Supply Chain Risk Management in the Container Liner Shipping Industry from a Strategic Point of View

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Abstract

One of the most significant current discussions in the container liner shipping industry (CLSI) is supply chain risk management (SCRM). In recent years, there has been an increasing interest in managing risk and reliability in the container supply chain from many viewpoints. This paper reviews the significant literature related to SCRM in the CLSI from a strategic point of view. By integrating the concept of the CLSI, the planning levels of container liner shipping and the concept of SCRM, questions have been raised about risk and uncertainty arising from the external environments (i.e. country-limited scope) and how can these factors influence the organisational reliability and capability of liner shipping operators (LSOs). Another question concerns how uncertain environments can influence the punctuality of containerships. So far, however, no research has been found that answered these questions which make further research is meaningful. For future research, this paper recommends an extensive assessment of a business environment-based risk and an evaluation of organizational reliability and capability of LSOs from the strategic point of view. Finally, it is worth mentioning that there is a research gap in both industry and academia on how to analyse and predict the punctuality of containerships (i.e. arrival and departure) under uncertain environments.

Keywords: supply chain risk management, container liner shipping industry, business-environment based risk, organisational reliability and capability, punctuality.

1. Introduction

Container liner shipping offers a number of benefits that can be listed as efficiency of the system and low environmental pollution impact (World Shipping Council 2012). A single large containership can be operated by only about 13 crew members assisted by modern computerised systems. These computerised systems are highly cutting-edge, helping a shipmaster to navigate a vessel by offering precise routing, and loading and unloading of thousands of containers for every voyage. In a single year, an individual large vessel can carry over 200,000 containers around the world. Therefore, it is noteworthy to mention that the container liner shipping system provides greater efficiency than any other transportation network (World Shipping Council 2012).

In the new era of globalisation, SCRM has become a central issue for the maritime transportation system. It is difficult to ignore that supply chains are increasingly exposed to many risks, and it is worth mentioning that the extreme risk to a business's sustainability lies along the wider supply chain rather than within the company itself (CLSCM 2003). Despite the increasing awareness of managing supply chain risk among practitioners, the concepts of supply chain vulnerability and SCRM are still in their infancy. Although many organisations have already managed risk, they have often overlooked the critical exposures along their supply chains (Jüttner *et al.* 2003). In the context of the maritime transportation system, it is noteworthy to mention that LSOs are still in the early stages of SCRM development in their strategic management.

2. The Overview of the CLSI

In the maritime transportation system, there are several interpretations of the term 'liner'. Branch (2007 page 51) defined liner shipping as an "activity of vessels that ply on a regular scheduled service between groups of ports". IHS Global Insight (2009 page 4) interpreted a liner system as "the part of a maritime industry that includes all operations and related infrastructures involved in scheduled ocean-borne shipping". In addition, World Shipping Council (2012) stated that liner shipping is "a service of transporting goods by means of high-capacity, ocean-going ships that transit regular routes on fixed schedules". Also, Qi & Song (2012 page 864) claimed that liner shipping has a unique characteristic: "the ships are usually deployed on a closed route with weekly frequency following a published schedule of sailings with a fixed port rotation, and laden/empty containers are loaded on/off the ships at each port-of-call". It is worth mentioning that the definition of liner shipping does not describe the size or speed of a liner vessel but its system, which sails based on scheduled services, regardless of whether slots are fully utilised or not (Branch 2007).

In 2014, 5,981 vessels were actively deployed on liner trades, representing 18,746,069 TEUs and 236,860,429 total deadweight tonnage including 5036 fully cellular vessels for 18,291,347 TEUs (Alphaliner 2014). The largest LSO in terms of container carrying capacity (i.e. TEUs) in 2014 is Maersk Line (Denmark), followed by the MSC (Switzerland) and CMA CGM (France). In 2014, it was estimated that about 60% of the orderbook of new vessels was the "leased" form or so-called "charter owners", while the remaining 40% were directly ordered by the LSOs (UNCTAD 2014).

UNCTADs Liner Shipping Connectivity Index (LSCI) has provided an indicator of each maritime nation's access to the global liner shipping network on a yearly basis. This LSCI is produced based on five elements that capture the deployment of containerships by LSOs to a country's port of call, which are: the number of ships; total container carrying capacity; the number of operators providing services with their own operated ships; the number of services provided; and the size (i.e. TEU) of the largest vessel deployed (UNCTAD 2014). Based on UNCTAD (2014), the country with the highest LSCI is China, followed by Hong Kong, Singapore, South Korea and Malaysia. Morocco, Egypt and South Africa are the three best-connected countries on the African continent, reflecting their strategic location at the corners of the continent. Panama has become the country with the highest LSCI in Latin America, benefiting from its canal and location at the crossroads of the main East-West and North-South routes.

The container supply chain has two main characters, which are nodes and links (Gurning 2011). The nodes are physical entities where container movement is interrupted and/or containers are handled (e.g. ports, consolidation centres, shipper's premises and buyer's premises). The links between nodes are characterised by mode of transport (i.e. road, rail and waterway). These links can be represented by vessels, trucks, trains, *etc*. In this paper, the operation scope of the container supply chain is limited to the port-to-port operations.

Container liner shipping operates between ports of call based on networked services (Christiansen *et al*. 2007). Figure 1 shows a simple container liner shipping network where a number of vessels (i.e. $VESSEL_1$, $VESSEL_2$ and $VESSEL_n$) sail around the network from $PORT_1$ to $PORT_n$ and turn back to $PORT_1$ to make a completed round trip. Strategically, the integrity of the container liner shipping network depends on the vessel reliability, the reliability and capability of an agency that represents the LSOs at each port of call, and the integration between inland carriers (i.e. trucks) and the external environment (i.e. country where the port, agency and inland carrier are located).

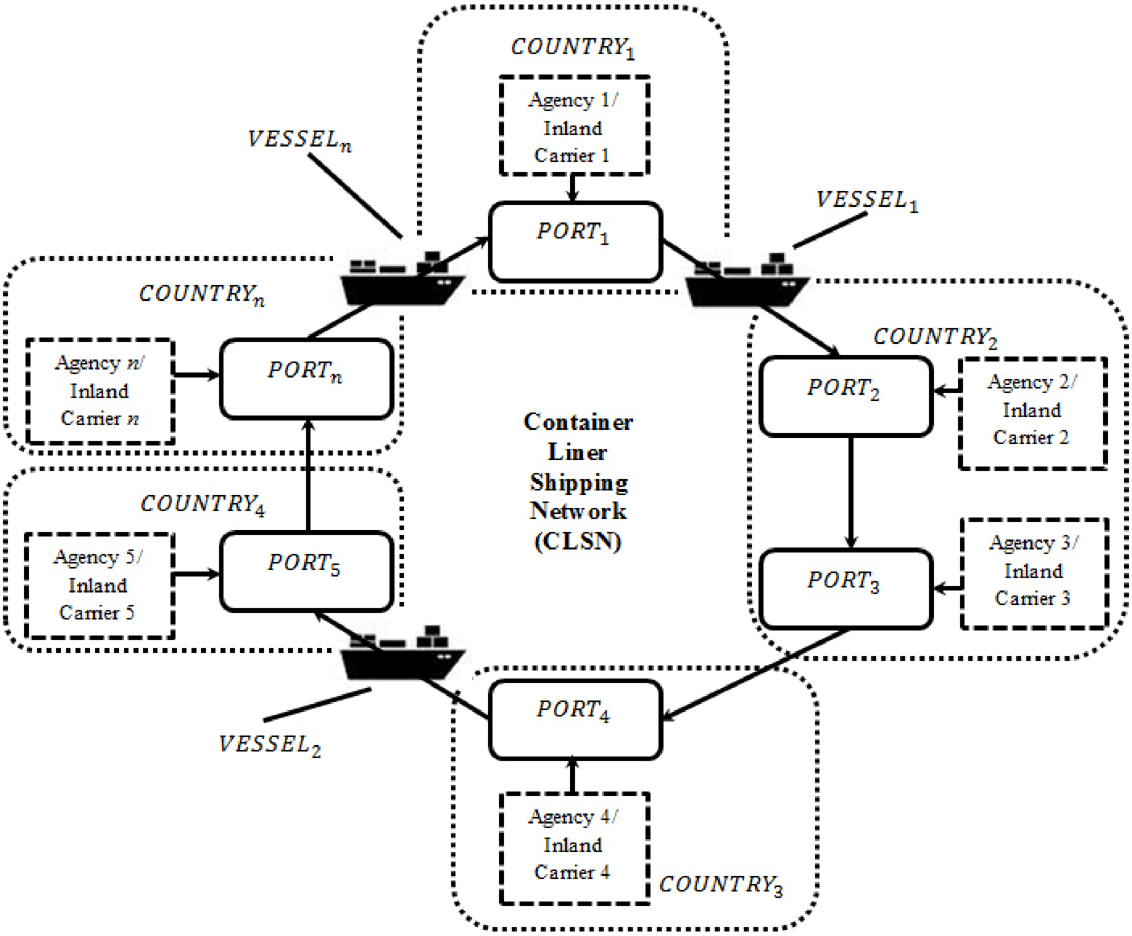

Figure 1. Container Liner Shipping Network

3. Planning Levels of Container Liner Shipping

In container liner shipping, there are three stages of planning levels, which can be listed as strategic, tactical and operational (Christiansen *et al.* 2007). Each of these planning stages consists of various specific problems, and a hierarchical interrelation exists between stage levels. In addition, the terms of decisions in each stage are different, ranging from a few hours to 10 years.

Strategic planning is concerned with a broad spectrum of problems extending from setting up liner services to engaging in contracts with allies. These strategic decisions are long-term decisions that need to be implemented for five to 10 years. Moreover, strategic decisions set the framework for tactical planning and guidelines for operational planning. Due to the length of the time horizon and the volatility of the CLSI, knowledge about the future is limited and associated with a high degree of uncertainty (Kjeldsen 2011). There are a number of issues that need to be solved at this level, such as service market selection, networking and transportation design, fleet size and mix decisions, port characteristics, ship characteristics and design (Christiansen *et al.* 2007).

Tactical planning is a level of planning that concentrates on medium-term decisions, which in liner shipping can be extended from two months up to one year. Due to the time horizon being shorter than for the strategic planning level, the information required for making tactical planning and decisions is reliable and available. The focus of this level in liner shipping is ship routing, ship scheduling and fleet deployment (Christiansen *et al.* 2007; Andersen 2010). Therefore, most of the decision criteria are dedicated to planning for ship routing, scheduling and fleet deployment (Christiansen *et al*. 2007).

Operational planning level is based on a short-term period that can be extended from a few hours to a few months (Kjeldsen 2011). The information as a source of decision-making at this stage is reliable and easy to obtain due the shorter time horizon. Liner shipping consists of high uncertainty in its operation and often changes dynamically depending on different situations. As a result, short-term review at this stage is necessary. Operational planning usually depends on the decisions made at the strategic and tactical stages. It focuses on a particular cargo, country, ship and port. The operational problem mainly involves steaming speed selection, ship loading, environmental routing and disruption management.

Disruptions in the container liner shipping operations can be listed in four levels: delay, deviation, stoppage and loss of platform service (Gurning 2011). With the new era of unprecedented changes, the operations have become extremely complex and vulnerable to many risks. There are many elements that can cause disruptions in the operations such as bad weather conditions, and political, economic and social factors. These elements strategically influence the performance of the CLSI.

4. Supply Chain Risk Management (SCRM)

Jüttner *et al*. (2003 page 201) defined SCRM as "the identification and management of risks for the supply chain, through a coordinated approach amongst supply chain members to reduce supply chain vulnerability as a whole". They also defined supply chain risk as the variation in the distribution of possible supply chain outcomes, their likelihood and their subjective values. The terms 'risk' and 'uncertainty' are repeatedly used interchangeably even though they are not the same. The distinction between risk and uncertainty is that risk can be measured while uncertainty cannot be measured, and the probabilities of the possible consequences are not known (Knight 1921). However, this distinction has been queried, and many scholars have already started to develop models for measuring uncertainty.

The past decade has seen the rapid development and transmission of SCRM in many subjects such as general concept of supply chain and perspectives, stock price performances, multinational network, operational flexibility, manufacturing and shareholder wealth (Kogut & Kulatikata 1994; Huchzermeier & Cohen 1996; Hendricks & Singhal 2003, 2005; Kleindorfer & Saad 2005; Tang 2006; Craighead *et al*. 2007; Trkman & McCormack, 2009). The evolution of SCRM literature began in 1994 when the first two articles by Kogut & Kulatikata (1994) and Huchzermeier & Cohen (1996) discovered the field of risk in a supply chain context from the perspective of flexibility (Colicchia & Strozzi 2012). Later, a considerable amount of literature related to SCRM was published in several main journals (e.g. International Journal of Production Economics, Journal of Operations Management, European Journal of Operational Research, Supply Chain Management: An International Journal, Production and Operations Management, Journal of the Operational Research Society and Management Science). It can be seen that the development of the theory of SCRM has been influenced by the evolution characterising the business environment (Colicchia & Strozzi 2012).

Several studies have focused on clarifying the concept of SCRM and identifying an agenda for current research, such as CLSCM (2003), Jüttner *et al.* (2003), Ritchie & Brindley (2007), Trkman & McCormack (2009) and Colicchia & Strozzi (2012). CLSCM (2003) argued that, in order to improve supply chain resilience, the supply chain vulnerabilities can be instigated from several different levels, and they are inextricably linked. There are four interlocking levels of analysis, which can be listed as follows (CLSCM 2003):

- *Level 1 - Process/value of a stream*. This level examines supply chain vulnerability from the prevailing engineering-based process perspective, seeing the supply chain as a linear 'pipeline' flowing through and between organisations in the network. The emphasis is firmly on the efficient, value-based management of individual workflows and their accompanying information (i.e. usually by product, *etc.*).
- *Level 2 – Assets and infrastructure dependencies.* This level represents supply chains in terms of asset and infrastructure dependencies (e.g. factories, distribution centres, retail outlets, trucks, trains, vessels, planes, *etc.*).
- *Level 3 – Organisations and inter-organisational networks*. This level views supply chains as inter-organisational networks. The focus is on the organisation (e.g. reliability and capability performances) that owns or manages the assets and infrastructure in the supply chain networks.
- *Level 4 – The environment.* This level focuses on the wider macroeconomic and natural environment within which organisations do business, assets and infrastructure are positioned, supply chains pass and value streams flow. Factors for consideration are the political, economic, social and technological elements of the operating and trading environment, as well as natural phenomena – geological, meteorological and pathological.

Additionally, Jüttner *et al*. (2003) suggested that supply chain risk sources can be categorised into three groups, which can be listed as follows:

- *Environmental risk*. These sources comprise any uncertainties arising from the interaction between supply chain and environment. These may be the result of socio-political actions (e.g. fuel protests or terrorist attacks) or acts of God (e.g. extreme weather or earthquakes).
- *Organisational risk*. These sources lie within the boundaries of the supply chain parties and range from labour (e.g. strikes), production uncertainties (e.g. machine failure) to IT-system uncertainties.
- *Network-related risk.* These sources arise from interactions between organisations within the supply chain. Whatever damage is caused by suboptimal interaction between the organisations along the supply chain is attributable to network-related risk sources. In this regard, environmental and organisational risks are sources of the various links in the supply chain.

Later, Trkman & McCormack (2009) proposed a preliminary research concept regarding a new approach to the identification and prediction of supply risk, based on suppliers' characteristics and performances, and the environment of the industry in which they operate. They highlighted that the major challenges posed to supply chains are due to a turbulent environment. Therefore, they argued that the earlier research often neglects an important division of risks, namely the origin of risks that can either be within a chain or from the outside environment. In order to distinguish between the different kinds of risks, the sources of uncertainty need to be separated into two different constructs (Trkman & McCormack 2009):

- *Endogenous uncertainty*. This source of uncertainty/risk is inside the supply chain and can lead to changing relationships between focal firm and suppliers.
- *Exogenous uncertainty*. This source of uncertainty/risk is from outside the supply chain.

5. Existing SCRM Studies in the Maritime Transportation System

In recent years, several attempts have been made to apply SCRM in the maritime transportation system with the focus on maritime network, container supply chain, multimodal supply chain, port and terminal operations (Barnes & Oloruntoba 2005; Yang *et al*. 2005; Bichou 2008; Yang *et al*. 2010; Gurning 2011; Yang 2011; Mokhtari *et al.* 2012; Vilko & Hallikas 2012; John *et al.* 2014; Loh & Thai 2014; Riahi *et al*. 2014). A summary of these studies is presented in Table 1.

Barnes & Oloruntoba (2005) explained that the complexity of interaction between ports, maritime operations and supply chain has created vulnerabilities and requires an extensive analysis. Bichou (2008) provided a conceptual explanation on modelling the maritime security assessment across the maritime network. Later, Loh & Thai (2014) proposed a model that can be used as a universal guide in assisting port management in managing port-related disruptions and seeking to reduce the occurrences of port-related supply chain disruption threats. Although these studies have been carried out to provide an assessment model, none of them has provided a mathematical approach in the assessment model.

A number of studies have provided a mathematical approach for assessing risk in the container supply chain. For example, Yang *et al*. (2005) provided a framework for assessing container supply chain-related risk by using a modified Formal Safety Assessment (FSA). This model emphasises the analysis of threats in the container supply chain with a high level of uncertainty from both safety and economic viewpoints. Yang *et al*. (2010) then developed a Fuzzy Evidential Reasoning (FER) approach for carrying out the security estimation of a vulnerable port system against terrorism attacks. They also developed a Bayesian Network (BN) for identifying vulnerable assets in a port security protection scenario. Gurning (2011) used a Markovian approach in analysing maritime disruptions. Yang (2011) proposed a loss exposure matrix for identifying the security risk in Taiwan's maritime supply chain security. Latest, Riahi *et al*. (2014) employed an Analytic Hierarchy Process (AHP) and BN for evaluating a container's security score. Some other related papers are Mokhtari *et al*. (2012), Vilko & Hallikas (2012) and John *et al*. (2014).

6. Critical Reviews for Future Research

Viewing from the strategic point of view, by integrating the concept of the CLSI, the planning levels of container liner shipping and the concept of SCRM, questions have been raised about risk and uncertainty arising from the external environment (i.e. country-limited scope) and how can these factors influence the organisational reliability and capability of LSOs. Another question concerns how uncertain environments can influence the punctuality of containerships in liner shipping operations.

As a result, for future research, this study will focus on developing frameworks for analysing, assessing and evaluating the aforementioned problems. Firstly, a mathematical model for assessing the business environment-based risk in a country from the CLSI's perspective needs to be developed. Secondly, a mathematical framework for evaluating the organisational reliability and capability of LSOs needs to be constructed. Thirdly, an appropriate approach for analysing the punctuality of a liner vessel to/from a particular port of call under uncertain environments needs to be established.

In particular, this paper proposes five main aspects need to be investigated for future research, as follows:

1. How can the business environment-based risk in a country be categorised and assessed from the CLSI's perspective? What is a suitable mathematical method for assessing this business environment-based risk?
2. How can the organisational reliability and capability of LSOs be categorised and evaluated? What is a suitable mathematical method for evaluating this organisational reliability and capability of LSOs?
3. How can the business environment-based risk influence the organisational reliability and capability of LSOs from the CLSI's perspective?
4. How can the arrival punctuality of a liner vessel be analysed and predicted under dynamic and uncertain environments? What is a suitable mathematical method for analysing arrival punctuality of a liner vessel under dynamic and uncertain environments?
5. How can the departure punctuality of a liner vessel be analysed and predicted under dynamic and uncertain environments? What is a suitable mathematical method for analysing the departure punctuality of a liner vessel under uncertain environments?

The external environment (i.e. business environment-based risk) has a profound influence on the organisational performances of LSOs. An unhealthy business environment will adversely affect LSOs in the context of operational reliability, knowledge management and financial capability (CLSCM 2003; Riahi *et al*. 2014). For example, natural disaster events (e.g. earthquake and tsunami) are catastrophic events that possibly cause port destruction and marine crew loss; as a result, natural disaster events will have a direct impact on operational reliability. On the other hand, social risks (e.g. demographic changes) in a country where LSOs operate can influence the labour quality and availability in the market, which may lead to insufficient workers or incompetent workers; ultimately, social risks influence the knowledge management of LSOs.

Table 1. Summary of the Previous SCRM Studies in the Maritime Supply Chain

Article's Title	Author	Focus	Methodology	Suggestion/Contribution
Assurance of security in maritime supply chains: Conceptual issues of vulnerability and crisis management	Barnes, P. & Olorubtoba, R. (2005)	Maritime supply chain	- Theoretical Explanation	- There is a need to examine the goodness-of-fit of security initiatives against business efficiency and competitiveness and to consider the training needs for crisis management capabilities.
Reliable container line supply chains - A new risk assessment framework for improving safety performance	Yang, Z.L., Bonsall, S., Wall, A. & Wang, J. (2005)	Container supply chain	- Modified Formal Safety Assessment	- This model emphasises the analysis of the threats in the container supply chain with a high level of uncertainty from both safety and economic viewpoints.
Security and risk-based models in shipping and ports: Review and critical analysis	Bichou K. (2008)	Maritime transportation network.	- Conceptual Explanation	- A conceptual piece that draws from the interplay between engineering and supply chain approaches to risk in the context of recent maritime security regulations.
Facilitating uncertainty treatment in the risk assessment of container supply chains	Yang, Z., Bonsall, S. & Wang, J. (2010)	Container supply chain	- Fuzzy Evidential Reasoning - Bayesian Network	- The outcomes of the models can provide decision-makers with a transparent tool to evaluate container supply chain safety and security policy options for a specific scenario in a cost-

				effective manner.
Maritime disruptions in the Australian-Indonesian wheat supply chain: An analysis of risk assessment and mitigation strategies	Gurning, R.O.S. (2011)	Australian-Indonesian wheat supply chain.	- Markovian Approach	- The results of this study indicate that maritime disruptions are an important issue for academic researchers as a theoretical discipline, and as a practical ground for examining such risk events in a complex supply chain network. - The balance of mitigation, adaptation, and intervention is important for any managers of a wheat supply chain network to understand.
Risk management of Taiwan's maritime supply chain security	Yang, Y.C. (2011)	Maritime supply chain in Taiwan.	- Loss Exposure Matrix	- The leading categories of Container Security Initiatives (CSI) risk factors are operational risk, physical risk and financial risk.
Decision support framework for risk management on sea ports and terminals using fuzzy set theory and evidential reasoning approach	Mokhtari, K., Ren, J., Roberts, C. & Wang, J. (2012)	Port and terminal operations	- Fuzzy Evidential Reasoning - Bayesian Network	- The proposed methodology and model in the form of decision support can be implemented at any specific port during the course of its risk management cycle, auditing and port-to-port risk evaluations.
Risk assessment in multimodal supply chains	Vilko, J.P.P & Hallikas, J.M. (2012)	Multimodal supply chains.	- Monte Carlo-based Simulation	- This paper illustrates the value of a holistic view towards actors in the supply chain attempting to assess the risks. - On the national or regional level it enhances understanding of such risks, their likelihood and consequences, which gives a good basis on which to prepare for and respond to supply chain actors in order to ensure the security of supply.
An integrated fuzzy risk assessment for seaport operations	John, A., Paraskevadakis, D., Bury, A., Yang. Z., Riahi, R. & Wang, J. (2014)	Seaport operations	- Evidential Reasoning	- The proposed approach could provide managers and infrastructure analysts with a flexible tool to enhance the resilience of the system in a systematic manner.
Managing port-related supply chain disruptions: A conceptual paper	Loh, H.S. & Thai, V.V. (2014)	Port operation	- Conceptual Explanation	- The proposed model serves as a universal guide in assisting port management in managing port-related disruptions and seeks to reduce the occurrences of port-related supply chain disruption threats.
A proposed decision-making model for evaluating a container's security score	Riahi, R., Li, K., Robertson, I., Jenkinson, I., Bonsall, S. & Wang, J. (2014)	Container supply chain	- Analytic Hierarchy Process - Bayesian Network	- The proposed methodology can be used for targeting those containers that pose a high risk to the container supply chain.

With the growing complexity in liner shipping operations due to uncertain environments, one of the biggest concerns is the punctuality of containerships. Delay, however, not only reduces the reliability value of the liner shipping operations but also incurs logistic costs to the customer as a consequence of additional inventory costs, and in some cases additional production cost (Notteboom 2006). Vessels may be delayed due to port congestion, port inefficiency, poor vessel conditions, rough weather, incapability and unreliability of an agency that represents LSOs at each port of call. These uncertainties are some of the reasons that may impede LSOs from providing on-time services to their customers.

By considering the three planning levels as discussed in Section 3, it is clear that no level has proposed risk and reliability management in the context of environment and organisation, or even in a general perspective. Therefore, it can be proposed in this paper to consider the assessment of the business environment-based risk and the evaluation of the organisational reliability and capability of LSOs at the strategic planning level. In addition, since disruption management (i.e. with the purpose to solve a problem when disruptions occur and get the vessel back on schedule) has been discussed at the operational level, what can be proposed at this level is a mathematical model as a decision support system for analysing and predicting the punctuality of containerships (i.e. arrival and departure) under uncertain environments.

Although extensive research has been carried out on SCRM in the field of maritime supply chain (i.e. Table 1), far too little attention has been paid to the environmental risk in a country-limited scope. Riahi *et al*. (2014) found that the reliability value of a country is the most significant factor in assessing container security. They considered four sub-elements for evaluation of the reliability value of a country (i.e. geopolitical, socio-political, economic and natural disaster). However, these four elements have not been investigated in depth in previous research due to the generality of the assessment criteria. Therefore, there is a knowledge gap for assessing the value of the business environment-based risk in a country from the CLSI's perspective needs to be developed.

7. Conclusion

The vulnerability of container liner shipping industry has necessitated the need for LSOs to assess the business environment-based risk, their organisational reliability and capability and the punctuality of their vessels by using appropriate mathematical models. Within this paper, the significant literature and the critical review of the current research are discussed. Also, the problem analysis and research gap have been highlighted. Finally, five main aspects for future research have been proposed.

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