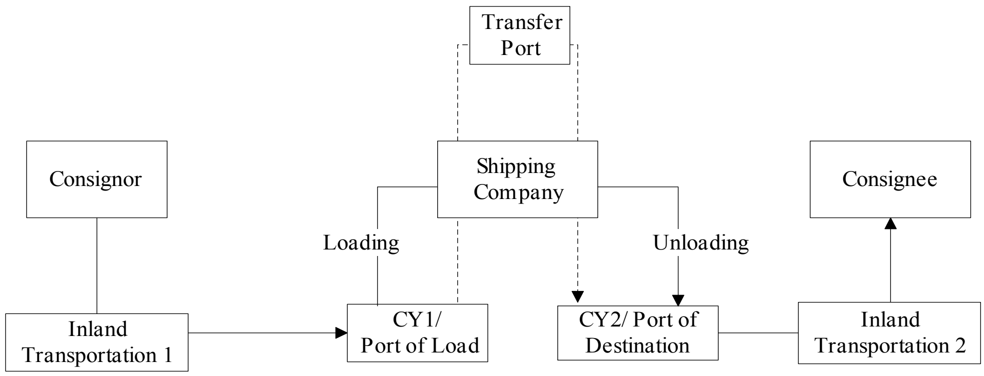


Figure 2

3. 下圖為我參考教科書及一些網路資訊，整理過後的現金流流程圖，如有錯誤，請依您的看法進行修改
Figure 3 is the payment flow that I organised from some text books and the internet. Could you please modify it if there is anything wrong within this flow chart?

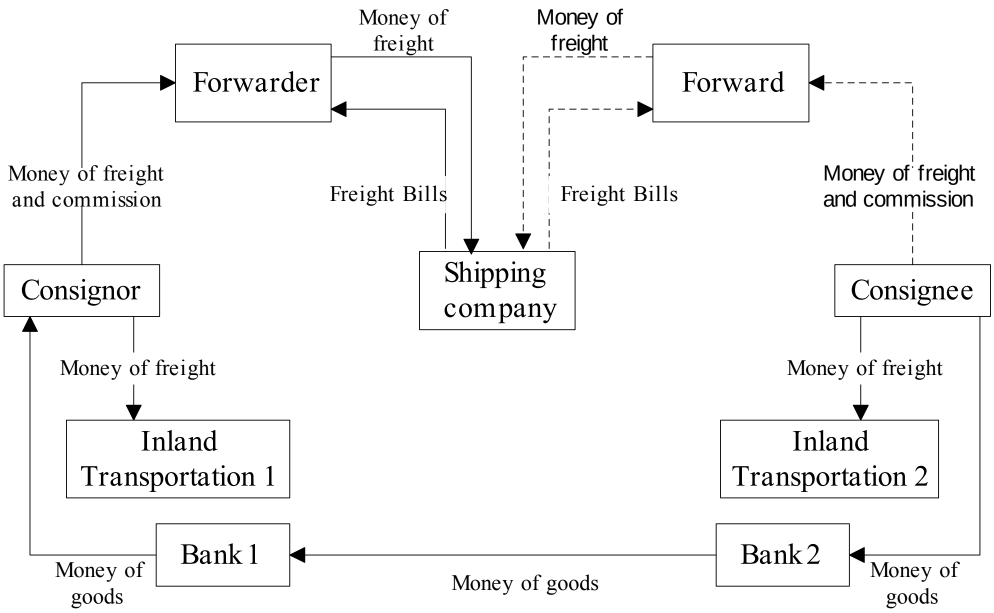


Figure 3

第二部分: 定義風險因子

Part 2: Identification of risk factors

1. 請問貴公司認為在資訊流方面，與供應鏈伙伴之間可能存在什麼樣的風險?
   In the information flow perspective, what are the possible risks between your company and your partners on the supply chain?

2. 請問貴公司認為在實體物流方面，與供應鏈伙伴之間可能存在什麼樣的風險?
   In the physical flow perspective, what are the possible risks between your company and your partners on the supply chain?

3. 請問貴公司認為在現金流方面，與供應鏈伙伴之間可能存在什麼樣的風險?
   In the payment flow perspective, what are the possible risks between your company and your partners on the supply chain?

4. 下表為過去文獻中提及與這三個流動相關的風險，您認為在海運業中也同時存在這些風險嗎? 此外，您還認為有哪些風險是下表中沒有提到的?
   The following table is the risks associated with the three flows that I summarised from existing studies. Do you think they exist in container shipping companies? Do you think there are any other risks that are not mentioned in this list?

Risks associated with information flow
Using different communication channels in the supply chain and consequently increasing the time of information transmission. (e.g. telephone, Email, EDI)
Supply chain partners not transmitting essential information on time
Processing documents being detained by government departments (e.g. customs)
Shipping company not transmitting essential information on time
Lack of information security during the information flow
Information asymmetry/incompleteness
Lack of information standardisation and compatibility
IT infrastructure breakdown or crash
Unsuitable human operation on IT infrastructure
Unsuitable human operation on application software
Risks associated with physical flow
Port strike
Port congestion (unexpected waiting times before berthing or before starting loading/discharging)
Port/terminal productivity being below expectations (loading/discharging)
Unstable weather
Inappropriate empty container transportation
Lack of flexibility of fleet size and designed schedules

Oil price rise
Damage to containers or cargo due to terminal operators’ improper loading/unloading operations
Cargo being stolen from unsealed containers
Damage caused by transporting dangerous goods
Damage to ship or quay due to improper berth operations
Attack from pirates or terrorists
Risks associated with payment flow
Change of currency exchange rate during payment process
Payment delay from partners or shippers
Unrealised contract with partners
Shippers going into bankruptcy
Shippers breaking the contract or reducing the container volume
Having partners with bad credit

第三部分: 定義風險管理策略

Part 3: Identification of risk mitigation strategies

1. 下表為過去文獻中提及的風險管理策略，您認為這些策略運用在海運業中合適嗎? 此外，您還認為有哪些策略是下表中沒有提到的?
   The following table is the risk mitigation strategies that I summarised from existing studies related to general supply chains, do you think they are appropriated in container shipping companies? Do you think there are any other strategies that are not mentioned in this list?

Intra-organisational level
Execute regular employee training (e.g. every year or half of year)
Use more advanced infrastructure (hardware and software)
Improve the security
Slow steaming and increase ships in the existed routes
Omit port-of-calls to keep original schedule when the ship has already been delayed
Include buffer times when designing the timetable/schedule
Intra-channel level
Enter a long-term contract with shippers
Information sharing with your partners without co-management (cooperation level)
Exchange ideas with partners to solve conflict or improve service quality (coordination level)
Collaboration with your partners, e.g. terminal operational company, inland transportation, involving joint long-term planning (collaboration level)
Trust your partners
Reward / assist partners who comply with shipping lines' initiatives
Shorten/ withdraw the contract with partners who have bad performance
Avoid too many partners
Inter-channel level
Form alliance with other shipping companies
Slot-exchange, slot charter, joint fleet, ship-charter with other container shipping companies
Acquire and merge with other shipping companies

Appendix 2 Face-to-Face Interview Transcriptions

Interviewee A:

[This interviewee did not want to be recorded by the recorder, and he could only spend no more than 30 minutes for the interview. As his job title is operation management, his answer mainly focused on risk associated with physical flow and its risk mitigation strategies. The following is the note of the result from his saying.]

Q: In the physical flow perspective, what are the possible risks between your company and your partners on the supply chain? Also, the following table is the risk mitigation strategies that I summarised from existing studies related to general supply chains. Do you think they exist in container shipping companies? Do you think there are any other strategies that are not mentioned in this list?

A: The risks associated with dangerous goods transportation could damage not only cargo, but also ships, which is more serious than cargo damage or transportation delay. Sometimes we lose the whole ship, cargo, and reputation because of dangerous goods explosion. However, dangerous goods transportation is our company’s niche market. The freight of dangerous goods is more expensive than normal cargo. The risks can be reduced through the support of an accurate information system, and our company can also earn a higher profit and gain more custom. Therefore, it is important to carefully check the details of the cargo. This can not only reduce the threat from dangerous goods, but also increase our reputation from customers and the customs authorities.

One more strategy that can reduce the impact of risk to ship operations, this is using advanced equipment such as dead-reckoning equipment or gyro sextant. Using advanced equipment on ship will definitely improve the safety when ships are sailing, they can also reduce the mistakes caused by human error.

Interviewee B:

[This interviewee is a vice-president of the shipping company, his answer therefore cover the three risk categories and their mitigation strategies. The following is the results from the interview.]

Q: Figure 1, 2 and 3 are the information flow, physical flow, and payment flow that I organised from some text books and the internet. Could you please modify it if there is anything wrong within these flow charts?

A: The flow chats are fine. But I will suggest you to add two government parts in information flow chart, in which the consignor will send the export documents to the government (in the export side country). After checking the documents, the government will return the export documents to the consignor. The same as the other side, the consignee should send the import documents to the government (in the import side country), and the government will return the import documents after checking.

Q: In the information flow perspective, what are the possible risks between your company and your partners on the supply chain?

A: In the risk associated with information flow, there is a risk factor that have to be mentioned, namely, the shippers' declaration. We have paid some penalties and our ship has once been detained because the documents for customs clearance were inconsistent with the shipper and the process was delayed. The reason is that our customer [the shipper] did not inform us that the contents of the cargos had been changed, or even the cargo information was hidden by the shipper.

Another risk factor associated with information flow is shippers hiding cargo information. We charge expensive freight and insurance for transporting expensive cargo and/ or dangerous goods. Some shippers hide the cargo information in order to save money. This action may produce serious consequence, such as explosion if the cargo is dangerous goods, or cargo damage if the cargo is frangible.

Q: In the physical flow perspective, what are the possible risks between your company and your partners on the supply chain?

A: In the risk associated with physical flow, I firstly will mention the freezing cargo. The majority of the cargos in freezer container transportation are fruit, high technology products, and chemistry material. These types of cargos need to be kept in certain and stable temperature. In order to maintain the temperature, we charge high fees for supplying extra electricity. [But] Sometimes the electricity failure in ports or on ships damages the high value cargos, and makes fruit decayed or high technology products overheated, then we have to pay huge penalty. Sometimes the shipper will lie to us, for example a shipper does not want the cargo anymore, and he just splashed some water on the cargos and did not want to take the cargos. Sometimes the large companies will threaten us that if we don’t pay the penalty, then they will never do our business. Sometimes the shippers ask some congressmen to lobby us. Therefore, there are many cased about cargo claims. The risk of dangerous goods transportation could damage not only cargos, but also ships, which is more serious than cargo damage or transportation delay. Sometimes we lose the whole ship, cargos, and reparations because of the dangerous goods explosion.

There is one very special type of risk associated with physical flow. One of our containers was stolen in a very special case. Several criminal organisations try to bribe several truck drivers. The bribed truck drivers will drive trucks to some occult places and change the containers if the containers have no seal security during re-export transportation. Even [the containers] have container seal security, they (the criminals) will cut off the top of containers and steal the goods without breaking the container seal. Sometimes, they (the criminals) have other trucks and containers which are exactly the same as the original one. They use the fake containers to replace the valued ones. This type of risk will not only affect our financial loss, but also reduce our reputation.

Q: In the payment flow perspective, what are the possible risks between your company and your partners on the supply chain?

A: In the risk associated with payment flow, in some cases, shippers may abandon cargos if the value of the cargos become low during the transportation, we therefore cannot receive the transportation fee if the contract is under FOB (Free On Board).

Q: The following table is the risk mitigation strategies that I summarised from existing studies related to general supply chains. Do you think they are appropriated in container shipping companies? Do you think there are any other strategies that are not mentioned in this list?

A: In the risk mitigation strategy part, in order to reduce the impact of delay on the ensuring part of the journey, three strategies are commonly used in our company for pursuing original schedules: (1) When the delay is not too serious, the ship will normally cancel the buffering time to pursue the original schedule if it is possible; (2) If the delay is more serious, and if the buffering time is not enough for the ship to pursue the original schedule, the ship will normally increase her navigating speed. However, this strategy will also increase the fuel consumption; and (3) When the delay is very serious, in order to pursue the original schedule, some ships may skip over one or more ports on her route. The cargos that are therefore discharged to other ports will be transported to their destination ports. This strategy, however, will significantly increase the operational costs and may have considerable impact on the reliability of the company.

In order to deal with payment delay, we have a specific department – operational payment department – to deal with the payment of income and outcome in our company. Their job is trying to get the payment from shippers as soon as possible, and make the payment to our partners as slow as possible. Some mighty shippers will ask to pay their payment after 3 or 4 months, but we will not allow the payment delay to small shippers. Sometimes we will just transfer the payment risks to forwarders.

Interviewee C:

[This interviewee could only have 30 minutes for interview. As this interviewee is a finance manager, his answer only focus on the risk associated with payment flow and the mitigation strategies.]

Q: In the payment flow perspective, what are the possible risks between your company and your partners on the supply chain? Also, the following table is the risk mitigation strategies that I summarised from existing studies related to general supply chains. Do you think they are appropriated in container shipping companies? Do you think there are any other strategies that are not mentioned in this list?

A: The transportation fees we get are usually calculated by USD. However, some shippers will still pay the bills by local currency, such as Euro or JPY. We need to afford the risk from the unstable currency exchange rate during payment process. The change of currency exchange rate during payment process sometimes makes us lose the profit. Although we can transfer some impacts of currency exchange risk [to shippers] by doing Currency Adjustment Factor (CAF), it could only be used in a huge fluctuation of currency exchange rate.

"Shippers going into bankruptcy" is also a risk associated with payment flow. Sometimes we need to handle or accept the risks from the shippers who bankrupt before making the payment. We need to do some survey about the shippers or supply chain partners. Avoid doing the business with the shippers who have bad credit or unstable finance [is very important to us].

But we do not need to handle all the shippers' bad behaviours as we only care about large shippers. Forwarder is the one who do the business with small shippers, who may highly possibility that have bad credit. So, sometimes we [shipping companies] will just transfer this risk to forwarders.

Interviewee D:

[This interviewee is a senior information manager, so his answer mainly focused on the risk associated with information flow]

Q: Figure 1 is the information flow (after modifying through the interviewee B) that I organised from some text books and the internet. Could you please modify it if there is anything wrong within this flow chart? (The dotted lines represent that the flows are not necessary to happen)

A: There are some errors in the information flow chat. For example, the S/O is in the wrong direction, it should be sent out from the consignor directly to the shipping company, or through the forwarder to the shipping company. After that, the shipping company will send out a master B/L to the forwarder, and the forwarder will sent a house B/L to the consignor.

Q: In the information flow perspective, what are the possible risks between your company and your partners on the supply chain? Also, the following table is the risk mitigation strategies that I summarised from existing studies related to general supply chains. Do you think they are appropriated in container shipping companies? Do you think there are any other strategies that are not mentioned in this list?

A: I have watched the risk factor table you gave. There are some information asymmetries existing between our company and the forwarder/ broker. Forwarders usually hold many small shippers and they will not give us these small shippers' information. However, unlike retailers or manufacturer, we do not really care about information asymmetry. According to 80/20 rule, compared to the cargo flow that starts from small shippers through brokers or forwarders to our company, the large shippers who can offer large scale cargo directly to us without brokers or forwarders are the ones that we really concern.

However, on the other side, the large shippers often request for extra services, such as organising holistic logistic information which includes inland transportation shifts and customs clearance date.… Large shippers may even request for forecasting inland transportation timetable for several months in the future.

Q: The following table is the risk mitigation strategies that I summarised from existing studies related to general supply chains. Do you think they are appropriated in container shipping companies? Do you think there are any other strategies that are not mentioned in this list?

A: Yes, we hold regular employee training sessions to train the relevant staff to avoid or at least reduce the effect of risks associated with information flow from failures caused by human errors when using IT systems.

Moreover, we have already used ISO 27001 to increase information security. ISO 27001 is a regulation that is used to keep business confidential.

We also implement IMGD Code, an international regulations, which can reduce potential risks in shipping operations when transporting dangerous goods

We need to do forecast on the transportation demand, although the forecasting could not achieve 100% correction. The normal model of management is called PDCA, which are planning, do, check, and action. Through shipping demand forecast, we can adjust the number of fleets we need to launch or remove in the following year. Therefore, planning is the important beginning of the management model. In order to forecast our [company's] budget, we have to consider many factors such as the forecast reports from the professional consultant company. The forecast sometimes maybe wrong, but doing forecast is necessary for us.

Interviewee E:

[This interviewee does not want to be recorded by the recorder. Moreover, as he is an information manager, his answer mainly focuses on the risk associated with information flow. The following is the note from the interview.]

Q: In the information flow perspective, what are the possible risks between your company and your partners on the supply chain?

A:

1. Information flow could impact on physical flow, but it cannot replace physical flow.
2. IT infrastructure is obviously the most important area of concern for us (information department); it is the core business in our department. Many information problems occur, for example, information storage or transmission failure, when the IT infrastructure fails.
3. Risks associated with information flow such as information inaccuracy will affect financial loss, reputation loss. Sometime we may get the penalty from the Customs because of the information inaccuracy on declaration.
4. Different countries' Customs and different shippers use different information systems. This makes our operation on information transmission more difficult.

Q: The following table is the risk mitigation strategies that I summarised from existing studies related to general supply chains. Do you think they are appropriated in container shipping companies? Do you think there are any other strategies that are not mentioned in this list?

A:

1. Our company holds regular employee training sessions to teach the necessary staff to avoid or at least reduce the effect of information risks from personal failures by using IT systems.
2. We have already used ISO 27001 to increase information security. ISO 27001 is an information security management system (ISMS) standard process that records every single employee to keep business confidential. On the other side, from the safety perspective, we implement IMGD Code, an international regulations, which can help reduce potential risks in shipping operations when transporting dangerous goods. This types of risk [dangerous goods transportation] has more serious impact than the previous one [information security risk], because it may harm to human life safety. In our company, we pay more attention on implementing safety rules and regulations.
3. There are two types of RFID, passive tag and active tag. The passive tag is not really useful for us as it only works in a close area and has only several gates connecting outside world, so that the reader can set up in the gates and read the information on the passive tag. For us, the containers are transported in an open area, which means all over the world, and this should use the active tag to actively send the cargo information to us if the cargo has been stolen. However, the active tag is quite expensive and we have around 80,000 to 100,000 containers transporting in the world. If our containers are all equipped with the RFID with active tag, this will be a big issue, and we have to consider it very carefully. Now, we still use the

normal seal and electronic seal and the e-seal is usually used in transit containers and expensive cargo containers.

Interviewee F:

[This interviewee could only provide 30 minutes]

Q: Figure 1, 2 and 3 are the information flow (after modifying through the interviewee B and D), physical flow and payment flow that I organised from some text books and the internet. Could you please modify it if there is anything wrong within these three flow charts? (The dotted lines represent that the flows are not necessary to happen)

A: I think the three flow charts are fine.

Q: The following table is the risks associated with the three flows that I summarised from existing studies. Do you think they are appropriated in container shipping companies? Do you think there are any other risks that are not mentioned in this list? Also, the following table is the risk mitigation strategies that I summarised from existing studies related to general supply chains. Do you think they are appropriated in container shipping companies? Do you think there are any other strategies that are not mentioned in this list?

A: As I don't have much time, I would only mention some part that may be really worth to be mentioned. In the risk mitigation strategies part, I suggest you to add one more strategy, cultivate loyal partners. We usually cultivate loyalty of our partners and make a long-term contract with shippers to reduce the uncertain transportation demand and these strategies could also maintain minimal revenue for us. This is very important because we [shipping company] do not produce any product, what we earned is from the service we provide, the cargo transportation. If there is no cargo to transport, we cannot survive. Therefore, I suggest you add this strategy.

Interviewee G:

[This interviewee could only spend no more than 30 minutes for the interview.]

Q: In the information flow perspective, what are the possible risks between your company and your partners on the supply chain? Also, the following table is the risk mitigation strategies that I summarised from existing studies related to general supply chains. Do you think they are appropriated in container shipping companies? Do you think there are any other strategies that are not mentioned in this list?

A: There are various information systems between different countries' customs and shippers. Among all the information systems, EDI (Electronic Data Interchange) is the most popular IT used in shipping companies and port authorities, because it can transmit information rapidly. However, there are still some supply chain partners who cannot afford the investment of EDI, and they transmit the required information through other information channels, such as email or telephone. The information transmitted through these different information channels is neither organised nor standardised. This disintegrated information transmission may cause information delay and inaccuracy. The advantages of EDI include formatted data, huge data capacity, quick data transition, and a basic hardware requirement. We usually ask our partners to use EDI to transmit the information in order to reduce the potential information risk.

Appendix 3 Email Interview Questions

Research Project on
Risk Management in Container Shipping Operations

Dear Sir/Madam,

My name is Chia-Hsun Chang; I am currently pursuing a PhD degree at the International Shipping and Logistics Group in the University of Plymouth under the supervision of Prof. Dong-Ping Song and Dr. Jingjing Xu. My research focuses on supply chain risk management in container shipping. Three dimensions of risk will be examined; namely, risks associated with information flow, risks associated with physical flow, and risks associated with payment flow. The purpose of the research is to investigate the factors in these three dimensions and to identify appropriate mitigating strategies. I was wondering if you would be kind enough to provide some insight into this issue by answering the questions below.

All the answers will be held in the strictest confidence, as this has always been the policy of the University of Plymouth. This survey will take you 10 – 15 minutes. In exchange for your help, I will send you a summary report of this survey if you wish.

I am aware that you must be very busy. As your opinion is very important for the study, I would be most grateful if you could spare some of your valuable time to complete this short questionnaire.

Yours faithfully,

Chia-Hsun Chang,
PhD Candidate,
Email: chia-hsun.chang@plymouth.ac.uk

University of Plymouth, Cookworthy Building,
Drake Circus, Plymouth Devon, UK, PL4 8AA
Tel: +44 (0)7575 012555
Fax: +44 (0)1752 585713

Section 1: Respondent Profile

1. Your Position:________________________________

2. How many years have you been working in the maritime field:
   ____

Section 2: Please tick Yes or No, and provide any comments that you may have.

1. The following table contains the risk factors and elements that I organised from previous studies and from a series of interviews.

Risks associated with information flow
Information Delay (InfoD)
1. Using different communication channels in the supply chain increases the time of information transmission. (e.g. telephone, Email, EDI)
2. Supply chain partners do not transmit essential information on time
3. Processing documents are detained by the government departments (e.g. customs)
4. Shipping company cannot transmit essential information on time
Information Inaccuracy (InfoI)
1. Lack of information security during the information flow
2. Information asymmetry/incompleteness
3. Lack of information standardisation and compatibility
4. Shippers request extra service information
5. Shippers hide cargo information (non-declare)
IT Problem (InfoIT)
1. IT infrastructure breakdown or crash
2. Unsuitable human operation on IT infrastructure
3. Unsuitable human operation on application software

Considering the above structure, elements contributing to **risks associated with information flow** are categorised into “information delay”, “information inaccuracy”, and “IT problem”. Do you think this categorisation is appropriate?

Risk element categories	**Yes**	**No**	**Any comments?**
Information delay			
Information inaccuracy			
IT problem			
Any other elements should be considered?			

2. The following table contains the risk factors and elements that I organised from previous studies and from a series of interviews.

Risks associated with physical flow
Transportation Delay (PhTD)
1. Port strike
2. Port congestion (unexpected waiting times before berthing or before starting loading/discharging)
3. Port/terminal productivity below expectations (loading/discharging)
4. Unstable weather
5. Unsuitable empty mile transportation
6. Container shortage (e.g. shippers use containers as storage, container revamp, unexpected demand)
7. Lack of flexibility of fleet size and designed schedules
8. Oil price rise
Cargo/asset loss or Damage (PhCD)
1. Damage to containers or cargos due to terminal operators' improper loading/unloading operations
2. Cargo stolen from unsealed containers
3. Damage caused by transporting dangerous goods
4. Damage to ship or quay due to improper berth operations
5. Damage to frozen cargos/ reefer containers due to electricity failure
6. Attack from pirates or terrorists

Considering the above structure, elements contributing to **risks associated with physical flow** are categorised into "transportation delay" and "cargo/asset loss or damage". Do you think this categorisation is appropriate?

Risk element categories	Yes	No	Any comments?
Transportation delay			
Cargo/asset loss or damage			
Any other elements should be considered?			

3. The following table contains the risk factors and elements that I organised from previous studies and from a series of interviews.

Risks associated with payment flow
Currency Exchange (PayCE)
1. Currency exchange during payment process
2. Financial crisis in the loan countries
Payment Delay (PayPD)
1. Payment delay from partners or shippers
2. Unrealised contract with partners
Non-Payment (PayNP)
1. Shippers go into bankruptcy
2. Shippers abandon cargos if the value of the cargos become lower during the transportation
3. Shippers break the contract and reduce the container volume
4. Have partners with bad credit

Considering the above structure, elements contributing to **risks associated with payment flow** (refers to risks associated with payments with shippers, freight forwarders, or ports in the logistics processes) are categorised into "currency exchange", "payment delay" and "non-payment". Do you think this categorisation is appropriate?

Risk element categories	**Yes**	**No**	**Any comments?**
Currency exchange			
Payment delay			
Non-payment			
Any other elements should be considered?			

Section 3: We have identified three groups of **risk mitigation strategies** for container shipping operations. Please add any other strategies that you think should also be included in the list and/or provide any comments that you may have on the ones that we have identified.

Intra-organisation strategies
Implement regular employee training
Use advanced equipment
Improve security
Implement international regulations (e.g. ISO27001, C-TPAT)
Implement slow steaming and deploy more ships in the same route
Reduce port time or cut port-of-calls when delay occurs
Design service schedules with buffer time
Intra-channel strategies
Collaborate with partners (e.g. terminal operators, freight forwarders, and inland distributors, etc.)
Enter into long term contracts with shippers
Reduce /withdraw contracts with partners with poor performance
Reward partners who follow your company's suggestions
Exchange ideas with partners to resolve conflicts and/or improve quality of service
Information sharing (e.g. provide tracking and tracing for shippers)
Avoid having too many partners
Choose partners more carefully
Trust your supply chain partners
Cultivate loyalty with your partners
Inter-channel strategies
Form alliance with other shipping companies
Exchange slots with other shipping companies
Merge with or acquire other shipping companies
Any other mitigation strategies/categories & comments:

Would you like to have a summary of this survey: ________
If yes, please provide your email address to receive summary:

____

THANK YOU ONCE AGAIN FOR YOUR KIND PARTICIPATION IN THIS SURVEY.

YOUR ANSWER WILL BE KEPT CONFIDENTIAL.

Appendix 4 Risk Factor and Mitigation Strategy

Questionnaire Survey

Questionnaire on "Risks in Container Shipping Operations"

Dear Sir/Madam,

My name is Chia-Hsun Chang; I am currently pursuing a PhD degree at the International Shipping and Logistics Group in the University of Plymouth.

The purpose of this questionnaire is to collect data for the fulfilment of the PhD's project. The objectives of this questionnaire are :

1. To identify the risk factors in container shipping operations;
2. To identify the risk mitigating strategies in container shipping operations.

This questionnaire will take you about 15 minutes to answer. According to your experience and opinion, please fill the appropriate answer in the following questions.

All the answers will be held in the strictest confidence, as this has always been the policy of the University of Plymouth.

Thank you for your help.

Your Sincerely,

Supervisors: Prof. Dong-Ping Song, Dr. Jingjing Xu

Researcher: Chia-Hsun Chang

University of Plymouth, International shipping & logistics group

Tel: +44 (0) 7575 012 555

Address: Cookworthy Building, Drake Circus, Plymouth, PL4 8AA

E-mail: chia-hsun.chang@plymouth.ac.uk

Likelihood				
Rare	Unlikely	Possible	Likely	Almost certain
0	1	2	3	4

Financial, reputation, safety and security consequences				
Insignificant	Minor	Moderate	Major	Catastrophic
0	1	2	3	4

<u>Section A:</u> The following questions are related to **Risks associated with information flow** in container shipping operations. According to your experience and opinion about the degree of likelihood and impacts, please fill the appropriate score in each of the following box:

Following questions are related to **<u>Information Delay</u>** risks in shipping supply chain	Likeli-hood	Financial loss	Reputation loss	Safety an security dam
1. Using different communication channels in the supply chain increases the time of information transmission. (e.g. telephone, Email, EDI)				
2. Supply chain partners do not transmit essential information on time				
3. Processing documents are detained by the government departments (e.g. customs)				
4. Shipping company cannot transmit essential information on time				
Following questions are related to **<u>Information Inaccuracy</u>** risks in shipping supply chain	Likeli-hood	Financial loss	Reputation loss	Safety an security dam
1. Lack of information security during the information flow				
2. Information asymmetry/incompleteness				
3. Lack of information standardisation and compatibility				
4. Shippers request extra service information				
5. Shippers hide cargo information				
Following questions are related to **<u>IT Problem</u>** risks in shipping supply chain	Likeli-hood	Financial loss	Reputation loss	Safety an security dam
1. IT infrastructure breakdown or crash				
2. Unsuitable human operation on IT infrastructure				
3. Unsuitable human operation on application software				

<u>Section B:</u> The following questions are related to **Risks associated with physical flow** in container shipping operations. According to your experience and opinion about the degree of likelihood and impacts, please fill the appropriate score in each of the following box:

Following questions are related to **<u>Transportation Delay</u>** risks in shipping supply chain	Likeli-hood	Financial loss	Reputation loss	Safety an security dam
1. Port strike				
2. Port congestion (unexpected waiting times before berthing or before starting loading/discharging)				
3. Port/terminal productivity below expectations (loading/discharging)				
4. Unstable weather				
5. Unsuitable empty mile transportation				
6. Container shortage (e.g. Shippers use containers as storage, container revamp, unexpected demand)				
7. Lack of flexibility of fleet size and designed schedules				
8. Cargos are detained by customs				

9. Oil price rise				
Following questions are related to **Cargo/Asset Damage** risks in shipping supply chain	Likeli-hood	Financial loss	Reputation loss	Safety an security dam
1. Damage to containers or cargos due to terminal operators' improper loading/unloading operations				
2. Cargo stolen from unsealed containers				
3. Damage caused by transporting dangerous goods				
4. Damage to ship or quay due to improper berth operations				
5. Damage to frozen cargos/ reefer containers due to electricity failure				
6. Attack from pirates or terrorists				

Section C: The following questions are related to **Risks associated with payment flow** in container shipping operations. According to your experience and opinion about the degree of likelihood and impacts, please fill the appropriate score in each of the following box:

Following questions are related to **Currency Exchange** risks in shipping supply chain	Likeli-hood	Financial loss	Reputation loss	Safety an security dam
1. Currency exchange during payment process				
2. Financial crisis in the loan countries???				
Following questions are related to **Payment Delay** risks in shipping supply chain	Likeli-hood	Financial loss	Reputation loss	Safety an security dam
1. Payment delay from partners or shippers				
2. Unrealised contract with partners				
Following questions are related to **No Payment** risks in shipping supply chain	Likeli-hood	Financial loss	Reputation loss	Safety an security dam
1. Shippers go into bankruptcy				
2. Shippers abandon cargos when cargos have already reached the port of destination				
3. Shippers break the contract and reduce the container volume				
4. Have partners with bad credit				

Section D: Following questions are related to the improvement of **Risk mitigating strategies** in container shipping operations. According to your experience and opinion, please click the appropriate ☐.

Following questions are related to **Intra-organisation** risk mitigating strategies in shipping supply chain	No impact ←→posit			
	1	2	3	4
1. Regular employee training (e.g. every year or half of year)	☐	☐	☐	☐
2. More advanced infrastructure (hardware and software)	☐	☐	☐	☐
3. Improve the security	☐	☐	☐	☐
4. Implement international regulations (e.g. ISO27001, C-TPAT, IMO regulations)	☐	☐	☐	☐
5. Slow steaming and increase ships in the existed routes	☐	☐	☐	☐
6. Omit port-of-calls to keep original schedule when the ship has already been delayed	☐	☐	☐	☐
7. Include buffer times when designing the timetable/schedule	☐	☐	☐	☐

Following questions are related to **Intra-channel** risk mitigating strategies in shipping supply chain	No impact ⟷ posit			
1. Cooperate with your partners (e.g. terminal operational company，inland transportation)	☐	☐	☐	☐
2. Make a long-term contract with shippers	☐	☐	☐	☐
3. Shorten/ withdraw the contract with partners who have bad performance	☐	☐	☐	☐
4. Reward / assist partners who comply with shipping lines' initiatives	☐	☐	☐	☐
5. Exchange ideas with partners to solve conflict or improve service quality	☐	☐	☐	☐
6. Share information with your partners	☐	☐	☐	☐
7. Avoid too many partners	☐	☐	☐	☐
8. Choose partners more carefully	☐	☐	☐	☐
9. Trust your partners	☐	☐	☐	☐
10. Cultivate loyalty of supply chain partners	☐	☐	☐	☐
Following questions are related to **Inter-channel** risk mitigating strategies in shipping supply chain	No impact ⟷ posit			
1. Form alliance with other shipping companies	☐	☐	☐	☐
2. Slot-exchange, slot charter, joint fleet, ship-charter with other container shipping companies	☐	☐	☐	☐
3. Acquire and merge with other shipping companies	☐	☐	☐	☐

<u>Section E:</u> Respondent's profile

1. How many years have you worked in the shipping industry?
   ☐ 1 - 5 years ☐ 6 - 10 years ☐ 11 - 15 years ☐ 16 - 20 years ☐ 21 - 25 years
☐ Over 25 years

2. What is your department in your company?

3. What is your professional role in your company?
   ☐ Vice president or above ☐ Manager/Assistant manager ☐ Director/Vice Director

   ☐ Clerk ☐ Sales representative ☐ Others (____________________)

4. What is your company's main business?
   ☐ Container shipping company ☐ Container shipping agency

   ☐ Others (____________________)

5. What is your company's ownership type?
   ☐ Local firm ☐ Foreign-owned firm ☐ Foreign-local firm ☐ Others (____________)

6. How many employees are in your company?
   ☐ 1 - 50 people ☐ 51 - 100 people ☐ 101~200 people ☐ 201~500 people ☐ over 500 people

Thank you once again for your kind participation in this survey.

Your answer will be kept confidential.

Appendix 5 AHP Questionnaire Survey

Expert Questionnaire on "Risk Management in Container Shipping"

Dear Sir/Madam,

My name is Chia-Hsun Chang; I am currently pursuing a PhD degree at the International Shipping and Logistics Group in the University of Plymouth.

The purpose of this questionnaire is to collect data for the fulfilment of my PhD's project. The objective of this survey is to identify the relative importance of mitigation risk strategies in container shipping operations.

It will take you approximately 20 minutes to complete this questionnaire. As you will see, the questionnaire starts with Part A including an introduction to the structure of the survey and an explanation about how the questionnaire should be completed. This is followed by Part B consisting of a number of questions about risk mitigation strategies and Part C consisting of 3 questions about your profile.

All the answers will be held in the strictest confidence, as this has always been the policy of the University of Plymouth.

Thank you very much in advance for your help.

Your sincerely,

Chia-Hsun Chang

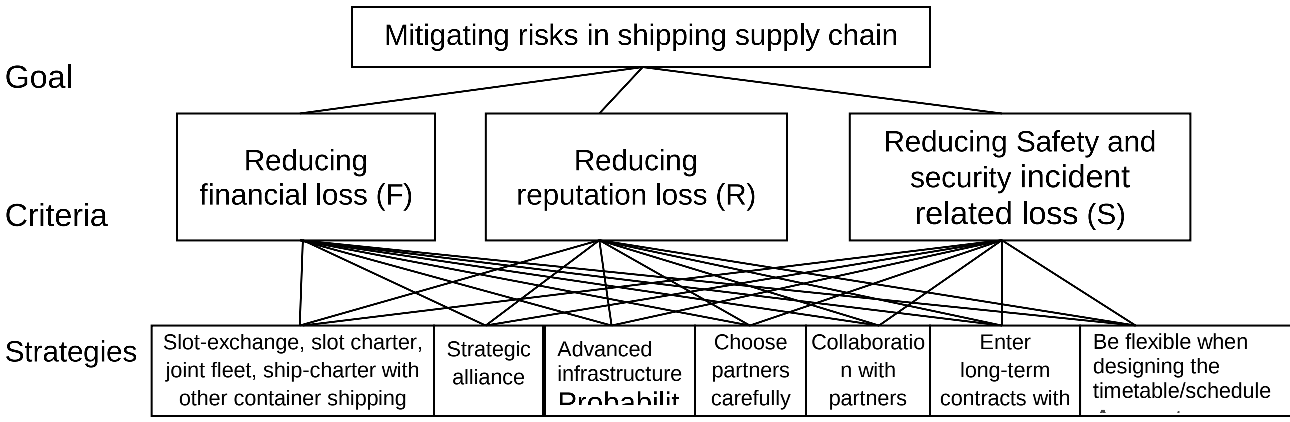
International shipping & logistics group, University of Plymouth

Address: Cookworthy Building, Drake Circus, Plymouth, PL4 8AA;

E-mail: chia-hsun.chang@plymouth.ac.uk Tel: +44 (0) 7575 012 555

Part A: Introduction and Explanation

The following figure is the AHP structure of this survey. The first level represents the research goal: mitigating risks in shipping supply chain. The second level consists of three criteria: reducing financial loss, reducing reputation loss and reducing safety and security incident related loss. At the third level the alternative mitigating strategies are listed, and they are identified from a previous survey.



The following example illustrates how the answers should be selected.

To compare two alternatives - “Form alliance with other shipping companies” and “Make a long-term contract with shippers” as shown below, if you think for “Reducing financial loss (F)” the former is 3 times more important than the latter, you should circle the number “3” on the left-hand side in the first row; if you think for “Reduce reputation loss (R)” the latter is 4 times more important than the former, you should circle the number “4” on the right-hand side in the second row as shown below.

Alternatives	Criteria	Increasing importance ← Increasing importance →	Alternatives
Form alliance with other shipping companies	F	9 8 7 6 5 4 (3) 2 1 2 3 4 5 6 7 8 9	Enter a long-term contract with shippers
	R	9 8 7 6 5 4 3 2 1 2 3 (4) 5 6 7 8 9	
	S	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	

Part B: Questionnaire

1) Regarding the three criteria at the second level, in your opinion what is the relative importance of “Reducing financial loss”, “Reducing reputation loss” and “Reducing safety and security incident related loss” in making risk mitigation strategies?

Criteria	Increasing importance ← Increasing importance →	Criteria

Reduce financial loss	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	Reduce reputation loss
Reduce financial loss	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	Reduce safety and security incident related loss
Reduce reputation loss	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	Reduce safety and security incident related loss

2) Regarding the alternative strategies at the third level, in your opinion what is the relative importance of the alternatives under each criteria (F, R, S) in making risk mitigation strategies?

Strategies	Criteria	Increasing importance ← Increasing importance →	Strategies
Slot-exchange, slot charter, joint fleet, ship-charter with other container shipping companies	F	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	Form alliance with other shipping companies
	R	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	
	S	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	
	F	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	Use more advanced infrastructures (hardware and software)
	R	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	
	S	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	
	F	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	Choose partners very carefully
	R	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	
	S	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	
	F	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	Collaboration with partners (e.g., terminal operational company, inland transportation) through making a joint long-term plan
	R	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	
	S	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	
	F	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	Enter a long-term contract with shippers
	R	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	
	S	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	
	F	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	Be flexible when designing the timetable/schedule
	R	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	
	S	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	
Form alliance with other shipping companies	F	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	Use more advanced infrastructures (hardware and software)
	R	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	
	S	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	
	F	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	Choose partners very

	R	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	carefully
	S	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	
	F	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	Collaboration with partners (e.g., terminal operational company, inland transportation) through making a joint long-term plan
	R	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	
	S	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	
	F	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	Enter a long-term contract with shippers
	R	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	
	S	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	
	F	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	Be flexible when designing the timetable/schedule
	R	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	
	S	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	
Use more advanced infrastructures (hardware and software)	F	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	Choose partners very carefully
	R	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	
	S	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	
	F	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	Collaboration with partners (e.g., terminal operational company, inland transportation) through making a joint long-term plan
	R	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	
	S	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	
	F	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	Enter a long-term contract with shippers
	R	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	
	S	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	
	F	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	Be flexible when designing the timetable/schedule
	R	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	
	S	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	
Choose partners very carefully	F	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	Collaboration with partners (e.g., terminal operational company, inland transportation) through making a joint long-term plan
	R	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	
	S	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	
	F	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	Enter a long-term contract with shippers
	R	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	
	S	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	
	F	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	Be flexible when designing the timetable/schedule
	R	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	
	S	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	
Collaboration with partners (e.g., terminal	F	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	Enter a long-term contract with shippers
	R	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	

operational company, inland transportation) through making a joint long-term plan	S	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	
	F	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	Be flexible when designing the timetable/schedule
	R	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	
	S	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	
Enter a long-term contract with shippers	F	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	Be flexible when designing the timetable/schedule
	R	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	
	S	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	

Part C: Your profile

1. How many years have you worked in the shipping industry?
☐ 1 - 10 years ☐ 11 - 15 years ☐ 16 - 20 years ☐ 21 - 25 years ☐ Over 25 years

2. What is your professional role/position in your company?
□ Vice president or above □ Manager/Assistant manager □ Director/Vice Director
☐ Clerk ☐ Sales representative ☐ Others (____________________)

3. What is your department?
☐ Vice president or above ☐ Information/document ☐ operation/shipping ☐ financial/accounting ☐ Others (____________________)

Appendix 6 Fuzzy AHP results

Sample 1

Step 1 Build fuzzy positive reciprocal matrix

Table 1.1 The fuzzy positive reciprocal matrix of three criteria

	Reduce financial loss	Reduce reputation loss	Reduce safety and security incident related loss
Reduce financial loss	(1, 1, 2)	(5, 6, 7)	(2, 3, 4)
Reduce reputation loss	(0.143, 0.167, 0.2)	(1, 1, 2)	(0.25, 0.333, 0.5)
Reduce safety and security incident related loss	(0.25, 0.333, 0.5)	(2, 3, 4)	(1, 1, 2)
C.R. = 0.015771			

Table 1.2 The fuzzy positive reciprocal matrix of seven strategies under reduce financial loss

		A	B	C	D	E	F	G
Reduce financial loss	A	(1, 1, 2)	(2, 3, 4)	(2, 3, 4)	(2, 3, 4)	(2, 3, 4)	(1, 2, 3)	(1, 2, 3)
	B	(0.25, 0.333, 0.5)	(1, 1, 2)	(0.333, 0.5, 1)	(0.167, 0.2, 0.25)	(0.167, 0.2, 0.25)	(0.143, 0.167, 0.2)	(0.143, 0.167, 0.2)
	C	(0.25, 0.333, 0.5)	(1, 2, 3)	(1, 1, 2)	(1, 1, 2)	(1, 1, 2)	(0.167, 0.2, 0.25)	(0.143, 0.167, 0.2)
	D	(0.25, 0.333, 0.5)	(4, 5, 6)	(0.5, 1, 1)	(1, 1, 2)	(1, 1, 2)	(0.143, 0.167, 0.2)	(0.167, 0.2, 0.25)
	E	(0.25, 0.333, 0.5)	(4, 5, 6)	(0.5, 1, 1)	(0.5, 1, 1)	(1, 1, 2)	(0.167, 0.2, 0.25)	(0.167, 0.2, 0.25)
	F	(0.333, 0.5, 1)	(5, 6, 7)	(4, 5, 6)	(5, 6, 7)	(4, 5, 6)	(1, 1, 2)	(1, 1, 2)
	G	(0.333, 0.5, 1)	(5, 6, 7)	(5, 6, 7)	(4, 5, 6)	(4, 5, 6)	(0.5, 1, 1)	(1, 1, 2)
C.R.=0.082091								

Table 1.3 The fuzzy positive reciprocal matrix of seven strategies under reduce reputation loss

		A	B	C	D	E	F	G
Reduce reputation loss	A	(1, 1, 2)	(1, 1, 2)	(1, 1, 2)	(1, 2, 3)	(1, 2, 3)	(1, 1, 2)	(1, 1, 2)
	B	(0.5, 1, 1)	(1, 1, 2)	(1, 1, 2)	(1, 1, 2)	(1, 1, 2)	(0.25, 0.333, 0.5)	(1, 1, 2)
	C	(0.5, 1, 1)	(0.5, 1, 1)	(1, 1, 2)	(1, 1, 2)	(1, 1, 2)	(0.25, 0.333, 0.5)	(0.167, 0.2, 0.25)
	D	(0.333, 0.5, 1)	(0.5, 1, 1)	(0.5, 1, 1)	(1, 1, 2)	(1, 1, 2)	(0.167, 0.2, 0.25)	(0.25, 0.333, 0.5)
	E	(0.333, 0.5, 1)	(0.5, 1, 1)	(0.5, 1, 1)	(0.5, 1, 1)	(1, 1, 2)	(0.25, 0.333, 0.5)	(0.25, 0.333, 0.5)
	F	(0.5, 1, 1)	(2, 3, 4)	(2, 3, 4)	(4, 5, 6)	(2, 3, 4)	(1, 1, 2)	(1, 1, 2)
	G	(0.5, 1, 1)	(0.5, 1, 1)	(4, 5, 6)	(2, 3, 4)	(2, 3, 4)	(0.5, 1, 1)	(1, 1, 2)
C.R.=0.043089								

Table 1.4 The fuzzy positive reciprocal matrix of seven alternatives under reduce safety and security incident related loss

		A	B	C	D	E	F	G
Reduce safety and security incident related loss	A	(1, 1, 2)	(2, 3, 4)	(2, 3, 4)	(1, 2, 3)	(2, 3, 4)	(1, 1, 2)	(1, 1, 2)
	B	(0.25, 0.333, 0.5)	(1, 1, 2)	(1, 1, 2)	(1, 1, 2)	(1, 2, 3)	(0.333, 0.5, 1)	(1, 1, 2)
	C	(0.25, 0.333, 0.5)	(0.5, 1, 1)	(1, 1, 2)	(1, 1, 2)	(1, 1, 2)	(0.25, 0.333, 0.5)	(0.167, 0.2, 0.25)
	D	(0.333, 0.5, 1)	(0.5, 1, 1)	(0.5, 1, 1)	(1, 1, 2)	(1, 1, 2)	(0.167, 0.2, 0.25)	(0.167, 0.2, 0.25)
	E	(0.25, 0.333, 0.5)	(0.333, 0.5, 1)	(0.5, 1, 1)	(0.5, 1, 1)	(1, 1, 2)	(0.25, 0.333, 0.5)	(0.167, 0.2, 0.25)
	F	(0.5, 1, 1)	(1, 2, 3)	(2, 3, 4)	(4, 5, 6)	(2, 3, 4)	(1, 1, 2)	(1, 1, 2)
	G	(0.5, 1, 1)	(0.5, 1, 1)	(4, 5, 6)	(4, 5, 6)	(4, 5, 6)	(0.5, 1, 1)	(1, 1, 2)
C.R.=0.037491								

Step 2 Calculate the fuzzy weights of fuzzy positive reciprocal matrix

Table 1.5 The geometric mean of TFN and the fuzzy weights of three criteria

	i =Financial loss	i = Reputation loss	i = Safety and security incident related loss
$\tilde{Z}_i^C$	(2.154, 2.621, 3.826)	(0.329, 0.382, 0.585)	(0.794, 1, 1.587)
$\widetilde{W}_i^C$	(0.359, 0.655, 1.167)	(0.055, 0.095, 0.178)	(0.132, 0.25, 0.484)

Table 1.6 The geometric mean of TFN and the fuzzy weights of seven strategies under reduce financial loss

	i =A	i = B	i = C	i = D	i = E	i = F	i = G
$\tilde{Z}_i^{FA}$	(1.486, 2.284, 3.337)	(0.241, 0.293, 0.425)	(0.481, 0.581, 0.93)	(0.531, 0.662, 0.93)	(0.492, 0.679, 0.869)	(2.012, 2.393, 3.546)	(1.822, 2.393, 3.212)
$\widetilde{W}_i^{FA}$	(0.112, 0.246, 0.472)	(0.018, 0.032, 0.06)	(0.036, 0.063, 0.132)	(0.04, 0.071, 0.132)	(0.037, 0.073, 0.123)	(0.152, 0.258, 0.502)	(0.138, 0.258, 0.455)

Table 1.7 The geometric mean of TFN and the fuzzy weights of seven strategies under reduce reputation loss

	i =A	i = B	i = C	i = D	i = E	i = F	i = G
$\tilde{Z}_i^{FA}$	(1, 1.219, 2.246)	(0.743, 0.855, 1.486)	(0.521, 0.679, 1)	(0.445, 0.615, 0.906)	(0.427, 0.662, 0.906)	(1.486, 2.015, 2.852)	(1.104, 1.723, 2.119)
$\widetilde{W}_i^{FA}$	(0.087, 0.157, 0.392)	(0.065, 0.11, 0.259)	(0.045, 0.087, 0.175)	(0.039, 0.079, 0.158)	(0.037, 0.085, 0.158)	(0.129, 0.259, 0.498)	(0.096, 0.222, 0.37)

Table 1.8 The geometric mean of TFN and the fuzzy weights of seven strategies under reduce safety and security incident related loss

	i =A	i = B	i = C	i = D	i = E	i = F	i = G
$\tilde{Z}_i^{FA}$	(1.346, 1.768, 2.852)	(0.701, 0.855, 1.575)	(0.472, 0.581, 0.906)	(0.42, 0.572, 0.82)	(0.365, 0.526, 0.743)	(1.346, 1.902, 2.737)	(1.346, 1.993, 2.38)
$\widetilde{W}_i^{FA}$	(0.112, 0.216, 0.476)	(0.058, 0.104, 0.263)	(0.039, 0.071, 0.151)	(0.035, 0.07, 0.137)	(0.03, 0.064, 0.124)	(0.112, 0.232, 0.457)	(0.112, 0.243, 0.397)

Step 3 Defuzzify the fuzzy weights and normalise the crisp weights

Table 1.9 The defuzzified and standardized weights of three criteria

	Financial loss	Reputation loss	Safety and security incident related loss
Defuzzified weights	0.727	0.11	0.289
Standardised weights	0.646	0.097	0.257

Table 1.10 The defuzzified and standardized weights of seven strategies under reduce financial loss

	A	B	C	D	E	F	G
Defuzzified weights	0.277	0.037	0.077	0.081	0.078	0.304	0.283
Standardised weights	0.244	0.032	0.068	0.071	0.068	0.267	0.249

Table 1.11 The defuzzified and standardized weights of seven strategies under reduce reputation loss

	A	B	C	D	E	F	G
Defuzzified weights	0.212	0.145	0.102	0.092	0.093	0.296	0.229
Standardised weights	0.181	0.124	0.088	0.079	0.08	0.253	0.196

Table 1.12 The defuzzified and standardized weights of seven strategies under reduce safety and security incident related loss

	A	B	C	D	E	F	G
Defuzzified weights	0.268	0.142	0.087	0.081	0.073	0.267	0.251
Standardised weights	0.229	0.121	0.075	0.069	0.062	0.229	0.215

Sample 2

Step 1 Build fuzzy positive reciprocal matrix

Table 2.1 The fuzzy positive reciprocal matrix of three criteria

	Reduce financial loss	Reduce reputation loss	Reduce safety and security incident related loss
Reduce financial loss	(1, 1, 2)	(1, 1, 2)	(1, 1, 2)
Reduce reputation loss	(0.5, 1, 1)	(1, 1, 2)	(1, 1, 2)
Reduce safety and security incident related loss	(0.5, 1, 1)	(0.5, 1, 1)	(1, 1, 2)
C.R. = 0.000			

Table 2.2 The fuzzy positive reciprocal matrix of seven strategies under reduce financial loss

		A	B	C	D	E	F	G
Reduce financial loss	A	(1, 1, 2)	(2, 3, 4)	(2, 3, 4)	(1, 2, 3)	(2, 3, 4)	(1, 1, 2)	(1, 1, 2)
	B	(0.25, 0.333, 0.5)	(1, 1, 2)	(2, 3, 4)	(2, 3, 4)	(2, 3, 4)	(0.25, 0.333, 0.5)	(1, 2, 3)
	C	(0.25, 0.333, 0.5)	(0.25, 0.333, 0.5)	(1, 1, 2)	(0.25, 0.333, 0.5)	(0.25, 0.333, 0.5)	(0.25, 0.333, 0.5)	(0.25, 0.333, 0.5)
	D	(0.333, 0.5, 1)	(0.25, 0.33, 0.5)	(2, 3, 4)	(1, 1, 2)	(1, 1, 2)	(0.25, 0.33, 0.5)	(0.25, 0.33, 0.5)
	E	(0.25, 0.333, 0.5)	(0.25, 0.333, 0.5)	(2, 3, 4)	(0.5, 1, 1)	(1, 1, 2)	(0.25, 0.333, 0.5)	(0.25, 0.333, 0.5)
	F	(0.5, 1, 1)	(2, 3, 4)	(2, 3, 4)	(2, 3, 4)	(2, 3, 4)	(1, 1, 2)	(2, 3, 4)
	G	(0.5, 1, 1)	(0.333, 0.5, 1)	(2, 3, 4)	(2, 3, 4)	(2, 3, 4)	(0.25, 0.333, 0.5)	(1, 1, 2)
C.R.= 0.073								

Table 2.3 The fuzzy positive reciprocal matrix of seven strategies under reduce reputation loss

		A	B	C	D	E	F	G
Reduce reputation loss	A	(1, 1, 2)	(1, 1, 2)	(1, 1, 2)	(1, 1, 2)	(1, 2, 3)	(1, 1, 2)	(1, 1, 2)
	B	(0.5, 1, 1)	(1, 1, 2)	(1, 1, 2)	(1, 1, 2)	(1, 1, 2)	(1, 2, 3)	(1, 1, 2)
	C	(0.5, 1, 1)	(0.5, 1, 1)	(1, 1, 2)	(1, 2, 3)	(1, 1, 2)	(1, 2, 3)	(1, 1, 2)
	D	(0.5, 1, 1)	(0.5, 1, 1)	(0.33, 0.5, 1)	(1, 1, 2)	(1, 1, 2)	(2, 3, 4)	(1, 1, 2)
	E	(0.333, 0.5, 1)	(0.5, 1, 1)	(0.5, 1, 1)	(0.5, 1, 1)	(1, 1, 2)	(2, 3, 4)	(2, 3, 4)
	F	(0.5, 1, 1)	(0.333, 0.5, 1)	(0.333, 0.5, 1)	(0.25, 0.333, 0.5)	(0.25, 0.333, 0.5)	(1, 1, 2)	(0.25, 0.333, 0.5)
	G	(0.5, 1, 1)	(0.5, 1, 1)	(0.5, 1, 1)	(0.5, 1, 1)	(0.25, 0.333, 0.5)	(2, 3, 4)	(1, 1, 2)
C.R.= 0.054								

Table 2.4 The fuzzy positive reciprocal matrix of seven alternatives under reduce safety and security incident related loss

		A	B	C	D	E	F	G
Reduce safety and security incident related loss	A	(1, 1, 2)	(1, 1, 2)	(1, 1, 2)	(1, 2, 3)	(1, 1, 2)	(2, 3, 4)	(2, 3, 4)
	B	(0.5, 1, 1)	(1, 1, 2)	(1, 1, 2)	(1, 1, 2)	(1, 1, 2)	(1, 1, 2)	(1, 1, 2)
	C	(0.5, 1, 1)	(0.5, 1, 1)	(1, 1, 2)	(1, 1, 2)	(0.33, 0.5, 1)	(1, 1, 2)	(1, 1, 2)
	D	(0.333, 0.5, 1)	(0.5, 1, 1)	(0.5, 1, 1)	(1, 1, 2)	(1, 1, 2)	(2, 3, 4)	(1, 1, 2)
	E	(0.5, 1, 1)	(0.333, 0.5, 1)	(1, 2, 3)	(0.5, 1, 1)	(1, 1, 2)	(2, 3, 4)	(2, 3, 4)
	F	(0.25, 0.333, 0.5)	(0.5, 1, 1)	(0.5, 1, 1)	(0.25, 0.333, 0.5)	(0.25, 0.333, 0.5)	(1, 1, 2)	(0.25, 0.333, 0.5)
	G	(0.25, 0.333, 0.5)	(0.5, 1, 1)	(0.5, 1, 1)	(0.5, 1, 1)	(0.25, 0.333, 0.5)	(2, 3, 4)	(1, 1, 2)
C.R.=0.069								

Step 2 Calculate the fuzzy weights of fuzzy positive reciprocal matrix

Table 2.5 The geometric mean of TFN and the fuzzy weights of three criteria

	i =Financial loss	$i =$ Reputation loss	$i =$ Safety and security incident related loss
$\tilde{Z}_i^C$	(1, 1, 2)	(0.794, 1, 1.587)	(0.63, 1, 1.26)
$\widetilde{W}_i^C$	(0.206, 0.333, 0.825)	(0.164, 0.333, 0.655)	(0.13, 0.333, 0.52)

Table 2.6 The geometric mean of TFN and the fuzzy weights of seven strategies under reduce financial loss

	i =A	$i =$ B	$i =$ C	$i =$ D	$i =$ E	$i =$ F	$i =$ G
$\tilde{Z}_i^{FA}$	(1.346, 1.768, 2.852)	(0.906, 1.92, 1.919)	(0.305, 0.39, 0.61)	(0.521, 0.662, 1.104)	(0.453, 0.624, 0.906)	(1.486, 2.192, 2.972)	(0.855, 1.24, 1.811)
$\widetilde{W}_i^{FA}$	(0.111, 0.216, 0.486)	(0.074, 0.158, 0.327)	(0.025, 0.048, 0.104)	(0.043, 0.081, 0.188)	(0.037, 0.076 0.154)	(0.122, 0.268, 0.506)	(0.07, 0.152, 0.309)

Table 2.7 The geometric mean of TFN and the fuzzy weights of seven strategies under reduce reputation loss

	i =A	$i =$ B	$i =$ C	$i =$ D	$i =$ E	$i =$ F	$i =$ G
$\tilde{Z}_i^{FA}$	(1, 1.104, 2.119)	(0.906, 1.104, 1.919)	(0.82, 1.219, 1.842)	(0.774, 1.06, 1.641)	(0.774, 1.24, 1.641)	(0.365, 0.512, 0.82)	(0.61, 1, 1.219)
$\widetilde{W}_i^{FA}$	(0.089, 0.153, 0.404)	(0.081, 0.153, 0.365)	(0.073, 0.1668, 0.351)	(0.069, 0.146, 0.313)	(0.069, 0.171, 0.313)	(0.033, 0.071, 0.156)	(0.054, 0.138, 0.232)

Table 2.8 The geometric mean of TFN and the fuzzy weights of seven strategies under reduce safety and security incident related loss

	i =A	$i =$ B	$i =$ C	$i =$ D	$i =$ E	$i =$ F	$i =$ G
$\tilde{Z}_i^{FA}$	(1.219, 1.511, 2.583)	(0.906, 1.104, 1.919)	(0.701, 0.906, 1.486)	(0.774, 1.06, 1.641)	(0.855, 1.369, 1.919)	(0.371, 0.534, 0.743)	(0.552, 0.855, 1.104)
$\widetilde{W}_i^{FA}$	(0.107, 0.206, 0.48)	(0.079, 0.15, 0.357)	(0.062, 0.123, 0.276)	(0.068, 0.144, 0.305)	(0.075, 0.187, 0.357)	(0.033, 0.073, 0.138)	(0.048, 0.116, 0.205)

Step 3 Defuzzify the fuzzy weights and normalise the crisp weights

Table 2.9 The defuzzified and standardized weights of three criteria

	Financial loss	Reputation loss	Safety and security incident related loss
Defuzzified weights	0.394	0.359	0.331
Standardised weights	0.364	0.331	0.305

Table 2.10 The defuzzified and standardized weights of seven strategies under reduce financial loss

	A	B	C	D	E	F	G
Defuzzified weights	0.244	0.172	0.053	0.092	0.083	0.284	0.164
Standardised weights	0.223	0.158	0.049	0.085	0.076	0.26	0.15

Table 2.11 The defuzzified and standardized weights of seven strategies under reduce reputation loss

	A	B	C	D	E	F	G
Defuzzified weights	0.184	0.176	0.183	0.161	0.178	0.079	0.14
Standardised weights	0.167	0.16	0.166	0.146	0.162	0.071	0.127

Table 2.12 The defuzzified and standardized weights of seven strategies under reduce safety and security incident related loss

	A	B	C	D	E	F	G
Defuzzified weights	0.235	0.173	0.139	0.158	0.196	0.077	0.12
Standardised weights	0.214	0.158	0.126	0.144	0.179	0.07	0.109

Sample 3

Step 1 Build fuzzy positive reciprocal matrix

Table 3.1 The fuzzy positive reciprocal matrix of three criteria

	Reduce financial loss	Reduce reputation loss	Reduce safety and security incident related loss
Reduce financial loss	(1, 1, 2)	(1, 1, 2)	(0.333, 0.5, 1)
Reduce reputation loss	(0.5, 1, 1)	(1, 1, 2)	(0.25, 0.333, 0.5)
Reduce safety and security incident related loss	(1, 2, 3)	(2, 3, 4)	(1, 1, 2)
C.R. = 0.016			

Table 3.2 The fuzzy positive reciprocal matrix of seven strategies under reduce financial loss

		A	B	C	D	E	F	G
Reduce financial loss	A	(1, 1, 2)	(1, 2, 3)	(1, 2, 3)	(1, 2, 3)	(1, 2, 3)	(1, 2, 3)	(1, 2, 3)
	B	(0.333, 0.5, 1)	(1, 1, 2)	(1, 2, 3)	(1, 2, 3)	(1, 2, 3)	(1, 2, 3)	(1, 1, 2)
	C	(0.333, 0.5, 1)	(0.333, 0.5, 1)	(1, 1, 2)	(1, 1, 2)	(0.333, 0.5, 1)	(1, 1, 2)	(1, 1, 2)
	D	(0.333, 0.5, 1)	(0.333, 0.5, 1)	(0.5, 1, 1)	(1, 1, 2)	(1, 2, 3)	(1, 1, 2)	(0.333, 0.5, 1)
	E	(0.333, 0.5, 1)	(0.333, 0.5, 1)	(1, 2, 3)	(0.333, 0.5, 1)	(1, 1, 2)	(1, 2, 3)	(1, 1, 2)
	F	(0.333, 0.5, 1)	(0.333, 0.5, 1)	(0.5, 1, 1)	(0.5, 1, 1)	(0.333, 0.5, 1)	(1, 1, 2)	(1, 1, 2)
	G	(0.333, 0.5, 1)	(0.5, 1, 1)	(0.5, 1, 1)	(1, 2, 3)	(0.5, 1, 1)	(0.5, 1, 1)	(1, 1, 2)
C.R.= 0.038								

Table 3.3 The fuzzy positive reciprocal matrix of seven strategies under reduce reputation loss

		A	B	C	D	E	F	G
Reduce reputation loss	A	(1, 1, 2)	(1, 1, 2)	(0.333, 0.5, 1)	(0.25, 0.333, 0.5)	(1, 1, 2)	(1, 1, 2)	(1, 1, 2)
	B	(0.5, 1, 1)	(1, 1, 2)	(1, 1, 2)	(0.333, 0.5, 1)	(1, 2, 3)	(1, 1, 2)	(1, 1, 2)
	C	(1, 2, 3)	(0.5, 1, 1)	(1, 1, 2)	(0.333, 0.5, 1)	(1, 1, 2)	(1, 1, 2)	(1, 1, 2)
	D	(2, 3, 4)	(1, 2, 3)	(1, 2, 3)	(1, 1, 2)	(1, 1, 2)	(1, 1, 2)	(1, 1, 2)
	E	(0.333, 0.5, 1)	(0.333, 0.5, 1)	(0.5, 1, 1)	(0.5, 1, 1)	(1, 1, 2)	(1, 1, 2)	(1, 1, 2)
	F	(0.333, 0.5, 1)	(0.5, 1, 1)	(0.5, 1, 1)	(0.5, 1, 1)	(0.5, 1, 1)	(1, 1, 2)	(1, 1, 2)
	G	(0.5, 1, 1)	(0.5, 1, 1)	(0.5, 1, 1)	(0.5, 1, 1)	(0.5, 1, 1)	(0.5, 1, 1)	(1, 1, 2)
C.R.= 0.053								

Table 3.4 The fuzzy positive reciprocal matrix of seven alternatives under reduce safety and security incident related loss

		A	B	C	D	E	F	G
Reduce safety and security incident related loss	A	(1, 1, 2)	(1, 1, 2)	(1, 1, 2)	(0.333, 0.5, 1)	(0.333, 0.5, 1)	(1, 1, 2)	(1, 1, 2)
	B	(0.5, 1, 1)	(1, 1, 2)	(1, 1, 2)	(1, 1, 2)	(1, 1, 2)	(1, 1, 2)	(1, 2, 3)
	C	(0.5, 1, 1)	(0.5, 1, 1)	(1, 1, 2)	(0.333, 0.5, 1)	(0.333, 0.5, 1)	(1, 1, 2)	(1, 1, 2)
	D	(1, 2, 3)	(0.5, 1, 1)	(1, 2, 3)	(1, 1, 2)	(2, 3, 4)	(1, 1, 2)	(1, 1, 2)
	E	(1, 2, 3)	(0.5, 1, 1)	(1, 2, 3)	(0.25, 0.333, 0.5)	(1, 1, 2)	(2, 3, 4)	(2, 3, 4)
	F	(0.5, 1, 1)	(0.5, 1, 1)	(0.5, 1, 1)	(0.5, 1, 1)	(0.25, 0.333, 0.5)	(1, 1, 2)	(1, 1, 2)
	G	(0.5, 1, 1)	(0.333, 0.5, 1)	(0.5, 1, 1)	(0.5, 1, 1)	(0.25, 0.333, 0.5)	(0.5, 1, 1)	(1, 1, 2)
C.R.= 0.057								

Step 2 Calculate the fuzzy weights of fuzzy positive reciprocal matrix

Table 3.5 The geometric mean of TFN and the fuzzy weights of three criteria

	i =Financial loss	$i =$ Reputation loss	$i =$ Safety and security incident related loss
$\tilde{Z}_i^C$	(0.693, 0.794, 1.587)	(0.5, 0.693, 1)	(1.26, 1.817, 2.884)
$\widetilde{W}_i^C$	(0.127, 0.24, 0.647)	(0.091, 0.21, 0.408)	(0.23, 0.55, 1.176)

Table 3.6 The geometric mean of TFN and the fuzzy weights of seven strategies under reduce financial loss

	i =A	$i =$ B	$i =$ C	$i =$ D	$i =$ E	$i =$ F	$i =$ G
$\tilde{Z}_i^{FA}$	(1, 1.811, 2.831)	(0.855, 1.346, 2.284)	(0.624, 0.743, 1.486)	(0.566, 0.82, 1.426)	(0.624, 0.906, 1.669)	(0.512, 0.743, 1.219)	(0.575, 1, 1.292)
$\widetilde{W}_i^{FA}$	(0.082, 0.246, 0.595)	(0.07, 0.183, 0.48)	(0.051, 0.101, 0.312)	(0.046, 0.111, 0.3)	(0.051, 0.123, 0.351)	(0.042, 0.101, 0.256)	(0.047, 0.136, 0.272)

Table 3.7 The geometric mean of TFN and the fuzzy weights of seven strategies under reduce reputation loss

	i =A	$i =$ B	$i =$ C	$i =$ D	$i =$ E	$i =$ F	$i =$ G
$\tilde{Z}_i^{FA}$	(0.701, 0.944, 1.669)	(0.774, 1, 1.739)	(0.774, 1, 1.739)	(1.104, 1.426, 2.479)	(0.599, 0.82, 1.346)	(0.575, 0.906, 1.219)	(0.552, 1, 1.104)
$\widetilde{W}_i^{FA}$	(0.062, 0.133, 0.328)	(0.069, 0.141, 0.342)	(0.069, 0.141, 0.342)	(0.098, 0.201, 0.488)	(0.053, 0.116, 0.265)	(0.051, 0.128, 0.24)	(0.049, 0.141, 0.217)

Table 3.8 The geometric mean of TFN and the fuzzy weights of seven strategies under reduce safety and security incident related loss

	i =A	$i =$ B	$i =$ C	$i =$ D	$i =$ E	$i =$ F	$i =$ G
$\tilde{Z}_i^{FA}$	(0.731, 0.82, 1.641)	(0.906, 1.104, 1.919)	(0.599, 0.82, 1.346)	(1, 1.426, 2.246)	(0.906, 1.426, 2.034)	(0.552, 0.855, 1.104)	(0.472, 0.774, 1)
$\widetilde{W}_i^{FA}$	(0.065, 0.114, 0.318)	(0.08, 0.153, 0.372)	(0.053, 0.114, 0.261)	(0.089, 0.197, 0.435)	(0.08, 0.197, 0.394)	(0.049, 0.118, 0.214)	(0.042, 0.107, 0.194)

Step 3 Defuzzify the fuzzy weights and normalise the crisp weights

Table 3.9 The defuzzified and standardized weights of three criteria

	Financial loss	Reputation loss	Safety and security incident related loss
Defuzzified weights	0.289	0.223	0.601
Standardised weights	0.26	0.2	0.54

Table 3.10 The defuzzified and standardized weights of seven strategies under reduce financial loss

	A	B	C	D	E	F	G
Defuzzified weights	0.277	0.213	0.128	0.132	0.149	0.117	0.144
Standardised weights	0.239	0.184	0.11	0.114	0.128	0.101	0.124

Table 3.11 The defuzzified and standardized weights of seven strategies under reduce reputation loss

	A	B	C	D	E	F	G
Defuzzified weights	0.154	0.162	0.162	0.232	0.13	0.134	0.138
Standardised weights	0.138	0.146	0.146	0.208	0.117	0.12	0.124

Table 3.12 The defuzzified and standardized weights of seven strategies under reduce safety and security incident related loss

	A	B	C	D	E	F	G
Defuzzified weights	0.139	0.177	0.128	0.219	0.211	0.123	0.111
Standardised weights	0.126	0.16	0.116	0.198	0.19	0.111	0.1

Sample 4

Step 1 Build fuzzy positive reciprocal matrix

Table 4.1 The fuzzy positive reciprocal matrix of three criteria

	Reduce financial loss	Reduce reputation loss	Reduce safety and security incident related loss
Reduce financial loss	(1, 1, 2)	(3, 4, 5)	(2, 3, 4)
Reduce reputation loss	(0.2, 0.25, 0.333)	(1, 1, 2)	(0.25, 0.333, 0.5)
Reduce safety and security incident related loss	(0.25, 0.333, 0.5)	(2, 3, 4)	(1, 1, 2)
C.R. = 0.063			

Table 4.2 The fuzzy positive reciprocal matrix of seven strategies under reduce financial loss

		A	B	C	D	E	F	G
Reduce financial loss	A	(1, 1, 2)	(1, 2, 3)	(1, 2, 3)	(2, 3, 4)	(1, 2, 3)	(2, 3, 4)	(2, 3, 4)
	B	(0.333, 0.5, 1)	(1, 1, 2)	(1, 2, 3)	(1, 2, 3)	(2, 3, 4)	(2, 3, 4)	(3, 4, 5)
	C	(0.333, 0.5, 1)	(0.333, 0.5, 1)	(1, 1, 2)	(1, 2, 3)	(1, 2, 3)	(0.333, 0.5, 1)	(2, 3, 4)
	D	(0.25, 0.333, 0.5)	(0.333, 0.5, 1)	(0.333, 0.5, 1)	(1, 1, 2)	(1, 1, 2)	(1, 1, 2)	(2, 3, 4)
	E	(0.333, 0.5, 1)	(0.25, 0.333, 0.5)	(0.333, 0.5, 1)	(0.5, 1, 1)	(1, 1, 2)	(1, 1, 2)	(1, 1, 2)
	F	(0.25, 0.333, 0.5)	(0.25, 0.333, 0.5)	(1, 2, 3)	(0.5, 1, 1)	(0.5, 1, 1)	(1, 1, 2)	(1, 1, 2)
	G	(0.25, 0.333, 0.5)	(0.2, 0.25, 0.333)	(0.25, 0.333, 0.5)	(0.25, 0.333, 0.5)	(0.5, 1, 1)	(0.5, 1, 1)	(1, 1, 2)
C.R.= 0.053								

Table 4.3 The fuzzy positive reciprocal matrix of seven strategies under reduce reputation loss

Reduce reputation loss		A	B	C	D	E	F	G
	A	(1, 1, 2)	(1, 1, 2)	(1, 1, 2)	(0.333, 0.5, 1)	(2, 3, 4)	(2, 3, 4)	(1, 2, 3)
	B	(0.5, 1, 1)	(1, 1, 2)	(2, 3, 4)	(2, 3, 4)	(2, 3, 4)	(2, 3, 4)	(2, 3, 4)
	C	(0.5, 1, 1)	(0.25, 0.333, 0.5)	(1, 1, 2)	(0.333, 0.5, 1)	(0.333, 0.5, 1)	(2, 3, 4)	(2, 3, 4)
	D	(1, 2, 3)	(0.25, 0.333, 0.5)	(1, 2, 3)	(1, 1, 2)	(2, 3, 4)	(2, 3, 4)	(2, 3, 4)
	E	(0.25, 0.333, 0.5)	(0.25, 0.333, 0.5)	(1, 2, 3)	(0.25, 0.333, 0.5)	(1, 1, 2)	(2, 3, 4)	(2, 3, 4)
	F	(0.25, 0.333, 0.5)	(0.25, 0.333, 0.5)	(0.25, 0.333, 0.5)	(0.25, 0.333, 0.5)	(0.25, 0.333, 0.5)	(1, 1, 2)	(0.333, 0.5, 1)
	G	(0.333, 0.5, 1)	(0.25, 0.333, 0.5)	(0.25, 0.333, 0.5)	(0.25, 0.333, 0.5)	(0.25, 0.333, 0.5)	(1, 2, 3)	(1, 1, 2)
C.R.= 0.078								

Table 4.4 The fuzzy positive reciprocal matrix of seven alternatives under reduce safety and security incident related loss

Reduce safety and security incident related loss		A	B	C	D	E	F	G
	A	(1, 1, 2)	(1, 1, 2)	(1, 2, 3)	(1, 1, 2)	(1, 1, 2)	(1, 2, 3)	(1, 2, 3)
	B	(0.5, 1, 1)	(1, 1, 2)	(1, 1, 2)	(1, 1, 2)	(1, 1, 2)	(2, 3, 4)	(1, 2, 3)
	C	(0.333, 0.5, 1)	(0.5, 1, 1)	(1, 1, 2)	(1, 1, 2)	(1, 2, 3)	(2, 3, 4)	(3, 4, 5)
	D	(0.5, 1, 1)	(0.5, 1, 1)	(0.5, 1, 1)	(1, 1, 2)	(1, 2, 3)	(2, 3, 4)	(3, 4, 5)
	E	(0.5, 1, 1)	(0.5, 1, 1)	(0.333, 0.5, 1)	(0.333, 0.5, 1)	(1, 1, 2)	(2, 3, 4)	(3, 4, 5)
	F	(0.333, 0.5, 1)	(0.25, 0.333, 0.5)	(0.25, 0.333, 0.5)	(0.25, 0.333, 0.5)	(0.25, 0.333, 0.5)	(1, 1, 2)	(1, 2, 3)
	G	(0.333, 0.5, 1)	(0.333, 0.5, 1)	(0.2, 0.25, 0.333)	(0.2, 0.25, 0.333)	(0.2, 0.25, 0.333)	(0.333, 0.5, 1)	(1, 1, 2)
C.R.= 0.038								

Step 2 Calculate the fuzzy weights of fuzzy positive reciprocal matrix

Table 4.5 The geometric mean of TFN and the fuzzy weights of three criteria

	i =Financial loss	$i =$ Reputation loss	$i =$ Safety and security incident related loss
$\tilde{Z}_i^C$	(1.817, 2.289, 3.42)	(0.368, 0.437, 0.693)	(0.794, 1, 1.587)
$\widetilde{W}_i^C$	(0.319, 0.614, 1.148)	(0.065, 0.117, 0.233)	(0.139, 0.268, 0.533)

Table 4.6 The geometric mean of TFN and the fuzzy weights of seven strategies under reduce financial loss

	i =A	$i =$ B	$i =$ C	$i =$ D	$i =$ E	$i =$ F	$i =$ G
$\tilde{Z}_i^{FA}$	(1.346, 2.155, 3.203)	(1.219, 1.842, 2.826)	(0.689, 1.06, 1.842)	(0.662, 0.82, 1.486)	(0.543, 0.701, 1.219)	(0.552, 0.807, 1.17)	(0.36, 0.512, 0.701)
$\widetilde{W}_i^{FA}$	(0.108, 0.273, 0.596)	(0.098, 0.233, 0.526)	(0.055, 0.134, 0.343)	(0.053, 0.104, 0.277)	(0.044, 0.089, 0.227)	(0.044, 0.102, 0.218)	(0.029, 0.065, 0.131)

Table 4.7 The geometric mean of TFN and the fuzzy weights of seven strategies under reduce reputation loss

	i =A	$i =$ B	$i =$ C	$i =$ D	$i =$ E	$i =$ F	$i =$ G
$\tilde{Z}_i^{FA}$	(1.042, 1.369, 2.34)	(1.486, 2.192, 2.972)	(0.662, 0.96, 1.486)	(1.104, 1.669, 2.479)	(0.673, 0.944, 1.426)	(0.318, 0.413, 0.673)	(0.387, 0.534, 0.869)
$\widetilde{W}_i^{FA}$	(0.085, 0.169, 0.413)	(0.121, 0.271, 0.524)	(0.054, 0.119, 0.262)	(0.09, 0.207, 0.437)	(0.055, 0.117, 0.251)	(0.026, 0.051, 0.119)	(0.032, 0.066, 0.153)

Table 4.8 The geometric mean of TFN and the fuzzy weights of seven strategies under reduce safety and security incident related loss

	i =A	$i =$ B	$i =$ C	$i =$ D	$i =$ E	$i =$ F	$i =$ G
$\tilde{Z}_i^{FA}$	(1, 1.346, 2.38)	(1, 1.292, 2.119)	(1, 1.426, 2.188)	(0.96, 1.575, 1.982)	(0.774, 1.17, 1.697)	(0.387, 0.534, 0.869)	(0.313, 0.41, 0.689)
$\widetilde{W}_i^{FA}$	(0.084, 0.174, 0.438)	(0.084, 0.167, 0.39)	(0.084, 0.184, 0.403)	(0.081, 0.203, 0.365)	(0.065, 0.151, 0.312)	(0.032, 0.069, 0.16)	(0.026, 0.053, 0.127)

Step 3 Defuzzify the fuzzy weights and normalise the crisp weights

Table 4.9 The defuzzified and standardized weights of three criteria

	Financial loss	Reputation loss	Safety and security incident related loss
Defuzzified weights	0.654	0.128	0.291
Standardised weights	0.61	0.119	0.271

Table 4.10 The defuzzified and standardized weights of seven strategies under reduce financial loss

	A	B	C	D	E	F	G
Defuzzified weights	0.299	0.26	0.156	0.124	0.104	0.112	0.07
Standardised weights	0.266	0.231	0.139	0.11	0.093	0.099	0.062

Table 4.11 The defuzzified and standardized weights of seven strategies under reduce reputation loss

	A	B	C	D	E	F	G
Defuzzified weights	0.196	0.288	0.132	0.226	0.129	0.058	0.075
Standardised weights	0.177	0.261	0.119	0.204	0.117	0.053	0.068

Table 4.12 The defuzzified and standardized weights of seven strategies under reduce safety and security incident related loss

	A	B	C	D	E	F	G
Defuzzified weights	0.203	0.19	0.204	0.21	0.163	0.078	0.061
Standardised weights	0.183	0.171	0.184	0.189	0.147	0.07	0.055

Sample 5

Step 1 Build fuzzy positive reciprocal matrix

Table 5.1 The fuzzy positive reciprocal matrix of three criteria

	Reduce financial loss	Reduce reputation loss	Reduce safety and security incident related loss
Reduce financial loss	(1, 1, 2)	(4, 5, 6)	(1, 2, 3)
Reduce reputation loss	(0.167, 0.2, 0.25)	(1, 1, 2)	(0.333, 0.5, 1)
Reduce safety and security incident related loss	(0.333, 0.5, 1)	(1, 2, 3)	(1, 1, 2)
C.R. = 0.005			

Table 5.2 The fuzzy positive reciprocal matrix of seven strategies under reduce financial loss

		A	B	C	D	E	F	G
Reduce financial loss	A	(1, 1, 2)	(1, 2, 3)	(1, 2, 3)	(1, 2, 3)	(1, 2, 3)	(0.25, 0.333, 0.5)	(1, 2, 3)
	B	(0.333, 0.5, 1)	(1, 1, 2)	(1, 2, 3)	(1, 1, 2)	(1, 2, 3)	(0.25, 0.333, 0.5)	(1, 2, 3)
	C	(0.333, 0.5, 1)	(0.333, 0.5, 1)	(1, 1, 2)	(1, 2, 3)	(1, 2, 3)	(0.2, 0.25, 0.333)	(1, 2, 3)
	D	(0.333, 0.5, 1)	(0.5, 1, 1)	(0.333, 0.5, 1)	(1, 1, 2)	(1, 2, 3)	(0.2, 0.25, 0.333)	(1, 2, 3)
	E	(0.333, 0.5, 1)	(0.333, 0.5, 1)	(0.333, 0.5, 1)	(0.333, 0.5, 1)	(1, 1, 2)	(0.2, 0.25, 0.333)	(1, 2, 3)
	F	(2, 3, 4)	(2, 3, 4)	(3, 4, 5)	(3, 4, 5)	(3, 4, 5)	(1, 1, 2)	(1, 2, 3)
	G	(0.333, 0.5, 1)	(0.333, 0.5, 1)	(0.333, 0.5, 1)	(0.333, 0.5, 1)	(0.333, 0.5, 1)	(0.333, 0.5, 1)	(1, 1, 2)
C.R.= 0.055								

Table 5.3 The fuzzy positive reciprocal matrix of seven strategies under reduce reputation loss

		A	B	C	D	E	F	G
Reduce reputation loss	A	(1, 1, 2)	(1, 1, 2)	(1, 1, 2)	(1, 1, 2)	(1, 1, 2)	(1, 2, 3)	(1, 2, 3)
	B	(0.5, 1, 1)	(1, 1, 2)	(1, 2, 3)	(1, 1, 2)	(1, 2, 3)	(1, 2, 3)	(1, 2, 3)
	C	(0.5, 1, 1)	(0.333, 0.5, 1)	(1, 1, 2)	(1, 1, 2)	(1, 1, 2)	(1, 1, 2)	(1, 1, 2)
	D	(0.5, 1, 1)	(0.5, 1, 1)	(0.5, 1, 1)	(1, 1, 2)	(1, 1, 2)	(1, 1, 2)	(1, 1, 2)
	E	(0.5, 1, 1)	(0.333, 0.5, 1)	(0.5, 1, 1)	(0.5, 1, 1)	(1, 1, 2)	(1, 1, 2)	(1, 1, 2)
	F	(0.333, 0.5, 1)	(0.333, 0.5, 1)	(0.5, 1, 1)	(0.5, 1, 1)	(0.5, 1, 1)	(1, 1, 2)	(1, 1, 2)
	G	(0.333, 0.5, 1)	(0.333, 0.5, 1)	(0.5, 1, 1)	(0.5, 1, 1)	(0.5, 1, 1)	(0.5, 1, 1)	(1, 1, 2)
C.R.= 0.015								

Table 5.4 The fuzzy positive reciprocal matrix of seven alternatives under reduce safety and security incident related loss

		A	B	C	D	E	F	G
Reduce safety and security incident related loss	A	(1, 1, 2)	(1, 2, 3)	(1, 2, 3)	(0.333, 0.5, 1)	(1, 1, 2)	(1, 2, 3)	(1, 2, 3)
	B	(0.333, 0.5, 1)	(1, 1, 2)	(1, 1, 2)	(0.333, 0.5, 1)	(0.333, 0.5, 1)	(1, 1, 2)	(1, 2, 3)
	C	(0.333, 0.5, 1)	(0.5, 1, 1)	(1, 1, 2)	(0.333, 0.5, 1)	(0.25, 0.333, 0.5)	(0.333, 0.5, 1)	(1, 1, 2)
	D	(1, 2, 3)	(1, 2, 3)	(1, 2, 3)	(1, 1, 2)	(0.25, 0.333, 0.5)	(0.333, 0.5, 1)	(1, 1, 2)
	E	(0.5, 1, 1)	(1, 2, 3)	(2, 3, 4)	(2, 3, 4)	(1, 1, 2)	(0.333, 0.5, 1)	(1, 1, 2)
	F	(0.333, 0.5, 1)	(0.5, 1, 1)	(1, 2, 3)	(1, 2, 3)	(1, 2, 3)	(1, 1, 2)	(1, 1, 2)
	G	(0.333, 0.5, 1)	(0.333, 0.5, 1)	(0.5, 1, 1)	(0.5, 1, 1)	(0.5, 1, 1)	(0.5, 1, 1)	(1, 1, 2)
C.R.= 0.086								

Step 2 Calculate the fuzzy weights of fuzzy positive reciprocal matrix

Table 5.5 The geometric mean of TFN and the fuzzy weights of three criteria

	i =Financial loss	i = Reputation loss	i = Safety and security incident related loss
$\tilde{Z}_i^C$	(1.587, 2.154, 3.302)	(0.382, 0.464, 0.794)	(0.693, 1, 1.817)
$\widetilde{W}_i^C$	(0.268, 0.595, 1.24)	(0.065, 0.128, 0.298)	(0.117, 0.276, 0.683)

Table 5.6 The geometric mean of TFN and the fuzzy weights of seven strategies under reduce financial loss

	i =A	i = B	i = C	i = D	i = E	i = F	i = G
$\tilde{Z}_i^{FA}$	(0.82, 1.402, 2.192)	(0.701, 1.042, 1.768)	(0.581, 0.906, 1.511)	(0.526, 0.82, 1.292)	(0.424, 0.61, 1.104)	(1.952, 2.737, 3.826)	(0.39, 0.552, 1.104)
$\widetilde{W}_i^{FA}$	0.064, 0.174, 0.406	(0.055, 0.129, 0.328)	(0.045, 0.112, 0.28)	(0.041, 0.102, 0.239)	(0.033, 0.076, 0.205)	(0.153, 0.339, 0.709)	(0.03, 0.068, 0.205)

Table 5.7 The geometric mean of TFN and the fuzzy weights of seven strategies under reduce reputation loss

	i =A	i = B	i = C	i = D	i = E	i = F	i = G
$\tilde{Z}_i^{FA}$	(1, 1.219, 2.246)	(0.906, 1.486, 2.284)	(0.774, 0.906, 1.641)	(0.743, 1, 1.486)	(0.635, 0.906, 1.346)	(0.543, 0.82, 1.219)	(0.492, 0.82, 1.104)
$\widetilde{W}_i^{FA}$	(0.088, 0.17, 0.441)	(0.08, 0.208, 0.448)	(0.068, 0.127, 0.322)	(0.066, 0.14, 0.292)	(0.056, 0.127, 0.264)	(0.048, 0.115, 0.239)	(0.043, 0.115, 0.217)

Table 5.8 The geometric mean of TFN and the fuzzy weights of seven strategies under reduce safety and security incident related loss

	i =A	i = B	i = C	i = D	i = E	i = F	i = G
$\tilde{Z}_i^{FA}$	(0.855, 1.346, 2.284)	(0.624, 0.82, 1.575)	(0.464, 0.635, 1.104)	(0.701, 1.042, 1.768)	(0.944, 1.369, 2.119)	(0.74, 1.219, 1.952)	(0.492, 0.82, 1.104)
$\widetilde{W}_i^{FA}$	(0.072, 0.186, 0.47)	(0.0.52, 0.113, 0324)	(0.039, 0.088, 0.227)	(0.059, 0.144, 0.364)	(0.079, 0.189, 0.437)	(0.065, 0.168, 0.402)	(0.041, 0.113, 0.227)

Step 3 Defuzzify the fuzzy weights and normalise the crisp weights

Table 5.9 The defuzzified and standardized weights of three criteria

	Financial loss	Reputation loss	Safety and security incident related loss
Defuzzified weights	0.648	0.146	0.318
Standardised weights	0.583	0.131	0.286

Table 5.10 The defuzzified and standardized weights of seven strategies under reduce financial loss

	A	B	C	D	E	F	G
Defuzzified weights	0.194	0.15	0.129	0.115	0.09	0.37	0.085
Standardised weights	0.172	0.132	0.114	0.101	0.079	0.327	0.075

Table 5.11 The defuzzified and standardized weights of seven strategies under reduce reputation loss

	A	B	C	D	E	F	G
Defuzzified weights	0.202	0.226	0.149	0.153	0.138	0.124	0.12
Standardised weights	0.181	0.204	0.134	0.137	0.124	0.112	0.108

Table 5.12 The defuzzified and standardized weights of seven strategies under reduce safety and security incident related loss

	A	B	C	D	E	F	G
Defuzzified weights	0.214	0.138	0.103	0.166	0.212	0.19	0.12
Standardised weights	0.187	0.121	0.09	0.145	0.185	0.166	0.105

Sample 6

Step 1 Build fuzzy positive reciprocal matrix

Table 6.1 The fuzzy positive reciprocal matrix of three criteria

	Reduce financial loss	Reduce reputation loss	Reduce safety and security incident related loss
Reduce financial loss	(1, 1, 2)	(1, 1, 2)	(1, 1, 2)
Reduce reputation loss	(0.5 ,1, 1)	(1, 1, 2)	(0.333, 0.5, 1)
Reduce safety and security incident related loss	(0.5 ,1, 1)	(1, 2, 3)	(1, 1, 2)
C.R. = 0.046			

Table 6.2 The fuzzy positive reciprocal matrix of seven strategies under reduce financial loss

		A	B	C	D	E	F	G
Reduce financial loss	A	(1, 1, 2)	(1, 2, 3)	(0.333, 0.5, 1)	(1, 2, 3)	(0.333, 0.5, 1)	(0.2, 0.25, 0.333)	(2, 3, 4)
	B	(0.333, 0.5, 1)	(1, 1, 2)	(0.333, 0.5, 1)	(0.333, 0.5, 1)	(0.25, 0.333, 0.5)	(0.143, 0.167, 0.2)	(0.333, 0.5, 1)
	C	(1, 2, 3)	(1, 2, 3)	(1, 1, 2)	(2, 3, 4)	(1, 1, 2)	(0.167;0.200;0.250)	(1, 1, 2)
	D	(0.333, 0.5, 1)	(1, 2, 3)	(0.25, 0.333, 0.5)	(1, 1, 2)	(1, 1, 2)	(0.2, 0.25, 0.333)	(2, 3, 4)
	E	(1, 2, 3)	(2, 3, 4)	(0.5 ,1, 1)	(0.5 ,1, 1)	(1, 1, 2)	(0.2, 0.25, 0.333)	(3, 4, 5)
	F	(3, 4, 5)	(5, 6, 7)	(4, 5, 6)	(3, 4, 5)	(3, 4, 5)	(1, 1, 2)	(6, 7, 8)
	G	(0.25, 0.333, 0.5)	(1, 2, 3)	(0.5 ,1, 1)	(0.25, 0.333, 0.5)	(0.2, 0.25, 0.333)	(0.125, 0.143, 0.167)	(1, 1, 2)
C.R.= 0.070								

Table 6.3 The fuzzy positive reciprocal matrix of seven strategies under reduce reputation loss

		A	B	C	D	E	F	G
Reduce reputation loss	A	(1, 1, 2)	(1, 2, 3)	(1, 1, 2)	(1, 1, 2)	(1, 1, 2)	(1, 1, 2)	(1, 2, 3)
	B	(0.333, 0.5, 1)	(1, 1, 2)	(0.25, 0.333, 0.5)	(0.333, 0.5, 1)	(0.25, 0.333, 0.5)	(0.25, 0.333, 0.5)	(0.333, 0.5, 1)
	C	(0.5 ,1, 1)	(2, 3, 4)	(1, 1, 2)	(2, 3, 4)	(1, 1, 2)	(0.25, 0.333, 0.5)	(1, 1, 2)
	D	(0.5 ,1, 1)	(1, 2, 3)	(0.25, 0.333, 0.5)	(1, 1, 2)	(1, 1, 2)	(0.25, 0.333, 0.5)	(2, 3, 4)
	E	(0.5 ,1, 1)	(2, 3, 4)	(0.5 ,1, 1)	(0.5 ,1, 1)	(1, 1, 2)	(0.2, 0.25, 0.333)	(3, 4, 5)
	F	(0.5 ,1, 1)	(2, 3, 4)	(2, 3, 4)	(2, 3, 4)	(3, 4, 5)	(1, 1, 2)	(3, 4, 5)
	G	(0.333, 0.5, 1)	(1, 2, 3)	(0.5 ,1, 1)	(0.25, 0.333, 0.5)	(0.2, 0.25, 0.333)	(0.2, 0.25, 0.333)	(1, 1, 2)
C.R.= 0.074								

Table 6.4 The fuzzy positive reciprocal matrix of seven alternatives under reduce safety and security incident related loss

		A	B	C	D	E	F	G
Reduce safety and security incident related loss	A	(1, 1, 2)	(1, 1, 2)	(1, 2, 3)	(1, 1, 2)	(1, 1, 2)	(1, 1, 2)	(1, 2, 3)
	B	(0.5 ,1, 1)	(1, 1, 2)	(1, 1, 2)	(1, 1, 2)	(1, 1, 2)	(0.333, 0.5, 1)	(1, 1, 2)
	C	(0.333, 0.5, 1)	(0.5 ,1, 1)	(1, 1, 2)	(2, 3, 4)	(1, 1, 2)	(0.333, 0.5, 1)	(1, 1, 2)
	D	(0.5 ,1, 1)	(0.5 ,1, 1)	(0.25, 0.333, 0.5)	(1, 1, 2)	(1, 1, 2)	(0.333, 0.5, 1)	(1, 2, 3)
	E	(0.5 ,1, 1)	(0.5 ,1, 1)	(0.5 ,1, 1)	(0.5 ,1, 1)	(1, 1, 2)	(0.333, 0.5, 1)	(1, 2, 3)
	F	(0.5 ,1, 1)	(1, 2, 3)	(1, 2, 3)	(1, 2, 3)	(1, 2, 3)	(1, 1, 2)	(1, 2, 3)
	G	(0.333, 0.5, 1)	(0.5 ,1, 1)	(0.5 ,1, 1)	(0.333, 0.5, 1)	(0.333, 0.5, 1)	(0.333, 0.5, 1)	(1, 1, 2)
C.R.= 0.041								

Step 2 Calculate the fuzzy weights of fuzzy positive reciprocal matrix

Table 6.5 The geometric mean of TFN and the fuzzy weights of three criteria

	i =Financial loss	$i =$ Reputation loss	$i =$ Safety and security incident related loss
$\tilde{Z}_i^C$	(1, 1, 2)	(0.55, 0.794, 1.26)	(0.794, 1.26, 1.817)
$\widetilde{W}_i^C$	(0.197, 0.327, 0.853)	(0.108, 0.26, 0.538)	(0.156, 0.413, 0.775)

Table 6.6 The geometric mean of TFN and the fuzzy weights of seven strategies under reduce financial loss

	i =A	$i =$ B	$i =$ C	$i =$ D	$i =$ E	$i =$ F	$i =$ G
$\tilde{Z}_i^{FA}$	(0.641, 0.96, 1.575)	(0.332, 0.445, 0.795)	(0.855, 1.133, 1.842)	(0.615, 0.82, 1.346)	(0.842, 1.292, 1.694)	(3.173, 3.888, 5.052)	(0.36, 0.501, 0.701)
$\widetilde{W}_i^{FA}$	(0.049, 0.106, 0.231)	(0.025, 0.049, 0.117)	(0.066, 0.125, 0.27)	(0.047, 0.091, 0.197)	(0.065, 0.143, 0.248)	(0.244, 0.43, 0.741)	(0.028, 0.055, 0.103)

Table 6.7 The geometric mean of TFN and the fuzzy weights of seven strategies under reduce reputation loss

	i =A	$i =$ B	$i =$ C	$i =$ D	$i =$ E	$i =$ F	$i =$ G
$\tilde{Z}_i^{FA}$	(1, 1.219, 2.246)	(0.345, 0.464, 0.82)	(0.906, 1.17, 1.811)	(0.673, 0.944, 1.426)	(0.763, 1.17, 1.448)	(1.669, 2.38, 3.168)	(0.401, 0.575, 0.855)
$\widetilde{W}_i^{FA}$	(0.085, 0.154, 0.39)	(0.029, 0.059, 0.143)	(0.077, 0.148, 0.315)	(0.057, 0.119, 0.248)	(0.065, 0.148, 0.252)	(0.142, 0.3, 0.55)	(0.034, 0.073, 0.149)

Table 6.8 The geometric mean of TFN and the fuzzy weights of seven strategies under reduce safety and security incident related loss

	i =A	$i =$ B	$i =$ C	$i =$ D	$i =$ E	$i =$ F	$i =$ G
$\tilde{Z}_i^{FA}$	(1, 1.219, 2.246)	(0.774, 0.906, 1.641)	(0.731, 0.96, 1.641)	(0.575, 0.855, 1.292)	(0.575, 1, 1.292)	(0.906, 1.641, 2.42)	(0.438, 0.673, 1.104)
$\widetilde{W}_i^{FA}$	(0.086, 0.168, 0.449)	(0.067, 0.125, 0.328)	(0.063, 0.132, 0.328)	(0.049, 0.118, 0.258)	(0.049, 0.138, 0.258)	(0.078, 0.226, 0.484)	(0.038, 0.093, 0.221)

Step 3 Defuzzify the fuzzy weights and normalise the crisp weights

Table 6.9 The defuzzified and standardized weights of three criteria

	Financial loss	Reputation loss	Safety and security incident related loss
Defuzzified weights	0.393	0.281	0.43
Standardised weights	0.356	0.254	0.39

Table 6.10 The defuzzified and standardized weights of seven strategies under reduce financial loss

	A	B	C	D	E	F	G
Defuzzified weights	0.117	0.057	0.14	0.101	0.147	0.451	0.059
Standardised weights	0.11	0.053	0.13	0.094	0.138	0.421	0.055

Table 6.11 The defuzzified and standardized weights of seven strategies under reduce reputation loss

	A	B	C	D	E	F	G
Defuzzified weights	0.182	0.068	0.164	0.13	0.151	0.316	0.079
Standardised weights	0.167	0.062	0.15	0.12	0.139	0.29	0.072

Table 6.12 The defuzzified and standardized weights of seven strategies under reduce safety and security incident related loss

	A	B	C	D	E	F	G
Defuzzified weights	0.201	0.149	0.153	0.13	0.143	0.244	0.105
Standardised weights	0.179	0.132	0.136	0.115	0.127	0.217	0.093

Sample 7

Step 1 Build fuzzy positive reciprocal matrix

Table 7.1 The fuzzy positive reciprocal matrix of three criteria

	Reduce financial loss	Reduce reputation loss	Reduce safety and security incident related loss
Reduce financial loss	(1, 1, 2)	(7, 8, 9)	(3, 4, 5)
Reduce reputation loss	(0.111, 0.125, 0.143)	(1, 1, 2)	(1, 1, 2)
Reduce safety and security incident related loss	(0.2, 0.25, 0.333)	(0.5, 1, 1)	(1, 1, 2)
C.R. = 0.046			

Table 7.2 The fuzzy positive reciprocal matrix of seven strategies under reduce financial loss

		A	B	C	D	E	F	G
Reduce financial loss	A	(1, 1, 2)	(1, 1, 2)	(1, 2, 3)	(1, 1, 2)	(1, 2, 3)	(1, 2, 3)	(1, 2, 3)
	B	(0.5, 1, 1)	(1, 1, 2)	(2, 3, 4)	(2, 3, 4)	(1, 2, 3)	(1, 2, 3)	(2, 3, 4)
	C	(0.333, 0.5, 1)	(0.25, 0.333, 0.5)	(1, 1, 2)	(1, 1, 2)	(1, 2, 3)	(1, 1, 2)	(1, 1, 2)
	D	(0.5, 1, 1)	(0.25, 0.333, 0.5)	(0.5, 1, 1)	(1, 1, 2)	(1, 1, 2)	(1, 1, 2)	(1, 1, 2)
	E	(0.333, 0.5, 1)	(0.333, 0.5, 1)	(0.333, 0.5, 1)	(0.5, 1, 1)	(1, 1, 2)	(0.333, 0.5, 1)	(1, 1, 2)
	F	(0.333, 0.5, 1)	(0.333, 0.5, 1)	(0.5, 1, 1)	(0.5, 1, 1)	(1, 2, 3)	(1, 1, 2)	(1, 2, 3)
	G	(0.333, 0.5, 1)	(0.25, 0.333, 0.5)	(0.5, 1, 1)	(0.5, 1, 1)	(0.5, 1, 1)	(0.333, 0.5, 1)	(1, 1, 2)
C.R.=0.025								

Table 7.3 The fuzzy positive reciprocal matrix of seven strategies under reduce reputation loss

		A	B	C	D	E	F	G
Reduce reputation loss	A	(1, 1, 2)	(1, 1, 2)	(1, 2, 3)	(1, 1, 2)	(1, 1, 2)	(1, 2, 3)	(1, 2, 3)
	B	(0.5, 1, 1)	(1, 1, 2)	(1, 2, 3)	(1, 1, 2)	(1, 1, 2)	(1, 1, 2)	(1, 2, 3)
	C	(0.333, 0.5, 1)	(0.333, 0.5, 1)	(1, 1, 2)	(1, 1, 2)	(1, 1, 2)	(0.333, 0.5, 1)	(1, 1, 2)
	D	(0.5, 1, 1)	(0.5, 1, 1)	(0.5, 1, 1)	(1, 1, 2)	(1, 1, 2)	(1, 1, 2)	(1, 1, 2)
	E	(0.5, 1, 1)	(0.5, 1, 1)	(0.5, 1, 1)	(0.5, 1, 1)	(1, 1, 2)	(1, 1, 2)	(1, 1, 2)
	F	(0.333, 0.5, 1)	(0.5, 1, 1)	(1, 2, 3)	(0.5, 1, 1)	(0.5, 1, 1)	(1, 1, 2)	(1, 1, 2)
	G	(0.333, 0.5, 1)	(0.333, 0.5, 1)	(0.5, 1, 1)	(0.5, 1, 1)	(0.5, 1, 1)	(0.5, 1, 1)	(1, 1, 2)
C.R.= 0.020								

Table 7.4 The fuzzy positive reciprocal matrix of seven alternatives under reduce safety and security incident related loss

		A	B	C	D	E	F	G
Reduce safety and security incident related loss	A	(1, 1, 2)	(1, 1, 2)	(1, 1, 2)	(1, 1, 2)	(1, 2, 3)	(1, 2, 3)	(1, 2, 3)
	B	(0.5, 1, 1)	(1, 1, 2)	(1, 1, 2)	(1, 2, 3)	(1, 2, 3)	(1, 2, 3)	(1, 2, 3)
	C	(0.5, 1, 1)	(0.5, 1, 1)	(1, 1, 2)	(1, 2, 3)	(1, 1, 2)	(0.333, 0.5, 1)	(1, 2, 3)
	D	(0.5, 1, 1)	(0.333, 0.5, 1)	(0.333, 0.5, 1)	(1, 1, 2)	(1, 1, 2)	(1, 1, 2)	(1, 2, 3)
	E	(0.333, 0.5, 1)	(0.333, 0.5, 1)	(0.5, 1, 1)	(0.5, 1, 1)	(1, 1, 2)	(0.333, 0.5, 1)	(1, 1, 2)
	F	(0.333, 0.5, 1)	(0.333, 0.5, 1)	(1, 2, 3)	(0.5, 1, 1)	(1, 2, 3)	(1, 1, 2)	(1, 2, 3)
	G	(0.333, 0.5, 1)	(0.333, 0.5, 1)	(0.333, 0.5, 1)	(0.333, 0.5, 1)	(0.5, 1, 1)	(0.333, 0.5, 1)	(1, 1, 2)
C.R.= 0.037								

Step 2 Calculate the fuzzy weights of fuzzy positive reciprocal matrix

Table 7.5 The geometric mean of TFN and the fuzzy weights of three criteria

	i =Financial loss	i = Reputation loss	i = Safety and security incident related loss
$\tilde{Z}_i^C$	(2.759, 3.175, 4.481)	(0.481, 0.5, 0.83)	(0.464, 0.63, 0.874)
$\widetilde{W}_i^C$	(0.446, 0.738, 1.21)	(0.078, 0.116, 0.224)	(0.075, 0.146, 0.236)

Table 7.6 The geometric mean of TFN and the fuzzy weights of seven strategies under reduce financial loss

	i =A	i = B	i = C	i = D	i = E	i = F	i = G
$\tilde{Z}_i^{FA}$	(1, 1.486, 2.251)	(1.219, 1.952, 2.737)	(0.701, 0.855, 1.575)	(0.673, 0.855, 1.346)	(0.483, 0.673, 1.219)	(0.599, 1, 1.511)	(0.445, 0.701, 1)
$\widetilde{W}_i^{FA}$	(0.084, 0.198, 0.492)	(0.102, 0.26, 0.535)	(0.059, 0.114, 0.307)	(0.057, 0.114, 0.263)	(0.041, 0.089, 0.238)	(0.050, 0.133, 0.295)	(0.037, 0.093, 0.195)

Table 7.7 The geometric mean of TFN and the fuzzy weights of seven strategies under reduce reputation loss

	i =A	i = B	i = C	i = D	i = E	i = F	i = G
$\tilde{Z}_i^{FA}$	(1, 1.346, 2.38)	(0.906, 1.219, 2.034)	(0.624, 0.743, 1.486)	(0.743, 1, 1.486)	(0.673, 1, 1.346)	(0.635, 1, 1.426)	(0.492, 0.82, 1.104)
$\widetilde{W}_i^{FA}$	(0.089, 0.189, 0.469)	(0.08, 0.171, 0.401)	(0.055, 0.104, 0.293)	(0.066, 0.14, 0.293)	(0.06, 0.14, 0.265)	(0.056, 0.14, 0.281)	(0.044, 0.115, 0.218)

Table 7.8 The geometric mean of TFN and the fuzzy weights of seven strategies under reduce safety and security incident related loss

	i =A	i = B	i = C	i = D	i = E	i = F	i = G
$\tilde{Z}_i^{FA}$	(1, 1.346, 2.38)	(0.906, 1.486, 2.284)	(0.701, 1.104, 1.669)	(0.662, 0.906, 1.575)	(0.512, 0.743, 1.219)	(0.662, 1.104, 1.768)	(0.413, 0.61, 1.104)
$\widetilde{W}_i^{FA}$	(0.083, 0.184, 0.49)	(0.075, 0.204, 0.47)	(0.058, 0.151, 0.344)	(0.055, 0.124, 0.324)	(0.043, 0.102, 0.251)	(0.055, 0.151, 0.364)	(0.034, 0.084, 0.227)

Step 3 Defuzzify the fuzzy weights and normalise the crisp weights

Table 7.9 The defuzzified and standardized weights of three criteria

	Financial loss	Reputation loss	Safety and security incident related loss
Defuzzified weights	0.768	0.128	0.149
Standardised weights	0.735	0.122	0.143

Table 7.10 The defuzzified and standardized weights of seven strategies under reduce financial loss

	A	B	C	D	E	F	G
Defuzzified weights	0.228	0.279	0.137	0.129	0.106	0.146	0.101
Standardised weights	0.202	0.248	0.122	0.115	0.094	0.13	0.09

Table 7.11 The defuzzified and standardized weights of seven strategies under reduce reputation loss

	A	B	C	D	E	F	G
Defuzzified weights	0.219	0.194	0.128	0.153	0.148	0.15	0.12
Standardised weights	0.197	0.175	0.115	0.138	0.133	0.135	0.108

Table 7.12 The defuzzified and standardized weights of seven strategies under reduce safety and security incident related loss

	A	B	C	D	E	F	G
Defuzzified weights	0.219	0.227	0.168	0.146	0.117	0.171	0.099
Standardised weights	0.191	0.198	0.146	0.127	0.102	0.149	0.087

Sample 8

Step 1 Build fuzzy positive reciprocal matrix

Table 8.1 The fuzzy positive reciprocal matrix of three criteria

	Reduce financial loss	Reduce reputation loss	Reduce safety and security incident related loss
Reduce financial loss	(1, 1, 2)	(4, 5, 6)	(1, 1, 2)
Reduce reputation loss	(0.167, 0.2, 0.25)	(1, 1, 2)	(0.333, 0.5, 1)
Reduce safety and security incident related loss	(0.5, 1, 1)	(1, 2, 3)	(1, 1, 2)
C.R. = 0.081			

Table 8.2 The fuzzy positive reciprocal matrix of seven strategies under reduce financial loss

		A	B	C	D	E	F	G
Reduce financial loss	A	(1, 1, 2)	(1, 1, 2)	(1, 1, 2)	(0.333, 0.5, 1)	(0.25, 0.333, 0.5)	(2, 3, 4)	(4, 5, 6)
	B	(0.5, 1, 1)	(1, 1, 2)	(0.333, 0.5, 1)	(0.333, 0.5, 1)	(0.2, 0.250, 0.333)	(1, 2, 3)	(3, 4, 5)
	C	(0.5, 1, 1)	(1, 2, 3)	(1, 1, 2)	(1, 2, 3)	(1, 2, 3)	(3, 4, 5)	(4, 5, 6)
	D	(1, 2, 3)	(1, 2, 3)	(0.333, 0.5, 1)	(1, 1, 2)	(0.333, 0.5, 1)	(1, 2, 3)	(2, 3, 4)
	E	(2, 3, 4)	(3, 4, 5)	(0.333, 0.5, 1)	(1, 2, 3)	(1, 1, 2)	(2, 3, 4)	(3, 4, 5)
	F	(0.25, 0.333, 0.5)	(0.333, 0.5, 1)	(0.2, 0.250, 0.333)	(0.333, 0.5, 1)	(0.25, 0.333, 0.5)	(1, 1, 2)	(1, 1, 2)
	G	(0.167, 0.2, 0.25)	(0.2, 0.250, 0.333)	(0.167, 0.2, 0.25)	(0.25, 0.333, 0.5)	(0.2, 0.250, 0.333)	(0.5, 1, 1)	(1, 1, 2)
C.R.= 0.055								

Table 8.3 The fuzzy positive reciprocal matrix of seven strategies under reduce reputation loss

		A	B	C	D	E	F	G
Reduce reputation loss	A	(1, 1, 2)	(1, 1, 2)	(1, 1, 2)	(0.2, 0.250, 0.333)	(0.333, 0.5, 1)	(1, 1, 2)	(4, 5, 6)
	B	(0.5, 1, 1)	(1, 1, 2)	(1, 1, 2)	(0.333, 0.5, 1)	(0.333, 0.5, 1)	(2, 3, 4)	(4, 5, 6)
	C	(0.5, 1, 1)	(0.5, 1, 1)	(1, 1, 2)	(1, 1, 2)	(1, 1, 2)	(1, 2, 3)	(4, 5, 6)
	D	(3, 4, 5)	(1, 2, 3)	(0.5, 1, 1)	(1, 1, 2)	(1, 1, 2)	(2, 3, 4)	(3, 4, 5)
	E	(1, 2, 3)	(1, 2, 3)	(0.5, 1, 1)	(0.5, 1, 1)	(1, 1, 2)	(4, 5, 6)	(4, 5, 6)
	F	(0.5, 1, 1)	(0.25, 0.333, 0.5)	(0.333, 0.5, 1)	(0.25, 0.333, 0.5)	(0.167, 0.2, 0.25)	(1, 1, 2)	(1, 1, 2)
	G	(0.167, 0.2, 0.25)	(0.167, 0.2, 0.25)	(0.167, 0.2, 0.25)	(0.2, 0.250, 0.333)	(0.167, 0.2, 0.25)	(0.5, 1, 1)	(1, 1, 2)

C.R.= 0.045

Table 8.4 The fuzzy positive reciprocal matrix of seven alternatives under reduce safety and security incident related loss

		A	B	C	D	E	F	G
Reduce safety and security incident related loss	A	(1, 1, 2)	(1, 1, 2)	(1, 1, 2)	(1, 1, 2)	(1, 1, 2)	(1, 2, 3)	(3, 4, 5)
	B	(0.5, 1, 1)	(1, 1, 2)	(1, 1, 2)	(1, 1, 2)	(1, 1, 2)	(2, 3, 4)	(5, 6, 7)
	C	(0.5, 1, 1)	(0.5, 1, 1)	(1, 1, 2)	(2, 3, 4)	(2, 3, 4)	(3, 4, 5)	(4, 5, 6)
	D	(0.5, 1, 1)	(0.5, 1, 1)	(0.25, 0.333, 0.5)	(1, 1, 2)	(1, 1, 2)	(2, 3, 4)	(4, 5, 6)
	E	(0.5, 1, 1)	(0.5, 1, 1)	(0.25, 0.333, 0.5)	(0.5, 1, 1)	(1, 1, 2)	(1, 2, 3)	(4, 5, 6)
	F	(0.333, 0.5, 1)	(0.25, 0.333, 0.5)	(0.2, 0.250, 0.333)	(0.25, 0.333, 0.5)	(0.333, 0.5, 1)	(1, 1, 2)	(1, 2, 3)
	G	(0.2, 0.250, 0.333)	(0.143, 0.167, 0.2)	(0.167, 0.2, 0.25)	(0.167, 0.2, 0.25)	(0.167, 0.2, 0.25)	(0.333, 0.5, 1)	(1, 1, 2)

C.R.= 0.026

Step 2 Calculate the fuzzy weights of fuzzy positive reciprocal matrix

Table 8.5 The geometric mean of TFN and the fuzzy weights of three criteria

	i =Financial loss	$i =$ Reputation loss	$i =$ Safety and security incident related loss
$\tilde{Z}_i^C$	(1.587, 1.71, 2.884)	(0.382, 0.464, 0.794)	(0.794, 1.26, 1.817)
$\widetilde{W}_i^C$	(0.289, 0.498, 1.044)	(0.069, 0.135, 0.287)	(0.144, 0367, 0.658)

Table 8.6 The geometric mean of TFN and the fuzzy weights of seven strategies under reduce financial loss

	i =A	$i =$ B	$i =$ C	$i =$ D	$i =$ E	$i =$ F	$i =$ G
$\tilde{Z}_i^{FA}$	(0.944, 1.14, 1.919)	(0.615, 0.906, 1.389)	(1.292, 2.065, 2.874)	(0.807, 1.292, 2.155)	(1.426, 2.034, 3.04)	(0.391, 0.492, 0.855)	(0.281, 0.363, 0.492)
$\widetilde{W}_i^{FA}$	(0.074, 0.137, 0.334)	(0.048, 0.109, 0.241)	(0.102, 0.249, 0.499)	(0.063, 0.156, 0.374)	(0.112, 0.245, 0.528)	(0.031, 0.059, 0.149)	(0.022, 0.044, 0.085)

Table 8.7 The geometric mean of TFN and the fuzzy weights of seven strategies under reduce reputation loss

	i =A	$i =$ B	$i =$ C	$i =$ D	$i =$ E	$i =$ F	$i =$ G
$\tilde{Z}_i^{FA}$	(0.828, 0.935, 1.641)	(0.891, 1.208, 1.919)	(1, 1.389, 2.034)	(1.369, 1.919, 2.753)	(1.219, 1.931, 2.521)	(0.403, 0.526, 0.82)	(0.259, 0.327, 0.427)
$\widetilde{W}_i^{FA}$	(0.068, 0.114, 0.275)	(0.074, 0.147, 0.322)	(0.083, 0.169, 0.341)	(0.113, 0.233, 0.461)	(0.101, 0.234, 0.422)	(0.033, 0.064, 0.137)	(0.021, 0.04, 0.072)

Table 8.8 The geometric mean of TFN and the fuzzy weights of seven strategies under reduce safety and security incident related loss

	i =A	$i =$ B	$i =$ C	$i =$ D	$i =$ E	$i =$ F	$i =$ G
$\tilde{Z}_i^{FA}$	(1.17, 1.346, 2.416)	(1.258, 1.511, 2.392)	(1.426, 2.1, 2.667)	(0.906, 1.258, 1.739)	(0.743, 1.188, 1.511)	(0.391, 0.543, 0.906)	(0.239, 0.289, 0.414)
$\widetilde{W}_i^{FA}$	(0.097, 0.163, 0.394)	(0.104, 0.184, 0.39)	(0.118, 0.255, 0.435)	(0.075, 0.153, 0.283)	(0.062, 0.144, 0.246)	(0.032, 0.066, 0.148)	(0.02, 0.035, 0.068)

Step 3 Defuzzify the fuzzy weights and normalise the crisp weights

Table 8.9 The defuzzified and standardized weights of three criteria

	Financial loss	Reputation loss	Safety and security incident related loss
Defuzzified weights	0.554	0.15	0.378
Standardised weights	0.512	0.138	0.35

Table 8.10 The defuzzified and standardized weights of seven strategies under reduce financial loss

	A	B	C	D	E	F	G
Defuzzified weights	0.16	0.121	0.266	0.177	0.27	0.069	0.047
Standardised weights	0.144	0.109	0.24	0.159	0.243	0.062	0.042

Table 8.11 The defuzzified and standardized weights of seven strategies under reduce reputation loss

	A	B	C	D	E	F	G
Defuzzified weights	0.133	0.164	0.183	0.251	0.243	0.071	0.042
Standardised weights	0.122	0.151	0.168	0.231	0.224	0.065	0.039

Table 8.12 The defuzzified and standardized weights of seven strategies under reduce safety and security incident related loss

	A	B	C	D	E	F	G
Defuzzified weights	0.191	0.205	0.262	0.162	0.148	0.074	0.038
Standardised weights	0.177	0.19	0.243	0.15	0.137	0.069	0.035

Sample 9

Step 1 Build fuzzy positive reciprocal matrix

Table 9.1 The fuzzy positive reciprocal matrix of three criteria

	Reduce financial loss	Reduce reputation loss	Reduce safety and security incident related loss
Reduce financial loss	(1, 1, 2)	(3, 4, 5)	(0.25, 0.333, 0.5)
Reduce reputation loss	(0.2, 0.25, 0.333)	(1, 1, 2)	(0.167, 0.2, 0.25)
Reduce safety and security incident related loss	(2, 3, 4)	(4, 5, 6)	(1, 1, 2)
C.R. = 0.074			

Table 9.2 The fuzzy positive reciprocal matrix of seven strategies under reduce financial loss

		A	B	C	D	E	F	G
Reduce financial loss	A	(1, 1, 2)	(1, 2, 3)	(2, 3, 4)	(2, 3, 4)	(1, 2, 3)	(0.333, 0.5, 1)	(2, 3, 4)
	B	(0.333, 0.5, 1)	(1, 1, 2)	(2, 3, 4)	(2, 3, 4)	(1, 2, 3)	(2, 3, 4)	(4, 5, 6)
	C	(0.25, 0.333, 0.5)	(0.25, 0.333, 0.5)	(1, 1, 2)	(1, 1, 2)	(1, 1, 2)	(0.333, 0.5, 1)	(1, 1, 2)
	D	(0.25, 0.333, 0.5)	(0.25, 0.333, 0.5)	(0.5, 1, 1)	(1, 1, 2)	(1, 1, 2)	(0.25, 0.333, 0.5)	(2, 3, 4)
	E	(0.333, 0.5, 1)	(0.333, 0.5, 1)	(0.5, 1, 1)	(0.5, 1, 1)	(1, 1, 2)	(0.333, 0.5, 1)	(2, 3, 4)
	F	(1, 2, 3)	(0.25, 0.333, 0.5)	(1, 2, 3)	(2, 3, 4)	(1, 2, 3)	(1, 1, 2)	(2, 3, 4)
	G	(0.25, 0.333, 0.5)	(0.167, 0.2, 0.25)	(0.5, 1, 1)	(0.25, 0.333, 0.5)	(0.25, 0.333, 0.5)	(0.25, 0.333, 0.5)	(1, 1, 2)
C.R.= 0.061								

Table 9.3 The fuzzy positive reciprocal matrix of seven strategies under reduce reputation loss

		A	B	C	D	E	F	G
Reduce reputation loss	A	(1, 1, 2)	(0.333, 0.5, 1)	(1, 1, 2)	(1, 1, 2)	(1, 1, 2)	(3, 4, 5)	(0.25, 0.333, 0.5)
	B	(1, 2, 3)	(1, 1, 2)	(2, 3, 4)	(2, 3, 4)	(2, 3, 4)	(3, 4, 5)	(1, 2, 3)
	C	(0.5, 1, 1)	(0.25, 0.333, 0.5)	(1, 1, 2)	(2, 3, 4)	(1, 2, 3)	(2, 3, 4)	(1, 2, 3)
	D	(0.5, 1, 1)	(0.25, 0.333, 0.5)	(0.25, 0.333, 0.5)	(1, 1, 2)	(0.333, 0.5, 1)	(1, 2, 3)	(0.333, 0.5, 1)
	E	(0.5, 1, 1)	(0.25, 0.333, 0.5)	(0.333, 0.5, 1)	(1, 2, 3)	(1, 1, 2)	(1, 2, 3)	(0.333, 0.5, 1)
	F	(0.2, 0.25, 0.333)	(0.2, 0.25, 0.333)	(0.25, 0.333, 0.5)	(0.333, 0.5, 1)	(0.333, 0.5, 1)	(1, 1, 2)	(0.333, 0.5, 1)
	G	(2, 3, 4)	(0.333, 0.5, 1)	(0.333, 0.5, 1)	(1, 2, 3)	(1, 2, 3)	(1, 2, 3)	(1, 1, 2)
C.R.= 0.053								

Table 9.4 The fuzzy positive reciprocal matrix of seven alternatives under reduce safety and security incident related loss

		A	B	C	D	E	F	G
Reduce safety and security incident related loss	A	(1, 1, 2)	(1, 2, 3)	(1, 1, 2)	(1, 2, 3)	(1, 2, 3)	(3, 4, 5)	(3, 4, 5)
	B	(0.333, 0.5, 1)	(1, 1, 2)	(1, 2, 3)	(1, 2, 3)	(2, 3, 4)	(2, 3, 4)	(2, 3, 4)
	C	(0.5, 1, 1)	(0.333, 0.5, 1)	(1, 1, 2)	(1, 2, 3)	(1, 2, 3)	(1, 2, 3)	(1, 2, 3)
	D	(0.333, 0.5, 1)	(0.333, 0.5, 1)	(0.333, 0.5, 1)	(1, 1, 2)	(1, 2, 3)	(1, 2, 3)	(1, 2, 3)
	E	(0.333, 0.5, 1)	(0.25, 0.333, 0.5)	(0.333, 0.5, 1)	(0.333, 0.5, 1)	(1, 1, 2)	(2, 3, 4)	(1, 2, 3)
	F	(0.2, 0.25, 0.333)	(0.25, 0.333, 0.5)	(0.333, 0.5, 1)	(0.333, 0.5, 1)	(0.25, 0.333, 0.5)	(1, 1, 2)	(1, 1, 2)
	G	(0.2, 0.25, 0.333)	(0.25, 0.333, 0.5)	(0.333, 0.5, 1)	(0.333, 0.5, 1)	(0.333, 0.5, 1)	(0.5, 1, 1)	(1, 1, 2)
C.R.= 0.035								

Step 2 Calculate the fuzzy weights of fuzzy positive reciprocal matrix

Table 9.5 The geometric mean of TFN and the fuzzy weights of three criteria

	i =Financial loss	$i =$ Reputation loss	$i =$ Safety and security incident related loss
$\tilde{Z}_i^C$	(0.909, 1.101, 1.71)	(0.322, 0.368, 0.55)	(2, 2.466, 3.634)
$\widetilde{W}_i^C$	(0.154, 0.28, 0.529)	(0.055, 0.094, 0.17)	(0.339, 0.627, 1.125)

Table 9.6 The geometric mean of TFN and the fuzzy weights of seven strategies under reduce financial loss

	i =A	$i =$ B	$i =$ C	$i =$ D	$i =$ E	$i =$ F	$i =$ G
$\tilde{Z}_i^{FA}$	(1.15, 1.768, 2.737)	(1.402, 2.015, 3.022)	(0.575, 0.662, 1.219)	(0.552, 0.731, 1.104)	(0.566, 0.869, 1.346)	(1, 1.575, 2.38)	(0.318, 0.424, 0.61)
$\widetilde{W}_i^{FA}$	(0.093, 0.22, 0.492)	(0.113, 0.251, 0.543)	(0.046, 0.082, 0.219)	(0.044, 0.091, 0.198)	(0.046, 0.108, 0.242)	(0.081, 0.196, 0.428)	(0.026, 0.053, 0.11)

Table 9.7 The geometric mean of TFN and the fuzzy weights of seven strategies under reduce reputation loss

	i =A	$i =$ B	$i =$ C	$i =$ D	$i =$ E	$i =$ F	$i =$ G
$\tilde{Z}_i^{FA}$	(0.82, 0.944, 1.694)	(1.575, 2.38, 3.445)	(0.906, 1.426, 2.034)	(0.445, 0.662, 1.06)	(0.543, 0.855, 1.369)	(0.323, 0.427, 0.731)	(0.807, 1.292, 2.155)
$\widetilde{W}_i^{FA}$	(0.066, 0.118, 0.313)	(0.126, 0.298, 0.636)	(0.073, 0.179, 0.375)	(0.036, 0.083, 0.196)	(0.043, 0.107, 0.253)	(0.026, 0.054, 0.135)	(0.065, 0.162, 0.398)

Table 9.8 The geometric mean of TFN and the fuzzy weights of seven strategies under reduce safety and security incident related loss

	i =A	$i =$ B	$i =$ C	$i =$ D	$i =$ E	$i =$ F	$i =$ G
$\tilde{Z}_i^{FA}$	(1.369, 2, 3.092)	(1.15, 1.768, 2.737)	(0.774, 1.346, 2.068)	(0.624, 1, 1.768)	(0.566, 0.82, 1.426)	(0.391, 0.492, 0.855)	(0.369, 0.521, 0.855)
$\widetilde{W}_i^{FA}$	(0.107, 0.252, 0.59)	(0.09, 0.222, 0.522)	(0.06, 0.169, 0.395)	(0.049, 0.126, 0.337)	(0.044, 0.103, 0.272)	(0.031, 0.062, 0.163)	(0.029, 0.066, 0.163)

Step 3 Defuzzify the fuzzy weights and normalise the crisp weights

Table 9.9 The defuzzified and standardized weights of three criteria

	Financial loss	Reputation loss	Safety and security incident related loss
Defuzzified weights	0.3	0.1	0.662
Standardised weights	0.283	0.094	0.623

Table 9.10 The defuzzified and standardized weights of seven strategies under reduce financial loss

	A	B	C	D	E	F	G
Defuzzified weights	0.244	0.276	0.099	0.101	0.12	0.215	0.058
Standardised weights	0.219	0.248	0.089	0.091	0.108	0.193	0.052

Table 9.11 The defuzzified and standardized weights of seven strategies under reduce reputation loss

	A	B	C	D	E	F	G
Defuzzified weights	0.142	0.326	0.194	0.094	0.121	0.062	0.185
Standardised weights	0.126	0.29	0.172	0.084	0.107	0.056	0.165

Table 9.12 The defuzzified and standardized weights of seven strategies under reduce safety and security incident related loss

	A	B	C	D	E	F	G
Defuzzified weights	0.284	0.25	0.189	0.148	0.122	0.074	0.076
Standardised weights	0.249	0.219	0.165	0.13	0.106	0.064	0.066

Sample 10

Step 1 Build fuzzy positive reciprocal matrix

Table 10.1 The fuzzy positive reciprocal matrix of three criteria

	Reduce financial loss	Reduce reputation loss	Reduce safety and security incident related loss
Reduce financial loss	(1, 1, 2)	(1, 1, 2)	(0.25, 0.333, 0.5)
Reduce reputation loss	(0.5, 1, 1)	(1, 1, 2)	(0.143, 0.167, 0.2)
Reduce safety and security incident related loss	(2, 3, 4)	(5, 6, 7)	(1, 1, 2)
C.R. = 0.046			

Table 10.2 The fuzzy positive reciprocal matrix of seven strategies under reduce financial loss

		A	B	C	D	E	F	G
Reduce financial loss	A	(1, 1, 2)	(2, 3, 4)	(1, 1, 2)	(0.333, 0.5, 1)	(1, 1, 2)	(1, 1, 2)	(1, 2, 3)
	B	(0.25, 0.333, 0.5)	(1, 1, 2)	(1, 1, 2)	(0.333, 0.5, 1)	(0.25, 0.333, 0.5)	(0.333, 0.5, 1)	(1, 1, 2)
	C	(0.5, 1, 1)	(0.5, 1, 1)	(1, 1, 2)	(0.333, 0.5, 1)	(0.333, 0.5, 1)	(0.333, 0.5, 1)	(1, 1, 2)
	D	(1, 2, 3)	(1, 2, 3)	(1, 2, 3)	(1, 1, 2)	(0.333, 0.5, 1)	(3, 4, 5)	(2, 3, 4)
	E	(0.5, 1, 1)	(2, 3, 4)	(1, 2, 3)	(1, 2, 3)	(1, 1, 2)	(2, 3, 4)	(3, 4, 5)
	F	(0.5, 1, 1)	(1, 2, 3)	(1, 2, 3)	(0.200, 0.25, 0.333)	(0.25, 0.333, 0.5)	(1, 1, 2)	(1, 1, 2)
	G	(0.333, 0.5, 1)	(0.5, 1, 1)	(0.5, 1, 1)	(0.25, 0.333, 0.5)	(0.200, 0.25, 0.333)	(0.5, 1, 1)	(1, 1, 2)
C.R.= 0.048								

Table 10.3 The fuzzy positive reciprocal matrix of seven strategies under reduce reputation loss

		A	B	C	D	E	F	G
Reduce reputation loss	A	(1, 1, 2)	(1, 1, 2)	(0.333, 0.5, 1)	(1, 1, 2)	(1, 1, 2)	(1, 1, 2)	(1, 1, 2)
	B	(0.5, 1, 1)	(1, 1, 2)	(1, 1, 2)	(1, 1, 2)	(0.333, 0.5, 1)	(0.333, 0.5, 1)	(1, 2, 3)
	C	(1, 2, 3)	(0.5, 1, 1)	(1, 1, 2)	(1, 1, 2)	(1, 2, 3)	(1, 2, 3)	(1, 2, 3)
	D	(0.5, 1, 1)	(0.5, 1, 1)	(0.5, 1, 1)	(1, 1, 2)	(1, 1, 2)	(2, 3, 4)	(3, 4, 5)
	E	(0.5, 1, 1)	(1, 2, 3)	(0.333, 0.5, 1)	(0.5, 1, 1)	(1, 1, 2)	(1, 1, 2)	(2, 3, 4)
	F	(0.5, 1, 1)	(1, 2, 3)	(0.333, 0.5, 1)	(0.25, 0.333, 0.5)	(0.5, 1, 1)	(1, 1, 2)	(1, 2, 3)
	G	(0.5, 1, 1)	(0.333, 0.5, 1)	(0.333, 0.5, 1)	(0.200, 0.25, 0.333)	(0.25, 0.333, 0.5)	(0.333, 0.5, 1)	(1, 1, 2)
C.R.= 0.053								

Table 10.4 The fuzzy positive reciprocal matrix of seven alternatives under reduce safety and security incident related loss

		A	B	C	D	E	F	G
Reduce safety and security incident related loss	A	(1, 1, 2)	(1, 1, 2)	(1, 1, 2)	(1, 2, 3)	(1, 1, 2)	(1, 1, 2)	(1, 2, 3)
	B	(0.5, 1, 1)	(1, 1, 2)	(0.333, 0.5, 1)	(1, 1, 2)	(1, 1, 2)	(1, 1, 2)	(1, 2, 3)
	C	(0.5, 1, 1)	(1, 2, 3)	(1, 1, 2)	(1, 1, 2)	(1, 1, 2)	(2, 3, 4)	(2, 3, 4)
	D	(0.333, 0.5, 1)	(0.5, 1, 1)	(0.5, 1, 1)	(1, 1, 2)	(1, 1, 2)	(3, 4, 5)	(3, 4, 5)
	E	(0.5, 1, 1)	(0.5, 1, 1)	(0.5, 1, 1)	(0.5, 1, 1)	(1, 1, 2)	(4, 5, 6)	(3, 4, 5)
	F	(0.5, 1, 1)	(0.5, 1, 1)	(0.25, 0.333, 0.5)	(0.2, 0.25, 0.333)	(0.167, 0.2, 0.25)	(1, 1, 2)	(1, 1, 2)
	G	(0.333, 0.5, 1)	(0.333, 0.5, 1)	(0.25, 0.333, 0.5)	(0.2, 0.25, 0.333)	(0.2, 0.25, 0.333)	(0.5, 1, 1)	(1, 1, 2)
C.R.= 0.056								

Step 2 Calculate the fuzzy weights of fuzzy positive reciprocal matrix

Table 10.5 The geometric mean of TFN and the fuzzy weights of three criteria

	i =Financial loss	i = Reputation loss	i = Safety and security incident related loss
$\tilde{Z}_i^C$	(0.63, 0.693, 1.26)	(0.415, 0.55, 0.737)	(2.154, 2.621, 3.826)
$\widetilde{W}_i^C$	(0.108, 0.179, 0.394)	(0.071, 0.142, 0.23)	(0.37, 0.678, 1.196)

Table 10.6 The geometric mean of TFN and the fuzzy weights of seven strategies under reduce financial loss

	i =A	i = B	i = C	i = D	i = E	i = F	i = G
$\tilde{Z}_i^{FA}$	(0.944, 0.17, 2.119)	(0.492, 0.599, 1.104)	(0.512, 0.743, 1.219)	(1.104, 1.739, 2.712)	(1.292, 2.034, 2.826)	(0.59, 0.855, 1.292)	(0.414, 0.635, 0.855)
$\widetilde{W}_i^{FA}$	(0.078, 0.15, 0.396)	(0.041, 0.077, 0.206)	(0.042, 0.096, 0.228)	(0.091, 0.224, 0.507)	(0.107, 0.262, 0.528)	(0.049, 0.11, 0.242)	(0.034, 0.082, 0.16)

Table 10.7 The geometric mean of TFN and the fuzzy weights of seven strategies under reduce reputation loss

	i =A	i = B	i = C	i = D	i = E	i = F	i = G
$\tilde{Z}_i^{FA}$	(0.855, 0.906, 1.811)	(0.662, 0.906, 1.575)	(0.906, 1.486, 2.284)	(0.96, 1.426, 1.87)	(0.774, 1.17, 1.739)	(0.575, 0.944, 1.369)	(0.369, 0.521, 0.855)
$\widetilde{W}_i^{FA}$	(0.074, 0.123, 0.355)	(0.058, 0.123, 0.309)	(0.079, 0.202, 0.448)	(0.083, 0.194, 0.367)	(0.067, 0.159, 0.341)	(0.05, 0.128, 0.268)	(0.032, 0.071, 0.168)

Table 10.8 The geometric mean of TFN and the fuzzy weights of seven strategies under reduce safety and security incident related loss

	i =A	i = B	i = C	i = D	i = E	i = F	i = G
$\tilde{Z}_i^{FA}$	(1, 1.219, 2.246)	(0.774, 1, 1.739)	(1.104, 1.511, 2.34)	(0.96, 1.346, 1.931)	(0.96, 1.534, 1.795)	(0.414, 0.0557, 0.774)	(0.343, 0.472, 0.731)
$\widetilde{W}_i^{FA}$	(0.087, 0.16, 0.404)	(0.067, 0.131, 0.313)	(0.096, 0.198, 0.421)	(0.083, 0.176, 0.348)	(0.083, 0.201, 0.323)	(0.036, 0.073, 0.139)	(0.03, 0.062, 0.132)

Step 3 Defuzzify the fuzzy weights and normalise the crisp weights

Table 10.9 The defuzzified and standardized weights of three criteria

	Financial loss	Reputation loss	Safety and security incident related loss
Defuzzified weights	0.203	0.145	0.713
Standardised weights	0.191	0.137	0.672

Table 10.10 The defuzzified and standardized weights of seven strategies under reduce financial loss

	A	B	C	D	E	F	G
Defuzzified weights	0.179	0.093	0.109	0.249	0.28	0.122	0.087
Standardised weights	0.16	0.083	0.097	0.223	0.251	0.109	0.078

Table 10.11 The defuzzified and standardized weights of seven strategies under reduce reputation loss

	A	B	C	D	E	F	G
Defuzzified weights	0.154	0.143	0.222	0.204	0.174	0.139	0.08
Standardised weights	0.138	0.128	0.199	0.183	0.156	0.124	0.072

Table 10.12 The defuzzified and standardized weights of seven strategies under reduce safety and security incident related loss

	A	B	C	D	E	F	G
Defuzzified weights	0.188	0.151	0.218	0.189	0.202	0.078	0.068
Standardised weights	0.172	0.138	0.199	0.173	0.184	0.071	0.062

Sample 11

Step 1 Build fuzzy positive reciprocal matrix

Table 11.1 The fuzzy positive reciprocal matrix of three criteria

	Reduce financial loss	Reduce reputation loss	Reduce safety and security incident related loss
Reduce financial loss	(1, 1, 2)	(1, 1, 2)	(0.25, 0.333, 0.5)
Reduce reputation loss	(0.5, 1, 1)	(1, 1, 2)	(0.25, 0.333, 0.5)
Reduce safety and security incident related loss	(2, 3, 4)	(2, 3, 4)	(1, 1, 2)
C.R. = 0.000			

Table 11.2 The fuzzy positive reciprocal matrix of seven strategies under reduce financial loss

		A	B	C	D	E	F	G
Reduce financial loss	A	(1, 1, 2)	(1, 2, 3)	(1, 2, 3)	(1, 1, 2)	(0.333, 0.5, 1)	(0.25, 0.333, 0.5)	(1, 2, 3)
	B	(0.333, 0.5, 1)	(1, 1, 2)	(1, 2, 3)	(0.25, 0.333, 0.5)	(0.25, 0.333, 0.5)	(0.25, 0.333, 0.5)	(2, 3, 4)
	C	(0.333, 0.5, 1)	(0.333, 0.5, 1)	(1, 1, 2)	(1, 1, 2)	(0.333, 0.5, 1)	(0.333, 0.5, 1)	(1, 2, 3)
	D	(0.5, 1, 1)	(2, 3, 4)	(0.5, 1, 1)	(1, 1, 2)	(1, 2, 3)	(0.333, 0.5, 1)	(1, 2, 3)
	E	(1, 2, 3)	(2, 3, 4)	(1, 2, 3)	(0.333, 0.5, 1)	(1, 1, 2)	(0.333, 0.5, 1)	(1, 2, 3)
	F	(2, 3, 4)	(2, 3, 4)	(1, 2, 3)	(1, 2, 3)	(1, 2, 3)	(1, 1, 2)	(1, 2, 3)
	G	(0.333, 0.5, 1)	(0.25, 0.333, 0.5)	(0.333, 0.5, 1)	(0.333, 0.5, 1)	(0.333, 0.5, 1)	(0.333, 0.5, 1)	(1, 1, 2)
C.R.= 0.075								

Table 11.3 The fuzzy positive reciprocal matrix of seven strategies under reduce reputation loss

		A	B	C	D	E	F	G
Reduce reputation loss	A	(1, 1, 2)	(1, 1, 2)	(1, 1, 2)	(1, 1, 2)	(0.333, 0.5, 1)	(0.25, 0.333, 0.5)	(1, 1, 2)
	B	(0.5, 1, 1)	(1, 1, 2)	(1, 2, 3)	(1, 1, 2)	(1, 1, 2)	(1, 1, 2)	(2, 3, 4)
	C	(0.5, 1, 1)	(0.333, 0.5, 1)	(1, 1, 2)	(1, 1, 2)	(1, 1, 2)	(0.333, 0.5, 1)	(1, 2, 3)
	D	(0.5, 1, 1)	(0.5, 1, 1)	(0.5, 1, 1)	(1, 1, 2)	(1, 1, 2)	(0.333, 0.5, 1)	(1, 1, 2)
	E	(1, 2, 3)	(0.5, 1, 1)	(0.5, 1, 1)	(0.5, 1, 1)	(1, 1, 2)	(0.333, 0.5, 1)	(1, 1, 2)
	F	(2, 3, 4)	(0.5, 1, 1)	(1, 2, 3)	(1, 2, 3)	(1, 2, 3)	(1, 1, 2)	(1, 2, 3)
	G	(0.5, 1, 1)	(0.25, 0.333, 0.5)	(0.333, 0.5, 1)	(0.5, 1, 1)	(0.5, 1, 1)	(0.333, 0.5, 1)	(1, 1, 2)
C.R.= 0.031								

Table 11.4 The fuzzy positive reciprocal matrix of seven alternatives under reduce safety and security incident related loss

		A	B	C	D	E	F	G
Reduce safety and security incident related loss	A	(1, 1, 2)	(1, 1, 2)	(1, 2, 3)	(1, 1, 2)	(1, 1, 2)	(0.25, 0.333, 0.5)	(1, 2, 3)
	B	(0.5, 1, 1)	(1, 1, 2)	(1, 2, 3)	(1, 1, 2)	(1, 1, 2)	(1, 1, 2)	(2, 3, 4)
	C	(0.333, 0.5, 1)	(0.333, 0.5, 1)	(1, 1, 2)	(1, 1, 2)	(1, 1, 2)	(0.333, 0.5, 1)	(1, 2, 3)
	D	(0.5, 1, 1)	(0.5, 1, 1)	(0.5, 1, 1)	(1, 1, 2)	(1, 1, 2)	(0.333, 0.5, 1)	(1, 1, 2)
	E	(0.5, 1, 1)	(0.5, 1, 1)	(0.5, 1, 1)	(0.5, 1, 1)	(1, 1, 2)	(0.333, 0.5, 1)	(1, 1, 2)
	F	(2, 3, 4)	(0.5, 1, 1)	(1, 2, 3)	(1, 2, 3)	(1, 2, 3)	(1, 1, 2)	(1, 2, 3)
	G	(0.333, 0.5, 1)	(0.25, 0.333, 0.5)	(0.333, 0.5, 1)	(0.5, 1, 1)	(0.5, 1, 1)	(0.333, 0.5, 1)	(1, 1, 2)
C.R.= 0.033								

Step 2 Calculate the fuzzy weights of fuzzy positive reciprocal matrix

Table 11.5 The geometric mean of TFN and the fuzzy weights of three criteria

	i =Financial loss	i = Reputation loss	i = Safety and security incident related loss
$\tilde{Z}_i^C$	(0.63, 0.693, 1.26)	(0.5, 0.693, 1)	(1.578, 2.08, 3.175)
$\widetilde{W}_i^C$	(0.116, 0.2, 0.464)	(0.092, 0.2, 0.368)	(0.292, 0.6, 1.168)

Table 11.6 The geometric mean of TFN and the fuzzy weights of seven strategies under reduce financial loss

	i =A	i = B	i = C	i = D	i = E	i = F	i = G
$\tilde{Z}_i^{FA}$	(0.701, 1.042, 1.768)	(0.521, 0.731, 1.17)	(0.534, 0.743, 1.426)	(0.774, 1.292, 1.842)	(0.807, 1.292, 2.155)	(1.219, 2.034, 3.074)	(0.374, 0.521, 1)
$\widetilde{W}_i^{FA}$	(0.056, 0.136, 0.359)	(0.042, 0.095, 0.237)	(0.043, 0.097, 0.289)	(0.062, 0.169, 0.374)	(0.065, 0.169, 0.437)	(0.098, 0.266, 0.623)	(0.03, 0.068, 0.203)

Table 11.7 The geometric mean of TFN and the fuzzy weights of seven strategies under reduce reputation loss

	i =A	i = B	i = C	i = D	i = E	i = F	i = G
$\tilde{Z}_i^{FA}$	(0.701, 0.774, 1.486)	(1, 1.292, 2.119)	(0.662, 0.906, 1.575)	(0.635, 0.906, 1.346)	(0.635, 1, 1.426)	(1, 1.739, 2.521)	(0.445, 0.701, 1)
$\widetilde{W}_i^{FA}$	(0.061, 0.106, 0.293)	(0.087, 0.177, 0.417)	(0.058, 0.124, 0.31)	(0.055, 0.124, 0.265)	(0.055, 0.137, 0.281)	(0.087, 0.238, 0.497)	(0.039, 0.096, 0.197)

Table 11.8 The geometric mean of TFN and the fuzzy weights of seven strategies under reduce safety and security incident related loss

	i =A	i = B	i = C	i = D	i = E	i = F	i = G
$\tilde{Z}_i^{FA}$	(0.82, 1.042, 1.842)	(1, 1.292, 2.119)	(0.624, 0.82, 1.575)	(0.635, 0.906, 1.346)	(0.575, 0.906, 1.219)	(1, 1.739, 2.521)	(0.42, 0.635, 1)
$\widetilde{W}_i^{FA}$	(0.071, 0.142, 0.363)	(0.086, 0.176, 0.418)	(0.054, 0.112, 0.31)	(0.055, 0.123, 0.265)	(0.049, 0.123, 0.24)	(0.086, 0.237, 0.497)	(0.036, 0.087, 0.197)

Step 3 Defuzzify the fuzzy weights and normalise the crisp weights

Table 11.9 The defuzzified and standardized weights of three criteria

	Financial loss	Reputation loss	Safety and security incident related loss
Defuzzified weights	0.23	0.21	0.643
Standardised weights	0.212	0.194	0.594

Table 11.10 The defuzzified and standardized weights of seven strategies under reduce financial loss

	A	B	C	D	E	F	G
Defuzzified weights	0.16	0.11	0.12	0.185	0.196	0.297	0.084
Standardised weights	0.139	0.096	0.104	0.161	0.17	0.258	0.073

Table 11.11 The defuzzified and standardized weights of seven strategies under reduce reputation loss

	A	B	C	D	E	F	G
Defuzzified weights	0.129	0.202	0.144	0.136	0.147	0.256	0.103
Standardised weights	0.116	0.181	0.129	0.122	0.132	0.229	0.092

Table 11.12 The defuzzified and standardized weights of seven strategies under reduce safety and security incident related loss

	A	B	C	D	E	F	G
Defuzzified weights	0.167	0.201	0.135	0.136	0.131	0.255	0.097
Standardised weights	0.149	0.18	0.121	0.121	0.116	0.228	0.086

Sample 12

Step 1 Build fuzzy positive reciprocal matrix

Table 12.1 The fuzzy positive reciprocal matrix of three criteria

	Reduce financial loss	Reduce reputation loss	Reduce safety and security incident related loss
Reduce financial loss	(1, 1, 2)	(4, 5, 6)	(0.25, 0.333, 0.5)
Reduce reputation loss	(0.167, 0.2, 0.25)	(1, 1, 2)	(0.143, 0.167, 0.2)
Reduce safety and security incident related loss	(2, 3, 4)	(5, 6, 7)	(1, 1, 2)
C.R. = 0.081			

Table 12.2 The fuzzy positive reciprocal matrix of seven strategies under reduce financial loss

		A	B	C	D	E	F	G
Reduce financial loss	A	(1, 1, 2)	(1, 1, 2)	(2, 3, 4)	(1, 2, 3)	(1, 2, 3)	(0.25, 0.333, 0.5)	(2, 3, 4)
	B	(0.5, 1, 1)	(1, 1, 2)	(1, 2, 3)	(1, 2, 3)	(1, 2, 3)	(0.167, 0.2, 0.25)	(1, 2, 3)
	C	(0.25, 0.333, 0.5)	(0.333, 0.5, 1)	(1, 1, 2)	(1, 1, 2)	(0.333, 0.5, 1)	(0.167, 0.2, 0.25)	(1, 1, 2)
	D	(0.333, 0.5, 1)	(0.333, 0.5, 1)	(0.5, 1, 1)	(1, 1, 2)	(0.333, 0.5, 1)	(0.25, 0.333, 0.5)	(1, 2, 3)
	E	(0.333, 0.5, 1)	(0.333, 0.5, 1)	(1, 2, 3)	(1, 2, 3)	(1, 1, 2)	(0.2, 0.25, 0.333)	(2, 3, 4)
	F	(2, 3, 4)	(4, 5, 6)	(4, 5, 6)	(2, 3, 4)	(3, 4, 5)	(1, 1, 2)	(2, 3, 4)
	G	(0.25, 0.333, 0.5)	(0.333, 0.5, 1)	(0.5, 1, 1)	(0.333, 0.5, 1)	(0.25, 0.333, 0.5)	(0.25, 0.333, 0.5)	(1, 1, 2)
C.R.= 0.042								

Table 12.3 The fuzzy positive reciprocal matrix of seven strategies under reduce reputation loss

		A	B	C	D	E	F	G
Reduce reputation loss	A	(1, 1, 2)	(0.333, 0.5, 1)	(0.333, 0.5, 1)	(0.333, 0.5, 1)	(0.333, 0.5, 1)	(1, 2, 3)	(1, 2, 3)
	B	(1, 2, 3)	(1, 1, 2)	(1, 2, 3)	(0.25, 0.333, 0.5)	(0.25, 0.333, 0.5)	(0.333, 0.5, 1)	(1, 2, 3)
	C	(1, 2, 3)	(0.333, 0.5, 1)	(1, 1, 2)	(0.333, 0.5, 1)	(0.333, 0.5, 1)	(1, 2, 3)	(1, 2, 3)
	D	(1, 2, 3)	(2, 3, 4)	(1, 2, 3)	(1, 1, 2)	(1, 2, 3)	(1, 2, 3)	(2, 3, 4)
	E	(1, 2, 3)	(2, 3, 4)	(1, 2, 3)	(0.333, 0.5, 1)	(1, 1, 2)	(2, 3, 4)	(1, 2, 3)
	F	(0.333, 0.5, 1)	(1, 2, 3)	(0.333, 0.5, 1)	(0.333, 0.5, 1)	(0.25, 0.333, 0.5)	(1, 1, 2)	(4, 5, 6)
	G	(0.333, 0.5, 1)	(0.333, 0.5, 1)	(0.333, 0.5, 1)	(0.25, 0.333, 0.5)	(0.333, 0.5, 1)	(0.167, 0.2, 0.25)	(1, 1, 2)
C.R.= 0.093								

Table 12.4 The fuzzy positive reciprocal matrix of seven alternatives under reduce safety and security incident related loss

		A	B	C	D	E	F	G
Reduce safety and security incident related loss	A	(1, 1, 2)	(1, 1, 2)	(1, 1, 2)	(1, 1, 2)	(1, 1, 2)	(1, 2, 3)	(1, 2, 3)
	B	(0.5, 1, 1)	(1, 1, 2)	(1, 2, 3)	(1, 1, 2)	(1, 1, 2)	(1, 2, 3)	(1, 2, 3)
	C	(0.5, 1, 1)	(0.333, 0.5, 1)	(1, 1, 2)	(2, 3, 4)	(2, 3, 4)	(1, 2, 3)	(1, 2, 3)
	D	(0.5, 1, 1)	(0.5, 1, 1)	(0.25, 0.333, 0.5)	(1, 1, 2)	(1, 2, 3)	(4, 5, 6)	(2, 3, 4)
	E	(0.5, 1, 1)	(0.5, 1, 1)	(0.25, 0.333, 0.5)	(0.333, 0.5, 1)	(1, 1, 2)	(1, 1, 2)	(2, 3, 4)
	F	(0.333, 0.5, 1)	(0.333, 0.5, 1)	(0.333, 0.5, 1)	(0.167, 0.2, 0.25)	(0.5, 1, 1)	(1, 1, 2)	(1, 1, 2)
	G	(0.333, 0.5, 1)	(0.333, 0.5, 1)	(0.333, 0.5, 1)	(0.25, 0.333, 0.5)	(0.25, 0.333, 0.5)	(0.5, 1, 1)	(1, 1, 2)
C.R.= 0.072								

Step 2 Calculate the fuzzy weights of fuzzy positive reciprocal matrix

Table 12.5 The geometric mean of TFN and the fuzzy weights of three criteria

	i =Financial loss	i = Reputation loss	i = Safety and security incident related loss
$\tilde{Z}_i^C$	(1, 1.186, 1.817)	(0.288, 0.322, 0.464)	(2.154, 2.621, 3.826)
$\widetilde{W}_i^C$	(0.164, 0.287, 0.528)	(0.047, 0.078, 0.135)	(0.353, 0.635, 1.111)

Table 12.6 The geometric mean of TFN and the fuzzy weights of seven strategies under reduce financial loss

	i =A	i = B	i = C	i = D	i = E	i = F	i = G
$\tilde{Z}_i^{FA}$	(1, 1.426, 2.246)	(0.701, 1.181, 1.697)	(0.464, 0.557, 1)	(0.464, 0.701, 1.17)	(0.641, 0.96, 1.575)	(2.34, 3.092, 4.2)	(0.365, 0.512, 0.82)
$\widetilde{W}_i^{FA}$	(0.079, 0.169, 0.376)	(0.055, 0.14, 0.284)	(0.037, 0.066, 0.167)	(0.037, 0.083, 0.196)	(0.05, 0.114, 0.264)	(0.184, 0.367, 0.703)	(0.029, 0.061, 0.137)

Table 12.7 The geometric mean of TFN and the fuzzy weights of seven strategies under reduce reputation loss

	i =A	i = B	i = C	i = D	i = E	i = F	i = G
$\tilde{Z}_i^{FA}$	(0.534, 0.82, 1.511)	(0.575, 0.891, 1.45)	(0.624, 1, 1.768)	(1.219, 2.034, 3.074)	(1.042, 1.669, 2.627)	(0.624, 0.882, 1.511)	(0.339, 0.457, 0.82)
$\widetilde{W}_i^{FA}$	(0.042, 0.106, 0.305)	(0.045, 0.115, 0.293)	(0.049, 0.129, 0.357)	(0.096, 0.262, 0.62)	(0.082, 0.215, 0.53)	(0.049, 0.114, 0.305)	(0.027, 0.059, 0.165)

Table 12.8 The geometric mean of TFN and the fuzzy weights of seven strategies under reduce safety and security incident related loss

	i =A	i = B	i = C	i = D	i = E	i = F	i = G
$\tilde{Z}_i^{FA}$	(1, 1.219, 2.246)	(0.906, 1.346, 2.155)	(0.944, 1.511, 2.246)	(0.906, 1.389, 1.842)	(0.635, 0.906, 1.346)	(0.438, 0.59, 1)	(0.381, 0.543, 0.906)
$\widetilde{W}_i^{FA}$	(0.085, 0.162, 0.431)	(0.077, 0.179, 0.414)	(0.08, 0.201, 0.431)	(0.077, 0.185, 0.354)	(0.054, 0.121, 0.258)	(0.037, 0.079, 0.192)	(0.032, 0.072, 0.174)

Step 3 Defuzzify the fuzzy weights and normalise the crisp weights

Table 12.9 The defuzzified and standardized weights of three criteria

	Financial loss	Reputation loss	Safety and security incident related loss
Defuzzified weights	0.307	0.082	0.667
Standardised weights	0.29	0.078	0.632

Table 12.10 The defuzzified and standardized weights of seven strategies under reduce financial loss

	A	B	C	D	E	F	G
Defuzzified weights	0.189	0.15	0.078	0.094	0.128	0.392	0.068
Standardised weights	0.171	0.136	0.071	0.086	0.117	0.357	0.062

Table 12.11 The defuzzified and standardized weights of seven strategies under reduce reputation loss

	A	B	C	D	E	F	G
Defuzzified weights	0.128	0.133	0.154	0.294	0.245	0.135	0.071
Standardised weights	0.111	0.114	0.132	0.253	0.211	0.116	0.061

Table 12.12 The defuzzified and standardized weights of seven strategies under reduce safety and security incident related loss

	A	B	C	D	E	F	G
Defuzzified weights	0.194	0.201	0.22	0.195	0.133	0.091	0.083
Standardised weights	0.174	0.18	0.197	0.175	0.119	0.081	0.074

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