The role of ports in supply chain disruption management

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**THE ROLE OF PORTS IN SUPPLY CHAIN DISRUPTION
MANAGEMENT**

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SCHOOL OF CIVIL AND ENVIRONMENTAL ENGINEERING

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ABSTRACT

The function of a port has evolved from a platform providing simple loading and unloading activities to a gateway that opens up numerous opportunities that proliferate economic benefits. Despite recognising the fact that ports have increased their significance in supply chains, little is known about the deficiencies in port operations or events originating from ports that threaten supply chain continuity. Addressing the vulnerability of ports helps to ensure ports' functionality and enhance supply chain resilience. This calls for contemporary studies on supply chain management to address the management of supply chain disruptions that originate from port operations. Therefore, this study has two main purposes: to study the magnitude of port-related supply chain disruption (PSCD) threats; and to examine the application of a management model which could minimize the disruptive potential of ports on supply chains.

This research has identified PSCD threats and synthesized the current literature into a management model that seeks to target operational deficiencies at ports. The management model is operationalized in three tiers, from the top management level to the front-line employees, with characteristics from risk management, business continuity management and quality management theories. The management model serves as a universal guide in assisting port management in managing port-related disruptions and seeks to reduce the occurrences of PSCD threats.

In-depth interviews have been conducted with senior managers from port operators and port users' entities to preliminarily substantiate the 19 identified disruptive port-related events and management model. Through the interviews with the management of industry players, the factors affecting the occurrences of the PSCD threats as well as the implementation of the management model were analyzed. Subsequently, two surveys were conducted. The first survey collected primary data

from port users, port operators and port authorities on the frequencies and consequences of PSCD threats. The purpose of the second survey was to gather primary data from port operators and port authorities to provide empirical evidence of the effects of the management model on port performance. From the first survey, risk matrices were generated to compare the perspectives of port operators and port users. Data collected from the second survey was analyzed using structural equation modeling (SEM) with AMOS 22.0.

The main conclusions of this research are that threats which require a higher level of attention are those related to the planning of port resources while threats that require a lower level of attention are those related to port security. The SEM results indicate that managing PSCD using the proposed model contributes positively to the identification of internal and external opportunities and, through that, to port's resilience of internal operations. This, in turn, positively influences the port's financial health and market reputation. This research fills the literature gaps by providing a risk assessment of port-related threats that have adverse effects on supply chain continuity from the perspectives of port operators and port users. Its findings highlight the areas that port management should focus on as well as the measures of managing PSCD holistically through strategic internal and external collaborative efforts.

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LIST OF ABBREVIATIONS

PSCD	Port-related Supply Chain Disruption
RQs	Research Questions
SRQs	Sub Research Questions
PDM	Management Model for PSCD Threats
C-TPAT	Customs-Trade Partnership Against Terrorism
DHS	US Department of Homeland Security
MTSA	US Maritime Transportation Security Act
DA_NET	Disruption Analysis Network
TSCD	Transshipment, Storage, Collection and Distribution of freight
VMT	Vehicle-miles Travelled
RM	Risk Management
BCM	Business Continuity Management
QM	Quality Management
TQM	Total Quality Management
FH	Financial Health
MR	Market Reputation
RIO	Resilience of Internal Operations
IEO	Internal and external opportunities
IAPH	International Association of Ports and Harbors
AAPA	American Association of Port Authorities
APP	Association of Pacific Ports

PMAESA	Port Management Association of Eastern and Southern Africa
SLA	Singapore Logistics Association
SSA	Singapore Shipping Association
ISPS code	International Ship and Port Facility Security code
CSI	Container Security Initiative
C-TPAT	24-Hour Advance Manifest Rule, Customer-Trade Partnership Against Terrorism
AEO	Authorized Economic Operator of the World Customs Organization
SEM	Structural Equation Modeling
CFA	Confirmatory Factor Analysis
RMR	Root Mean Square Residual
SRMR	Standardized Root Mean Square Residual
TLI	Tucker-Lewis Index
IFI	Bollen's Incremental Fit Index
CFI	Comparative Fit Index
RMSEA	Root Mean Square Error of Approximation
PNFI	Parsimony Normed-Fit Index
AVE	Average Variance Extracted
SPM	Singapore Plastic Manufacturer

CHAPTER 1. INTRODUCTION

1.1. Background

In global supply chains, seaports are critical transport nodes where value adding and logistics-related activities take place. However, as processes and operations in the ports increase in their complexities and range, the integration of ports into supply chain management creates a higher level of uncertainties for downstream planning product movement as well as information exchange. For that reason, deficiencies in the ports are capable of developing into augmented unsought effects in supply chains and these deficiencies can arise from operational inefficiencies, demand and supply imbalances and miscommunication between dyadic contracting parties. Especially since disruptions in current supply chain settings are already seeing adverse effects on most companies' profitability and reliability (Blanchard, 2006), ports should initiate a facilitating role in maintaining the efficient and effective management of product and information flow throughout the supply chains. Among the various causes of supply chain disruptions, deficiencies at the ports need to be defined as they are capable of disrupting webs of supply chains. To make matters worse, supply chain trends and practices increase the likelihood of a disruption occurring and exacerbate the effects of disruptions (Handfield et al., 2007, Kleindorfer and Saad, 2005). Hence, the potentiality of ports to administer seamless services, operations and transfer of cargo is obviously very much aspired by port users.

1.2. The Potential Impact of Ports on Supply Chains

The evolution of ports has witnessed the ports' increasing integration into global supply chains and the increasing assimilation and amalgamation of ports into supply chains (Pettit and Beresford, 2009) has amplified the potential of ports in supply chain disruptions. In 2011, the Great East Japan earthquake crippled Japanese north-eastern ports and caused damage to port facilities, warehouses and factories in the port areas, and has also affected many worldwide industries (Takahashi et al., 2011, Jolly, 2011). Not only were containers scattered or destroyed, port operations at six major ports could not resume for months while the equipment underwent

repairs. The shutdown of Sendai-Shiogama port proved to be difficult for even the big players in the electronics industry (Jolly, 2011). One of those affected is Sony which, in particular, subsequently reported a 10% decrease of sales on a year-on-year comparison partly due to the negative effects of the earthquake (Sony Global, 2011). Even though this paper will not explore natural catastrophe, since it does not originate from ports and neither is it part of port operations, this real world example illustrates the impact a malfunctioned port can have on the industries.

An instance of port-related cause of supply chain disruptions is the West Coast port strike in 2002. To assess the impact of the strike, Institute for Supply Management (ISM) conducted a survey involving 1,500 purchasing and supply management personnel (Institute for Supply Management, 2002) and the survey results are shown in Table 1.1. With almost half of all the respondents' supply chain activities being disrupted due to the port's shutdown, the results suggest evidence of ports playing a potentially significant role in disrupting supply chain activities. Furthermore, 21% of the respondents indicated that their businesses suffered huge expenses and another 20% suffered modest expenses when alternatives were used in response to the shutdown of West Coast.

Table 1.1: Results of West Coast Port Strike's Impact Assessment Survey

Effect on Normal Supply Chain Activity	% of Respondents
Harmed	41
No Impact	57
Benefitted	≤ 2

Source: Institute for Supply Management (2002)

An existing network may be mature enough to stabilize itself in events of disruptions and shocks, but this may not be the case in every network and this has been evidenced in the aforementioned examples. There is also a likelihood that

some smaller firms, though positioned in a stabilized network, may still have to be sacrificed as they may not have the adequate power or resources to overcome the crisis. While it is undeniable that not all disruptive events in the ports are capable of upsetting the rest of a supply chain as the existing supply chain network may be adequately competent to attenuate the disruptive impact stemmed from the ports, the intention of preventing such a situation reduces frustration for parties whose cargo are lodged in the delays or in complete port closures, and also avoids chaos in the anticipation of thwarting of plans.

Yet, since the introduction of containerization, the focus of research within the maritime industry revolved around improving internal operational efficiencies which does not reflect the actuality of port's integration with its peripherals. A handful of research studying the relationship and coordination of ports with its community (Notteboom, 2008, Van Der Horst and De Langen, 2008) is starting to appear.

1.3. Research Questions

In general, the objectives of this research are: (1) to perform an analysis of port-related supply chain disruption (PSCD) threats immanent in a port and (2) to design measures to contain and reduce PSCD consequences. PSCD threats are defined as operational risks inherent in port processes that are capable of disrupting the continuity of upstream and/or downstream supply chains. Hence, natural disasters and weather conditions that also result in disruptions are not in the scope of this research. The research questions (RQs) and sub research questions (SRQs) are as follows:

RQ1: How is the role of ports in inducing supply chain disruptions determined?

SRQ1: What are the implications of ports increasingly being integrated into supply chains?

SRQ2: What are the most commonly observed and perceived PSCD threats and consequences?

SRQ3: How severe are the PSCD consequences?

SRQ4: How can PSCD threats be detected?

RQ2: How can ports mitigate port-related supply chain disruptions effectively?

SRQ5: What are the mechanisms which the port should initiate to minimize port-related supply chain disruptions?

SRQ6: How should a holistic approach towards PSCD management be operationalized by the participants involved in port transport chains?

1.4. Research Purpose

There are two main objectives of this research: (1) to map out the risk profiles of PSCD threats and (2) to develop a management model for PSCD threats, abbreviated as “PDM”.

PSCD threats that affect supply chain continuity will be studied from the perspective of port operators and port users. The purpose of this is to ensure that the risk assessment reflects a more realistic and prudent view. As port users are directly affected by port disruptions, depending on the severities of the disruptions, their evaluation of the threats offers a valuable analysis of the extent that these threats pose to the supply chains. Therefore, this study aims to study the magnitude of PSCD threats on supply chain disruptions through examining the frequency and consequence of these threats.

This research also seeks to address the research questions by way of a management model that reflects a holistic management approach for port management to implement. While there have been several studies exploring risks in port operations, there has been no studies addressing a full set of operational risks from a holistic perspective, especially in connection with supply chain disruptions. Since the introduction of containerization, the focus of research within the maritime industry revolved around improving internal operational efficiencies which does not reflect the actuality of port's integration with its peripherals. Elaborate research on general supply chain disruption strategies emerged only in recent years, while studies on port disruption strategies concentrate on discrete disruption causes. These collectively epitomize the paucity of a port-wide holistic approach towards the management of port-related supply chain disruptions. The implementation of the management model aims to ensure supply chain resilience with the application of risk management, business continuity management and quality management principles.

The discussion of ports encompasses those that handle containers and non-containerized cargo such as vehicles, liquid and dry bulk. Passenger ports will not be analyzed as the research scope covers only the dire effects on cargo. The applicability of the proposed management model is confined neither to cargo handling types, nor to certain regions, nor to stages of maturity in its development. The generic relevance of the model renders a concrete basis for future studies that are expected to more specifically address the differences in port characteristics with regards to the resulted outcomes of the management model.

Hence, this research contributes to the development of a resilient port and supply chain continuity through describing the factors affecting the occurrences of PSCD threats and issues to consider in the implementation of the model. Collectively, the effects are reduced frequencies of PSCD threats, avoided and/or mitigated dire consequences as well as increased port resilience.

1.5. Structure of the Thesis

This opening chapter has provided the contextual background to this research and underlined the reasons for minimizing the supply chain disruption potential of ports through exploring the inherent PSCD threats. In this introductory chapter, the two objectives of this research are identified, namely the risk profiles of PSCD threats and the development of an effective PDM. Chapter 2 reviews selected literature which is organized into two main portions covering past studies related to supply chain disruption risk management and the changing role of ports as part of supply chains. Chapter 3 explains the conceptual framework in the identification of PSCD threats and the development of PDM. Chapter 4 describes the methodology employed by explaining the research process and approach, population and sampling frame and survey design. Chapter 5 and 6 discuss the results of the risk profiles of PSCD threats (RQ1) and management model (RQ2) respectively. The thesis ends with Chapter 7 which summarizes the results, discusses the academic and managerial implications of this research and identifies research limitations as well as areas for future research possibilities. Figure 1.1 shows an overview of the structure of this thesis.

Figure 1.1: Structure of Thesis

Source: Author

CHAPTER 2. LITERATURE REVIEW

2.1. Introduction

This chapter investigates past research which explored supply chain disruption management, port risks and mechanisms addressing port disruptions. To provide a relevant and generic perspective, the essential features of supply chain disruptions and strategies to minimize or avoid supply chain disruptions will be reviewed first. Next, in order to ascertain the implication of a port's integration into supply chains, the evolved role of a port needs to be established by way of addressing the changing role of ports in global supply chains and the integration of ports with supply chains. These will be followed by a review of commonly discussed operational port risks and corrective actions as these will shed some light on the requirements of a well-performing port. By considering the generic disruptions and strategies together with the parameters local to the port environment, a variety of PSCD threats and respective plan of actions can then be ameliorated.

2.2. Supply Chain Disruption Management

The recent rise in the number of calamities and terrorist acts has brought much attention to the vulnerabilities of supply chains. Having passed through many hands that span continents and cultures, the reliability and timeliness of freight delivery becomes increasingly difficult to be assessed. With a growing interest in minimizing supply chain risks, research in risk analysis of supply chains has been on the rise.

2.2.1. Disruptions in Supply Chains

Natural and man-made disruptions may induce undesired effects across the supply chains entailing an aggregated network of interconnected organisations. Supply chain disruptions frequently studied include the inability of transporting goods and

services to the end customer on time and/or in the right condition and the complete failure to move goods and services across to the end customers.

The effectiveness of integrated transportation entails the reliable movement of the right items in accurate amounts to the intended destination in good conditions (Morash and Clinton, 1997). As such, the impact that transportation capabilities can have on the effectiveness of supply chains cannot be underrated. The effects transportation capabilities have on supply chain operations are echoed in Stecke and Kumar (2009), who, like Morash and Clinton (1997), also considered both internal and external aspects of supply chains. Two of the factors inducing vulnerabilities identified by Stecke and Kumar (2009) pertain to transportation capabilities and they are the number of exposure points and increase in distance or time. Primarily, there are six basic failure modes in performance within a supply chain (Sheffi et al., 2003) and these are (a) disruptions at facilities, (b) disruptions in supply, (c) disruptions in transportation, (d) disruptions in communications, (e) disruptions in demand as well as (f) freight breaches. Port disruptions specifically belong to disruptions at facilities and are thus a category of supply chain failures as they are capable of contributing to supply chain disruptions.

Generally, deviations and disruptions can occur at the strategic, tactical and operational stages of planning, with variables during transportation or transshipment of goods conjointly acknowledged as possible forms of disruptions (Gaonkar and Viswanadham, 2004). Fundamental differences in business models of supply chain entities are likely to put a strain on the chain, making it more inclined to be disintegrated (Robinson, 2007), which can escalate into supply chain disruptions. The severity of these disruptions are likely to be attributed to factors such as density, complexity and node criticality of the supply chains (Craighead et al., 2007), while the varying degrees of supply chain failure impact is normally a consequence of weaknesses in different supply chain practices (Stecke and Kumar, 2009). At the same time, there are supply chain parameters which can increase the likelihood of a

disruption occurring (Handfield et al., 2007) and these amplifiers are stated in Table 2.1. Several of the parameters in Table 2.1 are commonly reported bottlenecks at ports as shown in Section 2.4 and this reiterates ports' contribution to supply chain disruptions. For instance, the instability of workforce, scarcity of qualified labour, poor communication, channel overload, strain on port infrastructure and lack of visibility of entire system are applicable to a port and are possible PSCD threats.

Table 2.1: Global Sourcing Amplifiers of Disruptions

	Supply Chain Parameters	Port-related
1	Instability of supplier's environment	
2	Number of brokers	
3	Length of lead-time	
4	Concentration or clustering of suppliers	
5	Scarcity of qualified labor	√
6	Instability of workforce	√
7	Degree of customs regulations	
8	Level of specialization of storage requirements	
9	Level of security requirements	
10	Level of demand for product (volume and variability)	
11	Level of legislative actions related to importing/exporting	
12	Poor communication	√
13	Level of regional/country political instability	
14	Number of transfer points	
15	Lack of vessel capacity and channel overload	√
16	Strain on port infrastructure	√
17	Potential for terrorism	√
18	Level of natural disasters	√
19	Lack of visibility of entire system/supply chain	√

Source: Author, adapted from Handfield et al. (2007)

On a same note, Netherlands Organisation for Applied Scientific Research has identified causes for each failure mode in supply chains (INTEGRITY and SMART-CM, 2008) as shown in Table 2.2. These modes are equally pertinent in the port environment. In this manner, the supply of stevedores and port workers, transportation of cargo through the port, deliverability of port service, communication network and infrastructure, and human resource issues regarding staff well-being and employment satisfaction, are rudiments where the list of PSCD threats can be expanded from.

There are qualitative and quantitative ways of determining impacts of risks. Impacts can be analyzed qualitatively using tools such as scenario building, likelihood-impact matrix, attribute analysis and Delphi forecasting while quantitative techniques include principles of probability, simulation and probability distributions (Frame, 2003). The qualitative and quantitative tools help determine the likely consequences with the occurrence of each risk when there is sufficient historical data for accurate analysis and when the management is seasoned in its business and disruption management.

While the qualitative tools offer opportunities to examine routine processes and operations from novel and creative perspectives (Frame, 2003), the consequences concluded would require categorization such that it would be clear which specific corresponding risks should be eliminated, avoided or reduced. It is not to say that qualitative techniques in impact analysis are less relevant as qualitative and quantitative tools address different aspects ultimately. Frame (2003) explained that good judgment and experiences would be essential to increase the accuracy of qualitative analysis of the impacts and these insights would be hampered when the individuals involved are constrained by the quantitative requirements.

Table 2.2: Causes of Failure Modes in a Supply Chain

Failure Modes	Port-related
<i>Causes of Disruption in Supply:</i>	
Sabotage of raw material inputs (e.g. food industry)	
Customs control delays	
Fire, explosion or natural disaster at plant of a supplier	
Blocked main transport infrastructure nodes	√
Supply disruption because of bad product quality and unclear product origin	
Strikes	√
Theft of goods at supplier DC, or at infrastructure node	√
Supply disruption due to manipulated/destroyed information systems	√
<i>Causes of Disruption in Transport:</i>	
Theft of trucks or cargo from trucks during transportation	√
On purpose manipulation of goods during transportation	√
Physical blocking of transportation (borders, road/rail blockage, etc.)	√
Sabotage of transport equipment / vehicles	√
Bombing or other planned destruction of vehicle, train, plane, etc.	√
Weather or other natural events causing delays	√
Smuggling of illegal goods together with normal freight flows	√
Manipulation of goods during transport (e.g. cold chain disruption)	√
<i>Causes of Disruption in production (internal):</i>	
Bombing or other planned destruction of production facility	
Sabotage of production equipment	
Fire or other natural disaster at plant	
Energy supply shortage	
Theft of goods from production plant	
Production disruption due to manipulated/destroyed information systems	
<i>Causes of Disruption in communication:</i>	
Systems failure of ERP, WMS, TMS, etc. systems	√
Cyber-attack aiming at theft or manipulation of data	√
Cyber-attack aiming at destruction of system	√
<i>Causes of Disruption in human resource:</i>	
Strikes	√
Direct attack at personnel at a facility	√
Personnel suffering from attack or disaster in a region (e.g. SARS)	√

Source: Author, adapted from INTEGRITY and SMART-CM (2008)

Disruptions are generally categorized according to their financial losses, disruption causes, levels of supply chain entities affected, whether the external market is affected and the duration of the disruption (Macdonald, 2008). A common way of segregating disruptions according to their severity is through the impact of the disruption in terms of dollars and cents (Waters, 2007). As can be seen, in identifying the types of supply chain disruptions, a typical way is segregation by the severity of the disruptions. However, the drawbacks are that not all consequences are quantifiable and a monetary range of consequence may be severe for a small enterprise but meagre for a large organization. Another problem encountered in the process of disruption quantification is that the consequences are usually perceived differently in different organizations (Waters, 2007).

Severity of the consequences can also be reflected through the length of time required before equilibrium is restored. Following this principle, the broad types of supply chain disruptions that Gaonkar and Viswanadham (2004) observed are deviation, disruption and disaster, each reflecting the nature of the supply chain uncertainty and are then quantified to determine the cost of each impact. Applying these three types of disruptions to the various nodes of supply, transportation, demand, facilities and communications would render delays and failure of deliverability in them. Similarly, a subsequent study on maritime transportation system by Berle et al. (2011) examines disruptions in the form of loss of supplies, interruption of own internal operations, sudden drop in customer demands, communication failure with external parties, inability to deliver product, running out of cash and unavailability of own people. Berle et al. (2011) then grouped these disruptions according to their frequency determined from surveys. Gurning et al. (2011) categorized the types of disruptions into delay, deviation, stoppage and the loss of service platform. A summary of the different types of supply chain disruption categorizations is presented in Table 2.3. The presentation of disruptions is determined to a great extent by the objective of the study, intended depth of the study, scope of the study and available data. Thus, it is not possible to list all

possible supply chain disruptions as they tend to be industry and organization-specific.

Table 2.3: Different Types of Supply Chain Disruption Categorization

Categorization of the Types of Supply Chain Disruptions Discussed	Studies
- Financial Losses	Macdonald (2008)
- Disruption Causes	
- Echelons of Supply Chains Affected	
- Association with External Environment Change	
- Duration of Disruptions	
- Financial Losses	Waters (2007)
- Deviation, disruption or disaster	Gaonkar and Viswanadham (2004)
- Frequency of Disruption Occurrences	Berle et al. (2011)
- Losses, interruption or unavailability	
- Delay, deviation, stoppage or loss of service platform	Gurning et al. (2011)

Source: Author, synthesized from various literature

Section 2.2.1 has characterised supply chain disruptions and provided the essence in defining PSCD threats in the supply chain context. Section 2.2.2 investigates strategies for these supply chain disruptions. The identification of supply chain disruptions causes and corrective actions would be able to shed some light on the requirements of a well-performing port as well as applicable strategies which ports can administer due to the port's enmeshment in global supply chains.

2.2.2. Strategies for Supply Chain Disruptions

As supply chain disruptions may give rise to undesirable economic aftermath, many scholars are prompted to explore various methods of coping with uncertainties in the current supply chain environment. As catastrophic world events heighten awareness of supply chain uncertainties in recent years, numerous studies have identified various mitigating and contingency strategies to minimise risks in global supply chains.

Risk analysis in supply chain disruption management observes two dimensions of strategies: reducing the prevalence and severity of risks, and increasing the chain's ability to sustain risks (Kleindorfer and Saad, 2005). The minimisation of supply chain risks requires effective and sustainable partnerships from which the parties can derive benefits (Kleindorfer and Saad, 2005). This is in line with the idea that supply chain firms should no longer compete individually; the firms need to understand the importance of establishing strong alliances with each other, while not losing focus on enhancing performance at both local and aggregate levels (Green et al., 2006). However, the fundamental characteristics of an organisation should be incorporated in the selection of these strategies (Stecke and Kumar, 2009), since the performance and effectiveness of the strategies implemented are dependent on operational complexities and inter-organisational learning (Manuj and Mentzer, 2008). Besides considering the above general characteristics, mitigation strategies and contingency planning also tend to be more adequate when industry-specific parameters are incorporated.

In the context of global supply chains, the drawing up of contingency plans comprises of examining current and alternative possible collaborations as well as suppliers, appraising the effects of existing strategies and assigning responsibility to an identified personnel for the execution of the plan (Pieri, 2010). The mapping of contingency strategies to enhance a firm's responsiveness requires appropriate

intra-organisational structuring and support as well as external collaboration (Skipper and Hanna, 2009).

Strategies to combat supply chain disruptions are related to product and supply flexibility, product availability, transportation flexibility and control of product demand (Tang, 2006). However, as Tang (2006) mentioned, challenges that come along with such strategies include costs and benefits trade-offs, presence of a strategic fit and the initiatives of an organisation in its execution of the strategies. There are two programming models developed by Gaonkar and Viswanadham (2004) to assist decision making in global manufacturers and suppliers selection so as to achieve supply chain robustness. One model has the objectives of minimising operating costs and the variability of total operating costs involved, while the other was formulated to minimise shortages in supplies in the event of a disruption. Continuous improvement on the implemented contingency plans enables the supply chain to tackle challenges more readily. As aforementioned, contingency planning does not end at interaction within a firm; cooperation between firms are just as imperative.

Supply chain visibility and agility coupled with a proactive management approach, increase a supply chain's capacity in dealing with risks (Pieri, 2010). The importance of visibility and accurate real-time information sharing between nodes is emphasised in Blackhurst et al. (2005b) as they play an indispensable role in ensuring supply chain flexibility and responsiveness. This sentiment is shared by most respondents in a survey which saw 70% of them agreeing that a higher level of communication and information sharing between supply chain participants are important when having to manage undesirable consequences following disruptions (Figliozzi and Zhang, 2010). The case of West Coast port, which caught many companies unprepared when talks of a likely strike went neglected, clearly illustrates the need for research in disruption related information and the existence of disruption triggers (Blackhurst et al., 2005b). Therefore, the importance of instilling

awareness of supply chain risk in the entire supply chain is apparent and has also been brought up by many personnel coming from multiple industries (Blackhurst et al., 2005b).

Alternatively, measures such as restructuring of supply chains can be adopted. When considering supply chain structures, firms should decide on the size of supplier base, extent of product diversification and coordination, depending on whether the firms are competing on cost, quality, flexibility or reliability (Neureuther and Kenyon, 2009). The importance of planning and selecting a facility and its network is reflected by Snyder et al. (2006) when they constructed an optimization model to measure the risks in the form of related costs involved. This model is formed based on facility location and network design and it takes into account the threat of disruptions, so that it serves to better plan for a more reliable supply chain. Leanness, resilience and flexibility are the usual typical desired objectives of restructuring or selection of supply chain networks.

It is not surprising that studies on supply chain resilience and flexibility have quickly gained attention. Evidence from simulation shows that recovery from supply chain disruptions can be enhanced by having more flexibility in batch sizes and schedules, while the severity of the disruption can be abated by increasing responsiveness and capacity of contingency plans (Schmitt and Singh, 2009). As available inventory plays an important part in maintaining customer service, the leanness of an organisation is capable of increasing the organization's exposure to risks when disruption strikes, though lean operations do provide savings on the other hand (Schmitt and Singh, 2009). As a resilient system has diversity, efficiency, adaptability and cohesion as its characteristics (Fiksel, 2003), Falasca et al. (2008) explains that resilience in supply chain is capable of lowering chances of disruptive events occurrences and reducing the impact of unanticipated outcomes. However, resilience comes at a price which will be determined by the framework proposed by Falasca et al. (2008) which provides a quantitative measure showing the

relationship between the factors of supply chain resilience while keeping in mind the practical tradeoffs present in the decision to increase resilience. The tradeoffs are elaborated from the three supply chain design characteristics addressed by Craighead et al. (2007), which have been mentioned in Section 2.2.1. Incorporating resilience hones the ability to deal with the possible repercussions of disruptions, such that it takes a shorter time before the supply chain regains its undisturbed momentum and performance (Falasca et al., 2008).

Notable cases of well-managed supply chain disruptions by organisations are explored and compared in Table 2.4 which implied that plausible essential traits in effective management of supply chain disruptions include responsiveness, flexibility, strong supplier relationships, organisation's ability to influence demand, commitment to organisation and uniformity in processes and procedures. Specifically, Handfield et al. (2007) presented a list of responses in reducing impact of disruptive events from the results of their interview and this is shown in Figure 2.1. In their study, the ability to identify a disruption and establishing continuity plans is emphasised. It is apparent that in order to achieve these, commitment within the organisation and collaboration with the organisation's peripherals will be required and this is reflected from the mechanisms in Figure 2.1. However, this thesis shall go a step further by introducing the relevant PSCD indicators for early detection of disruption and the PDM seeks to operationalise the mechanisms proposed by scholars.

Table 2.4: Supply Chain Disruptions Response Strategies

Year	Disruptive Event	Firm Affected	Responses	Reference(s)	Approach
2000	Lightning struck Philips' semiconductor plant in New Mexico, causing fire in which thousands of mobile phone chips perished. The plant was shut down for weeks.	Ericsson	Stuck with single-source supplier strategy, failed to make rapid response	Liu (2009), Tang (2006)	Responsive, Flexible Product Design, Multiple Supplier Base
		Nokia	Reconfigured their phone designs so that production could be shifted quickly to alternative suppliers		
1997	Many Indonesian suppliers could not fulfil orders as they had troubles paying for components and materials due to the devaluation of Rupiah during the currency crisis.	Li and Fung	Shifted some production to alternative suppliers in Asia, provided financial assistance to affected Indonesian suppliers so that orders can be received by the US customers on time.	Tang (2006)	Multiple Supplier Base
1997	All Toyota's Japanese plants stopped production after a fire broke out at main supplier Aisin Seiki Co. which produces 99% of Toyota's p-valves, an essential in all its cars' braking systems.	Toyota	Firms and suppliers from Aisin Seiki and Toyota's keiretsu helped produce p-valves. Toyota resumed its full production in 9 days	Sheffi (2005), Liu (2009)	Strong Relationship with Suppliers, Flexible Process

Year	Disruptive Event	Firm Affected	Responses	Reference(s)	Approach
1999	Earthquake in Taiwan disrupted flow of semiconductors for a few weeks	Apple	Struggled to satisfy thousands of customer's orders. Attempted to ship slower version of G4 computers as it could not modify configurations contracted and paid for	Sheffi (2005), Tang (2006)	Pricing Strategy
		Dell	Used attractive pricing to influence demand so that other available components could be utilized instead		
1994	A severe blizzard in Kentucky caused air hub for UPS and roads to be closed, travel ban imposed.	UPS	UPS took advantage of its interchangeable sorting machines and processes as it meant employees from other parts of the country can operate at other facilities.	Sheffi (2005)	Uniformity in Process, Procedures and Practices
2003	SARS outbreak resulted in most business meetings, conferences and flights to and from Southeast Asia to be cancelled.	DHL International Ltd	Continued serving clients in protective gear and convinced many conference organizers to send materials around the world as substitutes to the cancelled meetings	Sheffi (2005)	Focused and Passionate about upholding company's mission

Source: Author, synthesized from various literature

Figure 2.1: Risk Reduction Mechanisms

Source: Handfield et al. (2007)

As summarised by Chopra and Sodhi (2004), the characteristics of mitigation approaches typically take the following seven forms: (a) increase capacity, (b) acquire abundant suppliers, (c) increase responsiveness, (d) increase inventory, (e) increase flexibility, (f) pool or aggregate demand and (g) increase capability. These approaches are able to target supply chain risks and disruptions by decreasing the risks, though there may lie disadvantages in implementing the strategies. Ultimately, mitigation strategies are dependent on the setting and nature of the chains, therefore, ways of mitigating disruption risks need to be tailored for different supply chain environments to be effective (Kleindorfer and Saad, 2005).

The understanding of the extent a disruption has is beneficial to supply chains (Blackhurst et al., 2005b). Supply chain members need to bear in mind the proven fact that efficacy of a supply chain strategy ultimately lies in whether or not it can satiate the needs of the chain's end customers (Green et al., 2006). Mitigation strategies and contingency planning take many forms, and the effectiveness of these strategies boils down to eliminating root causes of the disruptions, which differ across organisations and industries. The strategies that ports utilise can be as extensive as to minimise supply chain disruptions that span across a variety of industries. After exploring risk management in supply chain disruptions, the boundaries of this research has been defined and this section has provided insights as to what is expected of a supply chain during disruptive events for it to return to equilibrium.

2.3. Ports as Part of Supply Chains

The role of ports in global supply chains has undergone drastic changes in the past few decades. These transformations that have taken place have redefined the significance of ports in supply chain networks. Hence, the changing role of ports will be reviewed to determine their role in inducing supply chain disruptions.

2.3.1. The Changing Role of Ports

The changing global trade patterns inevitably have an effect on ports. The growing attention on ports can be attributed to the importance in coordinating material flows and information exchanges, cost minimization and cargo handling (Ng, 2009). Lately, some studies have indicated a close relationship between the performance of ports and efficiency of logistical chains. This relationship is built up through many decades and established due to the change in port's role in supply chains.

Ports have transformed from a site for cargo and documentation transit, to an indispensable interface that, among the many factors, determines the efficacy of supply chain performance. The traditional ports were less engaged in hinterland integration and cooperating with the port community. The focus conventional ports engaged in was more on the port's stability and sustainability (Ng, 2009) in their context at that time. However, the post containerization era witnessed marked progress in value-addedness and increasing integration into supply chains (Pettit and Beresford, 2009). With the increased complexities in port operations (Carbone and De Martino, 2003), the evolution of ports has resulted in a "port regionalization" phase in port development (Notteboom and Rodrigue, 2005). With new value pools being identified in landside logistics (Robinson, 2006), research has explored how ports utilize value migration to enhance their attractiveness, create new functionalities and profit pools within the landside logistics community, and has also highlighted the benefits of having a well-connected integrator in delivering value to the end-customer (Weston and Robinson,

2008). With port centric logistics already emerging (Pettit and Beresford, 2009, Beresford et al., 2011), this phenomenon is expected to move towards agility (Paixao and Marlow, 2003, Lun et al., 2010b).

Comparing the changes since the transformation from traditional ports, UNESCAP (2002) presented its investigation of the evolutionary developments in port functions through three generations. The concept of classifying ports into different generations was initiated by UNCTAD in the 1990s (UNCTAD, 1990, UNCTAD, 1999). Ports once provided the convenience of cargo storage but this was eventually deemed insufficient in subsequent generations. Services such as cargo distribution, packing and processing, became important port functions for conventional and bulk cargo in ports of the second generation. The phenomenon of third generation ports saw emerging concepts of cooperation and information sharing with ports acting as the facilitator, and with technology playing a key role in information exchanges between the different stakeholders. Changes in port ownership, port development strategy and scope of port activities are apparent throughout the three generations.

In summary, Figure 2.2 depicts an overview of the evolutionary role of ports in different era. Pettit and Beresford (2011) have clearly identified the different roles ports played in supply chains since 1960s. One conspicuous direction especially since this new century, which port management has embarked on, is the task of encompassing a logistical perspective. Inevitably, port functions have become much more complex today, considering that the role of facilitating coordination has been conferred to the ports as more supply chain participants interact at this platform and a conservative approach is no longer sufficient for port business sustainability.

Figure 2.2: The Role of Ports in International Supply Chains

Source: Author, adapted from Pettit and Beresford (2011)

Consequently, the objectives of ports have deviated much; from being a region's gateway to a system that provides value-adding and facilitation services (Ng, 2009). Ports serve as the prime candidate for being facilitators as they provide locations at which the stakeholders come into contact. It is precisely because of the port's capacity in administering the connection of logistics functions throughout the supply chains that renders its influence in cargo flow along supply chains. Ports have been defined as critical links which deliver and capture value in value-driven chain systems, thereby changing their positions in business environments (Robinson, 2002). With ports being urged to adopt agility in their current processes to create better value (Paixao and Marlow, 2003), the features of agile ports have been defined and steps towards an agile approach for ports to undertake have been recommended (Lun et al., 2010b). Similarly, research has been done on studying port strategies from supply chain perspectives, emphasizing on responsiveness, agility and efficiency (Zhang et al., 2014). The need for

ports to be more agile is compelled by repercussions of port inefficiencies, which include unnecessary additional operating and transportation costs.

By examining the changing role of ports in supply chains, it is apparent that agility and resilience, being the common characteristics of effective and efficient supply chains, are expected deliveries of the port from now on. However, there are only a few studies on the features of ports of the future generations, and research on the mechanisms of working towards them is absent. An assessment of the level of integration of ports in supply chains will likely reveal areas of possible cooperation with port users and improvement for implementation of specific strategies.

2.3.2. Integration of Ports With Supply Chains

The convenience of modal transfer that comes with containerisation, increasing customer demands for door-to-door transportation accompanied by the flourish of trade and the benefits from global sourcing has collectively fuelled the integration of ports into supply chains. Generally, integration is divided mainly into horizontal and vertical integration, with horizontal integration heading towards monopoly of the same market or product, while vertical integration usually works towards gaining control over preceeding or subsequent nodes of a specific supply chain.

Research has shown that infusing supply chain management practices into building capabilities in ports shall produce beneficial impact (Song and Panayides, 2008). From a supply chain perspective, the benefits of internal and external integration or collaboration are the ability to produce feasible strategies that improve performance outcomes of the chains (Stank et al., 2001). The close relationship between integration diversity and port performance has been proven empirically, demonstrating that transport integration has become a crucial constituent of port performance (Ducruet and Van Der Horst, 2009). Likewise, port competitiveness is a function of competencies in

supply chain integration by the ports (Song and Panayides, 2008). Thus, though it has been proven that the restructuring of port ownership over the last two decades has an impact on port efficiency (Cheon et al., 2010), port performance has already taken on a different dimension that extends beyond efficiency within the port itself. However, very few port performance measurement techniques are related to supply chain concepts and studies have concluded a need and relevance to include the perspective of supply chain management in regulating port performance (Bichou and Gray, 2004).

The trend towards increased compulsion in integration arises from the realisation of the need to have holistic container terminal operations due to outsourcing and globalised trade (Tan, 2006). Figure 2.3 illustrates the movement of cargo once unloaded from liner vessels and the intimate relationship between maritime and inland transport systems. In most cases, ports integrate into supply chains for the sake of gaining competitive edge and reaping diversification benefits (Beresford et al., 2011). The port selection process for shippers comprises the degree of integration with supply chains as one of the determinants (Magala and Sammons, 2008). Dubai serves as a good example which takes advantage of its favourable location in the east-west routes, its facilities, ability to mobilise resources and governance structure in its integration (Jacobs and Hall, 2007).

Figure 2.3: Modal and Temporal Separation at Freight Transport Terminals

Source: Rodrigue and Notteboom (2009)

Considering the impact of inland cargo distribution on port development, a port's integration into hinterland is strengthened (Notteboom and Rodrigue, 2005). With the growing significance of port hinterland, coordination and cooperation with other transport nodes are anticipated means of creating synergies (Notteboom, 2008). The issue of globalization in liner business has resulted in some major players integrating their activities in ports by managing container port facilities and creating intermodal companies (Midoro et al., 2005).

In addition to more anticipated strategic alliances between liners and stevedores (Midoro et al., 2005), terminal operators are also expected to take on an active role in order to support the emergence of inland terminals in supply chains as it offers a solution to congested ports and unoptimised usage of storage time at deep sea terminals (Rodrigue and Notteboom, 2009). Suggestions for port operators also include introducing agility in horizontal and vertical integrations in logistics chains, as a manner to administer a dynamic port network (Paixao and Marlow, 2003). Furthermore, the degree of integration with other transportation providers involves the operational and commercial aspects before efficient delivery of value can be brought about (Robinson, 2006).

In order to create an environment for participants to integrate harmoniously, ports face the tough task of managing conflicts in business objectives, differences in business behaviours and incorporation of practices from other fields such as supply chain management. For example, the changes in perception and initiatives by Port Metro Vancouver through the last decade has provided valuable insights to measures which redefined its traditional functions (Heaver, 2011). The measures discussed by Heaver (2011) are mainly promotional, operational, regulatory, contractual roles and also intelligence. These evolved roles require a high level of cooperation from members of the port community, in addition to the port authority's receptiveness to alternatives and

realization that it has to reassess its role to better exercise its control. The Vancouver port community has been able to cope with the changes in market environment as Port Metro Vancouver was gradually willing to fulfill its leadership role in undertaking leadership initiatives, technologies development and gateway activities (Heaver, 2011).

In summary, the changing role of ports, importance of information sharing and close coordination between terminal operators, shippers, forwarders and shipping lines have also been emphasized in recent research (Rodrigue and Notteboom, 2009). Most importantly, ports have to embrace strategies that extend to encompass concepts of flexibility and performance of transport chains in the modeling of core competence on top of adopting new roles (Notteboom and Winkelmans, 2001). Creating a competent hinterland community requires close coordination within the cluster and the forms of integration recommended tend towards the formation of alliances and partnerships. Different ports have varying improvement alternatives, the success of which depends on the capabilities of participants of the alliances (De Langen and Chouly, 2004). It is therefore worthwhile to determine the problems involved and requirements for synergetic integration to thrive.

2.3.3. Challenges in Coordination and Integration

While shipping lines and logistics providers are caught up in a race to offer a full spectrum of transportation solutions, ports struggle to facilitate overall coordination and communication between the parties within the port community. There are challenges to overcome in consummating a port's integration into supply chains and a summary of the challenges is presented in Table 2.5.

Table 2.5: Challenges of Coordination and Integration

Challenges	Studies
<ul style="list-style-type: none"> • Fear of Losing Power in Service Provision 	Notteboom (2008)
<ul style="list-style-type: none"> • Absence of Synergies 	Bichou and Gray (2004)
<ul style="list-style-type: none"> • Unwillingness to Foster Partnerships 	Van Der Horst and De Langen (2008), Notteboom (2008)
<ul style="list-style-type: none"> • Differences between Organizations and at Intersections • Amount of Visibility in Information Sharing • Conflicting Interests • Coping with the Growth of Trade • Support from Local Government and Community 	Heaver (2011)
<ul style="list-style-type: none"> • Allocation of Gains • Market Competition • Risk Threshold • Lack of a Figure Assuming Responsibility 	Van Der Horst and De Langen (2008)
<ul style="list-style-type: none"> • Absence of Contractual Relationships 	Pallis and Vitsounis (2011), Robinson (2007)
<ul style="list-style-type: none"> • Discrepancies in Expectations of Port Authorities and Their Customers 	Pallis and Vitsounis (2011)

Source: Author, synthesized from various literature

With the integration of ports into supply chains, coordination problems arise as there is unwillingness in cooperative efforts with the hinterland community (Van Der Horst and De Langen, 2008). This unwillingness of ports in engaging partnerships or cooperation

is most likely due to the fear of losing port activities (Notteboom, 2008). In general, the level of coordination within a port community can be influenced by the following problematic areas (Heaver, 2011): the differences in planning, the capacities and operating procedures that take place in organisations. Unfortunately, these are inevitable in intersections where the ownership and responsibility of goods change hands. Besides, the flourishing trade growth further exacerbates the imbalances between different transport modes and discourages local government from cooperating as the local community becomes more vulnerable to congestion. The situation is made complex when intersecting parties have conflicting interests and when there is insufficient visibility on necessary information. Applying to the port environment, one example would be that difficulties in integration arise when shipping lines and ports both isolatedly attempt to optimise their own assets (Bichou and Gray, 2004).

On the same note, Van Der Horst and De Langen (2008) have also identified problems in hinterland coordination and these are pointed out in the remainder of this paragraph. Disparate allocation of gains allows the existence of free-riders in coordination. Competitiveness in the market is likely to deter disposition to cooperate; similarly, the absence of capability and willingness in active participation, especially in the case of smaller firms, hinder the coordination process. Risk averse practices with a narrow perspective has to be overcome before effort is committed throughout the entire chain. This attitude is aggravated by the presumption that results from cooperating for coordination is not guaranteed, yet the process is time-consuming. All these, coupled with a lack of an individual taking charge and responsibility, give rise to challenges in coordination (Van Der Horst and De Langen, 2008).

To complicate matters, some dyadic players in a port supply chain have operational relationships but not contractual relationships. Similarly, in a port terminal setting, regardless of whether it is a dedicated or non-dedicated terminal, the parties that have a commercial relationship might engage in a third party for the operational aspect of their

agreement (Pallis and Vitsounis, 2011). Pallis and Vitsounis (2011) named this kind of interaction as hybrid relations. The degree of integration of the chain will be reduced due to the lack of contractual relationships between dyadic parties (Robinson, 2007). Besides, the lack of contractual relationship can also cause variabilities and uncertainties in the port supply chain system. As there already exist conflicts in the intermodal channels (Taylor and Jackson, 2000), the above problems reiterate the need for adopting holistic cooperation within the port and its peripherals.

By employing Magala and Sammons' modeling framework which generates port choice as an element of the supply chain, taking into consideration the various attributes for different factors of supply chains and finally narrowing down to an 'actual choice' (Magala and Sammons, 2008), the relationship between or irrelevance of certain existing partnerships in ports would likely be revealed. For instance, when one of the final choices consists of Port A and 3PL X and minimal interaction is found between these two parties, then a deeper mutual connection should be established, in order to reduce possible chances of disruptions or problems. When port security is quantified in the port selection process, a feasible solution to avoid risks can be proposed (Norbis and Meixell, 2010). However, it has been discovered that the same type of port users identifies a diverse and even contradicting list of value drivers (Pallis and Vitsounis, 2011). Moreover, it was found that there are discrepancies between the expectations of port users have on port authorities and the concerns of the port authorities themselves (Pallis and Vitsounis, 2011). This calls for a more genuine mutual understanding between the port users and port authorities as, with that, the responsibility of coordinating port activities and information exchange can be better communicated and facilitated when assigned. The importance of information exchange has been affirmed by Lee et al. (2003). Simulation was used to analyse the impact of adopting partnership and information sharing as determinants in port operation strategies and it has been proven that strong partnerships and a higher level of information sharing at the terminal are favourable as they enhance port operation performance, which was measured in terms of container handling time for partnership as the factor and the number of vessels

served, time spent at berth and berth utilisation for information sharing (Lee et al., 2003). These results reinforce the importance of information sharing and interdependences within the port community.

The different forms of cooperation and coordination initiatives which ports can engage in would facilitate its integrative role in supply chains and evolution towards agility and resilience. In the process, the challenges of coordination would arise, affecting the level of willingness and degree of integration. The interaction between these aspects are displayed in Figure 2.4. As the PDM has the objective of reducing a port's potential in inducing supply chain disruptions, the challenges in integration would be relevant since a high level of internal and external communication and cooperation ought to be present for the actions in the framework to actualise.

Figure 2.4: Elements of Evolution into the Future Ports

Source: Author

2.3.4. Implications of Port's Integration into Supply Chains

Exploring the implications of a port's adoption of new roles and objectives in supply chains would assist in the identification of PSCD threats and define the context of PDM, such that the actions in the framework remain relevant to its peripheral setting.

Fundamentally, the changes in supply chain trends and practices would compel the necessity of a port's integration into the supply chain. Therefore, prominent changes in supply chain trends and practices shown in Figure 2.5 have an impact on ports. These trends would collectively result in larger vessel sizes and capacities, port traffic growth, cargo growth and expose the ports to greater vulnerabilities. The implications of a port's new role in supply chains are evident in recent research work as they are increasingly acknowledged and explored by researchers. Table 2.6 indicates the implications of a port's integration derived from past literature work.

Figure 2.5: Trends in Supply Chain Management

Source: Waters (2007)

Table 2.6: Evolved Area of Research on the Port's Role in Supply Chains

Related Theoretical Approach <i>(Implications addressed)</i>	Reflected in:
Multimodal Connectivity	Robinson (2002), Marlow and Paixão (2003), Paixão and Marlow (2003), Bichou and Gray (2004), De Langen and Chouly (2004), Lirn et al. (2004), Notteboom and Rodrigue (2005), Chang et al. (2008), Notteboom (2008), Song and Panayides (2008), Panayides and Song (2009)
Integration Initiatives	Notteboom and Winkelmans (2001), Bichou and Gray (2004), De Langen and Chouly (2004), Notteboom (2004), Notteboom and Rodrigue (2005), De Martino and Morvillo (2008), Notteboom (2008), Song and Panayides (2008), Panayides and Song (2009), Lun et al. (2010b), Heaver (2011)
Value-Added Services	Notteboom and Winkelmans (2001), UNESCAP (2002), Carbone and De Martino (2003), Paixão and Marlow (2003), Bichou and Gray (2004), Chang et al. (2008), Song and Panayides (2008), Panayides and Song (2009)
Adaptability	Notteboom and Winkelmans (2001), Paixão and Marlow (2003), Marlow and Paixão (2003), Tongzon and Heng (2005), Tongzon (2009), Lun et al. (2010b)
Efficiency	Estache et al. (2002), Tongzon (2002), Park and De (2004), Tongzon and Heng (2005), Mennis et al. (2008), Tongzon (2009)

Related Theoretical Approach <i>(Implications addressed)</i>	Reflected in:
Information Exchange and Communication	Paixão and Marlow (2003), Song and Panayides (2008), Panayides and Song (2009), Lun et al. (2010b)
Charges and Costs	Notteboom and Winkelmanns (2001), Lirn et al. (2004), Tongzon and Heng (2005), Chang et al. (2008), Tongzon (2009)
Diversification into Logistics Service Provision	Notteboom and Rodrigue (2005), Notteboom (2008), Rodrigue and Notteboom (2009), Beresford et al. (2011)
Agility	Paixão and Marlow (2003), Bichou et al. (2007), Lun et al. (2010b),
Training of Port Workers	World Bank (2000), Lun et al. (2010b), Heaver (2011)
Port Networking	Notteboom and Winkelmanns (2001), Paixão and Marlow (2003)
Security	Bichou (2004), Pinto and Talley (2006), Bichou (2008)
Source: Author, synthesized from various literature	

2.3.4.1. Multimodal Connectivity

The integration into supply chains certainly requires the necessary infrastructure for the cargo transfer. This aspect includes hinterland accessibility and intermodal transport connectivity which can include feeder connections. It is not surprising that this area of research will expect to receive even more attention as more ports expand their business into landside logistics.

2.3.4.2. Integration Initiatives

The existence of seamless multimodal connectivity has to be accompanied with effective integration plans and practices with supply chain members. These include interactive relationships in the form of strategic alliances and partnerships to enhance the port's collaboration with the supply chains. A high level of coordination and cooperative spirit will be required in such integrative initiatives.

2.3.4.3. Value-Added Services

The most prevalent sign of integration into supply chains is the provision of value-added services. However, the extent of value-added services provided by ports today has far exceeded that of the past. This is due to the increase in demand of value-adding services to ships and cargo especially in terms of port facilities and their ability in cargo handling and transfer. Some common examples are packaging and manufacturing. Nonetheless, the ability of ports to provide comprehensive services does not necessarily translate into seamless cargo flow.

2.3.4.4. Adaptability

As the concept of flexibility becomes popular in supply chains, being adaptable to customer needs and the changing market environment begin to gain attention in the dynamic maritime field. The new generation of ports is expected to be agile and this

requires adaptability and a great level of flexibility. The proximate relationship between ports and supply chains fuelled by the increased integration would require ports to adapt to the supply chain trends and practices in order to remain efficacious.

2.3.4.5. Efficiency

Port efficiency explored by most scholars revolves around equipment efficiency which is mainly about the hardware of ports, port layout and movement of cargo. Examples of measures are berth capacity, turnaround time, cargo handling rate, cargo throughput, etc. These usually form part of port performance, thus port efficiency is highly valued by port users and contributes to supply chain performance due to the increased presence of ports felt by supply chains.

2.3.4.6. Information Exchange and Communication

The prevalence of E-business in supply chains implies that the integration into supply chain is closely connected to information and communication as interoperability is required to ensure the exchange of information between entities before and during port operations. Seamless communication flow and useful information exchanges are thus highly valued as it ensures interoperability within the port and with the port's external parties. Moreover, the quality of information exchange and communication exchange establishes the level of agility and coordination of the port and affects port efficiency. This is due to the significance of information exchange and communication in business continuity planning and daily port operations. As a result, many studies have stressed the importance and value of effective communication and information exchanges in collaborations and integration.

2.3.4.7. Charges and Costs

Port charges and costs are inevitably a concern to port users, especially when ports are presently providing more than the traditional cargo transfer services due to its adoption of new role in supply chains. Tongzon and Heng (2005) explained that port charges contributed to a large portion of overall transportation costs, so ports with lower charges are preferred, *ceteris paribus*. Thus, ports are not considered as a standalone node with a basic charge, but rather, port charges are weighted as logistics costs and are capable of affecting port selection, though there can be other overriding factors in port selection which can justify higher port charges.

2.3.4.8. Diversification into Logistics Service Provision

Diversification into the logistics arm was driven by the demand for door-to-door transport, one-stop shipping and increasingly comprehensive services by either direct port clients or downstream customers, whose demand will eventually be pushed upstream. As a result of integration, logistics services which ports have diversified into include developing warehouses near ports but moving cargo distribution function inland and further away from port areas, developing inland rail freight terminals and port-centric logistics.

2.3.4.9. Agility

Agility is highly valued in supply chains, of which a port is always a part of. However, the application of agility in ports is rather novel. As ports are now part of the supply chains and become more susceptible to uncertainties of the supply chains they serve, agility would ensure the swift action of ports in avoiding the impacts of disruptive events.

2.3.4.10. Training of Port Workers

It is widely agreed that many accidents could have been avoided should there have been more focus on education of workers. Moreover, the integration of ports into supply chains has resulted in an expansion of services and transformation of processes. Hence, the efficient operation of new innovations, communication systems, processes and equipment would require appropriate training of the worker.

2.3.4.11. Port Networking

With growing vessel traffic and cargo volumes, port networking is imperative in business continuity planning of the port and in deriving synergies from cooperation with competing ports. The benefits of port networking include better cooperation with other transport nodes, complementarities and more efficient utilization of resources. These would in turn facilitate the port's integration into supply chains and the implementation of policies to incorporate agility and flexibility in the port.

2.3.4.12. Port Security

As mentioned, ports are exposed to more vulnerability in their integration into the supply chain. As a large number of entities and individuals interact within the port community and due to the embeddedness of ports in supply chains, ports begin to assume the responsibility of ensuring port operations are protected against potential risks and security threats.

New roles and responsibilities adopted by ports demonstrate the proximity between ports and supply chains. Thus, present ports are capable of generating supply chain disruptions and the implications of the port's new roles in supply chains explain the probable impact of the port-related drivers of disruptions.

2.4. Port-related Drivers of Disruptions

Past research, which have explored port bottlenecks and operational risks at ports, are able to identify the drivers of port-related disruptions and these drivers can be interconnected. For instance, a breach of security may cause the shutdown of a port, resulting in vessels to be re-routed to another nearby port and this may cause port congestion at the second port if it does not have adequate excess capacity to receive the extra cargo volumes.

Similarly, collisions in the port waters can also propagate disruptions by blocking water channels with the sunken ruins (Pinto and Talley, 2006), directly causing damage to port structures and shorelines or resulting in the closure of an implicated terminal. Collisions within the port waters can have more implications than a mere collision, especially when an oil spill or port closure is a result of the collision. Things are complicated when there are injuries or fatalities involved as investigations have to be carried out before debris are allowed to be removed and operations can resume. Moreover, some causes may be the consequences of a preceeding cause. For example, port congestion may be the consequence of improper planning on the port's side, and port congestion will in turn exacerbate the impact of the disruption.

Gurning (2011) has provided a comprehensive list of maritime disruptions causes, nonetheless, those that are port-related need not necessarily result in supply chain disruptions. Factors such as security level, infrastructure development, hinterland connectivity, demand and supply imbalances, port congestion and employment relationships make up common instances of maritime disruptive events (Gurning and Cahoon, 2009a).

As mentioned earlier, it is difficult to assess different port-related causes of supply chain disruptions individually as one apparent cause might be the result of another; the root cause of the disruption should be mitigated instead. To provide an overview of possible causes occurring in the ports, Table 2.7 shows the port-related causes of several disruptions and it provides a background for the development of PSCD threats in Section 3.1.1. One has to note that these might not be the primary or the only causes of the resulted supply chain disruptions; all these causes, when connected with one another, can increase the severity of disruptions. An investigation of these port-related disruption causes identifies the risks present inherently in port operations, management and communication with the periphery entities. The drivers are classified in this manner so that the ports will know which aspects to focus on, for instance, either internal productivity or relationship with the port community, to reduce disruptions.

Table 2.7: Port-Related Disruption Examples

No.	Port-related Disruptive Events	Effects on Supply Chains
1	Australian port strikes (Burgess, 2011)	Inability to fill orders; breach of contractual obligations
2	West Coast port strikes (Blackhurst et al., 2005b, Institute for Supply Management, 2002)	Delayed, duplicated or lost shipments of supplies, delayed shipments to customers, inventory build-up
3	Damaged wharf at Port Lincoln after a ship collision (Pedler, 2010)	Wharf closed to contain oil spill
4	MSC Chitra's collision in Mumbai (NDTV Correspondent, 2010)	Missing containers, shutdown of Mumbai Port and Jawaharlal Nehru Port Trust due to oil spill
5	Pipeline explosion in Dalian Port (Chow, 2010)	Shut down of port
6	Introduction of new customs clearance system in Tanzania (Crown Worldwide Moving & Storage, 2010)	Clearance times increased by threefold
7	Over-aged, defective or inadequate cargo handling equipment at the ports (Esq., 2001)	Low productivity, inefficiency and damage or loss of cargo, cargo discharge processes and stacking of cargo at Nigerian ports are slowed down
8	Port congestion in Thailand (Suwannakij and Javier, 2011)	Sugar prices driven up
9	Nigeria's port systems failed to change to adapt to high volume growth (Esq., 2001)	Serious "bunching" problem, whereby cargo are not cleared in time for new incoming ones
10	Ports in Sub-Saharan Africa do not have the necessary rail and road links, making them unable to reap the benefits of containerization and multi-modal transport corridors as containers have to go through packing in the ports (Esq., 2001, Ocean Shipping Consultants, 2008).	Movement of cargo and rate of clearance hampered, shipment delays

No.	Port-related Disruptive Events	Effects on Supply Chains
11	Miscommunication between Trade Daring and port/terminal personnel at Ponta da Madeira Brazil (Horck, 2008)	Vessel broke into two
12	Labor and severe container shortages at Chittagong (The Journal of Commerce Online, 2010)	Delays in cargo handling
13	Some major ports in Sub-Saharan Africa still lack modern port equipment (Ocean Shipping Consultants, 2008)	Productivity suffered severely
14	Terrorist attacks in Port of Mumbai in 2008 (World Port Source, 2011)	Undeclared
15	The ownership and leasing structures of Dalrymple Bay Terminal in Australia (Robinson, 2007)	Conflicts of interests, decision making processes hindered, disintegration of the coal supply chain
16	The 100% physical inspection regulation imposed by Federal Government of Nigeria (Esq., 2001)	Serious delays of vessel berthing
17	Labor standoff at West Coast ports (Layne, 2015, DePillis, 2015)	Retailers, such as Wal-Mart Stores Inc, experience delays in merchandise supplies

Source: Author, synthesized from various literature

2.4.1. Drivers from the Peripheral Environment

The importance of incorporating resilience in a port and other supply chain members has been emphasized in many studies since the September 11 attacks which brought attention to the exposed vulnerabilities apparent in many systems, and urged enterprises to strengthen their cognitive abilities. It has been discussed how an adequate cognitive architecture and process, when applied appropriately to a terminal, are able to prevent waterborne attacks, thereby improving the resilience of the port (Andalibi et al., 2008).

The expansion of port capacity in certain regions of the world has yet to catch up with the growth of sea-traded cargo volumes (Paul and Maloni, 2010). Without regulating this imbalance, re-directed cargo to another port due to disruptions would likely result in serious congestion problems at already congested ports that belong to the same network (Paul and Maloni, 2010).

2.4.2. Operational Drivers

The rate of loading and unloading process at the ports depends largely on the availability and status of the equipment. Mechanical failures in port equipment such as gantry cranes can decrease berthing and terminal availabilities and can result in a loss of income to both the users and terminal (Mennis et al., 2008). Unfortunately, port-related equipment problems are usually not seen as risks in a supply chain (Gurning, 2011), resulting in an absence of a comprehensive approach when addressing bottlenecks in the ports.

In addition, an analysis of accidents in ports found that there are four main causes of such accidents, namely (a) impact or collisions, (b) mechanical failures, (c) external and (d) human factors (Darbra and Casal, 2004). In the same study, the accidents are found to have most frequently occurred during the transportation process in the ports. The

range of activities the authors included during the transportation process are moving goods around in transportation vehicles and in vessels that enter and leave ports. In other words, the goods are more susceptible to accidents when in movement than in storage.

The handling of dangerous cargo deserves attention as accidents and fatalities involving dangerous goods can have serious repercussions which are capable of halting an entire supply chain. According to past events, activities in ports ranging from packaging, container stuffing and loading processes are discovered to be the main aspects responsible for releasing dangerous goods onboard vessels (Ellis, 2011). An analysis of port-related accidents involving hazardous substances revealed the sequence of events leading to a specific type of accidents, as well as a way to calculate probabilities of the accident (Ronza et al., 2003). It seems that there is much room for improvements in the port-side operations as it has been discovered that 91% of the contributing factors of dangerous goods release were generated before the loading takes place, while very few cases were the result of severe weather conditions and ship motions (Ellis, 2011). An example of a factor of accidents would be cargo self-ignition which sometimes is a result of misdeclaration of the cargo (Ellis, 2011).

2.4.3. Human Factors

On the other hand, human factors also play a role in port accidents and examples of these factors are a lack of work experience, which has been suggested that it cannot be resolved simply by staff training, and the ability to adapt to new skills and technologies (Fabiano et al., 2010). The inability to adapt is related to age as the older the staff, the less able he/she can utilise new technologies and this will in turn affect the severity of the accidents. Fabiano et al (2010) have also observed that the peak period of accidents occurring is during the summer months. This finding indicates that the frequency of accidents is associated with workload and productivity increase borne by the workers. Thus, the employment satisfaction of staff cannot be disregarded when looking for

means to reduce accidents. As clear instructions have to be given to ensure accurate procedures are being executed, effective communication is imperative between seamen and port workers.

At the port where individuals and entities interact at different levels, communication becomes an attribute of human factors and an ability of individuals which can affect the safety and quality of work accomplished in port areas as miscommunication would render an operation inappropriately executed or introduce unnecessary risks in the operations. At the ship-port interface, communication inevitably encounters challenges due to the intersection of multicultural diversities and gender differences (Horck, 2008). An example is the total loss of the bulk carrier named “Trade Daring”. The miscommunication between the port terminal manager and chief officer, together with existing structural failures, stresses, mishandling and inappropriately planned operations, Trade Daring broke into two pieces (Horck, 2008).

In essence, the port-related drivers of disruptions can come from the peripheral environment, internal operations and through communication during interaction between the internal and external parties. Hence, human factors are present and affect both the external and internal operations. The relationships between these drivers are displayed in Figure 2.6.

Figure 2.6: Relationship Between the Port-related Drivers of Disruptions

Source: Author

The bottlenecks in ports and port-related drivers of disruptions can be identified through combining findings and results of relevant past research. However, the port-related disruption causes explored in existing literature need not necessarily result in supply chain disruptions as the effects of the disruptions may be diminished as the cargo is transported out of the port, or the disruptive aftermath may not be powerful enough to result in a supply chain disruption. These port-related drivers of supply chain disruptions or PSCD threats should be determined to ascertain the mechanisms in reducing or eliminating occurrences of the threats.

2.5. Strategies for Port-Related Disruptions

In this subsection, strategies proposed for disruptions which occurred at the port will be discussed. There are several approaches to do so: by means of disruption occurrence prevention, disruption mitigation and incorporating contemporary concepts in the port management and movement of cargo along the port transport chains.

2.5.1. Disruption Prevention Mechanisms

The more favoured way in disruption management is preventing disruptions which usually denote increasing security and detecting potential risks as the objective is to eliminate the occurrence of disruptions. Analytical tools from the engineering and supply chain fields can be adopted in assessing port risks and security (Bichou, 2008). Amid approaching port security from the logistics and supply chain management perspective, one way to increase security standards in the maritime network is to have ports and their stakeholders predict outcomes of detected vulnerabilities across the ports' internal and external systems, in an integrated collaborative effort (Bichou, 2004).

The effectiveness and level of security within a supply chain affect characteristics such as direct and indirect costs, timeliness, conditions of goods and uncertainties, all of which make up the competitiveness of the supply chain (Banomyong, 2005). Furthermore, participation in security initiatives prevents cargo from being subjected to additional scrutiny. An example would be joining the Customs-Trade Partnership Against Terrorism (C-TPAT). It is only through complete cooperation that security can be infused and ensured throughout the chain. Otherwise, firms which opt out of such initiatives might end up hindering cargo processing. On the other hand, the negative aspects of C-TPAT are that applications are not dealt with promptly and the participants could not be appraised appropriately, thus the benefits of implementing it cannot be brought out (Brooks and Button, 2007).

Specifically, an empirical analysis of the impact of ISPS Code, CSI and 24-hour manifest rule on container terminal operations efficiencies has been carried out (Bichou, 2011). The results show that terminals implementing 24-hour manifest rule generally have lower efficiency than those without the 24-hour manifest rule, though there is higher efficiency gains in terms of technological change for those with the rule, and, the implementation of CSI has experienced a gain in terminal efficiency while terminals without CSI implementation have experienced a loss (Bichou, 2011). This may be due to CSI's "fast lane treatment" granted to containers that have already gained approval from the 24-hour manifest rule process which requires on-time, detailed and specific cargo information from the ocean carriers as well as risk analysis from the US authorities (Bichou, 2011). On the other hand, as interpretations of the ISPS Code vary across ports, an assessment of productivity gains or losses relating to the implementation of ISPS Code is tricky (Bichou, 2011).

Measures for ports have been introduced to maintain security standards within the ports and for the safe handling of dangerous cargo. Hence, it has been suggested that accurate declaration of cargo and its packaging should be maintained throughout the transport

chain (Darbra and Casal, 2004). The irony in implementing certain lengthy reporting procedures is that errors may be made or overlooked in the process of complying, increasing the potential dangers in port activities. Nevertheless, the long term effect and benefits may justify the costs of security measures. Ultimately, a well-performing supply chain requires connection and synchronisation for the continuous flow of goods between each point to occur. This in turn demands for security measures to be fulfilled at all the links in the supply chains.

The United States has been particularly active in its initiatives to counter security incidents. These range from establishing the US Department of Homeland Security (DHS), utilising radiation detectors in ports, implementation of the US Maritime Transportation Security Act (MTSA) and the ISPS Code to revised port security plans which involve having extra defense layers in preventing threats (Pinto and Talley, 2006). The existing strategies focus more on the threat prevention and detection phases, leaving responses to threats and recovery phases from threats less explored. These last two phases deserve attention as financial losses from an extended or even avoidable port shutdown due to insufficient viable response or recovery strategies can exceed the effects resulted from the security incident itself (Pinto and Talley, 2006).

2.5.2. Disruption Mitigation Mechanisms

Arrangements to mitigate disruptive effects of undesirable events require the efforts of internal port management as well as collaboration or involvement from external parties. Otherwise, the scope of actions and extent of relief to disruptions will be restricted.

The application of complex network theory has been proposed in the examination and modeling of shipping networks such that an undesirable event at a port can be simulated to show the global effect it has (Angeloudis et al., 2007). Alternatively, the Disruption Analysis Network (DA_NET) is another quantitative approach which can be used to

show propagation of attributes while measuring the impact on the system (Wu et al., 2007). By allowing each supply chain component and key attributes to be pre-set, this model offers an overview of those affected in its analysis, such that the users can acquire a better understanding of the radius of disruptive events in a supply chain. In modeling simulation, a useful tool to quantify disruption probabilities especially in the transportation processes is Markov chain, which has been applied to the wheat supply chain to evaluate the risks in the chain when maritime disruptive events occur (Gurning and Cahoon, 2009b). Incorporating disruption possibilities will facilitate planning and development of supply chains.

On the other hand, optimization models can be used to compare different scenarios and severities of disruptions that caused a redirection of vessels to other ports in a network (Paul and Maloni, 2010). These ocean-focused models can be integrated with those that study landside capacities for a more inclusive analysis. Such models are useful only in cases where actual disruptions occur as they provide an analysis of the extent and effects of disruptions that take place at ports.

To mitigate the impacts of collisions within port waters, a multi-level model of collision risk has been proposed by Chin and Debnath (2009). The purpose of this system is to act as a real-time system that allows pilots to carry out countermeasures according to the different severities of dangers worked out by the system (Chin and Debnath, 2009). In the event of a large US port closure due to terrorist attacks and natural catastrophe, a restoration model has been developed to restore vessels by rerouting them to other ports (Guerrero et al., 2008). However, a higher level of communication in the form of data sharing is required for the development of an adequately robust vessel restoration model. The implications of the model on intermodal firms are also of great concern to them. Thus, though the model offers an alternative when an event strikes, it only provides a preliminary stage of measure. Correspondence with international shipping and intermodal firms has to be present in the later part of model building.

2.5.3. Contemporary Concepts as Disruption Mitigation Strategies

In light of changing role of ports and increasing scope of intermodal transportation services at ports, the concept of using integrated centres for Transshipment, Storage, Collection and Distribution (TSCD) of freight has been suggested to improve cargo handling efficiency within the ports (Konings, 1996). Besides easing threats of port congestion, business accessibility will also be enhanced with the use of TSCD concept as benefits can be derived from the physical proximity. Satellite terminals involve a concept whereby part of cargo storage and consolidation functions are moved out of seaports (Slack, 1999). This raises hope of easing congested container berths and improving throughput performance within the seaports. The concepts of TSCD and satellite terminals illustrate one element of supply chain mitigation strategies, which is having strategic stock (Tang, 2006) since inventories are placed strategically in distribution centres and/or warehouses near ports.

The call for similar “port-centric logistics” approach is apparent in the United Kingdom through several significant partnerships under the pressure of thriving cargo volumes (Beresford et al., 2011). Examples of such partnerships are the ones between Tesco and Teesport, and DP World with London Gateway. However concerns such as operating costs, risks and responsibilities involved in transferring freight to satellite sites have to be addressed. On the other hand, alternative approaches to prevent port congestions are identifying substitute ports and creating proper forecasts that help generate supply balances while overseeing transiting demand and supply (Blanchard, 2007). There are yet to be suggestions available for these approaches to be combined or executed through specific actions.

Besides locating the distribution centres near the port of entry, they can be concentrated along a transportation corridor and each cluster is referred to as an ‘inland port’ which,

by allowing logistics integration, can reduce port congestion and provide better supply chain efficiencies (Rahimi et al., 2008). It has been proven mathematically that vehicle-miles travelled (VMT) will be greatly reduced with the introduction of a central inland port for a region (Rahimi et al., 2008). A location-allocation model, using VMT as a measure, when applied to a number of ports enables the user to identify exactly which is the inland port that has the most significant impact on transportation costs (Rahimi et al., 2008).

As insufficient containers are probable causes of delayed operations, the concept of foldable containers, for instances the SIO and Fallpac containers, has opened up new perspectives on reducing transshipment costs and container handling, as well as freeing up empty container storage space that can otherwise be used for conventional containers and port operations (Konings, 2005). Similarly, the Tworty container, allows huge cost savings even with the additional handling costs (Transport Research Institute, 2014).

In addition, facilitating any policies and strategies would require effective communication and acceptance within the community which require incorporating knowledge and understanding of the human resource field. Addressing the soft attributes of individuals in the port, Horck (2008) proposed that maritime education should be enforced and focus on ‘cultural awareness’, seeking to motivate, creating understanding between each other and a sense of belonging (Horck, 2008). Human resource management skills are essential competencies in shipping as expertise in technical knowledge fail to be actualised when precise instructions cannot be accurately given or received.

There are fundamentally three aspects in combating disruptions and they are preventing the disruption from occurring, mitigating the effects of disruptions and administering concepts which target disruptions. Contemporary concepts are more tailored due to the

peripheral market trends and practices as the concepts tend to introduce new perspectives which are able to alleviate disruption effects instead of in the form of specific actions which eliminate or mitigate corresponding disruption drivers. On the other hand, preventing and mitigating disruptions have the objectives of reducing and eliminating the occurrences of specific disruption drivers and thus these mechanisms will eventually ease the peripheral imbalances and drivers. Figure 2.7 matches the strategies to their respective drivers.

Figure 2.7: Strategies for Different Types of Port-related Drivers of Disruptions

Source: Author

According to the current literary work, three theoretical approaches can be identified. Particularly, preventive measures are related to risk management (RM), mitigation plans indicate the presence of business continuity management (BCM) and contemporary concepts have the objective of improving efficiency and quality of port services, hence quality management (QM) is the third approach. In disruption management, RM is an important process as it identifies risks which need to be reduced, eliminated and transferred as well as those that can be retained so that appropriate measures specifically for each type of risks can be formulated. BCM will address mitigative and contingency

plans for the organisation's recovery and risk prevention in the event of a disruption. Thus, risks that cannot be avoided in RM can be mitigated in BCM. QM will serve to facilitate the disruption management process, such that the objectives of the process are ensured, remain relevant and continuously improved. Hence, the inclusion of RM, BCM and QM will provide an aggregated protection from disruptions. Applying the triangulation of theories will then address the efficiency and effectiveness of this research by managing the PSCD threats, developing mitigation and contingency plans as well as ensuring the deliverability of the PSCD management process. Collectively, the three theories will be able to exercise an influence on PSCD consequences such that the supply chain disruption potential of the port is controlled.

As there exists a close relationship between ports and supply chains efficiencies, a better understanding of the changing trends in the roles ports play in supply chains would help to develop strategies that fit more appropriately in recent settings and practices. Thus, exploring the implications of port's integrative role in supply chains together with the theoretical approaches will be useful to investigate the practical requirements of reducing supply chain disruption potential of ports while addressing these implications. The bottom line is to address these implications in the process of managing the disruptions. Hence, Table 2.8 shows the implications of port's increasing integration into supply chains that will be addressed in the application of theoretical approaches and the related theoretical approach reflected in studies. A comparison with the theoretical approaches behind existing strategies will reveal the literature gaps.

Table 2.8: Related Theoretical Approach Reflected in Research

Related Theoretical Approach <i>(Implications addressed)</i>	Reflected in:
Risk Management <i>(Port Security)</i>	Bichou (2008), Pinto and Talley (2006), Darbra and Casal (2004), Bichou (2004), Brooks and Button (2007), Chin and Debnath (2009), Wu et al. (2007), Gurning and Cahoon (2009b)
Business Continuity Management <i>(Agility, Port Networking)</i>	Paul and Maloni (2010), Angeloudis et al. (2007), Wu et al. (2007), Guerrero et al. (2008), Blanchard (2007), Paixao and Marlow (2003), Rahimi et al. (2008)
Quality Management <i>(Multimodal Connectivity, Integration Initiatives, Value-added Services, Efficiency, Charges and Costs, Diversification into Logistics Service Provision, Training of Port Workers)</i>	Konings (1996), Slack (1999), Beresford et al. (2011), Konings (2005), Horck (2008)

Source: Author, synthesized from various literature

Firstly, strategies reflecting information exchange and communication and adaptability to manage port-related disruptions are absent. Secondly, the theoretical approaches might have been reflected from the research, however, the principles of the theoretical approaches were not applied. Thirdly, the research spectrum on strategies tends to be disintegrated. For instance, risk management applied in past research tends to focus on port security while risks at ports also comprise of workplace safety and intentional attacks. Lastly, no recommendations are present on how the strategies can be operationalised through specific actions. The responsibilities which different levels of the port should assume are also missing.

2.6. Literature Gaps

The review of literature reveals several key findings and limitations. Firstly, ports have increased their importance and integration in supply chains. The changing role of ports introduces implications from which port-related drivers of disruptions can be identified. The more commonly discussed port risks are port accidents, port-equipment failures, mishandling of dangerous goods, port congestion, inadequacy of labour skills, hinterland inaccessibility, breach of security and labor strikes. Human factors such as a lack of work experience and inadaptability to new skills and technologies also form part of port risks. However, what is uncertain is the consequences of these bottlenecks and risk areas on supply chains in light of changing roles of ports. This gap gives rise to SRQ1, SRQ2 and SRQ3. The absence of triggers for PSCD threat detection so that actions can be in place to avoid or reduce disruptions results in SRQ4. Collectively, SRQ1, SRQ2, SRQ3 and SRQ4 (see page 4) shall determine port's role in inducing supply chain disruptions and thus address RQ1 (PSCD threats).

Secondly, the investigations of disruptions by previous researchers are confined to actions and consequences within the port and not linked well to potential disruption in the supply chains. Thirdly, there are fundamentally three aspects in combating disruptions, namely, preventing the disruption from occurring, mitigating the effects of disruptions and administering concepts which target disruptions. What is absent in prior research is to recognize that disruptions can originate from the port itself and be propagated to supply chain entities despite acknowledging the increasing integration of ports. Very few studies have investigated the management of port disruptions from the supply chain perspective. This is an area of research deserving attention as the users and customers of the ports constitute global supply chains. These result in the formation of SRQ5 and SRQ6 (see page 4). Hence, SRQ5 and SRQ6 will be able to demonstrate how ports can mitigate PSCD, answering RQ2 (PDM).

The closest topic in the current literature is research on port agility. However, research on port agility is scant at this stage and studies on similar topics do not provide a comprehensive framework for implementation at ports. An integration of the relevant theories from the supply chain perspective would be meaningful as it would offer an universal approach to guide port management on the areas which they should focus on to effectively manage disruptions that originate from the port operations. Therefore, this research shall fill the literature gaps by determining how ports can manage port-related disruptive events, i.e. the PSCD Threats, which affect supply chain resilience. This research aims to integrate disruption strategies in a framework and the application of principles of RM, BCM and QM (Risk Management, Business Continuity Management and Quality Management) is to ensure that the objectives of the framework can be achieved. Hence, this research aims to provide recommendations based on academic work as well as suggestions from management from ports and port users, such that a more well-balanced and better-informed consensus can be reached in deciding strategies to implement while addressing conflicts of objectives in the port at the same time.

CHAPTER 3. THEORETICAL CORNERSTONES OF THE RESEARCH MODEL

3.1. Introduction

Chapter 3 explores the development of PSCD Indicators and the management model for PSCD threats through the conceptual framework concluded from previous literary work in Chapter 2.¹ The PSCD threats are identified and the components of the management model are developed through filling the literature gaps and an analysis of secondary data.

3.2. Development of PSCD Threats

Supply chain disruptions can be generated by port-related disruptions which are driven by risk areas in ports. Traditionally, as ports were rather simplistic in their service provision, the bottlenecks and risks in the port setting were more constrained to their immediate environment such that the productivity of each port operation was typically the main focus. However, the present trend of port's increasing integrative role into supply chains has altered the range and complexities of port service. Thus, with new areas of deficiencies arising, port's integration into supply chains generates implications which influence how PSCD threats can result in a disruption. Figure 3.1 displays how the connection between the risks in ports, port-related disruptions and implications of ports into supply chains relate to supply chain disruptions. The disruption potential of the port can be minimized by reducing or eliminating the *PSCD Threats* and this will be

¹ The following publications from the author are based on part of this chapter:

LOH, H. S. & THAI, V. V. 2014. Managing Port-related Supply Chain Disruptions: A Conceptual Paper. *The Asian Journal of Shipping and Logistics*, 30 (1), 97-116.

LOH, H. S. & THAI, V. V. 2015a. Management of Disruptions by Seaports: Preliminary Findings. *Asia Pacific Journal of Marketing and Logistics*, 27 (1), 146 - 162.

achieved through detection by the *PSCD Indicators* for the port to execute its respective actions and plans. Section 3.3 discusses PSCD Indicators in greater detail.

Figure 3.1: Development of PSCD Threats and Indicators

Source: Author

Based on reported accidents and past research in Section 2.4, several PSCD threats can be deduced. However, the literature is not complete in the identification of PSCD threats; for instance, equipment failure is a common threat resulting in shipment delays yet the event is usually not reported unless the consequence is severe. The more studied threats are port accidents, labor strikes, congestion and security. Therefore, the list of PSCD threats compiled in Table 3.1 shows both observed and deduced threats. They are organized into four main categories: (1) infrastructure threats, (2) planning threats, (3) manpower threats and (4) security threats. There are seven infrastructure threats related to the efficiency and adequacy of port equipment and infrastructure; four planning threats associated with congestions and shortages which arise mainly due to inadequate planning; three manpower threats related to human factors such as strikes and miscommunication; and five security threats.

Table 3.1: PSCD Threats

<i>Infrastructure Threats</i>	<i>Planning Threats</i>
Port Equipment Breakdown	Congestion in Waterway
Inadequate Port Cargo-Handling Equipment	Congestion within Terminals
Occupational Accidents	Congestion at Hinterland Transfer
Power Outage	Shortage of Facilities or Equipment
Breakdown of Vessel Traffic Management System	<i>Security Threats</i>
Breakdown of Port Information System	Trafficking
Collisions in Waterway	Smuggling/Contraband
<i>Manpower Threats</i>	Stowaway
Port Labor Strikes	Breaking in/Theft
Misinterpretation of Instructions at Workplace	Terrorist Attacks
Shortage of Manpower (not due to labor strikes)	

Source: Author

The purpose of this classification of PSCD threats is to draw immediate attention to the nature of the threat in terms of level of control the port has and to define the scope of actions that can be executed. In other words, threats under infrastructure are most likely related to maintenance or technology advancement in the port and are therefore closely connected to productivity of port operations. Actions at the local level will usually be sufficient to curb these problems. Thus, the initiative of the port in improving these areas is imperative. Next, congestions and insufficiency of resources are typical results of improper planning and forecasting. To remedy these threats, interaction and cooperation with external entities will offer much assistance. The PSCD threats presented under manpower are related to soft skills of workers throughout the port and are also susceptible to governmental pressures. The port is unlikely to reduce these threats by working alone. Finally, intentional terrorist attacks and other criminal acts are closely related to the strictness of surveillance and level of security defined by the port.

However, the port has least control in managing these PSCD threats as it has to work closely with relevant bodies and authorities.

The implications of port's integrative role into supply chains have increased the significance of the PSCD threats related to planning, manpower and security. The increasing integration has exposed ports to greater vulnerabilities reflected by the threats under planning, manpower and security. Due to closer working ties with external entities, uncommunicated adjustments in upstream or downstream supply chain nodes will result in imbalance of demand and supply within the port. In addition, the integration of ports sets a larger interactive environment which increases difficulties with the differences of more individuals coming into play. On the other hand, the increasing embeddedness of ports into supply chains breeds opportunities for disruptions as more loopholes and bottlenecks are revealed in its operations to accommodate the integration. Thus, planning activities are made more complex, greater reliance on manpower is developed and closer scrutiny is required in maintaining the port's security.

3.3. PSCD Indicators

The PSCD Indicators demonstrate an increase in the port's susceptibility to PSCD threats and seek to raise awareness on areas in the port operations and also act as early detection signs to prevent the escalation of PSCD threats into supply chain disruptions. In the development of the PSCD indicators, the direct causes of the PSCD threats are considered such that the indicators reflect factors affecting the occurrences of PSCD threats. Tables 3.2, 3.3, 3.4 and 3.5 list the PSCD Indicators for infrastructure, planning, manpower and security PSCD threats. It is suggested that the PSCD indicators be computed annually for year-on-year comparison and also monitored at regular time periods for decision making and timely execution of contingency plans. Indicators are usually compared year-on-year as seasons affect demand and introduce risks especially due to weather. Indicators that should be monitored at regular periods would be those

are on-going and related to safety, such as level of atmospheric pollution, level of soil pollution and safety margins. However, it is suggested to study the values of the indicators collectively since PSCD threats can be interconnected. It has to be noted that these indicators do not directly imply the possibility of a PSCD threat. For instance, the presence or absence of equipment substitutes do not affect the probability of port equipment failure, but the absence of equipment substitutes can affect the severity of equipment failure threat when no other contingency plans are in place. Another example is that minimal involvement of government or regulatory bodies increase the port's vulnerability to intentional attacks as information on criminal activities and terrorism is not something a port can obtain on its part.

Table 3.2: PSCD Indicators for Infrastructure Threats

Infrastructure Threats	PSCD Indicators
Port Equipment Breakdown	<ul style="list-style-type: none"> - Large amount of time lapsed after last maintenance - Long equipment downtime - Absence of equipment substitutes
Inadequate Port Cargo-Handling Equipment	<ul style="list-style-type: none"> - Low productivity of critical port equipment - Large amount of time the equipment spent on maintenance - Obsolescence of equipment
Occupational Accidents	<ul style="list-style-type: none"> - Increased level of atmospheric pollution - Increased level of soil pollution - Unconformities raised at audits - Low employee participation rate at safety drills - Minimal support from management in improving safety across port - Increased frequency of wrong instructions carried out
Power Outage	<ul style="list-style-type: none"> - Absence of power substitutes
Breakdown of Vessel Traffic Management System	<ul style="list-style-type: none"> - Loopholes revealed in test attacks - High reliance of operations on main communication network
Breakdown of Port Information System	
Collisions in Waterway	<ul style="list-style-type: none"> - Highly utilized berths - Low margins for safe execution of operations at berths - Frustration experienced by port and vessels during berthing - Frequent wrong instructions carried out - Presence of vessels under Flag of Convenience

Source: Author

Table 3.3: PSCD Indicators for Planning Threats

Planning Threats	PSCD Indicators
Congestion in Waterway	<ul style="list-style-type: none"> - High proportion of waterway occupied - Port is a region's gateway or transshipment hub - Closure of neighboring ports - Disruptions or congestions at neighboring ports - Outdated development plans
Congestion within Terminals	<ul style="list-style-type: none"> - Highly utilized yard and/or warehouse areas - Low margins for safe execution of operations at yard and/or warehouse areas - Long dwell time of cargo in port - Port is a region's gateway or transshipment hub - Frequent breakdown of cargo-handling equipment - Outdated development plans
Congestion at Hinterland Transfer	<ul style="list-style-type: none"> - High number of delayed service provision by operators - High reliance on single operator - Port is a region's gateway or transshipment hub - Frequent breakdown of hinterland infrastructure - Inadequate hinterland infrastructure
Shortage of Facilities or Equipment	<ul style="list-style-type: none"> - Facilities and/or equipment are highly utilized - Outdated development plans

Source: Author

Table 3.4: PSCD Indicators for Manpower Threats

Manpower Threats	PSCD Indicators
Port Labor Strikes	<ul style="list-style-type: none"> - Employees' complaints with union's involvement - High percentage of outsourced workers - High employee turnover rate - Employees' complaints on unfavorable working conditions and/or wage - High influence power of unions - Growing tension in labor conflicts and negotiations
Shortage of Manpower (not due to strikes)	<ul style="list-style-type: none"> - Increasing cost of labor - Policies that cause hinder employment process - Insufficient upgrading programs and courses for employees - Festive seasons - Presence of pandemic outbreak
Misinterpretation of Instructions at Workplace	<ul style="list-style-type: none"> - Frequent errors in execution of operations - Frustration experienced by port workers during operations due to miscommunication of instructions

Source: Author

Table 3.5: PSCD Indicators for Security Threats

Security Threats	PSCD Indicators
Trafficking	<ul style="list-style-type: none"> - Presence of security breaches - Minimal involvement of government agencies or port authorities in port operations and business
Smuggling/ Contraband	
Stowaway	
Breaking in/Theft	
Terrorist Attacks	<ul style="list-style-type: none"> - Presence of terrorist attacks in adjacent areas - Presence of disputes related to questions of sovereignty - Minimal involvement of government agencies or port authorities in port operations and business - Growing tension with extremists

Source: Author

There are two distinct features of the PSCD Indicators. Firstly, the main perception is that the port is no longer considered as a whole; the indicators which were once applied to the port system as a whole are now applied to the port's disintegrated operations. For instance, the computation of productivity is extended in its application to each type of critical port equipment in the determination of equipment adequacy. Similarly, utilisation rate is computed for resources, warehouses and yard areas and this will reflect chances of the imminent congestion at each space.

Secondly, the indicators are computed on a discrete basis for each functional entity. This is to prevent the chances of making up deficiencies at certain areas by efficiencies at another of the same function. For instance, the performance of each hinterland transport operator should be computed instead of obtaining an average rate for each mode or the port as a whole. Computing discrete results will reveal discrepancies of results between the operators. An indication of inefficient operator will then call for additional adequate hinterland infrastructure to be constructed or the scraping of obsolete equipment. On the same note, when all the operators are operating above optimal rates, development plans need to be revisited to ensure their relevance. The

same applies to the computation of productivity of critical port equipment and utilisation of facilities and/or equipment as the results are obtained for each type of equipment and resource.

In the development of PSCD Indicators, the significance of several areas have been identified. These areas include the availability of substitutes, backup plans, safety drills, support from management on safety projects as well as the presence of cooperation with employees, hinterland transport service operators and the government. Thus, the strategies for managing PSCD threats have been reflected through PSCD Indicators. The following section further discusses the development of the management model for PSCD threats.

3.4. Development of the Management Model for PSCD Threats (PDM)

From the review of literature, it is apparent that the significance of ports in supply chains has increased and port functions have become much more complex today. These changes affect the ports' ability in minimizing disruptions. With the network proximity between ports and their users, ports are expected to be engaged in a higher level of interaction with the external parties, especially those within the port community. Thus, conducting RM and planning for contingency together with the external parties are deemed to be necessary actions to combat disruptions. The PSCD threats are analyzed in RM process to assess the consequences and probability of the threats. On the other hand, BCM allows the impact of the PSCD threats to be analyzed in order to determine the necessary recovery and mitigation plans that are to be in place. Therefore, RM will identify PSCD threats that affect the core deliverability of the port and assess the suitability of existing and additional controls, while BCM drives the ability to recover from the disruptions.

Though there exists established risk management frameworks such as the RIMS Risk Maturity Model and COSO ERM framework, the applicability of PDM makes it superior to the existing frameworks. While the earlier frameworks focus largely on risk management, the PDM integrates principles from BCM and QM while at the same time allows the participation of the port's stakeholders. The PDM is able to offer a wider coverage and broader scope of applicability, therefore making it more comprehensive than existing frameworks.

With this background in mind, the business environment that ports are embedded in has generally become riskier as they are more vulnerable to uncertainties attributed to global inter-connected supply chain entities, which in turn are more reliant on the ports in ensuring the delivery of their customers' requirements. Therefore, the application of RM theories and the presence of business continuity plans are critical. RM approach is essential to identify, analyze and manage PSCD risks and is useful in raising risk

awareness within the port. On the other hand, the development of business continuity plans will enable the port management to maintain port operations in the event of a disruption. RM, together with BCM, will reduce the likelihood of disruption causes and also ensure the continuity of port operations during adversity. In other words, an application of both approaches provides a more holistic protection and view for port management in disruptions.

Global challenges need to be addressed so that the port management is able to adjust to increasing changes. Among the changes and trends in the industry, there arise opportunities which the management can make use of to address the challenges and boundaries faced. The ever-changing market environment which the port is situated in also leads to the need to examine the criteria of working towards minimization of its disruptive potential. Thus, the relevancy of any proposed changes at the port must be ensured and this is the reason for regular monitoring and review of practices and policies at the port. The complexities of different organizations vary in extent. Similarly, in the port industry, not every port is at an identical stage of maturity and establishment. This emphasizes the importance of identifying the requirements which the ports should work on internally to ensure the deliverability of action plans. In essence, it is similar to the theories of QM and a holistic approach adopted by the leadership will facilitate changes in operations, cultures or practices at the port.

3.5. Components of the Proposed Management Model

The management model is presented in three tiers for the directives to be operationalized. The first tier starts at the top management and is referred to as Institutional Bearings in the management model as the focus is on the level at which decision making takes place and these strategic directions will go on to affect the course of actions to be taken by the port to work towards the objectives. There are five Institutional Bearings and each of them constitutes the first tier of the management model. The Institutional Bearings are developed with the objective of minimizing

supply chain disruption potential of ports. The deliverability, supply chain dynamism and the new role of ports in supply chains were considered in the development of measures that increase port resilience. These five Institutional Bearings address the external challenges through a committed internal support throughout the port, with theories of RM, BCM and QM being applied. Specifically, risks should be reduced or eliminated through RM process. Alternatives and recovery plans have to be in place for emergencies and unavoidable risks and this is achievable through BCM process. Finally, akin to Kleindorfer and Saad (2005) who applied total quality management (TQM) principles in their implementation of risk mitigating tasks, QM ensures that the port is able to maintain its delivery of services.

Extending from the first tier, management policies will then be formed at the second tier and front-line actions will be implemented at the third tier. Consequently, the second and third tiers of the management model are named Management Policies and Operational Actions respectively as shown in Figure 3.2. The arrows in Figure 3.2 demonstrate the direction in which the Institutional Bearings will be enforced to manage the disruptive potential at the port and the application of RM, BCM and QM principles to the management model.

Figure 3.2 Application of Theories to the Management Model

Source: Author

Each institutional bearing is responsible for taking the port towards a certain directive. As can be seen in Figure 3.3, beneath each Institutional Bearing are two related Management Policies which help steer the port towards that particular direction stipulated by the Institutional Bearing. The Management Policies then expand into Operational Actions for detailed front-line actions.

Figure 3.3: Overview of the Management Model

Source: Author

3.5.1. PSCD Threats Defense Mechanisms

The first Institutional Bearing, PSCD Threats Defense Mechanisms, relates mainly to managing PSCD threats within the port and is addressed by Internal Risk Management and Mandatory Controls. Applying the principles of RM and BCM, the third tier translates Internal Risk Management into actions that ensure the employees acquire and share the necessary RM knowledge internally and carry out the fundamental risk

procedures diligently, such as conducting risk assessment and ensuring that risk levels are monitored. These enhance the ability to identify and prevent the occurrence of PSCD threats. On the same note, Mandatory Controls specifies that buffers and alternatives should be created in port equipment, systems and transportation solutions; port should ensure that it is sufficiently insured against damages and losses; and mitigation strategies should be well-documented, closely adhered to and catered for different types of risks. By doing these, the port prepares itself for expected and unanticipated incidents. Considering the changing market trends and business environment, these strategies are to be regularly evaluated to ensure their relevance and effectiveness. There are also existing mandatory safety and security rules and regulations that the port has to comply with as these initiatives contribute to mitigating risks in ports when effectively implemented.

3.5.2. Discrete PSCD Deviators

PSCD Impact Analysis and Disruption Recovery Planning are the Management Policies associated with Discrete PSCD Deviators, whose main aim is to reduce the impact of disruptions caused by PSCD threats. The key processes and operations at a port are dependent on the types of cargo handled. Relating them to a detailed record of incidents which previously resulted in disruptions helps reveal critical business functions where due regard should be given. Simulating scenarios of these areas and the occurrence of PSCD threats would then expose the extent of disruptions. With that information, port management is suggested to plan for disruption recovery through documenting detailed emergency response plans for each functional department; implementing systems that allow prompt contact with and response from internal management and employees; and conducting emergency drills that mandate the participation of all employees. These Operational Actions reflect the essence of planning ahead for contingency and sustainability. Implementing PSCD Threats Defense Mechanisms together with Discrete PSCD Deviators allow a more comprehensive protection from PSCD threats. This is because Discrete PSCD Deviators complements PSCD Threats Defense Mechanisms with recovery capabilities.

3.5.3. Collaborative PSCD Defense and Deviators

The third Institutional Bearing, Collaborative PSCD Defense and Deviators, reflects the port's efforts in managing PSCD threats and planning for contingency together with external parties comprising of supply chain parties and relevant agencies. Supply chain parties, who are port customers and port users, are the ones who feel the immediate impact of disruptions propagated from ports. It is therefore important to handle risks with them and involve them in measures that increase port resilience. Hence, Collaborative Working Relationships with Supply Chain Parties is suggested. Operational Actions corresponding to this Management Policy include information exchange with port users on the status of their cargo and port's berths in an accurate and timely manner; ensuring that contractors' default do not affect port's operations; collaborative risk management; involvement of external parties in port's emergency drills; implementation of communication systems that enable prompt contact with and response from external parties; agreement on labor welfare; and coordinated provision of alternative transportation for port's customers in times of disruptions.

Also placed under the third Institutional Bearing is another management policy named Collaborative Relationships with Relevant Agencies. The aim of this Management Policy is to tap on influential parties with resources that enable continuous improvement in the process of managing PSCD threats. Operational Actions include having agreements with government agencies, employees and management on employee welfare; collaborating with government agencies in risk and disruption management; adopting relevant guidelines or framework established by local industry professional standards or alike; and regularly conducting research and development with higher education institutions to improve on port operations. The purpose of these actions is to ensure that the capabilities of managing PSCD threats are being updated and continuously improved on and refined.

3.5.4. Port's Holism Towards PSCD Reduction

The above three Institutional Bearings administer the management of PSCD threats by increasing organizational resilience and mitigating consequences through a series of measures that require internal and external cooperation. Naturally, these concerted efforts can materialize when there is approval and support to do so. As the name suggests, Port's Holism towards PSCD Reduction is associated with the port's holistic attitude towards management of PSCD threats. Stemming from this Institutional Bearing are two Management Policies – Service Objectives Enhancement and Employee Involvement and Empowerment. Service Objectives Enhancement can be described as a pro-service attitude that ensures quality of PSCD management through its Operational Actions. Appropriate actions are ensuring commitment from all functional departments to provide quality port services; upgrading of employees' professional skills; identifying customers' thresholds for delays; understanding customers' current and future needs; soliciting views from customers and users as well as re-evaluating workflow processes to improve efficiency.

Furthermore, it is suggested that leadership should involve and empower the employees so that the employees feel valued and respected. Leadership is recommended to motivate employees to offer constructive feedback on process improvement through giving incentives and have their opinion collected through internal portals. The port management is also advised to delegate authority to front-line employees who can make wise decisions in a timely manner. This shall help prevent and mitigate disruptions. When there are policy changes, the port management is encouraged to communicate issues brought about by the changes through small group meetings with the employees. Therefore, the objective of the fourth Institutional Bearing is to ensure the deliverables of the PSCD management process while business profitability and cooperativeness in corporate culture are not compromised.

3.5.5. Monitor and Review of PSCD Management Process

Lastly, Monitor and Review of PSCD Management Process seeks to ensure the relevance of the PSCD management process and improvements on it. This is essential due to the dynamism of the industry that is filled with changing business trends. Hence, one action for Relevance Evaluation is to review disruption management strategies regularly. Not forgetting the importance of involvement of external parties, the port is encouraged to communicate regularly with them and other stakeholders on issues pertaining to disruption management as well as conduct post drill evaluation together with its users and customers. The purpose is to identify ways to cooperate and adapt to the changing landscape. Similarly, Recommendations for Improvement is a plan to continuously improve on existing practices in disruption management. It is proposed that this can be achieved by conducting thorough post drill and disruption analysis, adopting feedback and suggestions gathered from customers and employees wherever deemed useful and also apply previous lessons learnt. These lessons when shared with other industry players can help prevent same mistakes by another party and hence are also encouraged.

In summary, the management model for port-related supply chain disruptions consists of Institutional Bearings, Management Policies and Operational Actions derived from the theoretical approaches discussed in the previous subsections. The PSCD management model proposes actions which are applicable to all types of ports. The main objective of this management model is to target operational deficiencies at ports such that supply chain continuity can be enhanced through reduced port-related disruptive risks. As ports are now more embedded in supply chains than ever before, it is important to enhance the functionality of ports and the PSCD management model proposed in this paper is the first step to make this happen. As such, this model is of relevant contribution to both theory building and practical management of port-related supply chain disruption.

CHAPTER 4. RESEARCH METHODOLOGY

4.1. Introduction

This chapter presents the research design and approach of this study. An overview of the research process of this study will first be presented. Next, a conceptual framework showing the overall relationships between the constructs will be identified. After which, the research design will show how the data collection and analysis stages will be planned and research approach will address and justify the application of research methods.

4.2. Research Process

Throughout literature, the term research process has been given many definitions. Collis and Hussey (2009) has summarized a research to take on the following characteristics: (a) process of enquiry and investigation; (b) systematic and methodical; (c) increases knowledge; (d) thorough and rigorous methodology. Lussier (2011) has defined research as the “*systematic process through which new knowledge is discovered through answering questions*”.

The research topic and research questions of this study were selected based on the discussion by Lussier (2011) in his identification of six considerations in the selection of research questions. This study thus corresponds to them and they are related to the level of interest in the topic by the author, willingness to acquire expertise in the research area, value to the academia and industry of the study, sufficiency of literature, feasibility of conducting the research and openness to change. As discussed in the beginning chapter, this research seeks to explore how port-related disruptive events affect supply chain continuity and this is answered by addressing the first research question and its sub-research questions:

RQ1: How is the role of ports in inducing supply chain disruptions determined?

SRQ1: What are the implications of ports increasingly being integrated into supply chains?

SRQ2: What are the most commonly observed and perceived PSCD threats and consequences?

SRQ3: How severe are the PSCD consequences?

SRQ4: How can PSCD threats be detected?

The second research question and its sub-research questions help us understand how ports can manage these disruptions in an effective manner:

RQ2: How can ports mitigate port-related supply chain disruptions effectively?

SRQ5: What are the mechanisms which the port should initiate to minimize port-related supply chain disruptions?

SRQ6: How should a holistic approach towards PSCD management be operationalized by the participants involved in port transport chains?

Besides the stages of problem formulation, the research process also involves planning for data collection and selecting the most appropriate methodology for data analysis. As stated by Collis and Hussey (2009), the purpose of a research includes (a) to review and synthesize existing knowledge; (b) to investigate existing situations or problems; (c) to provide solutions to problems; (d) to explore and analyze more general issues; (e) to construct or create new procedures or systems; (f) to explain new phenomenon; (g) to generate new knowledge; (h) or a combination of any of the above.

In order to answer the research questions of this study, three management theories were applied in the research process and they were risk management, business continuity management and quality management principles. The application of these theories was

justified as it was attributed to literature gaps, discussion with the author's supervisor and other industry experts as well as the author's observation in this research area. The industry experts are management from port operating companies and their demographic data are provided in Table 4.5 in sub-section 4.7.1. The development of measurement items of each construct thus followed the principles of the three management theories. The general research process followed by this study to answer the two research questions is shown in Figure 4.1.

Figure 4.1: Research Overview

Source: Author

4.3. Research Design

After stating clearly the research questions, the study must be designed in such a way that the questions will be answered. In general, the research design is the planning of data collection and selection of data analysis methods which include indicating the sample, variables and measures in relation to the research objectives, such that the research questions can be answered (Lussier, 2011, Jarzemskiene, 2009, Ketchen et al.,

2008). There are many forms of research processes discussed in literature. A research can possess the nature of an exploratory or conclusive study, fieldwork, case study, desk-bound or laboratory work, qualitative or quantitative methods, cross-sectional or longitudinal and descriptive or causal type of analysis (Lussier, 2011, Zikmund, 2007, Gable, 1994). Lussier (2011) has summarized and presented eight dimensions of a research as shown in Figure 4.2.

Type of Study	<ul style="list-style-type: none"> • Exploratory or conclusive/formal
Data Collection <ul style="list-style-type: none"> - Time dimension of data collection - Research environment of data collection 	<ul style="list-style-type: none"> • Secondary, observation, or survey - cross-sectional or longitudinal - fieldwork or deskwork/lab
Manipulating variables	<ul style="list-style-type: none"> • Experimental or ex post facto
Data analysis <ul style="list-style-type: none"> - Purpose of study/data analysis - Goal of data analysis 	<ul style="list-style-type: none"> • Qualitative or quantitative/statistical - Descriptive or inferential/causal - To explain, predict or control

Figure 4.2: Classification of Research Designs

Source: Author, adapted from Lussier (2011)

The research design of this study used both qualitative and quantitative nature in the data collection and analysis processes. An overview of the research design of this study is provided by Figure 4.3. Primary data were collected through interviews and surveys, while the results were analyzed statistically. In this manner, the qualitative analysis from interviews and secondary data assisted in the development of questionnaires and inferences were then made and supported through a quantitative method.

Figure 4.3: Research Design of Study

Source: Author

At the first step of the research design, the topic was selected, research questions were clearly stated and the research purpose and objectives underlay the value of this study. The process of the operations from upstream supplier to the port and then from port to downstream entities were considered and overseen right at the beginning to define the research scope. SRQ1 is regarding the implications of port's integration into supply

chain and thus was answered through a review of related literature. By doing so, all port-related operations and processes were recognized and this research maintained its relevance. The secondary data was then looked into in order to identify reported cases of port-related supply chain disruptions. In this way, a list of PSCD threats and consequences was determined and deduced. On the same note, literature on disruption management was studied and the applicable mitigation and prevention strategies were analyzed. Coupled with the principles of risk management, business continuity management and quality management, a framework for managing port-related supply chain disruptions was proposed for port management.

Hypotheses were then developed, specifying the variables and measurement items enabling the research questions to be answered. In addition to establishing the risk matrix for port-related supply chain disruptions, the other purpose of conducting the survey was to ensure that the proposed management model conforms to a practical framework that is relevant in its applicability. Thus the management model was revised wherever deemed necessary after analyzing the interview results. The management model contains measurement items that reflect the three pronged approach – risk management, business continuity management and quality management theories – which built it. These measurement items were grouped under constructs according to the theories that developed them and were included in the questionnaires distributed to the port operators who then indicated how well they have done in terms of the measurement items and port performance related to disruption management.

The next step of the research design for this study was the process of primary data collection. Interviews were conducted with industry professionals to facilitate discussion of PSCD threats, their respective consequences and the course of actions taken at their individual ports. Professionals from the port operators and port user entities were selected to provide different perspectives and concerns from different sides in a port community. Their comments and any additional risks and consequences were

compiled with the one derived from secondary data. The selection of the professionals, population and sampling frames will be discussed in more details in Section 4.6. The survey methodology required careful design of questionnaires, and pre-test and piloting of questionnaires which identified areas for revision. After the responses were received, the responses needed to be carefully edited, coded and entered, and measures were in place to control errors to prepare the data for analysis. As such, the qualitative results from the interviews were incorporated into the questionnaires. Therefore, SRQ2 and SRQ3 were answered. The understanding of the origin of the threats will enable the development of PSCD indicators which detect a PSCD threat. In other words, the results for SRQ2 and SRQ3 allowed SRQ4 to be answered together with a review of related literature.

SRQ5 and SRQ6 were answered through the survey results by showing the relationships between the proposed management model and port performance in terms of port-related disruption management through Structural Equation Modeling (SEM). The simulation exercise in Appendix J aims to complement the SEM results through a practical illustration of figures related to time, costs and volumes. Hence, the outcome of this research is that the two research questions are answered with both qualitative and quantitative perspectives.

4.4. Research Approach

Qualitative and quantitative methods are the primary options for research methods. A qualitative research differs from a quantitative one in terms of the size of sample, its focus, the methods of analysis used and objectives, among other things. The nature of a quantitative research is that it is more focused on presenting information in a scientific and numerical way (Page and Meyer, 2000), while that of a qualitative research is related to observations, descriptions and explanations (Lussier, 2011). Table 4.1 illustrates the main differences between a qualitative and quantitative research. It is

helpful to first pay attention to the goal of the study when selecting the type of method to use so that the research objectives can be fulfilled.

Table 4.1: Quantitative versus Qualitative Research

Quantitative Research	Qualitative Research
1. Seeks to explain phenomena.	1. Seeks to understand phenomena.
2. Tests research questions (hypotheses).	2. Uses critical thinking to understand, rather than test.
3. Uses closed-ended, brief questions.	3. Uses open-ended, in-depth questions.
4. Uses a large sample size.	4. Uses a small sample size.
5. Data are collected, then analyzed once (questionnaire completed once).	5. Data are collected and analyzed as an ongoing process (may include multiple interviews with the same person).
6. There is a clear end to the data-collection process.	6. There is no clear end to the data-collection process.
7. Uses statistics to analyze data.	7. Does not use statistics to analyze data.
8. Results are objectively determined.	8. Results are subjectively determined.
9. Conclusions are reported to be generalized to population.	9. Conclusions are reported to help understand phenomena.

Source: Lussier (2011)

The goal of this study is to identify ways which port management can adopt to effectively manage port-related supply chain disruptions. There is hence an implied causal relationship, between disruption management performance and the proposed actions that make up the management model, which needs to be tested and validated in the data analysis process. Methods such as tests of difference, tests of interaction, tests of association, tests of prediction and tests of interrelationship are research designs which will help achieve the objectives of this study. These are statistical designs and belong to quantitative methods. As there was an absence of port-related supply chain disruptions studies in literature, interviews were useful in the data collection stage prior

to the development of a questionnaire. The use of interviews will allow the researcher to probe for details and ensure that the measurement items in the questionnaire, which are to be developed at the next stage, remain relevant and suitable. Such interviews tend to be open-ended and in-depth in order to serve its purpose of understanding the field of study. In other words, this study used both quantitative and qualitative methods – data triangulation. Both the perspectives of port operators and port users were considered in the data collection process. In addition, a simulation involving a port user was added after the statistical analysis to support the results of data analyzed and thus, a between-method, which is a triangulation of both quantitative and qualitative methods, was employed. This methodology adds a stronger validity to the conclusions by using different methods to support the results (Lussier, 2011).

With regards to data collection, there are three methods: (1) secondary, (2) observation and (3) survey (Lussier, 2011). Secondary data are those that are found in published work and historical statistical records. Observation is related to qualitative research design and requires effort in observing behaviors and patterns of people and objects (Zikmund, 2007). According to Zikmund (2007), researchers often use two kinds of observation methods, human and mechanical observation to gather information on human behavior or action, verbal behavior, spatial relations, temporal patterns, physical objects, verbal and pictorial records and expressive behavior. Examples of what can be observed are shown in Table 4.2.

Survey method involves asking respondents for information either verbally or through a questionnaire (Zikmund, 2007). Surveys are also a primary data collection method and can take the form of face-to-face interviews, telephone interviews, online questionnaires and written questionnaires (Ketchen et al., 2008, Zikmund, 2007). The purpose of these procedures is to collect facts or information from the target respondents. The data collected enables the identification of the inherent trends and patterns, provision of a measurement of attitudes or an explanation to behavioral characteristics. Surveys

provide a flexible and efficient way of collecting data about a population, especially when the sample is geographically wide-spread.

Table 4.2: Examples of What can be Observed

Phenomenon	Example
Human behavior or action	Workers' movement patterns in a factory
Verbal behavior	Statements made by airline travelers waiting line
Spatial relations	Proximity of middle managers' offices to the president's office
Temporal patterns	How long workers take to perform a task
Physical objects	How much paper office workers recycle
Verbal and pictorial records	How many illustrations appear in a training booklet
Expressive behavior	Facial expressions, tone of voice, and other forms of body language

Source: Zikmund (2007)

Inevitably, with every method used, whether quantitative or qualitative, there would be disadvantages. Thus, what is important is to minimize the errors and to increase the accuracy of any selected method. The errors affect the accuracy of surveys but can be minimized by an appropriate selection of the samples and proper administration of the survey. The accuracy of surveys can be increased with the use of well-constructed questions with proper instructions. Before the questionnaires are distributed, pre-tests and pilot-testing will ensure improvements on the questionnaires, hence reducing the chances of misinterpreting the questions. Specific measures undertaken to address errors and accuracy will be explained in later sections of this chapter.

Weighing the merits and shortcomings of each technique, the most appropriate research design and methods can then be selected. Participants of this research were located around the world, hence the method used to collect data from the above participants needed to provide geographical flexibility and at the same time should not compromise on the depth of information collected. In-depth interviews have high response rates and allow opportunities for feedback and confirmation of information. Surveys in the form of questionnaires allow respondents who are geographically dispersed to participate in the study at a time of their convenience. Using electronic mail, time and cost to collect data from the respondents through questionnaires will not be an issue. As the data intended to be collected involved information regarding organizational strategies and security, participants might be reluctant or uncomfortable in the presence of the researcher when probed. On the other hand, if questionnaires are sent to them instead, the respondents can remain anonymous. When the respondents are not able to provide accurate information for this study, the respondents can approach colleagues who are more suitable to give answers. Hence, the use of survey methodology was justified.

4.5. Research Hypotheses Development

The previous chapter discussing the development of conceptual framework has presented the reasons for the dimensions of the management model. Specifically, the management model for PSCD threats (PDM) consists of 10 groups which further expand into 45 measurement items. The measurement items collectively reflect the triangulated application of risk management, business continuity management and quality management. Table 4.3 shows the relationship between the principles of RM, BCM and QM and the 45 measurement items.

Table 4.3: Relationship between The Three Theories and Measurement Items

Related Theoretical Approach <i>(Relevant sections in questionnaire)</i>	Reflected in:
Risk Management <i>(B1, B2, B7, B9)</i>	Joint Standards Australia/Standards New Zealand Committee OB-007 (2004b), Bichou (2008), Pinto and Talley (2006), Darbra and Casal (2004), Bichou (2004), Brooks and Button (2007), Chin and Debnath (2009), Wu et al. (2007), Gurning and Cahoon (2009b), Handfield et al. (2007), Pinto and Talley (2006), Blackhurst et al. (2005a), Christopher and Peck (2004), Ronza et al. (2003)
Business Continuity Management <i>(B3, B4, B7, B9)</i>	Joint Standards Australia/Standards New Zealand Committee OB-007 (2004a), Paul and Maloni (2010), Angeloudis et al. (2007), Wu et al. (2007), Guerrero et al. (2008), Blanchard (2007), Paixao and Marlow (2003), Rahimi et al. (2008)
Quality Management <i>(B5, B6, B7, B8, B9, B10)</i>	Coetzee (2005), Konings (1996), Slack (1999), Beresford et al. (2011), Konings (2005), Horck (2008), Greening and Rutherford (2011), Fabiano et al. (2010), Kleindorfer and Saad (2005)

Source: Author, synthesized from various literature

The essential purpose of PDM is to minimize the disruptive potential of the port, and hence it seeks to improve port performance in terms of financial and non-financial metrics. It can be seen from Table 1 that several variables are extracted and classified according to their effects on four main aspects of port performance. These aspects are

associated with the dimensions of the balanced scorecard used by numerous private, public and non-profit organizations around the world (Kaplan 2010). The balanced scorecard is primarily concerned with measuring performance from financial perspective, customer perspective, process perspective and learning perspective as elaborated in various studies (Kaplan 2010, Perlman, 2013, Huang et al., 2009, Logman, 2004). To address these dimensions, the port performance in this research will be measured by four constructs, namely financial health (FH), market reputation (MR), resilience of internal operations (RIO) and internal and external opportunities (IEO). Table 4.4 shows the linkage between the four constructs and the measurement items (Appendix F, Part C) in the questionnaire.

Table 4.4: Relationship between Balanced Scorecard Constructs and Measurement Items

Balance Card Constructs	Variables in Questionnaire	Related studies
Financial perspective	<p><i>(Financial Health)</i></p> <p>Presence of financial difficulties, financial growth, financial benefits, fines and penalties received, financial ratios and profits</p>	Zhang et al. (2014), Lun et al. (2010b), Christopher and Peck (2004), Mason and Nair (2013), Paul and Maloni (2010), Chin and Debnath (2009), Guerrero et al. (2008), Mennis et al. (2008), Handfield et al. (2007), Tang (2006), Paixao and Marlow (2003)
Customer perspective	<p><i>(Market reputation)</i></p> <p>Ability to redesign and resume internal operations, improvement in operational efficiencies, an experience of disruptions</p>	Mennis et al. (2008) Tongzon and Heng (2005), Lirn et al. (2004)
Process	<i>(Resilience of Internal</i>	

Balance Card Constructs	Variables in Questionnaire	Related studies
perspective	<i>Operations)</i> Market share, customer retention, customers' complaints, attraction of new customers, customers' satisfaction	Ellis (2011), Ponomarov and Holcomb (2009), Bichou (2008), Handfield et al. (2007), Pinto and Talley (2006), Blackhurst et al. (2005a), Christopher and Peck (2004), Ronza et al. (2003)
Learning perspective	<i>(Internal and External Opportunities)</i> Skills and knowledge of employees, engagement in technology and acquirement of capabilities, intensity and frequency of training and learning opportunities, improvement in disruption management process, improvement in employee turnover rates	Beresford et al. (2011), Greening and Rutherford (2011), Fabiano et al. (2010), Rodrigue and Notteboom (2009), Skipper and Hanna (2009), Horck (2008), Handfield et al. (2007), Kleindorfer and Saad (2005), Bichou and Gray (2004), Baum et al. (2003), Heide and Stump (1995)

Source: Author, synthesized from various literature

These perspectives are sufficiently wide-ranged to address port performance from the financial, customer, process and learning and growth of the effects from the implementation of the PDM (Kaplan and Norton, 1992).

The PDM was derived from the principles of RM, BCM and QM. The predominant purpose of PDM was to reduce supply chain disruptions that originate from port operations. A resilient system has diversity, efficiency, adaptability and cohesion as its characteristics (Fiksel, 2003) and Falasca et al. (2008) explains that resilience in supply

chain is capable of lowering chances of disruptive events occurrences and reducing the impact of unanticipated outcomes. With higher flexibilities, adaptability and efficiencies, the severity of the disruption can be abated by increasing responsiveness and capacity of contingency plans (Schmitt and Singh, 2009, Craighead et al., 2007), resulting in better performance. The measures that constitute PDM therefore seek to enhance port's disruption management by increasing the resilience of port operations, giving rise to:

H₁: PDM has a direct and positive effect on RIO.

Port performance has already taken on a different dimension that extends beyond efficiency within the port itself (Song and Panayides, 2008, Lun et al., 2010a, Ducruet and Van Der Horst, 2009). The idea that supply chain firms should no longer compete individually leads to the understanding that firms need to recognize the importance of establishing strong alliances with each other, while not losing focus on enhancing performance at both local and aggregate levels (Green et al., 2006). The application of RM, BCM and QM principles highlights the importance of continuous improvement and assessment through cooperation within the port and collaboration with external parties. In addition, PDM seeks to result in effective and sustainable partnerships from which the parties can derive benefits (Kleindorfer and Saad, 2005). When conducted effectively, the innovation and growth perspective experienced by the port would be facilitated. Therefore, the resulting outcome of PDM would have an effect on internal and external opportunities:

H₂: PDM has a direct and positive effect on IEO.

Internal and external opportunities are particularly related to the growth and learning opportunities of the port employees to better assess, identify and handle threats. Through such opportunities, professional skills of employees can be enhanced and areas to be improved can be identified, collectively resulting in increased capability which will result in other effects. The different forms of cooperation and coordination initiatives

which ports can engage in would facilitate its integrative role in supply chains and evolution towards agility and resilience (De Langen and Chouly, 2004, Lun et al., 2010a). Thus, internal and external opportunities are expected to have a direct and positive effect on reliable operations:

H₃: IEO has a direct and positive effect on RIO.

Furthermore, the increased resilience of internal operations will inevitably reinforce the trust that port users have on the port as well as bringing about higher and repeated earnings for the services and value provided. Value proposition at the port depends on its internal processes which, when improved, reduce costs (Kaplan and Norton, 2004). Financial health is a lagging indicator of the performance-driving measures (Kaplan and Norton, 2004, Huang et al., 2009) which, in this study, are represented by the constructs of “Resilience of Internal Operations”. Impacts of port-related disruptions, e.g., route diversion, port lockout, accidents, cargo loss, are usual consequences of low quality in RIO. On the other hand, seamless cargo flow through the port would understandably result in reduced compensation, revenue increases and build up customers’ confidence. Hence, PDM is expected to improve disruption management at the port in the form of increased port resilience which will consequently produce healthy financial outlook and better market reputation. The above leads to the following hypotheses:

H₄: RIO has a direct and positive effect on FH.

H₅: RIO has a direct and positive effect on MR.

As explained above, the relationship between PDM and market reputation is not direct. Business reputation depends on the quality of value proposition and good customers’ perception of port management which in turns translate into better finances due to repeated existing port customers and new businesses. Hence, financial health is a derived effect or a lagging measure (Perlman, 2013) as the development of customers’

trust and confidence is fundamental to the profitability and relevance of businesses. Thus, this connection leads to the development of:

H₆: MR has a direct and positive effect on FH.

The theoretical model is presented in Figure 4.4.

Figure 4.4: Theoretical model

Source: Author

4.6. Population and Sampling

The decision on the population to be selected is determined by the scope of research and other practical considerations. Depending on the areas intended to be covered by the research and the research objectives, data collection can be carried out locally or involving respondents from more than one nation. Practical concerns include time and cost required for the data collection process. In this case, the extent of involvement in port supply chains was the focal point in determining the suitable candidates in data collection.

4.6.1. Population Frame

According to the research questions, participants were not restricted to the types of cargo handled, size of organization or market orientation. In fact a composition of respondents with those differences allowed an investigation on a variation of response characteristics. However, the respondents were narrowed down to two groups – port operators and port users. Ports are the ones playing the vital role in any port-related supply chain disruption and naturally they will be involved in the data collection process. Port users, on the other hand, are the ones directly impacted by consequences of those disruptions and are thus included as well. There were two objectives of the survey, the first objective was to establish a risk matrix and the second objective was to explore the relationship between the proposed management model and disruption performance. Different groups of respondents were suitable for the two objectives as the concerned parties involved differ.

The first research question was addressed by developing a risk matrix. When considering the participants to be included in the population frame for the risk matrix, it was necessary that they are familiar with the likelihood and consequences for each PSCD threat, which are the two axes that make up the risk matrix. In addition, they should be part of supply chains in which ports are used and have felt the impact of a port-related supply chain disruption. Clearly, the involvement of the port operators and port authorities was indispensable as they were the subjects of this study. They were able to comment on the appropriateness of the findings as well as provide instances of relevant past cases or data. Ports that handle containers and non-containerized cargo such as vehicles, liquid and dry bulk were included in the analysis. Passenger ports were not analyzed as the research scope covered only the consequences of PSCD threats on cargo. After the collection of data, an analysis was also made for prevailing differences among categories of participants to investigate if the differences have attributed to variation in responses.

The ports' stance on PSCD threats offers only a one-sided viewpoint of the risk matrix as other supply chain entities would have felt the impact differently. Therefore, besides the port, these participants also comprised of the stakeholders of the port. The stakeholders were limited to entities that have a proximate relationship with ports and those with direct interest in the cargo transported through ports to ensure the accuracy of data collected and their knowledge in the data required. Therefore, cargo owners, freight forwarders, shipping owners and ship management companies were included in the population frame. Cargo owners who were approached comprised mainly of sea freight forwarders and/or logistics companies since they were usually the representatives of the real cargo owners. However, the geographic location of these companies should not influence the results as the import and export ports used by these entities vary widely and are located all over the world. Hence, there were no restrictions on the geographical locations of port users' entities.

The second research question was about the management model. For the management model, as it involves the familiarity of operations and practices within the port, port operators and port authorities were appropriate participants. For this research, it was decided that ports of all sizes and regions be among the participants as there had been no previous studies that offered a general framework for ports of all types to adhere to. This study seeks to provide that as groundwork for future progression into specific guidelines tailored for different categories of subjects. Port authorities were involved as they hold regulatory powers over policies and investments which can affect the effectiveness of implemented strategies. The target population for the survey and the intended objectives are shown in Figure 4.5.

Figure 4.5: Target Population

Source: Author

4.6.2. Sampling Frame

From the populations decided in previous section, samples were selected. This study undertook two distinct stages of primary data collection, the first stage was to conduct in-depth interviews and the second was the distribution of questionnaires to the samples.

In-depth interviews

In selecting participants for in-depth interviews, convenience sampling was used for samples of both port management and port users as these participants were likely to show greater willingness to participate in the study.

Questionnaire

As there are two objectives of the survey, there were two versions of questionnaires – one for the ports and the other for the port users. The first objective is to build the risk matrix and this involved two target population, the port management and port users. For port management samples, port operators and port authorities who are members of International Association of Ports and Harbors (IAPH) (2013), American Association of Port Authorities (AAPA) (2013), Association of Pacific Ports (APP) (2013), and Port Management Association of Eastern and Southern Africa (PMAESA) (2013) were approached as there were member directories on their websites. The author had also written to other major port associations that had no members listed on their website for help in distributing the questionnaires, but received replies that it was not allowed. To ensure sufficient information was yielded about the population, smaller ports which were not listed in the abovementioned databases had also been reached out to. Hence, the sample also comprised of ports found in the directory of World Port Source (2013). The World Port Source provided a large and comprehensive database of existing ports worldwide.

On the other hand, for the sampling of port users, local entities who are members of Singapore Logistics Association (SLA) (2013) and Singapore Shipping Association (SSA) (2013) were written to. Global shipping lines found in Alphaliner (2013) and international freight forwarders from the directory of The International Federation of Freight Forwarders Associations (FIATA) (2013) were approached as well. In addition to the abovementioned databases, participants whom the author met at seminars and conferences also made up the sample.

The second objective of the survey is to validate the management model and the same samples of port management selected for the development of risk matrix were approached. Figure 4.6 summarizes the sampling frame of this study.

Figure 4.6: Sampling Frame

Source: Author

For the distribution of questionnaire, total sampling was performed on the samples selected for port management and port users to collect as much information as possible. The intended recipients of the questionnaires were those of managerial positions or above as responses required were related to the operations, policies and strategies at the organization. When contact information of these recipients was not accessible in the directories named above, the websites of the ports and port users were accessed individually and contact information of top-level executives or senior management were retrieved wherever available.

In total, eleven in-depth interviews were carried out and the questionnaires were distributed to 845 ports and 1519 port users. The sampling frames were justified as they provided a good mix of multi-national organizations that collectively provided valuable insights on the influence of the PSCD threats on global supply chains and perspectives for the proposed management model.

4.7. Primary Data Collection

There were no existing questionnaires suitable for use to answer the research questions, therefore the questionnaires needed to be developed first. For that to be done, secondary data and literary works were examined and this enabled the list of PSCD threats and the measurement items in the management model to be conceived. Then in-depth interviews were conducted with port management and port users. The main objectives of the interviews with the port operators and port users were to identify how port-related events affect supply chain continuity, to obtain comprehensive insights on the existing practices and to assess the practicality and requirements for the implementation of the management model for PSCD threats. The interviews together with pre-testing and pilot-testing enabled the questionnaire to be finalized and upon finalizing, the questionnaire were distributed to the samples.

4.7.1. In-depth Interviews

Interviews can take the form of face-to-face interviews or telephone interviews. Telephone interviewing includes central location interviewing, computer-assisted telephone interviewing and computerized, voice-activated telephone interviews (Zikmund, 2007). Face-to-face interviews take place in the presence of the researcher and offer a channel for feedback and to gather information through asking questions and for opinions as well as probing into the interviewees' memory for related information. Telephone interviews have the same function but the researcher is not physically at the

interview scene and hence visual medium cannot be transmitted. Central location interviewing is a method of conducting telephone interviews from a central location and is typically used by research agencies. A computer-assisted telephone interview utilizes computer technology and is a type of interviewing in which the interviewer sits in front of a computer and enters responses from interviewees. This is a form of highly structured interview and responses that do not correspond to pre-coded answers will be rejected. Computerized, voice-activated telephone interviews are more suitable for short and simple questionnaires as the system reads questions to the interviewees whose single-word responses will be registered by the computer.

For this research, face-to-face interviews were conducted with interviewees who were based in Singapore and telephone interviews were conducted with two interviewees who were based in Australia and Vietnam. Face-to-face interviews have high participation rates, enable the researcher to probe and can last longer. Telephone interviewing was selected for interviewees who were overseas because of speed and the low cost it incurs. It has been mentioned that convenience sampling was the method used in selecting interviewees as there will be higher willingness to share information and their insights with people they know. As shown in Table 4.5, six in-depth face-to-face interviews were conducted with port management in Singapore and one telephone interview each with port management from an Australian and a Vietnamese port operator. From port users' sample, a tanker management company, shipping line company and a cargo owner from the petrochemical industry were interviewed face-to-face. All interviewees were of managerial positions and the interviews took place between late January 2013 and mid-March 2013.

Table 4.5: Participants of In-depth Interviews

Location	Port Management	Port Users	Total
Singapore	6	3	9
Australia	1	0	1
Vietnam	1	0	1
Total	8	3	11

Source: Author

In designing the structure and questions for the in-depth interviews, the four stages of interviews proposed by Gillham (2000) were adopted. At the start of the interviews, an introduction of the author and this research was given. The work on the research and developments till its current stage was explained to the interviewees to bring in the themes of the research. The interviewees were then asked questions related to the themes before the author brought the interviews to an end. The interviewees were of managerial positions, with one of them as a top-level executive, and all of them had many years of experience in their industries. Hence, the interviews were semi-structured but in-depth, such that the interviewees could elaborate more instead of being led to short responses by the interviewer. With their background, the interviewees could share more information based on their extensive knowledge and experience in this way as compared to a more formal and highly structured questionnaire-based interviews. Due to the structure of the interviews, the questions asked did not follow the same sequence from one interview to another. See Appendix A for interview questionnaires for port users. Additional questions were probed whenever clarification was needed during the interviews. Therefore, after the introductory phase, general questions were asked first followed by more specific questions and questions of similar themes were grouped together. This helped the interviewees to focus on a theme and recall events relevant to the theme before moving on to the next. After these stages, the interviewees would have a better understanding of the research and they were asked for their feedback on the study at the closing phase.

The interviews with port management focused on the likelihood and consequences of PSCD threats and the appropriateness of the management model. The interviews started with the interviewees' views of ports' role in supply chains. The questions were then narrowed down to the challenges experienced at their ports presently and in the past and if there were measures to counter them. See Appendix B for interview questionnaires for port operators. Tabulated information on the management model was presented to the interviewees with whom the author conducted face-to-face interviews as the components were explained to them. For interviewees in Australia and Vietnam, the information was sent to them through electronic mail. Then, the port management were asked to comment on the management model after it was explained to them and any feedback or opportunities for improvement on the model and study was recorded. Similarly, the interviews with port users began with their perception on the role ports play in their supply chains. The interviewees were then asked about the occurrences and impact of the PSCD threats that affected their organization, effectiveness of existing and past collaborations with the ports and their attitudes towards how the port have handled disruptions. At the end of the interviews, the interviewees were asked for their opinions on the research and demographic questions related to their organizations and their experiences in their respective industries. Notes were taken throughout the interviews and voice recordings were done whenever it was allowed and possible. The topics covered by the interviews are related to the conceptual framework and thus include internal and external risk management, contingency measures, disruption recovery, quality enhancement, collaboration relationships with external parties and government agencies and continuous improvement.

4.7.2. Objectives of Survey

This research utilized surveys as its primary data collection method. The purposes of the surveys were to provide generalizable measurement of the likelihood and consequences of PSCD threats and to explore the relationship between the management model and port performance in disruption management. Currently, such data does not exist. There are no statistical data or historical data on the frequency and impact of each PSCD

threat by the port industry or their customers. There is also no existing framework that stipulates recommended actions or useful reminders for port management to implement. Thus, surveys were used to provide such information and reveal underlying trends, which will be discussed and the analysis will be useful for future studies.

4.7.3. Design of Questionnaire

The purpose of distributing questionnaire is to gather information from the respondents. According to Cooper and Schindler (2013), there are three phases in the process of instrument design. Phase 1 involves selecting scale type, communication approach and process structure according to the research questions, ensuring that the research scope will be covered sufficiently. Phase 2 constructs and refines measurement questions such that the questionnaire meets five goals: (1) accuracy in responses, (2) sufficient amount of information is gathered, (3) avoidance in answering specific questions is discouraged, (4) completion of questionnaire and (5) leaving respondents with a positive attitude about participating in the survey. Phase 3 further refines the instrument and a pre-test is conducted. The design of questionnaire in this research fulfills these three phases. For this research, the objective of the questionnaire developed for the risk matrix is to collect data on the frequency of occurrences of each PSCD threat and their extent of impact on supply chains, while the questionnaire for the management model seeks to establish the relationship between the measurement items and the disruption performance indicators which would then validate the management model. These two objectives provide answers to the two research questions of this research.

To meet these objectives, two sets of questionnaires were distributed. Both questionnaires were kept as short as possible to increase response rate (Judd et al., 1991). Both sets of questionnaires shared the same title “Study of Port-Related Supply Chain Disruption Management” but the first questionnaire was two pages long and comprised of two parts, while the second questionnaire was five pages long and consisted of four parts. In the process of constructing the questionnaires, attention was given to the

phrasing of questions, the way questions were asked, the sequence of questions asked and the layout of the questionnaire to accomplish the criteria of designing a relevant and accurate questionnaire (Zikmund, 2007). A majority of the questions in both questionnaires asked were fixed-alternative questions and questions that asked for feedback and input to share relevant measurement items not stated in the questionnaires were open-ended. These open-ended questions sought to capture relevant and additional comments, thus enhancing the content validity of the questionnaire. The questions were specific and were phrased using simple language that made understanding easier to keep the interest of respondents and increased the chances of receiving completed questionnaires. To ensure that the relevancy and accuracy of the questionnaire was achieved as much as possible, questions and items that were leading, loaded, ambiguous or double-barreled were avoided. Like personal interviews, an introduction of the author and study were given. Hence, a cover letter was developed and since the questionnaires were distributed using email due to the geographical flexibility, low cost and convenience this channel of communication provides, the cover letter made up the content of the email. See Appendices C and D for cover letters. The cover letter contained a brief introduction of the author, research purpose, an appeal to respondents for their participation as their contribution would be valuable, general instructions on participating, time frame set for return of questionnaires, guarantee of confidentiality, author's contact and appreciation for their participation by offering to share with the respondents the research findings. These will be explained in more detail in Section 4.7.5.

The first set of questionnaire attached in Appendix E was distributed only to port users as its main aim was to collect data for the purpose of a risk matrix. As mentioned, there were two parts in this questionnaire – Part A and Part B. The first question in Part A was an open-ended question asking respondents to name a port frequently used by their organization. The respondents were then asked to indicate the frequency of occurrences and the extent of impact of 19 PSCD threats in the second question. This question also provided some spaces for respondents to include any additional PSCD threats that were

not listed in the questionnaire as well as their likelihood and consequences. The second question in Part A used a five-point ordinal measurement scale which ranged from 1 (least frequent and negligible impact) to 5 (most frequent and worst impact). The purpose of the first question was to ensure that the respondents would answer the second question based on a port that their organizations were familiar with so that their responses would then offer a fairer and more accurate impression of the PSCD threats. Part B consisted of questions asking respondents about their organizations, their functional areas and designations in their organizations and experience in the industry. Checklist and simple-dichotomy questions were the format used in the nine questions wherever appropriate.

The second questionnaire was distributed to port management. See Appendix F for this set of questionnaire. Its purpose was to gather information for the risk matrix and on the validation of the management model. There were four parts in the questionnaire. In Part A, respondents were asked to indicate the likelihood and consequences of the 19 PSCD threats using the same measurement scale as the one used in the first questionnaire administered to the port users. Similarly, sufficient spaces were provided for respondents to state other PSCD threats, their likelihood and consequences. Part B collected the respondents' attitude on mitigating approaches at their ports. There were 45 measurement items which respondents were asked to rate using the 5-point Likert scale, with 1 indicating 'strongly disagree' and 5 as 'strongly agree'. Respondents were also asked to input other relevant and feasible approaches or measures that had not been mentioned in the questionnaire. The 20 items in Part C collected information on port performance, particularly in disruption performance, using the similar 5-point Likert scale. Therefore, Part A sought to gather data for the development of the risk matrix while responses to Parts B and C were analyzed to establish relationships between the management model and disruption performance at the ports. The final part, Part D, asked questions for classification purposes and was similar to Part B in the questionnaire distributed to port users.

Both sets of questionnaires ended with two open-ended questions, one asking for feedback to improve on this research and the other for the contact details of respondents should they wish to receive an executive summary of this research. The last line in the questionnaires then thanked the respondents for their participation.

The samples used for the questionnaire comprised of respondents belonging to organizations from around the globe. However, as the sampling frame of port management was smaller than that of port users, it comprised of more organizations from around the globe and the questionnaire designed for them was much longer than that for the port users, the questionnaire for the port management were translated into Chinese, Korean and Vietnamese in a bid to increase the participation rate and were distributed to ports in China, South Korea and Vietnam respectively. The remaining ports from all other countries received the questionnaire in English. To reduce inaccuracies in translation due to the differences that exist when multiple cultures are involved, back translation is the extra step in designing questionnaires to respondents from those three countries (Zikmund, 2007). The translation process is displayed in Figure 4.7.

At the first stage, the English version of the questionnaire was sent to pre-test respondents through email to seek their comments on the overall structure, wording and phrasing. The results of pre-test are discussed in the following section. The feedback collected from the pre-test stage was considered in the decision of modifying the questionnaire. Modified questionnaires were then sent back to the participants of the pre-test group for further comments and the final versions of questionnaires were then developed when all participants agreed on the changes. Then, the modified questionnaire was translated into Chinese by the author. The Korean version was provided by a professional translation service provider based in Korea and the Vietnamese version was provided by a Vietnamese native who is a professional in the maritime research industry working in Singapore. The layout of the questionnaire was

kept the same in translation to facilitate data coding and entering as the author was not familiar with Korean and Vietnamese languages. After which, a backward translation from Chinese, Korean and Vietnamese to English was performed to ensure that inconsistencies and errors in the translation process can be identified. The back translation for each language was done by the author's colleagues. They were selected as those languages are their native language and they are researchers in the maritime industry so they can ensure that there is consistency in the technical and conceptual terms. The last step was the finalization of the translated versions which were then developed and distributed.

Figure 4.7: The Translation Process

Source: Author, adapted from Thai (2006)

4.7.4. Pre-testing of Questionnaire

As mentioned in the previous section, the questionnaires were sent to participants for pre-testing. 17 participants were selected for the pre-test and they included professionals from the maritime industry who are port managers, researchers, lecturers, professionals in supply chain entities as well as professionals from industries that are not related to maritime. These participants were asked to review the cover letters and questionnaires to identify areas for improvement. Approaching participants who were not part of sampling frames in the pre-test would help provide opinion from a broader perspective which was necessary especially for research that involves respondents from all over the world. The participants involved in the pre-test stage were asked to rate the questionnaires in terms of its length, how well they understood the objectives of each part of the questionnaire, layout, length of time they took to complete, instructions, how concise the wordings were and if there were any leading and double-barreled questions. See Appendix G for the feedback form used in pre-testing. Based on all the feedback and comments collected, the following modifications were made:

- After the pre-test, the instructions in the questionnaires were given in bullet points instead of paragraphs to facilitate reading.
- The tables that were initially used to define the scale used for indicating likelihood of occurrences and consequences of the PSCD threats were removed and the definitions were refined and listed in a bulleted format.
- In Part A, some descriptions of PSCD threats were refined to be more concise and easier to understand. For instance, ‘Vessel Traffic Service Breakdown’ (A5) was renamed as ‘Breakdown of Vessel Traffic Management System’ (A5); ‘Port Community System/Network System Shutdown’ (A6) was renamed as ‘Breakdown of Port Information System’ (A6) and ‘Labor Strikes’ (A12) became ‘Port Labor Strikes’ (A12). In particular, ‘Shortage of Resources’ (A11) which was previously categorized as ‘Planning Threats’ was renamed ‘Shortage of Facilities or Equipment’ (A11) classified under ‘Planning Threats’ and ‘Shortage of Manpower (not due to labor strikes)’ (A13) classified under

‘Manpower Threats’. This is to reflect the fact that resources refer to both equipment and manpower.

- In the questionnaire to port management, the codes assigned to each item were changed to facilitate data recording at a later stage and the measurement items in Part B were shortened as comments that they were too lengthy were received. The number of items measuring per factor was reduced wherever possible by combining items measuring the same concept or moving the items to another more relevant factor. For instance, B6.1 (originally B25) was moved to the factor named ‘Employment Involvement and Empowerment’ as it is related to motivating employees to be involved in process improvement. B2.7 is an additional item. It was added to acknowledge the importance of adhering to security initiatives such as the International Ship and Port Facility Security code (ISPS code), the Container Security Initiative (CSI), the 24-Hour Advance Manifest Rule, Customer-Trade Partnership Against Terrorism (C-TPAT), and the Authorized Economic Operator (AEO) of the World Customs Organization, which can contribute to mitigating risks in seaports when effectively implemented. B8.4 was also added to reflect the importance of continuous improvement through research and development.
- For the questionnaire designed for port management, the phrasing of the items was revised so that it is more specific and makes measurement more precise. For instance, C11 and C12 originally contained the phrase ‘very quickly’ and C20 had the words ‘very low’, but they did not specify how quickly or how low. As different respondents may have different interpretation of the phrases, the revised questionnaire avoided using vague representation of measurement. In the revised questionnaire, the phrase ‘such that effects of disruptions are minimized’ was added to C11 and C12 so that respondents have a standardized sense of quickly, while ‘very low’ was removed from C20.

In addition to the above changes, for both sets of questionnaires, grammatical errors were corrected and there were also changes made to the layout of the tables used in both questionnaires to make the questionnaire neater and less cluttered. Overall, there were no major changes to any part of the questionnaires and the feedback on the items offered a good foundation for the revision of questionnaire. After which, pilot testing on the questionnaire for port users was conducted with five respondents from the port users' sampling frame and the questionnaire for port management was pilot tested with nine respondents from the port management's sampling frame. The purpose of pilot testing was to identify any potential problems if the questionnaires were to be mass distributed and to ensure that the objectives of the research can be met. Results from the pilot testing revealed that there were no issues or problems with the survey and hence the revised questionnaires were translated and then distributed.

4.7.5. Administration of Questionnaire Distribution

The revised questionnaires were distributed electronically to all port users and port management in the sampling frame. The cover letters which included a brief introduction of the author and research made up the body of the emails. The questionnaires were sent as attachments in the emails and the respondents were required to send the completed questionnaires back to the author through email or fax. Also in the body of the email was an alternative way to answer the questionnaire, which was through an online survey software called Qualtrics. The web address of the online questionnaire was provided in the email body. Several measures were deployed to increase the participation rates of the two questionnaires.

Firstly, the cover letters stated clearly the objectives of the study. As the recipients were from the port industry or were involved in or oversee the port supply chains to some extent, knowing that the research purpose revolved around what they knew made the study relevant and attractive to them. This would keep them interested in reading further.

Secondly, bearing in mind that it is usually the management who tend to be more interested in participating, wherever information was available, the contact of managers of the port user entities and port management were recorded in the mailing list. Sending the questionnaires directly to their individual email accounts instead of the organization's general contact offered personalization and ensured a higher opportunity that the questionnaires reached the inboxes of the intended recipients.

Thirdly, the respondents' time is valuable and the lengths of the questionnaires were kept as short as possible. As mentioned, the length of the questionnaire for port users was two pages long and that for port management was five pages. These were considered acceptable by the participants in the pre-test stage. A short questionnaire is an important measure as it encourages the respondents to start and complete the questionnaires.

Fourthly, the cover letters appealed for their help and support and explained that they would also get to benefit from well-functioning port-related supply chains which is the main outcome that this study hopes to achieve. Moreover, the findings of this research was offered to the respondents. These provided inducement and incentives for their participation.

Next, the format of the questionnaires was one of the measures as well. The questionnaires were created as a form which the respondents can simply click to check their selections and click on boxes to type in their responses for open-ended questions. This made the questionnaires simple and user-friendly. The questionnaires were created in Microsoft Word which is a widely used application, and thus provides familiarity in the answering process. The online survey software saves the responses and enables respondents to continue from where they had stopped previously; the respondents can

also work on the questionnaires on their mobile phones while on the go. This online platform hence provides convenience and encourages participation from respondents who are technologically savvy or less desk-bound.

In addition, the cover letters let the recipients know that only summarized results of the survey would be reported and the results would not be linked to any individual or specific organization. Hence, no sensitive information such as name, age or name of organization was asked in the questionnaires. This assured them of their anonymity and confidentiality.

Finally, deadlines were stated clearly in the cover letter to speed up the respondents' participation. Reminders were sent to respondents who missed the due dates and a repeated appeal for their participation was made along with the reminders. See Appendices H and I for samples of reminder letter sent to port users and port operators. Such follow-ups were useful as respondents were very busy and tended to attend to urgent matters at work first. After which, they failed to remember about the questionnaires. The reminders helped to bring in many more responses and also demonstrated to them that the author is serious and sincere in asking for their help.

The above tactics were useful as 104 questionnaires were returned from port management and 123 were collected from port users. The response rate was 12.31% for port management and 8.1% for port users. A higher response rate is expected if the author was able to personally call or visit the organizations. However, as this survey involved a large number of overseas organizations, time and costs were the limitations. There also existed a reluctance to participate as English is not predominantly used in many countries.

4.7.6. Data Preparation

In data preparation process, the raw data were edited, coded and entered for analysis (Cooper and Schindler, 2013). The purpose of editing the data was to ensure that the data is accurate, consistent and uniformly entered. Therefore, the collected data were scanned for errors and omissions before the data was recorded. For instance, there were a few respondents from both port users and port management who misunderstood the instructions for Part A. The author then contacted the respondents again to explain about the right way of answering before full data could be collected. Several respondents also indicated revenue in different currencies and thus these data was reconstructed to achieve standardization. The responses entered in demographics were scanned thoroughly to ensure that the respondents fulfilled the characteristics of the sampling frame. For example, out of the 104 responses collected from port management, one returned questionnaire was excluded in the analysis due to the fact that it only handles passengers. Hence, the participant was disqualified.

The responses were also checked for item non-response (Lussier, 2011). In the case where many respondents omitted the same question, that question should be considered to be dropped to ensure that there is no bias. However, for both sets of questionnaires, this was not an issue, though there were very few respondents who omitted one or two questions. For these respondents, the measurement level used for those omitted questions allowed an average value to be plugged in and hence this method was used to deal with item non-response. However, a second questionnaire received from the port management sampling frame was excluded in the analysis as the part on risk matrix was not completed. As the respondent had left several questions in Part A unanswered, an average value was not used to replace the blanks to avoid introducing bias. Responses from two other respondents, also from the port management sampling frame, were discarded as they left at least one section of Part B (mitigating approach) or Part C (port performance) of the questionnaire unanswered. In total, all returned questionnaires collected from the port users were complete and could be used, while three returned questionnaires from the port management were excluded from analysis as they had

omitted a significant number of questions unanswered and another one from the port management group did not meet the criteria of a cargo-handling port and hence was also excluded from analysis.

The coding process assigns numbers or symbols to the responses in order to allow the answers to be grouped into categories (Lussier, 2011, Cooper and Schindler, 2013). The fixed-alternative questions were pre-coded and responses were recorded according to the numbers already assigned to the available choices. Questions which were open-ended were coded according to guidelines proposed by Cooper and Schindler (Cooper and Schindler, 2013). They suggested that categorizing of open-ended data set should be appropriate to research questions, exhaustive, mutually exclusive and derived from a single dimension. Hence, the open-ended responses collected were coded in a manner that reflects the guidelines, so that it facilitated analysis of results of the different response categories in Chapters 5 and 6. For questions related to demographics of the respondents, the choices were coded after the responses were collected, for example, a question with choices 'Yes' and 'No' would be assigned values '1' and '2' respectively.

The entering of data was done as soon as a returned questionnaire was edited and coded. This is so that follow up can be done with the respondents should there be any misinterpretation of the instructions. The data were first entered into an Excel spreadsheet. Each respondent was given a unique ID in the first column and their responses were entered in cells in a horizontal manner such that one respondent takes up one row in the spreadsheet. As there were two sets of questionnaires, input from the port management was saved in another sheet, separate from the input from port users to avoid confusion in the data preparation process. However, after all responses were collected, as responses from both port management and port users were required for the development of risk matrix, all responses to Part A were then combined in another sheet. After all responses have been collected, checked, coded and entered into the spreadsheet, the data set was then transferred to SPSS.

4.8. Statistical Analysis

The qualitative data collected from in-depth interviews were manually analyzed and insights have been incorporated into the design of the questionnaires. The data collected from questionnaire responses were analyzed using Excel, SPSS version 21.0 and AMOS version 22.0, which were both the latest versions as of 2013. Excel was used to draw the risk matrices, SPSS was used to analyze descriptive statistics and AMOS was used to provide inferential analysis. SPSS is a software developed for statistical analysis through entering data, performing exploratory data analysis and many useful statistical facilities as compared to Excel. SPSS is adequately competent in handling large data sets. AMOS was used to perform Structural Equation Modeling (SEM) on the primary data. SEM is a statistical technique which has the capabilities to test complex relationships between measured and latent variables as well as the relationships among the latent variables. Hence, SEM is used instead of solely factor analysis or multiple regression. Besides AMOS, there are other similarly proficient software that can be used for the same purposes. LISREL, EQS, Mplus, SAS PROC CALIS are some examples of alternatives, but they are not used in this research as AMOS is relatively user-friendly as it does not require the modeler to have programming knowledge and it has a graphic interface that allows visual representation of variables, which enhances communication of results (Cunningham and Wang, 2005).

4.9. Error Control Measures

According to Thai (2006), many researchers have emphasized the importance of controlling biases which exist in two forms – instrumental biases and response biases. Instrumental biases are related to the design of research instruments, which in this research is the surveys, while response biases are produced by respondents. The questionnaires were worded and phrased carefully in a manner that avoided instrumental biases which are presented in the form of questions that are complex, leading and loaded, ambiguous, double-barreled, sensitive or too personal and questions

that contain built-in assumptions (Zikmund, 2007). According to the results from pre-test, the questionnaires were free from these biases. To prevent inconsistencies, the same measurement units were applied throughout the questionnaires which primarily used a five-point scale with 1 being the lowest value for strongly disagree and 5 as the highest value for strongly agree. Given that the questions were more concise as they were shortened in the revised questionnaires while not compromising on specificity, an outcome agreed by all the participants in pre-test stage, instrumental biases were minimized in this research.

In relation to response biases, several measures were in place to control the biases. Before the interviews, the interviewees were sent, through email, an attachment specifying the introduction of the research, the research objectives and key areas of inquiries so that they could be adequately prepared for the interviews yet they could not prepare answers beforehand. The interviews were conducted at the participants' offices or venues mutually agreed by both the participants and the author. These were some measures to control errors as participants might give unreliable responses if they were distracted, unwell or unprepared (Lussier, 2011). As the interviews were pre-arranged at the interviewees' convenience, they would have time to prepare psychologically for the interviews and they also had the freedom to cancel the appointment should they feel unwell. In addition, the interviewer avoided agreeing or disagreeing with the interviewees' opinions to avoid leading or encouraging them to answer in a certain way. For the questionnaires, the deadlines stipulated for respondents to return their answers were not unreasonable. The respondents were requested to return the completed questionnaires within two weeks from the time the questionnaire was sent for the first time, and the 'earliest convenient time' for subsequent reminders. Both the online questionnaires platform and the attachment could be answered halfway and continued at another time. Hence, the respondents had the flexibility and freedom to work on the questionnaires as and when they are comfortable. The returned questionnaires were checked to see if respondents had given the same answers to sections or a sequence of questions as these responses indicate that the respondents might not have given truthful

or reliable answers. Errors produced by the participants can be controlled using these methods.

4.10. Summary

This chapter has presented an explanation and justification for the research design and methodology. The research objectives were met through a development of risk matrices and validation of a management model built on a triangulated application of the principles of risk management, business continuity management and quality management. The survey methodology was used to collect primary data for this research. The PSCD threats and measurement items used in questionnaires were decided upon from literature review and the results of interviews with industry professionals. The target population for the questionnaires were port management and port users from all over the world and the selection of sampling frames had been discussed. The data collection process involved carefully designing the questionnaires, administering the questionnaires in a way that increased participation rates, meticulous data preparation and a series of measures to control biases. The work done in methodology is the preliminary step leading to the analysis of results.

CHAPTER 5. RESULTS – PERCEPTION OF PSCD THREATS AND CONSEQUENCES

5.1. Demographics of Respondents

This chapter² presents the empirical results of the survey conducted with port operators and port users on the likelihood and consequences of PSCD threats. A total of 2364 questionnaires were distributed to 845 port operators and 1519 port users worldwide. 104 responses were collected from port operators and 123 responses were collected from port users samples. The figures accounted for 12.31% of response rate from port operators and 8.10% from port users. Table 5.1 shows the response rates for both samples.

Table 5.1: Response Rates for Both Samples

	Distributed	Received	
		Number	Response Rate
Sample			
Port Operators	845	104	12.31%
Port Users	1519	123	8.10%
Total	2364	227	9.60%

Source: Author

For sections related to risk matrices, a total of 227 responses had been collected from port management and users. Of the 227 responses, 104 came from port operators and

² The following publication from the author is based on part of this chapter:

LOH, H. S. & THAI, V. V. 2015a. Management of Disruptions by Seaports: Preliminary Findings. Asia Pacific Journal of Marketing and Logistics, 27 (1), 146 - 162.

123 from port users. Responses from two operators were not used as one of them was a passenger port and the other did not complete the section that was meant for risk matrix. All responses from port users were used. Therefore, of the 227 responses collected for risk matrix, 225 of them were used for analysis in this research. A breakdown of proportion of responses from port users and port operators that make up the total number of responses used for risk matrix is shown in Figure 5.1.

Figure 5.1: Proportion of Respondents from Each Sample

Source: Author

Respondents who are port operators handled containers, liquid bulk, dry bulk, vehicles, a combination or all of the above. Figure 5.2 shows the different types of cargo handled by the port managers.

Figure 5.2: Types of Cargo Handled by Respondents who are Port Managers from Port Operators and Port Authorities

Source: Author

Respondents from the port users consist of shipping lines, freight forwarders, NVOCCs, cargo owners, vessel owners, vessel management companies and combinations of the above types. Figure 5.3 shows the breakdown of each type of organization from respondents who are port users. The majority of the port users are headquartered in Asia, followed by Europe and North America. Both African and South American headquarters share the same proportion and the smallest group comes from Oceania. However this imbalance does not result in biasness in the analysis as these companies answered the questionnaire based on the ports used most frequently by them instead of any practice by their organization. Figure 5.4 shows the location of their headquarters.

Figure 5.3: Types of Port Users

Source: Author

Figure 5.4: Locations of Headquarters of Port Users

Source: Author

Almost half of the port users indicated that their organizations do not conduct disruption management or have similar risk-related management. A majority of the port users do not conduct disruption management or similar risk-related management jointly with the ports. Figures 5.5 and 5.6 depict such risk-related practices at their organizations.

Figure 5.5: Proportion of Port Users who Conduct Disruption Management

Source: Author

Figure 5.6: Proportion of Port Users who Conduct Disruption Management Jointly with Ports

Source: Author

More details on the demographics of port operators who responded are provided in Table 5.2 and that of port users are provided in Table 5.3. Table 5.4 shows the demographics of all respondents used in the results of risk matrix, combining port users and port operators.

Table 5.2: Demographics of Port Operators for Risk Matrix

	Number of Valid Respondents	Percent of Respondents
<i>Number of Employees</i>		
Less than 100	22	21.57%
100-499	40	39.22%
500-999	14	13.73%
1,000-4,999	8	7.84%
5,000-9,999	7	6.86%
More than 10,000	7	6.86%
Not Answered	4	3.92%
Total	102	100.00%
<i>Functional Area</i>		
Operations	33	32.35%
Non-Operations	53	51.96%
Both	11	10.78%
Not Answered	5	4.90%
Total	102	100.00%
<i>Designation</i>		
Executive	31	30.39%
Manager	24	23.53%
Senior Management	26	25.49%
Top-level Executive	10	9.80%
Others	7	6.86%
Not Answered	4	3.92%
Total	102	100.00%
<i>Experience</i>		
Less than 1 year	3	2.94%
1 - 5 years	19	18.63%
5+ - 10 years	14	13.73%
10+ - 20 years	30	29.41%
More than 20 years	32	31.37%
Not Answered	4	3.92%
Total	102	100.00%

Source: Author

Table 5.3: Demographics of Port Users for Risk Matrix

	Number of Valid Respondents	Percent of Respondents
<i>Number of Employees</i>		
Less than 100	40	32.52%
100-499	37	30.08%
500-999	10	8.13%
1,000-4,999	9	7.32%
5,000-9,999	3	2.44%
More than 10,000	24	19.51%
Not Answered	0	0.00%
Total	123	100.00%
<i>Functional Area</i>		
Operations	63	51.22%
Non-Operations	42	34.15%
Both	17	13.82%
Not Answered	1	0.81%
Total	123	100.00%
<i>Designation</i>		
Executive	34	27.64%
Manager	44	35.77%
Senior Management	32	26.02%
Top-level Executive	9	7.32%
Others	3	2.44%
Not Answered	1	0.81%
Total	123	100.00%
<i>Experience</i>		
Less than 1 year	7	5.69%
1 - 5 years	17	13.82%
5+ - 10 years	14	11.38%
10+ - 20 years	30	24.39%
More than 20 years	55	44.72%
Not Answered	0	0.00%
Total	123	100.00%

Source: Author

Table 5.4: Demographics of all Respondents for Risk Matrix

	Number of Valid Respondents	Percent of Respondents
<i>Number of Employees</i>		
Less than 100	62	27.56%
100-499	77	34.22%
500-999	24	10.67%
1,000-4,999	17	7.56%
5,000-9,999	10	4.44%
More than 10,000	31	13.78%
Not Answered	4	1.78%
Total	225	100.00%
<i>Functional Area</i>		
Operations	96	42.67%
Non-Operations	95	42.22%
Both	28	12.44%
Not Answered	6	2.67%
Total	225	100.00%
<i>Designation</i>		
Executive	65	28.89%
Manager	68	30.22%
Senior Management	58	25.78%
Top-level Executive	19	8.44%
Others	10	4.44%
Not Answered	5	2.22%
Total	225	100.00%
<i>Experience</i>		
Less than 1 year	10	4.44%
1 - 5 years	36	16.00%
5+ - 10 years	28	12.44%
10+ - 20 years	60	26.67%
More than 20 years	87	38.67%
Not Answered	4	1.78%
Total	225	100.00%

Source: Author

5.2. Results

In this section, descriptive statistics for each group of respondents will be presented followed by their respective risk matrices. The highest and lowest risk scores assigned by different groups will be highlighted and risk matrices will be developed based on the different nature of respondents to assess if there is a difference in their perception towards PSCD threats.

5.2.1. Descriptive Statistics

As there were two groups of respondents who answered the sections on risk matrix, their responses were tabulated separately to assist in the evaluation of their attitudes towards PSCD Threats. The mean scores for likelihood and consequences for each category of PSCD Threats assigned by port operators, port users and both groups combined are shown in Table 5.5. A higher score for likelihood indicates higher possibility of the threat occurring and a higher score for consequences indicates worse impact of the threat. Planning threats (A8-A11) were ranked the highest for likelihood by both port operators and port users. For consequences, planning threats (A8-A11) were ranked highest by port operators while infrastructure threats (A1-A7) were ranked highest by port users. Security threats (A15-A19) were assigned lowest values for likelihood and consequences by both the port operators and port users groups. When their responses were combined, planning threats (A8-A11) were ranked highest for likelihood and consequences scores, while security threats (A15-A19) were lowest.

The port operators group was further divided into three main categories to evaluate possible differences in their responses. Out of the 102 usable responses, two respondents did not indicate the type of cargo handled at their ports, hence they were not included in this part of the analysis. As the types of cargo handled will render different information exchanged, infrastructure and requirements at the ports, variation in responses from different types of ports is expected. Though ports can also be

differentiated with respect to their geographical locations, unless a reasonably high enough number of responses were collected from each region, a comparison made among them would not be very meaningful as in the case of this research. Thus, the three categories of port operators in terms of the types of cargo handled were ports that handle only containers, those with non-containerized cargo and those which handle both containers, bulk and/or vehicles (multi-purpose ports). Table 5.6 shows that container ports ranked planning threats (A8-A11) as the highest for likelihood and consequences. This result is the same for ports that handle non-containerized cargo while multi-purpose ports ranked planning threats (A8-A11) as the highest likelihood and manpower threats (A12-A14) as the worst consequences. Security threats (A15-A19) were ranked lowest for both likelihood and consequences by all three types of ports.

Similarly, the port users group was divided into two main categories – those that own, operate and/or manage vessels and those that do not. Therefore, shipping lines, ship owners and ship management companies made up the first category and the second category comprised mainly of cargo owners and freight forwarders/NVOCCs. These two groups represented differing perspectives – one that is ship-oriented and the other is relatively cargo-oriented. Their responses for each category of PSCD threats are recorded in Table 5.7. The figures in the table show that port users who were involved in owning, operating or managing vessels ranked planning threats (A8-A11) as the highest for likelihood and infrastructure threats (A1-A7) as the lowest for consequences. Non-vessel-related port users ranked planning threats (A8-A11) as the highest for both likelihood and consequences. Security threats (A15-A19) received the lowest values for both likelihood and consequences scores by port users regardless of the group they belonged to.

Table 5.5: Scores Assigned to PSCD Threats Categories

	N	Mean	Std. Deviation
<u>Port Management</u>			
<i>Likelihood</i>			
Planning Threats	102	2.34	1.01
Manpower Threats	102	1.91	0.76
Infrastructure Threats	102	1.89	0.67
Security Threats	102	1.48	0.57
<i>Consequences</i>			
Planning Threats	102	2.52	0.96
Manpower Threats	101	2.14	0.82
Infrastructure Threats	102	2.07	0.78
Security Threats	102	1.68	0.84
<u>Port Users</u>			
<i>Likelihood</i>			
Planning Threats	123	2.33	0.77
Manpower Threats	123	1.75	0.64
Infrastructure Threats	123	1.63	0.55
Security Threats	123	1.39	0.61
<i>Consequences</i>			
Infrastructure Threats	123	2.14	0.84
Manpower Threats	122	2.14	0.95
Planning Threats	123	2.12	0.71
Security Threats	123	1.75	0.91
<u>Port Management and Users</u>			
<i>Likelihood</i>			
Planning Threats	225	2.33	0.89
Manpower Threats	225	1.82	0.70
Infrastructure Threats	225	1.75	0.62
Security Threats	225	1.43	0.59
<i>Consequences</i>			
Planning Threats	224	2.30	0.85
Manpower Threats	224	2.14	0.89
Infrastructure Threats	225	2.11	0.81
Security Threats	225	1.72	0.87

Source: Author

Table 5.6: Scores Assigned to PSCD Categories by Different Types of Ports

	N	Mean	Std. Deviation
<u>Container Ports</u>			
<i>Likelihood</i>			
Planning Threats	33	2.73	0.98
Infrastructure Threats	33	2.18	0.69
Manpower Threats	33	2.11	0.76
Security Threats	33	1.60	0.62
<i>Consequences</i>			
Planning Threats	33	2.44	0.92
Manpower Threats	33	1.97	0.75
Infrastructure Threats	33	1.97	0.84
Security Threats	33	1.47	0.66
<u>Non Container Ports</u>			
<i>Likelihood</i>			
Planning Threats	30	2.62	1.12
Manpower Threats	30	2.17	0.83
Infrastructure Threats	30	2.04	0.73
Security Threats	30	1.51	0.53
<i>Consequences</i>			
Planning Threats	30	3.07	1.02
Manpower Threats	29	2.28	0.85
Infrastructure Threats	30	2.14	0.78
Security Threats	30	1.68	0.91
<u>Multi-purpose Ports</u>			
<i>Likelihood</i>			
Planning Threats	37	1.79	0.67
Infrastructure Threats	37	1.57	0.40
Manpower Threats	37	1.57	0.55
Security Threats	37	1.37	0.55
<i>Consequences</i>			
Manpower Threats	37	2.22	0.86
Planning Threats	37	2.13	0.72
Infrastructure Threats	37	2.11	0.75
Security Threats	37	1.88	0.91

Source: Author

Table 5.7: Scores Assigned to PSCD Categories by Different Types of Ports Users

	N	Mean	Std. Deviation
<u>Liners/Ship owners/Ship Management</u>			
<i>Likelihood</i>			
Planning Threats	74	2.17	0.60
Manpower Threats	74	1.64	0.59
Infrastructure Threats	74	1.55	0.51
Security Threats	74	1.26	0.49
<i>Consequences</i>			
Infrastructure Threats	74	2.17	0.77
Manpower Threats	74	2.16	0.92
Planning Threats	73	2.07	0.57
Security Threats	74	1.79	0.98
<u>Non-vessel-related Organization</u>			
<i>Likelihood</i>			
Planning Threats	49	2.56	0.93
Manpower Threats	49	1.92	0.69
Infrastructure Threats	49	1.75	0.60
Security Threats	49	1.59	0.72
<i>Consequences</i>			
Planning Threats	49	2.18	0.88
Infrastructure Threats	49	2.10	0.94
Manpower Threats	49	2.10	1.01
Security Threats	49	1.69	0.78

Source: Author

5.2.2. Risk Scores

The scores for each PSCD Threat by all different groups of respondents are provided in Tables 5.8, 5.9 and 5.10. Risk scores are calculated by multiplying likelihood scores with consequences scores (Waters, 2007). First, risk scores for each type of risks were calculated using this method for each response. Then, the risk scores were averaged and reported in Tables 5.8, 5.9 and 5.10. The highest risk scores for each column are in bold while the lowest are underlined.

From the perspective of port operators, the highest risk score of 7.51 was assigned to Congestion within Terminals (A9). This PSCD threat also received the highest risk score of 6.02 from port users and 6.70 when both the responses from port operators and users were combined. The lowest risk score assigned by port operators was 1.99 for Stowaway (A17), while that assigned by port users was 2.16 for Trafficking (A15), with Stowaway (A17) coming close as second lowest with a risk score of 2.24. When the responses of port operators and port users were combined, Trafficking (A15) received the lowest score of 2.10 and Stowaway (A17) was the second lowest with a risk score of 2.12.

Both containers and multi-purpose ports gave highest risk scores of 9.09 and 4.89 respectively to Congestion within Terminals (A9). Ports that do not handle containers witnessed the highest risk score of 9.93 to Shortage of facilities or equipment (A11) and the lowest score of 1.87 to Trafficking (A15), and this PSCD threat also received the lowest risk score of 2.06 from ports handling only containerized cargo. On the other hand, the lowest risk score of 1.84 was assigned by multi-purpose ports to Stowaway (A17).

Both categories of port users assigned the highest risk scores of 5.51 and 6.80 to Congestion within Terminals (A9). This result was in line with that of container and multi-purpose ports. Shipping lines, ship owners and ship management companies gave the lowest risk score of 2.06 to Breaking in/Theft (A18), while the other category of port users gave the lowest risk score of 1.88 to Stowaway (A17).

Table 5.8: Scores Assigned to Each PSCD Threats by the Different Groups of Respondents

	Label on Graph	PSCD Threats	Port Operators			Port Users			Port Operators and Users		
			L	C	Risk	L	C	Risk	L	C	Risk
Infrastructure Threats	A1	Port Equipment Breakdown	2.45	2.17	5.53	2.09	2.07	4.57	2.25	2.12	5.01
	A2	Inadequate Port Cargo-Handling Equipment	2.12	2.20	5.16	1.60	2.04	3.63	1.84	2.11	4.33
	A3	Occupational Accidents	2.08	1.78	3.92	1.72	2.13	3.91	1.88	1.98	3.92
	A4	Power Outage	1.62	2.05	3.47	1.37	2.04	3.01	1.48	2.04	3.22
	A5	Breakdown of Vessel Traffic Management System	1.65	2.03	3.43	1.48	2.31	3.40	1.56	2.18	3.42
	A6	Breakdown of Port Information System	1.84	2.03	4.01	1.49	1.76	2.97	1.65	1.88	3.44
	A7	Collisions in Waterway	1.51	2.26	3.52	1.65	2.64	4.30	1.59	2.47	3.95
Planning Threats	A8	Congestion in Waterway	2.01	2.25	4.83	2.42	2.06	5.20	2.24	2.15	5.03
	A9	Congestion within Terminals	2.61	2.61	7.51	2.60	2.16	6.02	2.61	2.37	6.70
	A10	Congestion at Hinterland Transfer	2.49	2.60	7.39	2.27	2.08	5.10	2.37	2.32	6.14
	A11	Shortage of Facilities or Equipment	2.26	2.60	6.74	2.02	2.17	4.83	2.13	2.36	5.69
Man-power Threats	A12	Port Labor Strikes	1.75	2.45	4.37	1.69	2.63	4.61	1.72	2.55	4.50
	A13	Shortage of Manpower	2.01	2.09	4.37	1.78	2.11	3.99	1.88	2.10	4.16
	A14	Misinterpretation of Instructions at Workplace	2.00	1.93	4.10	1.78	1.67	3.29	1.88	1.79	3.66
Security Threats	A15	Trafficking	1.41	1.44	2.03	1.41	<u>1.54</u>	<u>2.16</u>	1.41	<u>1.50</u>	<u>2.10</u>
	A16	Smuggling/Contraband	1.59	1.57	2.52	1.48	1.64	2.60	1.53	1.61	2.56
	A17	Stowaway	1.39	<u>1.41</u>	<u>1.99</u>	1.32	1.66	2.24	1.35	1.55	2.12
	A18	Breaking in/Theft	1.74	1.56	2.87	1.48	1.55	2.40	1.60	1.55	2.61
	A19	Terrorist Attacks	<u>1.25</u>	2.42	3.02	<u>1.28</u>	2.37	3.34	<u>1.27</u>	2.39	3.20

L=Likelihood, C=Consequences

Source: Author

Table 5.9: Scores Assigned to Each PSCD Threats by the Different Types of Port Operators

	Label on Graph	PSCD Threats	Purely Containers			Non-containers			Multi-purpose		
			L	C	Risk	L	C	Risk	L	C	Risk
Infrastructure Threats	A1	Port Equipment Breakdown	2.76	2.17	6.48	2.63	2.32	6.15	2.11	2.05	4.38
	A2	Inadequate Port Cargo-Handling Equipment	2.36	2.09	5.55	2.43	2.43	6.47	1.72	2.14	3.96
	A3	Occupational Accidents	2.52	1.85	5.03	2.13	1.90	4.40	1.69	1.67	2.70
	A4	Power Outage	1.79	1.82	3.82	1.70	2.03	3.43	1.43	2.27	3.27
	A5	Breakdown of Vessel Traffic Management System	1.91	2.00	4.15	1.87	2.13	3.90	1.27	1.95	2.46
	A6	Breakdown of Port Information System	2.15	2.06	4.91	1.87	1.90	3.80	1.57	2.11	3.41
	A7	Collisions in Waterway	1.78	1.81	3.76	1.63	2.23	3.57	1.22	2.59	3.27
Planning Threats	A8	Congestion in Waterway	2.33	1.94	5.15	2.23	2.72	6.42	1.57	2.14	3.30
	A9	Congestion within Terminals	3.09	2.64	9.09	2.77	3.03	8.90	2.06	2.24	4.89
	A10	Congestion at Hinterland Transfer	2.94	2.61	8.76	2.77	3.18	9.80	1.86	2.11	4.14
	A11	Shortage of Facilities or Equipment	2.58	2.58	7.61	2.70	3.33	9.93	1.70	2.03	3.59
Man-power Threats	A12	Port Labor Strikes	2.00	2.06	4.67	1.87	2.33	4.20	1.46	2.95	4.41
	A13	Shortage of Manpower	2.03	2.06	4.67	2.47	2.22	5.42	1.65	2.00	3.32
	A14	Misinterpretation of Instructions at Workplace	2.31	1.81	4.52	2.21	2.32	5.20	1.61	1.74	2.97
Security Threats	A15	Trafficking	1.55	<u>1.30</u>	<u>2.06</u>	1.33	<u>1.43</u>	<u>1.87</u>	1.38	1.57	2.16
	A16	Smuggling/Contraband	1.70	1.39	2.45	1.60	1.63	2.77	1.51	1.68	2.43
	A17	Stowaway	1.48	<u>1.30</u>	2.09	1.53	1.47	2.13	<u>1.22</u>	<u>1.49</u>	<u>1.84</u>
	A18	Breaking in/Theft	2.00	1.48	3.21	1.87	1.70	3.43	1.43	1.54	2.22
	A19	Terrorist Attacks	<u>1.27</u>	1.88	2.55	<u>1.20</u>	2.19	2.52	1.30	3.11	3.92

L=Likelihood, C=Consequences

Source: Author

Table 5.10: Scores Assigned to Each PSCD Threats by the Different Types of Port Users

	Label on Graph	PSCD Threats	Liners/Ship owners/ship management			Non-vessels-related Organizations		
			L	C	Risk	L	C	Risk
Infrastructure Threats	A1	Port Equipment Breakdown	2.07	2.01	4.35	2.12	2.16	4.90
	A2	Inadequate Port Cargo-Handling Equipment	1.45	1.91	2.92	1.84	2.24	4.71
	A3	Occupational Accidents	1.62	2.01	3.41	1.88	2.33	4.67
	A4	Power Outage	1.30	2.05	2.82	1.47	2.02	3.31
	A5	Breakdown of Vessel Traffic Management System	1.42	2.59	3.52	1.57	1.90	3.22
	A6	Breakdown of Port Information System	1.43	1.69	2.78	1.57	1.88	3.24
	A7	Collisions in Waterway	1.53	2.95	4.37	1.82	2.18	4.20
Planning Threats	A8	Congestion in Waterway	2.20	2.04	4.74	2.76	2.08	5.88
	A9	Congestion within Terminals	2.53	2.10	5.51	2.71	2.24	6.80
	A10	Congestion at Hinterland Transfer	2.23	1.99	4.67	2.33	2.20	5.76
	A11	Shortage of Facilities or Equipment	1.73	2.14	4.05	2.45	2.20	6.00
Man-power Threats	A12	Port Labor Strikes	1.74	2.73	5.00	1.61	2.47	4.02
	A13	Shortage of Manpower	1.58	2.14	3.50	2.08	2.06	4.73
	A14	Misinterpretation of Instructions at Workplace	1.59	1.61	2.85	2.06	1.78	3.96
Security Threats	A15	Trafficking	1.31	1.58	2.08	1.56	1.48	2.29
	A16	Smuggling/Contraband	1.32	1.65	2.26	1.71	1.63	3.10
	A17	Stowaway	1.28	1.88	2.47	<u>1.37</u>	<u>1.33</u>	<u>1.88</u>
	A18	Breaking in/Theft	1.27	<u>1.52</u>	<u>2.06</u>	1.80	1.59	2.92
	A19	Terrorist Attacks	<u>1.14</u>	2.32	2.74	1.51	2.43	4.24

L=Likelihood, C=Consequences

Source: Author

As there were two main groups of respondents for risk matrix, a test of difference at 95% was carried out to assess if there is a statistically significant difference in the scores assigned to the likelihood and consequences of PSCD Threats when answering the questionnaires. Table 5.11 shows that there was a slight difference in mean and standard deviation between the two groups of respondents. Table 5.12 shows that the significance value was 0.07, which means that the null hypothesis is accepted and there is no significant difference between the port operators and port users in assigning likelihood scores at significance level of 0.05.

Table 5.11: Descriptive Statistics for Both Groups for Likelihood Scores

Respondents	N	Mean	Std. Deviation	Std. Error Mean
Port Operators	102	1.88	0.64	0.06
Port Users	123	1.73	0.54	0.05

Source: Author

Table 5.12: T-test for Equality of Means for Likelihood Scores

	t	df	Sig. (2- tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
						Lower	Upper
Equal variances assumed	1.87	223	0.06	0.15	0.08	-0.01	0.30
Equal variances not assumed	1.84	197.01	0.07	0.15	0.08	-0.01	0.31

Source: Author

Similarly, a test of difference was also carried out for scores assigned to consequences of PSCD Threats. Table 5.13 shows that there was smaller differences in mean and standard deviation of scores assigned to consequences as compared to scores assigned to

likelihood. Table 5.14 shows that the significance value was 0.7, which means that the null hypothesis is accepted and there is no significant difference between the port operators and port users in assigning consequence scores at significance level of 0.05.

Table 5.13: Descriptive Statistics of Both Groups for Consequence Scores

Respondents	N	Mean	Std. Deviation	Std. Error Mean
Port Operators	102	2.07	0.64	0.06
Port Users	123	2.03	0.74	0.07

Source: Author

Table 5.14: T-test for Equality of Means for Consequence Scores

	t	df	Sig. (2- tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
						Lower	Upper
Equal variances assumed	0.38	223	0.71	0.04	0.09	-0.15	0.22
Equal variances not assumed	0.38	222.62	0.70	0.04	0.09	-0.15	0.22

Source: Author

5.2.3. Risk Matrices

Risk Matrices were then developed based on the scores in Tables 5.8, 5.9 and 5.10. Risk matrices based on data collected from port operators, port users and port operators and users combined are depicted in Figures 5.7, 5.8 and 5.9 respectively. Each matrix is divided into four quadrants. Region 1 contains PSCD threats with relatively lower likelihood and consequences scores assigned. Region 3 shows PSCD threats with the highest likelihood and consequences scores and hence more attention should be paid to these threats. The remaining PSCD threats fall in Region 2. For both groups of respondents, all planning threats (A8-A11) were in Region 3 and security threats (A15-A19) with the exception of Terrorist Attacks (A19) which fell into Region 1. In comparison to other security threats, Terrorist Attacks (A19) was given higher consequences and lower likelihood scores and, as a result, it fell in Region 2 for both groups.

Figure 5.7: Risk Matrix Based on Responses Collected from Port Operators

Source: Author

Figure 5.8: Risk Matrix Based on Responses Collected from Port Users

Source: Author

Figure 5.9: Risk Matrix Based on Responses Collected from Port Operators and Users

Source: Author

Figures 5.10, 5.11 and 5.12 are matrices for container ports, ports that do not handle containers and ports that handle both containers and other cargo respectively. As can be seen from these risk matrices, in addition to the four quadrants, there was an additional portion, Region 4, where a few PSCD threats can be found. These risks were not necessarily the ones with the highest risk scores. This region was added onto the risk

matrices to depict the differences in perception towards PSCD threats by different types of port operators in comparison to other respondents. PSCD threats that fall in Region 4 are those that receive higher consequences and/or likelihood scores and thus, more focus is recommended for these threats. Specifically, threats that fell in Region 4 were Congestion within Terminals for container ports (A9); Congestion within Terminals (A9), Congestion at Hinterland Transfer (A10) and Shortage of Facilities or Equipment (A11) for ports that do not handle containers; and Terrorist Attacks (A19) for multi-purpose ports. Particularly, the responses from multi-purpose ports differed from those of the other two types of ports. In Figure 5.12, many PSCD threats received relatively lower scores for likelihood. As a result, most of the threats ended up in Regions 1 and 2. On the other hand, the threats were more spread out in risk matrices for container ports and ports that handle non-containerized cargo.

Figure 5.10: Risk Matrix Based on Responses Collected from Ports that Handle Only Containers

Source: Author

Figure 5.11: Risk Matrix Based on Responses Collected from Ports that do not Handle Containers

Source: Author

Figure 5.12: Risk Matrix Based on Responses Collected from Ports that Handle Containers and Other Types of Cargo

Source: Author

The risk matrices based on responses from different types of port users are presented in Figures 5.13 and 5.14. Organizations which are non-vessel related recognized more threats in Region 3 than shipping lines, ship owners and ship management companies. For non-vessel-related organizations, planning threats (A8-A11) received higher scores of likelihood and consequence and thus were mostly found in Region 3. For shipping lines, ship owners and ship management companies, though planning threats (A8-A11) with the exception of Shortage of Facilities or Equipment (A11) were also found Region 3, these threats possessed lower risk scores than those assigned by non-vessel-related organizations. Collisions in Waterway (A7) was ranked the worst in terms of consequences by port users that manage or operate vessels while Port Labor Strikes (A12) had the highest mean score of consequences for those whose organizational functions are non-vessel-related.

Figure 5.13: Risk Matrix Based on Responses Collected from Port Users who are Shipping Lines, Ship Owners or Ship Management Companies

Source: Author

Figure 5.14: Risk Matrix Based on Responses Collected from Port Users who are Non-vessel-related Organizations

Source: Author

In summary, planning threats (A8-A11) generally had higher mean and standard deviation while security threats (A15-A19) had lower mean and standard deviation for likelihood and consequences scores assigned by all respondents in most cases. Congestion within Terminals (A9) received the highest mean score for likelihood and risk score, while the responses from the different groups of respondents were mixed in scores assigned to threats for consequences. Terrorist Attacks (A19) received the lowest mean score for likelihood in most cases. Trafficking (A15) and Stowaway (A17) had the lowest mean score for both consequences and risk scores in most cases. A summary table of results is provided by Table 5.15. The results will be discussed in more details in the following section.

Table 5.15: Summary of Mean and Risk Scores – Individual PSCD Threats

		Port Operators	Port Users	Port Operators and Port Users	Port Operators			Port Users	
					Container	Non-container	Multi-purpose	Liner/Ship Owner/ Ship Management	Non-vessel-related
Highest	Likelihood	Congestion within Terminals	Congestion within Terminals	Congestion within Terminals	Congestion within Terminals	Congestion within Terminals Congestion at Hinterland Transfer	Port Equipment Breakdown	Congestion within Terminals	Congestion in Waterway
	Consequences	Congestion within Terminals	Collisions in Waterway	Port Labor Strikes	Congestion within Terminals	Shortage of Facilities or Equipment	Port Labor Strikes	Collisions in Waterway	Port Labor Strikes
	Risk Score	Congestion within Terminals	Congestion within Terminals	Congestion within Terminals	Congestion within Terminals	Shortage of Facilities or Equipment	Congestion within Terminals	Congestion within Terminals	Congestion within Terminals
Lowest	Likelihood	Terrorist Attacks	Terrorist Attacks	Terrorist Attacks	Terrorist Attacks	Terrorist Attacks	Stowaway	Terrorist Attacks	Stowaway
	Consequences	Stowaway	Trafficking	Trafficking	Trafficking Stowaway	Trafficking	Stowaway	Breaking in/Theft	Stowaway
	Risk Score	Stowaway	Trafficking	Stowaway	Stowaway	Trafficking	Stowaway	Breaking in/Theft	Stowaway

Source: Author

5.3. Discussion of Results

5.3.1. The role of ports in supply chain disruptions

The in-depth interviews conducted with industrial professionals revealed that there was a high level of consensus among port operators and their users that ports play a critical role in supply chains. All of the port operators interviewed felt that their ports are playing an important role in the supply chains of their customers as their ports are “*the interface to meet the demands of the end customers*” as one interviewee had put it. Though this interface has the potential of contributing to supply chain disruptions, it is also capable of mitigating disruptions, for example, the port can play a part in helping shipping lines to “*catch up on the variability in their vessel schedules*”, a usual circumstance of severe weather conditions and seasons. This reiterates a port’s role in supply chain disruption management and that ports are indeed more embedded in supply chains.

According to the interviewees and the results of the survey, not every one of the identified 19 PSCD threats had occurred at their ports and they also felt that different ports face different challenges. The results from Table 5.15 support this viewpoint as the PSCD threat with highest likelihood and worst consequence faced by ports handling different types of cargo are not the same.

Planning threats, particularly congestion within terminals, can be rather common at certain regions, while the same threats are reduced to a minimal level at other ports in a different region. For instance, as an interviewee pointed out, “*congestions at the port have become a norm in some regions... that the downstream entities would already have planned for more margins*”. However, there were certain ports where disruptions due to congestions were reduced to a minimal. Infrastructure (A1-A7) and manpower (A12-A14) threats were mainly clustered in Region 2 of risk matrices for multi-purpose ports. Ports that handle non-containerized cargo had assigned higher scores for

manpower threats (A12-A14) than other ports. On the other hand, trafficking (A15), smuggling (A16), stowaway (A17), theft (A18) and terrorism (A19) were less frequently found at these ports and all security threats (A15-19), except terrorist attacks (A19), were generally thought to be having a minimal effect on supply chains when they occurred. This view was shared by both the port operators and port users.

While the risk matrix in Figure 5.9 shows that port operators and port users generally felt that planning threats (A8-A11), especially congestion within terminals (A9), occur most frequently, Figures 5.7 and 5.8 show that they had differing views on the damage propagated by the threats. In particular, respondents from ports handling containerized and non-containerized cargo perceived that planning threats (A8-A11) pose higher dangers in terms of the consequences they bring, while port users were more concerned with collisions in waterway (A7) as their attention tend to be on the direct impact of these threats on their cargo and vessels. Collisions in waterway (A7) naturally result in higher chances of damage and loss to the cargo and vessels as compared to congestion within port terminals. When the responses of port users were separated into vessel and non-vessel related organizations, the difference in perspectives was more evident. Specifically, the vessel-related group perceived that collisions in waterways (A7) would have brought the worst consequences while the non-vessel related group selected strikes to be the threat that would result in the worst consequences. External parties will understandably be more interested in a business relationship with the port management when they are shown how such an approach could benefit them. In port operators' cooperation and collaboration with port users, it is advantageous for both external parties and port operators to understand each other's perspectives as common grounds could then be created for more balanced efforts in the cooperation. Safeguarding the port users' assets – vessels and cargo, would be of paramount importance to them, thus these are point of interests which the port management should consider as well.

Other relevant PSCD threats raised by respondents include wrong positioning of containers, sanctions, lack of manpower at customs, delays in updating export list and vessels' ETA delayed. The occurrences of these threats are expected to be in relation to the effectiveness of information exchange, experience and proficiency of employees in carrying out tasks, and the adequacy of planning of port processes. The findings derived from the 19 identified PSCD threats are expected to enhance these aspects nonetheless. Efforts in managing collaborations and communications with port users have direct effects on information exchange between the port and its users. Additionally, measures that generally reinforce planning capabilities, port infrastructure and professional skills of port employees are relevant in managing these threats.

5.3.2. Factors affecting occurrences of PSCD threats

Types of cargo handled

Different types of cargo handled give rise to different types of risks. Depending on the types of cargo moved, in some cases, ports can be the “*most important part in supply chains*”, as pointed out by an interviewee. Examples of such cases are the bulk cargo, especially when the cargo owners have their facilities at the ports to receive or store the cargo once they are unloaded. In these situations, equipment breakdowns or congestions at the ports will immediately cause a delay or a halt in the supply of the cargo, resulting in fewer opportunities to catch up on the delays as such possibilities could otherwise have arisen during the transportation of cargo from the ports to the cargo owners.

On the other hand, ports handling containerized cargo utilize automated systems to a larger extent in cargo handling processes. This affects the extent of labor-intensiveness and the frequency of communication at the ports, hence, resulting in different occurrences of PSCD threats faced. Labor and communication play important roles in the handling of non-containerized cargo which requires mostly non-automated systems of loading and unloading procedures as compared to the benefits and convenience

brought about by containerization. Thus, when handling this type of cargo, the potential of PSCD threats hinge on the level of labor-intensiveness and communication. The benefits of standardization offered by containerized cargo explains smaller variability in the potential of security threats across all containerized ports due to the presence of security initiatives tailoring to containerized cargo. However, one difficulty with handling containerized cargo is the complexity of cargo arrangement, often resulting in repositioning and restacking of containers, thus exposing the cargo to delays. The level of security threats may be affected by the previous and first port of call as the vessels and cargo are subjected to varying degrees of investigations, depending on the requirements at that port. As such, transshipment ports assume a lesser extent of responsibility on transshipment cargo as compared to import and export ports on import and export cargo.

Market trends

Planning and infrastructure threats are closely related to, as the name suggests, planning ahead. With larger vessels ordered by the shipping lines, the remedies for the PSCD threats unavoidably require capital intensive investments either in the building of infrastructure or the provision and maintenance of the port equipment. This concern has been expressed by a few interviewees belonging to different ports. Sources of capital and revenue can be better established with the intervention of the government. Port's integrative role into supply chains has increased the range and complexities of service provision. The increased integration has altered the demands of port users. Meeting the needs of port users requires capital intensive investments on port infrastructure. The construction and developments of port infrastructure depend on the profiles of port customers. Understanding the profile of their customers helps to understand the needs of the customers so that necessary facilities are constructed to handle their fleets. This will also safeguard the ports against inadequacy and insufficiency in infrastructure and equipment, which may give rise to congestions and resource shortages. Thus, planning together with the government and port users involves planning for sufficiency, adequacy

and contingency as well sustainability. The following quote from an interviewee illustrates this view:

“We ... work together with our customers; to make sure that we are ready when they are ready, as they like to buy bigger ships...We need to know the profile of our customers so that we can ensure that the necessary facilities are there when needed... The facilities must match.”

Business environment

Both the interviewees who were port operators and port users acknowledged the seriousness of congestion and the demand for adequate facilities or infrastructure at the port. Infrastructure threats and planning threats appear to be rampant in developing countries while particularly low in threat levels in areas where there are mentions of very proximate working relationships with its government. Ports belonging to the caliber of the latter group work closely and harmoniously with the government with regards to issues on future capacity expansion to ensure their capability in staying relevant in future market environment with the trends of larger vessels and higher cargo turnover in meeting the future needs of the port customers.

Congestion is often related to the absence of “*suitable and sufficient*” facilities, as described by one of the managers from a port. Developments in infrastructure is costly and might require legislative or regulatory approvals, thus government play an important role in planning to target the PSCD threats related to the hardware at the port. The participation or intervention of government can take the form of modes of investments to fund port development projects which are essentially costly. However, bureaucracy is likely to create inefficiencies. In particular, the role that the local government, regulators and port authority plays in security threats is straightforward since they are directly involved in enforcing security initiatives. However, the level of security threats in a port is also dependent on the previous port of call of the vessels and

the origin of the cargo which might result in the cargo being subjected to investigations, thorough checks, quarantine, and problems at customs clearance as security lapses are detected at a port with stricter requirements. For this reason, it is understandable that the extent of responsibility assumed in managing security and criminal threats differs in a transshipment port and in import and export ports. A closer and effective working relationship with the government is thus recommended in managing security threats, but the challenges in fostering such a connection are largely on the local business culture, political agenda and the influence of the government.

The extent of government intervention and support varies in different regions and depends largely on the government leadership style, which in turn forms part of the local business cultures. Standards are challenges as social and cultural factors determine which practice is acceptable. An interviewee at a port pointed out that the impact posed by the PSCD threats might have been assumed in planning stages at supply chain entities such that the effects or consequences of the threats are reduced. In such cases, certain risks might be acknowledged as norms in business operations. In regions where regulatory ambiguity exists, there are higher chances of a misalignment of expectations. Similarly, corrupt practices result in detrimental effects on the port's business management due to the competitive disadvantages that come along with corruption. Figure 5.15 shows three factors that highlight the dynamics of the PSCD threats and their respective impacts.

Figure 5.15: Factors affecting occurrences of PSCD Threats

Source: Author

Generally, threats that require a higher level of attention are Terrorist Attacks and all planning threats, namely Congestion in Waterway, Congestion within Terminals, Congestion at Hinterland Transfer and Shortage of Facilities or Equipment. Infrastructure and manpower threats tend to possess relatively lower frequencies and less severe impacts while security threats are mostly found to be associated with the lowest frequencies and minor impacts. However, of the manpower threats, port labor strikes should be given higher level of attention as the risk matrices show that it does have a higher degree of impact on supply chains. The factors that affect the potential of PSCD threats in supply chain disruptions can be attributed to the working relationship with the government and port users, regulated safety and security levels, externalities from the market environment, level of preparedness and types of cargo handled at the port. Specific recommendations for different threats and ports vary, but the general essence of managing these threats is to consider the abovementioned factors in devising strategies to reduce disruptions.

CHAPTER 6. RESULTS – MANAGEMENT MODEL

6.1. Demographics of Respondents

This chapter³ discusses the results and findings of the PDM. For sections on the management model, the survey was conducted with only port operators and port authorities. A total of 845 questionnaires were distributed and 104 responses were received. The response rate was 12.31%. Out of the 104 responses, 100 were deemed useful for analysis. Four responses were unable to be used as one of them was a passenger port and the remaining three had at least one section left empty. Table 6.1 gives the breakdown of the number of completed questionnaires received and used in this study from both samples.

Table 6.1: Number of Completed Questionnaires Received and Used

Sample	Distributed	Received	
		Total	Used
Port Operators and authorities	845	104	100
Total	845	104	100

Source: Author

³ The following publications from the author is based on part of this chapter:

LOH, H. S. & THAI, V. V. 2015a. Management of Disruptions by Seaports: Preliminary Findings. Asia Pacific Journal of Marketing and Logistics, 27 (1), 146 - 162.

LOH, H. S. & THAI, V. V. 2015b. Managing Port-related Supply Chain Disruptions (PSCD): A Management Model and Empirical Evidence. Maritime Policy & Management, In press.

The majority of the respondents are involved in their port's disruption management as shown in Figure 6.1. A further breakdown of the details of the respondents is available in Table 6.2.

Figure 6.1: Respondent's Involvement in Disruption Management at Respective Ports

Source: Author

Then, tests of differences were carried out to assess the effects of respondents' functional area, designation and involvement in disruption management on scores assigned to management model measures as well as port performance. ANOVA tests were carried out on functional area and designation on mitigating measures and performance scores. The results are shown in Tables 6.3 and 6.4 respectively. Independent t-test was carried out on respondent's involvement in disruption management as there were only two groups for this category. The results are shown in Tables 6.5 and 6.6.

Table 6.2: Demographics of Respondents for Management Model

	Number of Respondents	Percentage of Respondents
<i>Types of Cargo Handled</i>		
Containers only	33	33.00%
Bulk only	17	17.00%
Vehicles only	4	4.00%
Combinations	46	46.00%
Not Answered	0	0.00%
Total	100	100.00%
<i>Number of Employees</i>		
Less than 100	22	22.00%
100-499	41	41.00%
500-999	14	14.00%
1,000-4,999	8	8.00%
5,000-9,999	7	7.00%
More than 10,000	7	7.00%
Not Answered	1	1.00%
Total	100	100.00%
<i>Functional Area</i>		
Operations	33	33.00%
Non-Operations	54	54.00%
Both	11	11.00%
Not Answered	2	2.00%
Total	100	100.00%
<i>Designation</i>		
Executive	31	31.00%
Manager	24	24.00%
Senior Management	26	26.00%
Top-level Executive	10	10.00%
Others	7	7.00%
Not Answered	2	2.00%
Total	100	100.00%
<i>Experience</i>		
Less than 1 year	3	3.00%
1 - 5 years	20	20.00%
5+ - 10 years	14	14.00%
10+ - 20 years	30	30.00%
More than 20 years	32	32.00%
Not Answered	1	1.00%
Total	100	100.00%
<i>Location of port</i>		
Africa	2	2.00%
Asia	67	68.00%
Europe	15	15.00%
North America	7	7.00%
South America	1	1.00%
Oceania	4	4.00%
Unknown	3	3.00%
Total	100	100.00%

Source: Author

Table 6.3: Descriptive Statistics of Functional Area and Designation on Scores
Assigned to Management and Port Performance Sections

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Min	Max
					Lower Bound	Upper Bound		
<u>Mitigating Measures</u>								
<i>Functional Area</i>								
Non-Operations	54	3.75	0.43	0.06	3.63	3.87	2.51	4.76
Operations	33	3.83	0.45	0.08	3.67	3.99	2.96	4.82
Both	11	4.05	0.46	0.14	3.74	4.36	3.44	4.91
Total	98	3.81	0.45	0.05	3.72	3.90	2.51	4.91
<i>Designation</i>								
Executive	31	3.86	0.51	0.09	3.67	4.04	2.51	4.96
Managerial	60	3.80	0.45	0.06	3.69	3.92	2.62	4.91
Others	7	3.87	0.41	0.16	3.48	4.25	3.11	4.26
Total	98	3.82	0.46	0.05	3.73	3.92	2.51	4.96
<u>Port Performance Measures</u>								
<i>Functional Area</i>								
Non-Operations	54	3.60	0.44	0.06	3.49	3.72	2.1	4.4
Operations	33	3.63	0.51	0.09	3.45	3.81	2.35	4.6
Both	11	3.89	0.53	0.16	3.53	4.25	3.2	5
Total	98	3.65	0.48	0.05	3.55	3.74	2.1	5
<i>Designation</i>								
Executive	31	3.72	0.38	0.07	3.58	3.86	3.1	4.6
Managerial	60	3.61	0.52	0.07	3.47	3.74	2.1	5
Others	7	3.65	0.53	0.20	3.16	4.14	2.95	4.4
Total	98	3.65	0.48	0.05	3.55	3.74	2.1	5

Source: Author

Table 6.4: ANOVA test on the Functional Area and Designation

	Sum of Squares	df	Mean Square	F	Sig.
<u>Mitigating Measures</u>					
<i>Functional Area (Operations and Non-operations)</i>					
Between Groups	0.83	2	0.41	2.12	0.13
Within Groups	18.56	95	0.20		
Total	19.38	97			
<i>Designation (Executives, Managerial, and others)</i>					
Between Groups	0.07	2	0.03	0.16	0.85
Within Groups	20.54	95	0.22		
Total	20.61	97			
<u>Port Performance Measures</u>					
<i>Functional Area (Operations and Non-operations)</i>					
Between Groups	0.76	2	0.38	1.69	0.19
Within Groups	21.28	95	0.22		
Total	22.04	97			
<i>Designation (Executives, Managerial, and others)</i>					
Between Groups	0.25	2	0.13	0.55	0.58
Within Groups	21.80	95	0.23		
Total	22.05	97			

Source: Author

Table 6.5: Descriptive Statistics for Involvement in Disruption Management Group

	N	Mean	Std. Deviation	Std. Error Mean
<u>Mitigating Measures</u>				
Yes	72	3.85	0.40	0.05
No	24	3.72	0.57	0.12
<u>Port Performance Measures</u>				
Yes	72	3.67	0.45	0.05
No	24	3.57	0.58	0.12

Source: Author

Table 6.6: T-test for Equality of Means for Respondent's Involvement in Disruption Management Group

						95% Confidence Interval of the Difference	
t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper	
<u>Mitigating Measures</u>							
Equal variances assumed	1.23	94	0.22	0.13	0.11	-0.08	0.34
Equal variances not assumed	1.03	30.82	0.31	0.13	0.13	-0.13	0.39
<u>Port Performance Measures</u>							
Equal variances assumed	0.89	94	0.38	0.10	0.11	-0.13	0.33
Equal variances not assumed	0.79	32.98	0.44	0.10	0.13	-0.16	0.36

Source: Author

There were six choices for functional area in the questionnaire. Overall, 65 respondents were involved in operations and 11 of the 65 were also involved in planning and other non-operations functions. ANOVA tests results show that the significance value for functional area on management and port performance measures were 0.13 and 0.19 respectively. Therefore, it is concluded that the null hypothesis is accepted and there is no significant difference between those involved in operations, non-operations or both in scores assigned to management as well as port performance measures at significance levels of 0.05.

For designation, the respondents were either at the executive or managerial level. Respondents who selected the option "others" gave designations which were unclear as to whether they belonged to the managerial level or not. Hence, ANOVA tests were

conducted on the three groups: executive, managerial and others. ANOVA tests results also show that the significance value for designation on management and port performance measures were 0.85 and 0.58 respectively. In other words, the null hypothesis is accepted and there is no significance difference between those who are of executive, managerial levels and those who are not in scores assigned to management as well as port performance measures at significance levels of 0.05.

Independent-samples t-tests results show that the significance value for involvement in disruption management on management and port performance measures were 0.31 and 0.44 respectively. Thus, the null hypothesis is accepted and there is no significance difference (in the responses) between those involved in disruption management at their ports and those who are not in scores assigned to management as well as port performance measures at significance levels of 0.05.

6.2. Results

This section begins with the presentation of descriptive statistics. Then, there are alternative models which are to be tested and compared in addition to the theoretical model presented in Chapter 4. The alternative models will be compared using fit indices. The measurement model fit and validity issues will then be addressed. The most appropriate model will be established and the model validation and explanation will be presented.

6.2.1. Descriptive Statistics

The minimum, maximum, mean and standard deviation scores assigned to management and port performance measures are shown in Table 6.7. For mitigating measures, “Internal Risk Management” received a highest mean of 4.14 and “Collaborative Relationships with Relevant Agencies” received a lowest mean of 3.53 but a highest

standard deviation of 0.80. “Service Objectives Enhancement” had a lowest standard deviation of 0.47. For port performance measures, C10 (see Appendix F) had a highest mean of 4.01, while C15 had the lowest mean of 3.05 but also a highest standard deviation of 1.15. On the other hand, C14 had the lowest standard deviation of 0.57.

Table 6.7: Descriptive Statistics of Scores Assigned to Management and Port Performance Measures

	Min	Max	Mean	Std. Deviation
Internal Risk Management (Items B1.1-B1.4)	1.75	5	4.14	0.60
Mandatory Controls (Items B2.1-B2.7)	2.67	5	3.98	0.49
PSCD Impact Analysis (Items B3.1-B3.3)	2.67	5	4.09	0.57
Disruption Recovery Planning (Items B4.1-B4.3)	2.33	5	4.01	0.63
Service Objectives Enhancement (Items B5.1-B5.6)	2.17	5	3.97	0.47
Employee Involvement and Empowerment (Items B6.1-B6.4)	1.75	5	3.70	0.69
Collaborative Working Relationships with Supply Chain Parties (Items B7.1-B7.7)	2	5	3.61	0.54
Collaborative Relationships with Relevant Agencies (Items B8.1-B8.4)	1.62	5	3.53	0.80
Relevance Evaluation (Items B9.1-B9.3)	1.33	5	3.65	0.77
Recommendation for Improvement (Items B10.1-B10.4)	1.75	5	3.74	0.66
Financial Health (Items C1-C5)	1.80	5	3.52	0.69
Market Reputation (Items C6-C10)	2.20	5	3.62	0.53
Resilience of Internal Operations (Items C11-C15)	1.80	5	3.68	0.55
Internal and External Opportunities (Items C16-C20)	1.80	5	3.79	0.58

Source: Author

6.2.2. Use of Item Parceling

In usual situations, when structural equations modeling (SEM) is used, every individual item will be an indicator of the latent construct it belongs to. An optional premodeling step in SEM is parceling, which is a process that sums or averages items and the parcels are then used as the manifest indicator (Little, 2013). There are many advantages of parceling. When the requirement of multivariate normality is not met in SEM, the parcels formed may approximate a normal distribution (Coffman and MacCallum, 2006). However, simulation has suggested that the effects of modeling nonnormally distributed variables in SEM are that the chi-square values are inflated, which thus increases the chances of rejecting the model when it should not be rejected, though parameters estimates remain rather accurate (Kline, 2010). The use of many individual items in SEM is problematic and causes a poor fit, thus parceling is introduced (Marsh et al., 1998). Another widely-quoted advantage of using parcels is that the proposition of aggregation enables parceling to increase reliability (Little, 2013, Kishton and Widaman, 1994) which results in more true-score variance (Little, 2013). In addition the use of parceling does not result in loss of estimation precision in SEM (Graham and Tatterson, 2000).

In the case of this survey, there was no comparison between samples and the indicators were formed based on well-established concepts and principles from previous studies which means that model misspecification and masked additional latent constructs were not an issue, thus the use of parceling was justified. Parceling was carried out in this research as there was a large number of indicators used and sample size was not large. The use of more indicators results in a better representation of the latent construct (Coffman and MacCallum, 2006). This view is also supported by Rushton, Brainerd and Pressley (1983), who proved that the use of parcels enabled relationships between conceptually similar constructs to be revealed while individual items were not able to demonstrate that. Thus, instead of deleting items to a number that is appropriate and

comfortable for SEM applications to manage, the use of parceling prevents incorrect inferences and avoids the situation of removing essential indicators which have been included in this research based on previous studies.

Parcels can be created using the subset-item-parcel approach or all-item-parcel approach (Matsunaga, 2008). Subset-item-parcel approach involves random or non-random selection of forming subsets of items and each subset constitutes a parcel. All-item parcel is an aggregation of all items and using composite scales as indicators of the constructs. The two methods can be used together. Firstly, PDM was considered as a single construct and the means of indicators were used to form three parcels, P1, P2 and P3, instead of sums as the number of items going into the parcels differ (Little, 2013). Items B1, B3, B7, B8 in the questionnaire were used to form P1, items B4, B2, B10 were used to form P2 and items B5, B6, B9 were used to form P3. Secondly, port performance, including disruption management, has four constructs – RIO, IEO, MR and FH. Items C1-C5 in Part C of the questionnaire were formed for FH, items C6-C10 for MR, items C11-C15 for RIO and items C16-C20 for IEO. Therefore, each of these four constructs had one item and two parcels. In creating these parcels, the highest loadings and the lowest were parcelled together, thus it was not a random selection of items. For example, items C3 and C5 were parcelled to form FH1, C1 and C2 formed FH2, while C4 remained as an item as its loading is the third highest out of the five items. This approach is the domain representative method which Kishton and Widaman (1994) concluded to be the better method. Then, the modification indices were examined for every construct and loadings were checked to ensure homogeneity. Confirmatory factor analysis (CFA) was then run and the fit indices will then be evaluated.

6.2.3. Measurement Model Fit

In SEM, attention will be given to the measurement model and the structural model. These two components decide whether a hypothesis can be accepted or not. In this

research, four alternative models were tested and compared. Firstly, the measurement model is the component that displayed the model's constructs, indicator variables and the connection between them. Figure 6.2 shows the baseline model of this research. The fit indices were examined and the construct validity and reliability were evaluated in the assessment of the measurement model. On the other hand, the structural model is the model that determined the stated or predicted the relationship between specific constructs.

In this section, the measurement and theoretical models were first identified and three alternative models were proposed. Figure 6.3 is the theoretical model hypothesized in Chapter 4 and Figures 6.4, 6.5 and 6.6 show the remaining alternative structural models. Thus, M2, M3, M4 and M5 are nested models and M2 is the theoretical model. Figure 6.4 shows that M3 is a partially mediated model while M4 in Figure 6.5 is a non-mediated model and M5 in Figure 6.6 is a fully mediated model. CFA was performed on M1 and following the modification indices, C6 and RIO2 (C13 and C14) were removed to achieve better fit. The three items asked if the market share of the respondent's port has been increasing, has experienced constant improvement in its operational efficiencies, and if collaborations between the respondent's port and its partners have improved efficiency levels of its internal processes and operations. The removal of these items does not jeopardize the measurement of the objectives. Remaining items related to market reputation as well as disruption management performance in terms of threat levels and effectiveness of collaborations can replace what could have been captured by the removed items.

Figure 6.2: The Measurement Model – M1

Source: Author

Figure 6.3: Theoretical Model of Research – M2

Source: Author

Figure 6.4: Alternative Model – M3

Source: Author

Figure 6.5: Alternative Model – M4

Source: Author

Figure 6.6: Alternative Model – M5

Source: Author

A comparison was made among the alternative models to examine the relationships between constructs. The fit indices of all the models are shown in Table 6.8. There are three main types of fit measures: absolute fit measures, incremental fit measures and parsimony fit measures (Hair et al., 2006). Absolute fit measures how appropriately the theoretically deduced model fits the sample data (Hooper et al., 2008, McDonald and Ho, 2002). The Chi-square test, root mean square residual (RMR) and standardized root mean square residual (SRMR) are popular examples of absolute fit measures. Incremental fit measures how well a priori model fits as compared to a baseline model

(Hair et al., 2006). These indices are relative fit indices (McDonald and Ho, 2002) that compare the chi-square value to a baseline model (Hooper et al., 2008). The Tucker-Lewis Index (TLI), Bollen's Incremental Fit Index (IFI) and Comparative Fit Index (CFI) are common examples used as relative fit indices (Tanaka, 1993, Maruyama, 1997, Hooper et al., 2008). Parsimony fit measures whether the specified model is parsimonious (Hair et al., 2006) using tests such as the root mean square error of approximation (RMSEA) and the Parsimony Normed-Fit Index (PNFI). The indexes stated above are reported in combination in Table 6.8.

Table 6.8: Comparison of Fit Indices

Model	df	χ^2 (p-value)	RMSEA (90% CI)	SRMR	CFI	TLI	IFI	PNFI
M1	55	71.670 (0.065)	0.055 (0.000 ; 0.089)	0.0504	0.975	0.964	0.975	0.636
M2	59	74.891 (0.079)	0.052 (0.000 ; 0.085)	0.0526	0.976	0.968	0.976	0.679
M3	55	71.670 (0.065)	0.055 (0.000 ; 0.089)	0.0504	0.975	0.964	0.975	0.636
M4	59	98.203 (0.001)	0.082 (0.052 ; 0.110)	0.0794	0.940	0.921	0.942	0.655
M5	57	71.678 (0.091)	0.051 (0.000; 0.085)	0.0505	0.978	0.969	0.978	0.659

Source: Author

In the assessment of measurement model validity, there is no one best test that portrays how good the model is (Hair et al., 2006). Researchers have suggested different

statistical tests for this purpose and they should be examined together. A commonly used goodness of fit index is χ^2 or the chi-square test statistic (Brown, 2006). The measurement model which was also named M1 in this research has a chi-square of 71.67 with 55 degrees of freedom and a p-value higher than 0.05. Thus, there was an acceptable model fit and the proposed model was accepted. The chi-square was also non-significant, suggesting that the model was consistent with the observed data. Other evidence of adequate fit between the hypothesized model and sample data includes the examination of relative chi-square which is obtained by dividing the chi-square fit index by degrees of freedom. As such, M1 had a relative chi-square of less than 2 and this ratio lies in the recommended range (Carmines and McIver, 1981).

Next, a badness of fit index and a goodness of fit index should be evaluated and this is satisfied by an examination of RMSEA and CFI (Hair et al., 2006). RMSEA is 0.055 which fulfils the cut-off criteria set by Steiger and Lind (1980). CFI is 0.975 which well exceeds the criteria of 0.95 (Bentler, 1990). Other fit indices presented in Table 6.8 also fulfil the cut-off criterion recommended by several researchers: SRMR < 0.8 (Bentler, 1995), TLI > 0.95 (Tucker and Lewis, 1973) and IFI > 0.95 (Bollen, 1989). There is no standard or a cut-off value widely agreed upon for PNFI, but a typical PNFI value should be approximately 0.5 (Byrne, 1998). Therefore, it can be concluded that acceptable model fit has been established from the examination of multiple indices.

6.2.4. Reliability and Validity of Measurement Model

The construct validity of the model measures how well the measured set of items reflect what they are proposed to measure, that are the theoretical latent constructs (Hair et al., 2006). It was assessed through an investigation of convergent validity, discriminant validity and nomological validity. It has to be noted that face validity had already been established through literature review and the initial phase of data collection that included conducting interviews, pre-testing and pilot testing processes. Convergent validity is a more rigorous approach than face validity and it can be measured by: (1)

factor loadings, (2) average variance extracted (AVE) and (3) reliability. The standardized loadings estimates, average variance extracted and reliability estimates of all latent constructs in the measurement model are reported in Table 6.9.

As can be seen from Table 6.9, all standardized loadings estimated at least 0.5, which satisfies the guidelines by Hair et al (2006). The recommended criterion is that the factor loadings should be at least 0.5 and those above 0.7 exhibit “significant explanatory power for that factor” (Karavdic, 2006). The results from Table 6.9 shows that the lowest loading was 0.583 and there were only two other loadings below 0.7 (C12 and MR1). Therefore, it can be concluded that all factor loadings were significant and adequately met the requirements for convergent validity.

Table 6.9: Standardized Loadings Estimates, Average Variance Extracted and Reliability Estimates of Measurement Model

	PDM	FH	MR	RIO	IEO
P1	0.890				
P2	0.906				
P3	0.894				
FH1		0.795			
FH2		0.712			
C4		0.724			
MR1			0.617		
MR2			0.703		
RIO1				0.717	
C12				0.686	
IEO1					0.841
IEO2					0.741
C17					0.583
Average Variance Extracted	80.41%	55.44%	43.74%	49.23%	53.21%
Construct Reliability	0.92	0.79	0.61	0.66	0.77

Source: Author

The next measure to examine convergent validity was the AVE, which was a more stringent test than the examination of factor loadings. It was not provided by AMOS software and had to be computed manually for all latent constructs by dividing the sum of the squared standardized factor loadings by the number of items or using the formula:

$(\sum_{i=1}^n \lambda_i^2) / n$. All except MR and RIO had AVE estimates above 0.5. Though Hair et al (2006) recommended AVE estimates to be at least 0.5, according to (Liu et al., 2011) the AVE values of MR approximate those recommended by Fornell & Larcker (1981) which are in line with those by Hair et al (2006).

However, an additional measure was performed to further prove that there was convergent validity. This procedure involved, for each construct, dividing the square of the sum of all factor loadings belonging to that construct by the sum of that and the error variance terms for that construct or by using the formula:

$(\sum_{i=1}^n \lambda_i)^2 / [(\sum_{i=1}^n \lambda_i)^2 + (\sum_{i=1}^n \delta_i)]$. This formula calculates the construct reliabilities of each latent construct. This method is a more rigorous test than the commonly reported Cronbach's alpha or coefficient alpha which has several weaknesses (Cronbach and Shavelson, 2004, Garver and Mentzer, 1999, Raykov, 1998, Raykov, 1997). The rule of thumb set by Hair et al (2006) is that the construct reliability estimates that are at least 0.7 suggest good reliability, and those between 0.6 and 0.7 are acceptable. The results from Table 6.9 shows that all construct reliability estimates fulfilled this requirement as the lowest value was 0.61 and the highest was 0.92. Therefore, an evaluation of the construct reliabilities indicated that there is internal consistency as the construct reliabilities of all constructs satisfied the guideline of 0.6, with three of the constructs displaying good reliability and PDM faring exceptionally well, with a value of 0.92.

Another method used by Netemeyer et al (1990) to reinforce convergent validity was to conduct a chi-square test difference between an unconstrained model and a constrained

one for the factors with AVE values below 0.5. Following the same test and since the discriminant validity needs to be assessed as well, the results for the chi-square test differences of all factors are reported in Table 6.10. The cells that read error are AMOS runs where estimates could not be calculated as there was a bad model fit. As compared to the unconstrained model in which χ^2 (55, N=100, $p<0.05$) = 71.67, the chi-square values in Table 6.10 indicate that there was a significant improvement in fit of the unconstrained model. In other words, the differences in chi-square values are significant in all cases and the constrained model is rejected. The results from Table 6.10 show that the constructs were distinct from each other and thus, there was discriminant validity in the measurement model. This test of unidimensional nature to establish discriminant validity between the constructs has been widely accepted by researchers (Deery et al., 1999, Bagozzi et al., 1991, Anderson and Gerbing, 1988).

Table 6.10: Chi-square test difference

Constructs	PDM	FH	MR	RIO	IEO
PDM	-	error	error	error	error
FH	error	-	123.461	104.621	114.123
MR	error	123.461	-	error	error
RIO	error	104.621	error	-	110.949
IEO	error	114.123	error	110.949	-

Source: Author

Lastly, nomological validity was tested. Nomological validity considers if the correlations between constructs are rational. Thus, the constructs correlations were needed in determining nomological validity. From AMOS output, the covariances and correlations tables were inspected. Tables 6.11 and 6.12 show the covariances table and correlations table respectively and they show that all correlations between the constructs were positive and significant at a level of 0.05. Table 6.13 reports the correlation matrix in which the diagonal values show the construct variances, the values below the construct variances are correlation estimates obtained from Table 6.12 and the figures above the construct variances were computed by squaring the correlations. The results

of Table 6.13 are evidence that nomological validity was achieved as the signs and significance of the proposed correlation relationships among the latent constructs in the measurement model were deemed to have positive correlation relationships between them.

Table 6.11: Covariances Table of Measurement Model

		Estimate	S.E.	C.R.	P
PDM	↔ FH	.181	.042	4.342	***
PDM	↔ MR	.113	.032	3.500	***
PDM	↔ RIO	.201	.044	4.565	***
PDM	↔ IEO	.230	.042	5.472	***
FH	↔ MR	.181	.049	3.681	***
FH	↔ RIO	.285	.065	4.406	***
FH	↔ IEO	.241	.055	4.356	***
MR	↔ RIO	.224	.055	4.062	***
MR	↔ IEO	.134	.041	3.245	.001
RIO	↔ IEO	.260	.058	4.492	***

Source: Author

Table 6.12: Correlations Table of Measurement Model

	Estimate
PDM $\leftrightarrow$ FH	.62
PDM $\leftrightarrow$ MR	.58
PDM $\leftrightarrow$ RIO	.74
PDM $\leftrightarrow$ IEO	.85
FH $\leftrightarrow$ MR	.70
FH $\leftrightarrow$ RIO	.79
FH $\leftrightarrow$ IEO	.67
MR $\leftrightarrow$ RIO	.93
MR $\leftrightarrow$ IEO	.55
RIO $\leftrightarrow$ IEO	.77

Source: Author

Table 6.13: Correlation Matrix of Measurement Model

Constructs	PDM	FH	MR	RIO	IEO
PDM	1	0.38	0.33	0.54	0.71
FH	0.62	1	0.48	0.62	0.45
MR	0.58	0.70	1	0.86	0.31
RIO	0.74	0.79	0.93	1	0.60
IEO	0.85	0.67	0.55	0.77	1

Source: Author

6.2.5. Model Comparison

As competing models have been proposed, this section selects the model that best explains the data through an examination of statistical tests. In other words, that is the model that will most likely be replicated in a different sample that belongs to the same population (Hoyle, 2012). M2, M4 and M5 were nested in M3. A chi-square test of difference was hence used as the main test to examine if the differences in chi-square

values of the models were significant. For M3, χ^2 (55, N=100, $p>0.05$) = 71.67 and for M4, χ^2 (59, N=100, $p<0.05$) = 98.203. Comparing M3 and M4, the chi-square change was 26.533 for $df = 4$, which was significant ($p<0.05$). In other words, adding mediating paths would have explained the data better than not adding (Yuan and Bentler, 2004). For M5, χ^2 (57, N=100, $p>0.05$) = 71.678. Comparing M3 and M5, chi-square change was insignificant. Hence, M5 which was more parsimonious, explains the data as well as M3. Comparing M2 and M5, the change in chi-square was insignificant ($p>0.05$), with a difference of 3.213 for $df = 2$. This implies that removing paths from IEO to FH and MR have explained the data as well as when they have been added. In this case, the more parsimonious model, that is M2, was preferred.

6.2.6. *The Structural Model*

The previous section has provided evidence that M2 was the most fitting model selected after statistical testing and comparison with other alternative models. Figure 6.7 displays the full model of M2. In evaluating the theoretical model, its standardized residuals were inspected. Standardized residuals are presented in matrix form in AMOS output as shown in Table 6.14. These values represent the differences between observed and fitted covariance terms and should preferably be small, ranging from -4.0 to 4.0 (Byrne, 2001, Hair et al., 2006). In addition, the modification indices had been examined to determine if further freeing of paths were suggested such that model fit could be improved significantly. From Table 6.14, it is justifiable that no additional estimation or freeing of paths is recommended. This conclusion is consistent with the results of standardized direct and indirect effects between latent constructs as shown in Table 6.15. Therefore, both the matrix and modification indices obtained from AMOS output as well as the results of total effects all suggest that there are no issues with model fit and model specification problems.

6.2.7. Testing of Hypotheses

Table 6.16 shows that most of the correlations between the constructs are positive and significant at a level of 0.05. The results suggest that Hypotheses 2, 3, 4 and 5 are supported; Hypotheses 1 and 6 are not supported.

Figure 6.7: Path coefficients of structural model

Source: Author

Table 6.14: Standardized Residuals Covariances of Theoretical Model

	C17	IEO2	IEO1	C12	RIO1	MR2	MR1	C4	FH2	FH1	P1	P2	P3
C17	.000												
IEO2	-.511	.000											
IEO1	.018	.136	.000										
C12	.674	-.021	.195	.000									
RIO1	.249	-.652	.108	-.065	.000								
MR2	.819	-.373	-.465	.151	-.315	.000							
MR1	-.094	-1.714	-.451	.790	.825	.000	.000						
C4	.723	1.042	.827	-.394	.053	.601	-.913	.000					
FH2	1.233	-.257	-.650	-.442	.296	.879	-.859	-.107	.000				
FH1	.285	-.016	.281	-.757	.208	-.265	-.128	-.043	.115	.000			
P1	.176	.119	-.465	.588	-.294	.793	-.776	.225	.489	1.042	.000		
P2	-.321	.249	-.013	.295	-.376	-.538	-.246	-.129	-1.107	-.030	.056	.000	
P3	.356	.135	.127	.246	-.151	-.406	-.482	.829	-.347	.380	-.054	-.009	.000

So

Source: Author

Table 6.15: Standardized Direct and Indirect Effects between Latent Constructs

	PDM	IEO	RIO	MR
Direct				
IEO	0.845			
RIO	0.300	0.505		
MR			0.847	
FH			0.781	0.038
Indirect				
IEO				
RIO	0.427			
MR	0.615	0.428		
FH	0.590	0.411	0.032	
Total				
IEO	0.845			
RIO	0.726	0.505		
MR	0.615	0.428	0.847	
FH	0.590	0.411	0.813	0.038

Source: Author

Table 6.16: Estimates of structural model

Hypothesis	Paths	Estimate	C.R.
H ₁	PDM→RIO	0.30	1.31
H ₂	PDM→IEO	0.85*	8.65
H ₃	IEO→RIO	0.51*	2.05
H ₄	RIO→FH	0.78*	2.24
H ₅	RIO→MR	0.85*	4.40
H ₆	MR→FH	0.04	0.11

*Result is significant at C.L. 95%

Source: Author

6.3. Discussion of Results

6.3.1. Findings from Hypothesis Testing

It is seen that the proposed PDM had a significant and positive effect on internal and external opportunities. To a large extent, disruption management improves port performance in terms of development and optimization of existing capabilities. The improvements in internal capabilities in this manner can be conducted through internal and external means. These improvements have positive effects on port operation performance which are leveraged on as drivers for tangible and intangible advantages. While there was strong significant influence of PDM on internal and external opportunities, the relationship between PDM and resilience of internal operations was not significant. The reason could be that improvements in core resilience require the development of both tangible assets and upgrading of internal capabilities which are objectives of internal and external opportunities identification. Therefore, the relationship between PDM and resilience was rendered insignificant. To support this view, the relationship between the management model and internal resilience was fully

mediated by internal and external opportunities with total effects of 0.51 (see Figure 6.7). The influence of internal and external opportunities was significant on resilience of port operations. Considering this result, the importance of the PDM can be explained by increasing the resilience of port through a series of continuous improvements that are conducted both internally and a competence acquired from external opportunities.

The relationship between the PDM and financial health of a port was attributed by both direct and indirect effects from the resilience of its operations on its financial health. The significant and positive effects from resilience of port operations on its financial health further reiterated the implications of port resilience. The strong relationship between the resilience of internal operations and financial health can be explained by the inherent characteristics of resilience from which financial stability and substantial savings were generated from reliable operations and rapid recovery. Similarly, resilience had an approximately equally strong influence on the port's market reputation, with a total and direct effects. Contrary to what was previously hypothesized, the influence of market reputation on financial health is not significant with weak direct effects. The unique nature of port's competitive landscape suggests that financial health in this respect could most likely be a result of customer retention as other factors such as geographical location, proximity to trading areas and hinterland connectivity are among important considerations of potential port customers. Therefore, other strategic decisions with respect to regional development will likely complement a reputation of high resilience.

6.3.2. Implementation of the management model

It is highly consistent among interviewees from the port operator group in their agreement that the directives guided by the institutional bearings are relevant and capable of managing port-related disruptions. The port operators interviewed expressed that they are largely satisfied with the risk management process at their own ports,

though a few commented that there is definitely room for improvement. The following is a summary of points raised during the interviews by the experts:

1. Employees play a vital role in managing disruptions
2. Both port users and port management appreciate efforts in collaboration among them and the government
3. Contingency planning, risk management and human resource management at ports are highly regarded by both port users and management
4. Differences in business cultures create difficulties in managing expectations
5. Investments to fund disruption management is a challenge to overcome
6. Cost should not be compromised in port service; low cost remain valuable to port users

Generally, there are three main issues to consider when implementing the proposed management model and they are further elaborated below.

Employee recruitment and retention

The majority of the interviewees who were port operators revealed that they rely heavily on their front-line workers together with technology in threat identification. This is also the reason why these ports try to retain experienced employees as they are often more competent in managing exceptions. Business continuity plans may be well-documented, but are sometimes executed haphazardly. The critical underlying factor is the experience of those involved who initiate the emergency response plans. This is explained by one of the interviewees:

“Usually, whoever is involved in the case will solve the problem as soon as possible; so it all depends on the person’s experience and if he/she had come across similar cases previously... Sometimes, we will just tell the older and more experienced workers ‘Hey, take a look’, then they will solve it.”

As every situation is unique, the employees who carry out daily operations need to rely on past experience and their vigilance to identify indications of underlying risks, as illustrated in a typical comment as below:

“We have performance indicators across systems. There are also triggers, so we know when the performance is not at optimal. However, the indicators do vary, depending on weather, moisture level... So, we do see variations.”

Therefore, it has to be ensured that all employees are well-equipped with the necessary knowledge and upgraded professional skills in workplace safety and risk management. Improvements in the professional skills of employees help ensure that they stay relevant and possess the necessary technological and technical capabilities. The training of employees should work towards increasing the level of awareness in risk management, technology utilization and operational efficiency. The psychological wellness of employees is also critical in everyday work performance. Thus, issues regarding the welfare and plight of port employees at work warrant attention. Apathy and avoidance from the management tend to generate greater resentment and grievances among the employees. Hence, though a win-win outcome may not always pan out, getting the employees involved and rewarded are imperative in making them feel appreciated. However, one major challenge faced is to connect the individual employees and motivating them, so that they can contribute to the shared aspiration and business network considering that there is much reliance on manpower in daily operations and disruption management process.

In addition, time plays a critical role in disruption management and the interviewees suggested that delegating the front-line workers with authority to act accordingly and responsibly in their daily operations is one way of minimizing the occurrence of disruptions, and in some cases, the potential or impact of a threat. As a result, the risk management knowledge, technical competencies and experience of the workers affect the capability of the port in disruption management. This raises the issue of outsourcing

port workers. Many ports outsource workers to reduce costs and to ensure that there is sufficient manpower. However, the safety standards and training of the outsourced workers are likely not to be overseen by the port. Thus, the port has to be very selective in the type of functions to be outsourced. In addition, a few of the interviewees recalled that their port was at a losing end when one of their major contractors went on a strike and the port “*had to scramble and ask for help from other contractors to replace those workers*”. To avoid losing responsiveness and becoming overly reliant on external parties, one solution is to control the percentage of outsourced workers. This will ensure that the result of outsourcing is in-line with the initial objective, that is, to reduce uncertainties instead of being exposed to higher level of uncertainties.

Financial and information flows

Externally, the port also has to exercise risk management processes contingency planning together with other parties. These external parties include the government and the port users who will likely be affected by disruptions that originate from the port. One observation is that, in most cases, the port mostly works with the shipping lines and hauliers among the port users. Apart from port users, some ports also work closely with the unions. The concerns of investment costs have been raised by the interviewees from the port management. At ports where there were collaborations with the local government, the port management were able to plan for many years ahead. This is because national trade and investment plans are indicative of the port’s development potential and advantages. However, the needs and profiles of the port users, especially shipping lines, will also directly affect the sufficiency and adequacy of future plans. Evaluation of market environments and customers’ profiles help to ensure effective plans through gathering of pertinent information. Challenges faced in the process of disruption management undertaken by the port require the cooperation and feedback from its users to be appropriately addressed. The extent of participation of port users in the implementation of the management model requires such information to be communicated with the ports.

Threshold of port users

Business cultures vary and this is one concern expressed during the interviews. This is a tricky issue as the port management needs to balance between applying the same level of strictness in their regulations and allowing flexibility while compromising on safety standards, since flexibility in business transactions may be more highly valued in one region than in another. One consequence is losing customers who require more flexibility. In regions where business cultures allow rules and regulations to be less rigid or even vague and open to interpretation, a port with practices that are strict tends to lose out on flexibility. An interviewee has experienced a difficulty in this issue, recalling that *“We lose customers who need more flexibility... when we rejected customers and asked them to rectify some problems, they asked why somewhere else let them in.”*

Another difficulty in addressing this concern is that the port users have different levels of tolerance for disruptions. One critical factor that the port users place much emphasis on is cost and this point has been raised by the port users during the interviews. Therefore, it would be wise if the port operators understand the threshold of their customers and ensure that their performance lies within the boundaries, if not on the frontier. For the case of import and export ports, the port users are price sensitive and can easily opt for cheaper alternatives, as long as the extent of possible disruptions at the cheaper port lies within their threshold. A few interviewees commented on the cost in disruption management, emphasizing that *“It is expensive... sometimes what customer wants is productivity and that will mean increase cost, but customers don’t want to pay that extra”*. This is also illustrated in the comment of another interviewee as follows:

“Our job is to help customers minimize delays and demurrage... by ensuring that there is warehouse availability and berth availability. If we increase handling rate, we will incur more costs, but we bear the costs... We understand the industry; we take a

broader view and absorb the costs...We try to provide good service at reasonable price... to stay in the business.”

In summary, it is the leveraging of resources that matters. The development of a strategic architecture for leveraging corporate resources and ensuring that it is in line with the corporate strategic intent brings about the need for a managerial culture that encourages committed teamwork and the ability to think ahead with the capacity to manage changes. This capability of the port forms a tool for communicating with its customers and other external constituents. With the functionality of the ports focused, the management is also expected to rethink and strategize along the market opportunity horizon for long term sustainable growth and thus the port is encouraged to monitor and review its existing plans and processes. This is where active management of opportunity gaps through re-evaluation of management policies and management of performance gaps on various business dimensions relevant to the port take place. This applies not only to different time horizons, but also to different market segments.

The interviews and surveys produced findings that corroborate the principles of the proposed management model for PSCD threats, supporting the significance of risk assessment, disaster recovery planning, involvement of employees and management, collaborations with members of the port community and continuous improvement on the disruption management process. Six indicators that affect the implementation of the management model have been identified: employee recruitment and retention, information flows, financial flows, flexibility, cost and port users' threshold. These are the factors that the port should consider in the successful facilitation of model implementation.

Appendix J introduces a major chemical manufacturer based in Singapore. The simulation exercise in the Appendix J illustrates the impact of the disruption from

SPM's perspective. A comparison in costs will be made with the usual non-disruption situation and when disruption strikes without the implementation of the PDM. All information and data obtained and used in the simulation exercise were derived primarily from the interviews and also from the company website. Please refer to Appendix J for more details.

CHAPTER 7. CONCLUSION

7.1. Summary of Results

The role of ports in supply chains has evolved from simply a platform for cargo transfer to a supply chain node that is expected to be agile due to its increased integration into supply chains. With respect to the new role, there exist risk areas, which are referred to as PSCD threats, that are capable of disrupting supply chains. Based on the contemporary literature review and interviews with professionals from the industry who are port operators and users, a list of common PSCD threats and a management model have been introduced and validated. An overview of the findings can be found in Figure 7.1. Dotted arrows in Figure 7.1 refer to absence of validation that establish relationships between constructs.

Figure 7.1: Summary of findings

Source: Loh and Thai (2015a)

This research has examined the role of ports in supply chain disruptions through the establishment of the portfolio of each PSCD threat based on data collected from port operators and port users. The PSCD threats are divided into four categories, infrastructure threats, manpower threats, planning threats and security threats. These are

the underlying threats capable of resulting in disruptions at port operators. The results show that planning threats (A8-A11) had higher mean, while security threats (A15-A19) had lower mean scores of likelihood and consequences assigned by all respondents in most cases. Congestion within Terminals (A9) received the highest mean score of likelihood and risk score, while the responses from the different groups of respondents were mixed in scores assigned to threats for consequences. Terrorist Attacks (A19) received the lowest mean score for likelihood in most cases. Trafficking (A15) and Stowaway (A17) had the lowest mean score for both consequences and risk scores in most cases. The factors that affect the occurrences of PSCD threats are market trends, business environment and types of cargo handled at the port. The results benefit both port operators and port users as they bring attention to areas which port management should focus on to ensure resilience for their ports which in turn benefits their users.

The other objective of this research is to operationalize measures and actions for the purpose of minimizing port-related supply chain disruptions. Hence, a port-related supply chain disruption management model was proposed and validated. The management model seeks to ensure supply chain resilience by ensuring that the PSCD threats are managed and that the impact of the disruptive consequences is mitigated. The management model was synthesized from the application of RM, BCM and QM theories and was presented in three tiers such that the directives can be operationalized from the top management to the front-line employees. There were five institutional bearings at the top management level and ten management policies at the second tier, which were further expanded into operational actions at the third tier. The proposed PSCD management model takes into consideration the changing role of ports and requires collaborative working relationships internally within the organization as well as with external parties.

In the implementation of the management model, three factors were raised during the interviews as issues and concerns to consider. These included employee recruitment and

retention, financial and information flows and port users' threshold. The SEM results suggest that the proposed PDM has positive impact on port performance ultimately, in terms of the port's financial health and market reputation. Therefore, the research findings corroborate the effectiveness of principles applied in the proposed model, supporting the significance of risk assessment, disaster recovery planning, involvement of employees and management, collaborations with members of the port community and continuously improvement on the disruption management process.

The approach of the combined theoretical application of the three principles behind the management model presented in this research cannot be found in existing literature. In general, the PSCD threats and the management model are the main outcomes of this paper. Through these findings, it is hoped that the port management are now provided with a guideline in their management of threats in everyday port operations and a direction that aims to reduce the disruptive potential of their ports, such that supply chain resilience can be ensured.

7.2. Academic Implications

This research provides several academic contributions.

Identification of PSCD Threats

First, it has identified a list of PSCD threats which is currently absent in prior research despite recognizing the fact that ports play a significant role in supply chains. The investigation on the PSCD threats has shed light on operational issues that require attention and also the impact experienced by different categories of port operators and users. Secondly, this present study determines the extent to which ports play the role in supply chain disruptions, enabling the frequency and consequence of each threat to be defined arithmetically, hence illustrating a comparison of frequency and impact of each threat. On top of that, the evaluation of PSCD threats takes into account the perspectives from supply chain entities and different types of port operators. Taking their

perspectives into consideration would render future studies aiming to increase port resilience and supply chain continuity to remain relevant and feasible.

Development of Management Model

The triangulated application of RM, BCM and QM principles in disruption management has been validated to provide benefits to ports. This approach is absent in current literature and is able to provide a more comprehensive protection and mitigation of PSCD threats. In terms of theory building, this study has provided a framework and operational guidelines to minimize port-related supply chain disruptions, which are currently less focused in the literature. The research draws principles from supply chain perspectives in order to present a more comprehensive and feasible approach to disruption management in the contemporary port environment. Hence, this research clarifies our understanding of the role that ports play in supply chain disruptions. It adds to the scant body of literature on port resiliency and enhances the understanding of the trade-offs that are to be considered by the port in disruption management. The management model also provides a concrete basis for future studies that are tailored to address the different port characteristics. This study thus provides a theoretical foundation for future studies with relevant contributions to port resiliency and supply chain continuity.

7.3. Managerial Implications

In addition to the academic implications, the findings of this study also offer practical managerial implications for both port operators and port users.

Identification of PSCD Threats

This study assists port management with respect to their strategic decision making and policy development. Specifically, the results of this study encourage an increased contingency level at ports through determining the areas which should warrant focus. In

this respect, a more realistic view of where operations can fail will be reflected, assuring the deliverables of port services. The determination of the role of each threat in disruptions facilitates efficient and effective allocation of resources. The results suggest a collaborative working relationship with the government and port users, while maintaining a healthy and cooperative internal organizational culture. As the findings reveal the concerns of supply chain entities who are users and customers of the ports, they suggest areas which port management can establish strategic cooperation and coordination with the external entities. Internally, more effort and emphasis should be placed on raising risk awareness and risk management training as the port is reliant on the employees' vigilance in identification of potential threats and mitigation of disruptions. Port management can then identify essential skills and knowledge to be acquired and shared among employees. On the other hand, port users are provided with a basis of assessment of the risk level at the ports they use and the extent of the impact on themselves, thereby allowing them to account for exceptions in their planning to maintain the sustainability of their supply chains and the continuity of their operations.

Development of Management Model

The management model serves as a guideline and framework for port management in their disruption management. This study has also identified areas where the port management can focus on, without compromising on costs and quality of the services provided. The effective implementation of the management model is expected to enhance the functionality of port operations, thus assisting port management in retaining its clientele.

The SEM results reveal the significance of the management model as a framework to ensure port performance in terms of increased organizational resilience that brings about benefits from valuable corporate assets. With regards to internal policy development and implementation, the proposed holistic approach in disruption management had been validated to have a positive impact on port performance. The results of this study also

indicate that both self-regulating and collaborative initiatives on transformation into a resilient port have positive influence on the organizational performance and corporate image. Hence, it is encouraged that emphasis be placed on the internalization of cultures incorporating RM, BCM and QM through the emergence of new responsibilities delegated to employees, introduction of new skills and the involvement and participation of external bodies in disruption management. The need for port management to respond to its own vulnerabilities and uncertainties from its business environment is a strategic imperative. However, the capability to do so is likely to be complemented and leveraged on with the effects from the development on a larger scale that involves regional cooperation across industries and systems of governance.

As the management model improves the resilience of the port and its adaptability to disruptions, cargo in ports can then be successfully delivered to downstream supply chain entities or to the cargo owners with fewer hiccups. For the upstream supply chain entities, they will be freed from the liability and costs of holding the cargo if the cargo can be delivered in a timely manner.

7.4. Research Limitations and Future Research Directions

The current proposed PSCD indicators only offer detection of PSCD threats. However, when threats cannot be totally avoided or eliminated, an additional set of disruption recovery indicators shall provide an evaluation of the port's capability in disruption management. A future research opportunity could be to assess the port's capability in disruption recovery. On the same note, the actions to increase the recovery capabilities of the port following a PSCD should also be defined to create an even more comprehensive coverage from the disruption.

Another limitation is that the evaluation of each PSCD threat was restricted by assigning a value to its frequency and consequence. Hence, future work can also be

carried out to examine frequencies and consequences of different levels of severities of a threat. In the analysis of risk matrices, three types of ports were investigated – purely container ports, non-container ports and multi-purpose ports. As tanker terminals are likely to experience higher risk levels due to the cargo handled, future research on PSCD threats can address tanker terminals separately. For each of the risk matrices, the naming of the regions follows the usual categorization for 2x2 matrices and this resulted in two quadrants named Region 2. However, the strategies that port management can use to address the risks in each of the two Region 2 might be different. Future studies can explore the differences of the PSCD threats in Region 2 and further categorize the threats. Due to the small number of respondents, analyses could not be conducted according to the respondents' geographical locations and organisational sizes. It would be meaningful if future studies could evaluate the threats based on different regions of ports and port users for a comparison of perspectives.

It has to be noted that the implementation of the management model might produce different extents of outcomes and effects, depending on the maturity of the ports and market setting the port is situated in. Such differences in results was not shown in this study as the responses received from ports of different regions and stages of development were not balanced. This limitation should be addressed in future similar studies. Hence, future studies should also analyze the effects of the management model in different regional settings or markets, as well as ports handling different cargo types. Although this study has some limitations, the academic and managerial implications reveal areas where port management should establish strategic capability to increase port resilience and enhance sustainability in the current business landscape.

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APPENDICES

Appendix A: Interview Questionnaire for Port Users

1. In your opinion, do ports contribute in any way to supply chain disruptions?
2. Do you think that ports are playing an important role in the supply chains of your organization?
3. In the case of your organization, had there been any supply chain disruptions that were caused by port disruptions?
4. Regarding disruption management with seaports:
 - a. Does your organization collaborate with ports to manage disruptions? If yes, can you describe these collaborations?
 - b. Have these collaborations been successful and why?
 - c. Are there any changes to the collaborations that you wish to see? If yes, what are they?
5. Are you in direct contact with the port? How do you communicate with the port?
6. What is your assessment or evaluation on how ports manage disruptions?
7. In your opinion, which port(s) manages disruptions very well and why do you think so?
8. In your opinion, in which ways can ports manage disruptions better?/What changes or improvements would you like to see in how ports manage disruptions?
9. Do you have any comments or recommendations for improvement in this study?

Appendix B: Interview Questionnaire for Port Operators

1. What is your view on the role of ports in supply chains?
2. Do you think that your port is playing an important role in the supply chains of your customers?
3. In the case of your port, had there been any case that has led to supply chain disruptions?
4. Regarding disruption management within your port.
 - a. How is a disruption discovered at your port?
 - b. What is the usual course of action following a disruption?
 - c. Have you encountered any difficulties in the process of managing the threats and disruptions? If yes, what were they and how were they solved?
 - d. What is your assessment or evaluation on how your port manages disruptions?
 - e. Are there any changes to disruption management at your port that you wish to see? If yes, what are they?
5. Regarding disruption management with external parties.
 - a. Does your port collaborate with external parties to manage disruptions? If yes, can you describe these collaborations?
 - b. Have these collaborations been successful and why?
 - c. Are there any changes to the collaborations that you wish to see? If yes, what are they?
6. Please refer to the table that briefly describes the components in the management model in the information sheet. The model contains actions which when implemented are expected to reduce chances of port disruptions and to mitigate losses should a disruption occur.
 - a. Are there other approaches or measures that are not reflected in the management model but have been used by your port to manage the threats? If yes, please briefly describe them.
 - b. Is there anything else you feel is important or wish to include or change in the model?
7. Do you have any comments or recommendations for improvement in this study?

Appendix C: Cover Letter for Port Users

Dear Sir/Mdm,

Good day.

My name is Loh Hui Shan, a Ph.D candidate at Nanyang Technological University, Singapore. I am writing to seek your help in a research study on *'The Role of Ports in Supply Chain Disruption Management'*. The objectives of this research are to explore the magnitude of port-related threats that could potentially lead to disruptions in supply chains and design measures to contain and reduce consequences of such threats. Thus, the port-related supply chain disruption (PSCD) threats and their corresponding consequences have to be identified, so that measures can be designed to target them and to minimise the occurrences of supply chain disruptions resulted from disruptive events at seaports. I need your help in the attached questionnaire for supply chain organizations or port users on experiences in supply chain disruptions as a result of events or risks at seaports.

The valuable input from your organization is very important to us and will help to shed light on building resilient and adaptable ports, so that operations at upstream or downstream supply chain entities such as your organization will not be adversely affected and that your customers' expectations can be delivered in a timely manner. Hence, I hope you could take some of your valuable time to participate in this survey by or at your earliest convenient time.

After completing the questionnaire, kindly send it back to us by email to hsloh1@e.ntu.edu.sg. Alternatively, the questionnaire can be completed online by accessing the link below:

https://qtrial.qualtrics.com/SE/?SID=SV_3mk88ga8M8YAYv3

The participation of your organization is very important to the success of this study. Please rest assured that all responses will be completely confidential and anonymous. In addition, the results of the survey will be summarized and the results will not be linked to any specific organization or individual. As a token of appreciation, a free executive summary of the study will be sent to you if you so wish.

Thank you very much in advance for participating in this study. If you encounter any problems or questions, please do not hesitate to contact me at hsloh1@e.ntu.edu.sg / [+65 9128 5619](tel:+6591285619) or Asst Prof Thai Van Vinh at vvthai@ntu.edu.sg / [+65 6790 5331](tel:+6567905331).

Sincerely,
Loh Hui Shan

Division of Infrastructure Systems and Maritime Studies,
School of Civil and Environmental Engineering,
Nanyang Technological University, N1-B4b-07, 50 Nanyang Avenue, Singapore 639798
<http://www.ntu.edu.sg/cee>

Appendix D: Cover Letter for Port Operators and Authorities

Dear Sir/Mdm,

My name is Hui Shan Loh, a Ph.D candidate at Nanyang Technological University, Singapore. I am writing to seek help from the management of port operators/authorities in a research study on The Role of Ports in Supply Chain Disruption Management. The objectives of this research are to explore the magnitude of port-related threats that could potentially lead to disruptions in supply chains and relevant design measures to contain and reduce consequences of such threats. Thus, the port-related supply chain disruption (PSCD) threats and their corresponding consequences have to be identified. These threats are controllable risks related to port operations; hence natural disasters are excluded from this study. Measures will be developed to target them and to minimize the port's potential in stimulating port-related supply chain disruptions. I would greatly appreciate if a senior representative from your management can complete the attached questionnaire on experiences in risk and disruption management at ports.

The valuable input from your organization is very important to us and will help to shed light on building resilient and adaptable ports, thereby enhancing your port's competitive edge. Hence, I hope your representative could take some of his/her valuable time to participate in this survey by or at his/her earliest convenient time.

After completing the questionnaire, kindly send it back to us by email to hsloh1@e.ntu.edu.sg. Alternatively, the questionnaire can be completed online by accessing the link below:

Follow this link to the Survey:

[Take the Survey](#)

Or copy and paste the URL below into your internet browser:

[https://qtrial.qualtrics.com/WRQualtricsSurveyEngine/?Q_SS=dmTakjOVd2xFnqB_5j9hMD1nMVHcVTL&_](https://qtrial.qualtrics.com/WRQualtricsSurveyEngine/?Q_SS=dmTakjOVd2xFnqB_5j9hMD1nMVHcVTL&_=1)
[=1](#)

If your organization manages the operations of more than one terminal, please answer the questionnaire with respect to the one handling the largest cargo volume. The participation of your organization is very important to the success of this study. Please rest assured that all responses will be completely confidential and anonymous. In addition, the results of the survey will be summarized and the results will not be linked to any specific organization or individual. As a token of appreciation, a free executive summary of the study will be sent to the respondent if he/she so wishes.

Thank you very much in advance for participating in this study. If you encounter any problems or questions, please do not hesitate to contact me at hsloh1@e.ntu.edu.sg / +65 9128 5619 or Asst Prof Thai Van Vinh at vvthai@ntu.edu.sg / +65 6790 5331.

Sincerely,
Hui Shan, Loh (Ms.)

Division of Infrastructure Systems and Maritime Studies,
School of Civil and Environmental Engineering,
Nanyang Technological University, N1-B4b-07, 50 Nanyang Avenue, Singapore 639798
<http://www.ntu.edu.sg/cee>

Appendix E: Questionnaire for Port Users

Study of Port-Related Supply Chain Disruption Management

- ❖ This survey comprises two parts. Part A explores the types of port-related supply chain disruption (PSCD) threats and their consequences and Part B seeks to obtain demographic information.
- ❖ There are no right or wrong answers to the questions in this survey. Please answer truthfully.
- ❖ PSCD Threats are controllable port-related threats that disrupt supply chain continuity. These threats are related to port operations and hence exclude natural disasters and weather events.

A. PSCD Threats and Their Consequences

1. Please state the name of a port that your organization uses most frequently:

2. Using the definitions of the scale used below, please indicate the likelihood of occurrence of each of the following PSCD threats and their respective consequences, if they had affected or would probably affect your organization, by selecting the most appropriate response in the table. *Please answer this question with respect to the port you have stated in your answer to Question 1 above.*

Definition of Scale:

- L1** - Rare; no previous occurrence or may only occur in exceptional circumstances
L2 - Unlikely; <25% of the time
L3 - Possible; 25% to 50% of the time
L4 - Likely; >50% to 75% of the time
L5 - Frequent; >75% of the time
C1 - Negligible effects; operations remain unaffected
C2 - Delays in momentum of usual operations, schedules and/or delivery of goods and/or services to customers
C3 - Deviation in transportation plans, costs, usual operations, schedules, quality and/or amount of delivered goods and/or services to customers
C4 - Temporary stoppage or interruption in usual operations and/or delivery of goods and/or services to customers
C5 - Loss of service platform; loss of ability to carry out operations and/or to fulfil customers' demand

No.	PSCD Threats	Likelihood					Consequences				
		L1	L2	L3	L4	L5	C1	C2	C3	C4	C5
Infrastructure Threats											
A1	Port Equipment Breakdown	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
A2	Inadequate Port Cargo-Handling Equipment	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
A3	Occupational Accidents	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
A4	Power Outage	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
A5	Breakdown of Vessel Traffic Management System	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
A6	Breakdown of Port Information System	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
A7	Collisions in Waterway	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Planning Threats											
A8	Congestion in Waterway	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
A9	Congestion within Terminals	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
A10	Congestion at Hinterland Transfer	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
A11	Shortage of Facilities or Equipment	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Manpower Threats											
A12	Port Labour Strikes	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

Appendix F: Questionnaire for Port Operators and Authorities

Study of Port-Related Supply Chain Disruption Management

- ❖ This survey comprises four parts. Part A explores the types of port-related supply chain disruption (PSCD) threats and their consequences; Part B focuses on approaches that mitigate the PSCD threats and Part C assesses port performance. The last part, Part D, seeks to obtain demographic information.
- ❖ There are no right or wrong answers to the questions in this survey. Please answer truthfully.
- ❖ PSCD Threats are controllable port-related threats that disrupt supply chain continuity. These threats are related to port operations and hence exclude natural disasters and weather events.

A. PSCD Threats and Their Consequences

1. Using the definitions of the scale used below, please indicate the likelihood of occurrence of each of the following PSCD threats and their respective consequences, if they had happened or would probably occur at your port, by selecting the most appropriate response in the table.

Definition of Scale:

- L1* - Rare; no previous occurrence or may only occur in exceptional circumstances
L2 - Unlikely; <25% of the time
L3 - Possible; 25% to 50% of the time
L4 - Likely; >50% to 75% of the time
L5 - Frequent; >75% of the time
- C1* - Negligible effects; operations remain unaffected
C2 - Delays in momentum of usual operations, schedules and/or delivery of goods and/or services to customers
C3 - Deviation in transportation plans, costs, usual operations, schedules, quality and/or amount of delivered goods and/or services to customers
C4 - Temporary stoppage or interruption in usual operations and/or delivery of goods and/or services to customers
C5 - Loss of service platform; loss of ability to carry out operations and/or to fulfil customers' demand

No. PSCD Threats		Likelihood					Consequences				
		L1	L2	L3	L4	L5	C1	C2	C3	C4	C5
Infrastructure Threats											
A1	Port Equipment Breakdown	☒	☐	☐	☐	☐	☐	☐	☐	☐	☐
A2	Inadequate Port Cargo-Handling Equipment	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
A3	Occupational Accidents	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
A4	Power Outage	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
A5	Breakdown of Vessel Traffic Management System	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
A6	Breakdown of Port Information System	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
A7	Collisions in Waterway	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Planning Threats											
A8	Congestion in Waterway	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
A9	Congestion within Terminals	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
A10	Congestion at Hinterland Transfer	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
A11	Shortage of Facilities or Equipment	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Manpower Threats											
A12	Port Labour Strikes	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
A13	Shortage of Manpower (not due to labour strikes)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

No.	PSCD Threats	Likelihood					Consequences				
		L1	L2	L3	L4	L5	C1	C2	C3	C4	C5
A14	Misinterpretation of Instructions at Workplace	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
<i>Security Threats</i>											
A15	Trafficking	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
A16	Smuggling/Contraband	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
A17	Stowaway	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
A18	Breaking in/Theft	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
A19	Terrorist Attacks	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
<i>Others, if any:</i>											
		☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
		☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
		☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

B. Mitigating Approaches

2. Please indicate your attitude towards the following statements about mitigating PSCD threats at your port by selecting the number that most represents your perception in the table below.

1 – Strongly Disagree 2 – Disagree 3 – Neutral / Not Sure 4 – Agree 5 – Strongly Agree

No.	Mitigating PSCD Threats	1	2	3	4	5
B1	<i>Internal Risk Management</i>					
B1.1	We share risk identification and management knowledge among our management.	☐	☐	☐	☐	☐
B1.2	Our employees are knowledgeable in workplace safety and/or risk management.	☐	☐	☐	☐	☐
B1.3	We carry out risk assessment to specify the likelihood of occurrence of different risks in our port and their potential consequences.	☐	☐	☐	☐	☐
B1.4	We have mechanisms or measures that monitor our risk level. (For example, by arranging for safety audits to monitor risk level at our port, early warning systems, having safety checklists)	☐	☐	☐	☐	☐
B2	<i>Mandatory Controls</i>					
B2.1	We create buffers and provide alternatives in our equipment, infrastructure, communication systems, administrative sites, power supplier and hinterland transportation service solutions.	☐	☐	☐	☐	☐
B2.2	We develop mitigation strategies and measures that are catered for different types of risks.	☐	☐	☐	☐	☐
B2.3	We clearly document all our mitigation strategies.	☐	☐	☐	☐	☐
B2.4	We ensure that the steps in the documented strategies are closely adhered to.	☐	☐	☐	☐	☐
B2.5	We evaluate our mitigation strategies and measures frequently.	☐	☐	☐	☐	☐
B2.6	We ensure that we are sufficiently insured against infrastructure damage, business interruption and other liabilities.	☐	☐	☐	☐	☐
B2.7	We comply with all mandatory safety and security rules and regulations.	☐	☐	☐	☐	☐
B3	<i>PSCD Impact Analysis</i>					
B3.1	We clearly identify the key operations at our port.	☐	☐	☐	☐	☐
B3.2	We keep a detailed record of incidents which previously resulted in disruptions.	☐	☐	☐	☐	☐
B3.3	We always simulate scenarios of identified risks in order to accurately identify potential disruptions.	☐	☐	☐	☐	☐
B4	<i>Disruption Recovery Planning</i>					

B4.1	We document detailed emergency response plans for each functional department.	☐	☐	☐	☐	☐
B4.2	We have systems that allow prompt contact with and response from our management and staff all the time.	☐	☐	☐	☐	☐
B4.3	Our emergency drills require the mandatory participation of all of our staff.	☐	☐	☐	☐	☐
B5	<i>Service Objectives Enhancement</i>					
B5.1	All our functional departments are committed in ensuring the quality of our services at all times.	☐	☐	☐	☐	☐
B5.2	The professional skills of all our employees are constantly upgraded.	☐	☐	☐	☐	☐
B5.3	We track our customers' tolerance for shipment delays.	☐	☐	☐	☐	☐
B5.4	We understand the current and future needs of our customers.	☐	☐	☐	☐	☐
B5.5	We have a portal for our customers to voice out their opinions and provide their feedback on the quality of our services.	☐	☐	☐	☐	☐
B5.6	We re-evaluate our workflow processes regularly to improve our efficiency.	☐	☐	☐	☐	☐
B6	<i>Employee Involvement and Empowerment</i>					
B6.1	We give incentives to our employees when they provide constructive suggestions on process improvement.	☐	☐	☐	☐	☐
B6.2	Our front-line staff have delegated authority to make timely and wise decisions during disruptions.	☐	☐	☐	☐	☐
B6.3	We have an internal portal to collect staff feedback and suggestions on improvements or changes at our port.	☐	☐	☐	☐	☐
B6.4	We conduct small group meetings to effectively communicate policy changes with the non-management staff.	☐	☐	☐	☐	☐
B7	<i>Collaborative Working Relationships with Supply Chain Parties</i>					
B7.1	We update and inform our port users the status of their cargo and our berths.	☐	☐	☐	☐	☐
B7.2	Our operations are unaffected even when any of our contractors defaults.	☐	☐	☐	☐	☐
B7.3	We have measures that enable risk identification, analysis and treatment together with external supply chain parties.	☐	☐	☐	☐	☐
B7.4	Our emergency drills require the participation of port users and customers.	☐	☐	☐	☐	☐
B7.5	We have systems that allow prompt contact with and response from external parties all the time.	☐	☐	☐	☐	☐
B7.6	We have agreements with external transport service providers to provide alternative transportation for our customers when we cannot perform the services.	☐	☐	☐	☐	☐
B7.7	We have agreements with all companies, which have their employees working at our port, on labour welfare to reduce chances of labour disputes.	☐	☐	☐	☐	☐
B8	<i>Collaborative Relationships with Relevant Agencies</i>					
B8.1	We have agreements with the government agencies, our employees and management on the welfare of our staff to reduce labour disputes.	☐	☐	☐	☐	☐
B8.2	We collaborate with the relevant government agencies to manage risks and disruptions.	☐	☐	☐	☐	☐
B8.3	We adopt guidelines or framework related to emergency planning or disruption management established by the local industry professional standards or alike.	☐	☐	☐	☐	☐
B8.4	We conduct collaborative research and development (R&D) with higher education institution(s) regularly to improve on our operations.	☐	☐	☐	☐	☐
B9	<i>Relevance Evaluation</i>					
B9.1	We review our disruption management strategies regularly.	☐	☐	☐	☐	☐
B9.2	We encourage the participation of the port users and customers in our post drill and disruption analysis to understand disruption management from their perspectives.	☐	☐	☐	☐	☐
B9.3	We communicate regularly with external parties, port stakeholders and/or other ports on issues pertaining to disruption management.	☐	☐	☐	☐	☐
B10	<i>Recommendation for Improvement</i>					
B10.1	We conduct post drill and disruption analysis to identify areas for	☐	☐	☐	☐	☐

improvement.

B10.2	We adopt feedback and suggestions collected from our customers and staff in our disruption management.	☐	☐	☐	☐	☐
B10.3	We share lessons learnt on disruption management with other industry players through forums.	☐	☐	☐	☐	☐
B10.4	We apply lessons learnt from previous incidents in our disruption management.	☐	☐	☐	☐	☐

3. If there are other approaches or measures that are not reflected in the above table but have been used by your port to manage PSCD threats, please briefly describe them.

C. Port Performance

4. Please indicate how much you agree with the following statements regarding performance of your port by selecting the number that most represents your view in the table below.

1 – Strongly Disagree 2 – Disagree 3 – Neutral / Not Sure 4 – Agree 5 – Strongly Agree

No.	Performance Indicators	1	2	3	4	5
C1	We have never experienced financial difficulties.	☐	☐	☐	☐	☐
C2	We have enjoyed sustained financial growth.	☐	☐	☐	☐	☐
C3	We have never been issued fines, penalties or warnings during audits and/or safety inspections.	☐	☐	☐	☐	☐
C4	The collaborations with our partners have reaped concrete financial benefits.	☐	☐	☐	☐	☐
C5	Our financial ratios and net profit has always remained healthy.	☐	☐	☐	☐	☐
C6	Our market share has been increasing.	☐	☐	☐	☐	☐
C7	We have been able to retain majority of our customers.	☐	☐	☐	☐	☐
C8	We have never received complaints from our customers that they experience delays, deviations, stoppage or loss of service platform caused by our operations or people.	☐	☐	☐	☐	☐
C9	Collaborations with our supply chain partners and/or relevant agencies have attracted new customers for us.	☐	☐	☐	☐	☐
C10	Our customers have expressed that they are very satisfied with our overall service quality.	☐	☐	☐	☐	☐
C11	We are able to redesign our internal operations very quickly, such that effects of disruptions are minimized.	☐	☐	☐	☐	☐
C12	Our internal operations resume very quickly if we experience a delay, deviation, stoppage or loss of service platform, such that effects of disruptions are minimized.	☐	☐	☐	☐	☐
C13	We have experienced constant improvement in our operational efficiencies.	☐	☐	☐	☐	☐
C14	Collaborations with our partners have improved efficiency levels of our internal processes and operations.	☐	☐	☐	☐	☐
C15	We have never experienced delays, deviations, stoppage or loss of service platform.	☐	☐	☐	☐	☐
C16	Our employees are equipped with the necessary skills and knowledge in responding to and managing infrastructure, planning, manpower and security threats.	☐	☐	☐	☐	☐

C17	We increasingly engage in technology and continue acquiring capabilities to respond to and manage infrastructure, planning, manpower and security threats.	☐	☐	☐	☐	☐
C18	We have increased the intensity and frequency of training and learning opportunities that help raise risk awareness among our employees.	☐	☐	☐	☐	☐
C19	Collaborations with our partners have improved our port's ability in identifying, analyzing and assessing our infrastructure, planning, manpower and security threats.	☐	☐	☐	☐	☐
C20	We have seen constant improvement in our employee turnover rate.	☐	☐	☐	☐	☐

D. Demographic Information about Your Organization and Yourself

- D1. Type(s) of cargo handled: ☐ Containers ☐ Liquid Bulk ☐ Dry Bulk
☐ Passengers ☐ Vehicle ☐ Others:
- D2. Throughput in 2012:
- D3. Total number of employees: ☐ <100 ☐ 100-499 ☐ 500-999
☐ 1,000-4,999 ☐ 5,000-9,999 ☐ 10,000+
- D4. Your functional area: ☐ Strategic Planning ☐ Logistics Planning ☐ Operations
☐ Health, Safety & Environment ☐ Others:
- D5. Your designation: ☐ Executive ☐ Manager ☐ Senior Management
☐ Top-Level Executive ☐ Others:
- D6. Your experience in the port industry: ☐ <1 year ☐ 1 to 5 years ☐ 5+ to 10 years
☐ 10+ to 20 years ☐ >20 years
- D7. Are you involved in risk/crisis/disruption management at your port ☐ Yes ☐ No

D8. If you have comments or recommendations to improve this study, please share your thoughts.

D9. If you wish to receive an executive summary of the study, please indicate an email address which we can send to. This will not be shared with another party.

~ Thank you very much for your valuable time and sharing your expertise with us~

Appendix G: Feedback Form Used in Pre-testing

Dear Sir/Mdm,

Thank you very much for taking time to help me in the pre-testing of the questionnaire. As the purpose of reviewing the questionnaire is to improve on it, I appreciate your comments. Please indicate (*by circling the most appropriate number*) your opinion on the questionnaire by completing the table below:

No.		Strongly Disagree		Strongly Agree			If you have chosen answers 1, 2 or 3, please specify the question(s) or section(s) of your concern
		1	2	3	4	5	
1	I understand the objective of each part in the questionnaire.	1	2	3	4	5	N.A.
2	The questions in each part of the questionnaire are appropriate to measure their intended objective.	1	2	3	4	5	N.A.
3	I could follow the layout of the questionnaire easily.	1	2	3	4	5	N.A.
4	The length of the questionnaire is appropriate.	1	2	3	4	5	N.A.
5	The instructions in the questionnaire are easy to follow.	1	2	3	4	5	N.A.
6	I did not have to think too long when answering the questions.	1	2	3	4	5	
7	The wordings of the questions are concise.	1	2	3	4	5	
8	The wordings of the questions are clear.	1	2	3	4	5	
9	The questions are easy to understand.	1	2	3	4	5	
10	The questions asked did not make me feel uncomfortable, irritated or embarrassed.	1	2	3	4	5	
11	There is only one intended query in each question.	1	2	3	4	5	
12	The questions asked did not hint me to answer in a particular way.	1	2	3	4	5	

Comments and suggestions:

Appendix H: Reminder Letter Sent to Port Users

Dear Sir/Madam,

Good day.

We at Nanyang Technological University have recently sent an email and a questionnaire to you asking for your help on a research study entitled '*The Role of Ports in Supply Chain Disruption Management*'. If you have already completed and returned the questionnaire, we would like to thank you very much for your contribution to this research. However, if you have not yet responded, we would highly appreciate if you do so since your response is extremely important to our study. Please find attached with this email the questionnaire for your kind input. Alternatively, the questionnaire can be completed by accessing the link below:

https://qtrial.qualtrics.com/SE/?SID=SV_3mk88ga8M8YAYv3

Please kindly complete the questionnaire by or at your earliest convenient time.

To thank you for your help in participating in our study, a summary of results will be sent to you if you so wish.

Should you have questions or wish to know more about this study, please feel free to contact me at hsloh1@e.ntu.edu.sg / [+65 9128 5619](tel:+6591285619) or Asst Prof Thai Van Vinh at yvthai@ntu.edu.sg / [+65 6790 5331](tel:+6567905331).

Sincerely yours,
Loh Hui Shan

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Appendix I: Reminder Letter Sent to Port Operators and Authorities

Dear Sir/Madam,

Good day.

We at Nanyang Technological University have recently sent an email and a questionnaire to you asking for your help on a research study entitled '*The Role of Ports in Supply Chain Disruption Management*'. If you have already completed and returned the questionnaire, we would like to thank you very much for your contribution to this research. However, if you have not yet responded, we would highly appreciate if you do so since your response is extremely important to our study. Please find attached with this email the questionnaire for your kind input. Alternatively, the questionnaire can be completed by accessing the link below:

https://qtrial.qualtrics.com/SE/?SID=SV_5mzGfxQYF3NAatn

Please kindly complete the questionnaire by or at your earliest convenient time.

To thank you for your help in participating in our study, a summary of results will be sent to you if you so wish.

Should you have questions or wish to know more about this study, please feel free to contact me at hsloh1@e.ntu.edu.sg / [+65 9128 5619](tel:+6591285619) or Asst Prof Thai Van Vinh at yvthai@ntu.edu.sg / [+65 6790 5331](tel:+6567905331).

Sincerely yours,
Loh Hui Shan

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Appendix J: Numerical Simulation

J.1. Introduction

This section introduces a major chemical manufacturer based in Singapore. The names of the company and its products have been changed to protect its identity. A comparison in costs will be made with the usual non-disruption situation and when disruption strikes without the implementation of the PDM. Interviews were conducted with an executive from the logistics department. The executive has 10 years of working experience with the company and is familiar with the financial flows and physical distribution of the cargo. The data used in the simulation are actual figures provided by the company from the year 2012. All information and data obtained and used in this simulation exercise were derived primarily from the interviews and also from the company website.

J.2. Background of Singapore Plastic Manufacturer (SPM)

Singapore Plastic Manufacturer (SPM) is a major manufacturer in the petrochemical industry since 1980s. It grew steadily over the next 20 years and has since become one of the region's largest producers, diversifying from its niche in manufacturing into the provision of a wide range of supply chain solutions. In 2013, SPM produced 50 different products, of which 80% were sold through cargo trading house to almost 300 customers worldwide. The profit was approximately USD\$9 million and asset value was about USD\$35 million for the year 2012.

The core business of SPM is supplying six main patented chemical products. The names of these products are omitted to ensure confidentiality guaranteed to the company. Below is a brief description and application of each product:

1. **PE** is an easily processed material that offers excellent clarity and strong bonding and sealing strengths. It is used in food packaging, shrink wrapping, zipper storage bags, films for industrial packaging, etc

2. **EA** possesses physical toughness and good processability which enable it to be used in a variety of foam, thermal insulation material and as an adhesion between solar cell.
3. **PP1**'s excellent high-speed processability, high clarity and other properties allow it to be developed into a wide range of household products and yarn applications.
4. **PP2** offers high clarity, excellent impact strength and stability. Hence it is a material commonly used in feeding bottles and infusion bottle applications.
5. **PP3** demonstrates superior sealing, barrier, adhesiveness and optical properties and is thus used for food packaging, cigarette packaging and lamination films.
6. **PP4** has high heat resistance, high impact and stiffness balance and is super high gloss. It is used in bathroom equipment, coffee-maker and automobile parts.

The production of these products utilizes advanced technology and the products provide a variety of industrial applications and a wide array of consumer goods. The production process is on-going, with the production plant operating 24-hours a day. The cost involved in the production process is USD\$1650/MT. Production rates are largely determined by oil prices, forecasts in selling prices and seasonal peaks. Thus, fluctuations in productions are not unusual especially when plastics are considered a commodity. Due to festive seasons, there is higher demand for the products. Hence, production peaks from October to January with a rate of 2800MT/day and is at its lowest from June to September with a rate of 2200MT/day. From February to May, production is at its average rate of 2500MT/day. To cushion itself from the ill effects of uncertainties, the production process is such that 60% is pulled by customers' orders and 40% of production is stored as inventory. The finished products are stored in the warehouse for one to two months, depending on the period of demand.

The locations of SPM's customers are mainly in China, Japan and other South-East Asian countries. SPM's customers are either manufacturers or traders. A typical order from one customer ranges between 1 TEU to 20 TEUs. These are 20-foot long containers and the usual mode of transportation to the customers is by sea.

J.3. The SPM Supply Chain

The general process from point of sale inquiry to product delivery is shown in Figure J.1. The process starts with a sales order. As soon as it is officially created, its in-house planning systems transmit the information to its production planner who will then start planning for production schedule for that batch of order. Before production begins for the order, raw materials will be ordered from Japanese suppliers. The supplies of raw materials will be shipped from Japan. After which, the production process will be activated and the finished products will be stored in a warehouse. The finished products are stored in the warehouse for two month during off-peak seasons (June – September), one month during peak period (October – January) and one and a half months during remaining months (February – May). Restuffing process at the warehouse is automated and stuffing rate is 2.5TEU/hr. Unstuffing process is manual and the rate is slower, at 1TEU/hr. As SPM sells products on CIF terms, the shipping department then arranges for delivery of product by sea freight to the customers' port.

Figure J.1: Order Fulfilment Process at SPM

Source: Author, synthesized from interviews with SPM's employee

The network of suppliers, production plants, warehousing sites and customers for PE, EA, PP1, PP2, PP3 and PP4 comprised the SPM supply chain and is depicted in Figure J.2. As can be seen from the figure, SPM is positioned before the manufacturers of consumer products. There are several other entities in its downstream supply chain and uncertainties occurring earlier at the chain tend to have its ill effects felt down the chain. In this case, manufacturers, distribution centers, retailers and end consumers would be able to feel the impact.

Figure J.2: SPM Supply Chain

Source: Author, synthesized from interviews with SPM's employee

The flow of materials within SPM supply chain is provided by Figure J.3. Raw materials are transported from Japanese suppliers and stored in SPM warehouse in Singapore till it is needed for production. At the production plant, raw materials are converted into the finished products which are then kept at an in-transit storage area near production site and then transported to finished products warehouse till it is ready to be packed by in-house contractors and transported to the export port for shipment to the customers' port.

Figure J.3: Flow of Materials from Suppliers to Consumers

Source: Author, synthesized from interviews with SPM's employee

The flow of materials is expected to follow the stages shown in Figure J.3 in usual situations. However, in the case of an occurrence of PSCD threat, alternatives might be undertaken. This will likely result in modifications to material flow in terms of time spent at each stage and routes taken to reach the next stage. Therefore, the costs involved at each stage will be different in such situations, depending on the actions taken.

J.4. Simulation

During the occurrence of PSCD threat, there are four main categories of outcomes. Cases 1 and 2 depict two expected outcomes when the management model is implemented - disruptions are avoided or mitigated. This section demonstrates the difference between the four cases in terms of costs involved. The costs reflect time spent as well since time is reflected by storage cost, manpower charges, warehouse cost, inventory holding cost and transportation cost. However, the outcomes are hypothetical and thus do not indicate the presence of a supply chain disruption management plan at SPM. This exercise seeks to illustrate the impact of different outcomes to ascertain the importance of port disruption potential by using realistic data. More specifically,

- Case 1: Containers stored at finished goods warehouse for 15 days then trucked to PSA and used the first shipping line (SL1) for sea transportation to Guangzhou port. No disruptions experienced or negligible disruptive effects felt.
- Case 2: Containers stored at finished goods warehouse for 15 days and stayed for additional six hours before being trucked to PSA and used SL1 for sea transportation to Guangzhou port. Twelve hours delays experienced.
- Case 3: Containers stayed at finished goods warehouse for 15 days then trucked to PSA. However, as PSA experienced a major accident in its waterway and investigation is undergoing, PSA is temporary closed. SPM decides to transport the containers through Jurong Port instead. As SL1 does not call at Jurong Port, containers are then retrucked from PSA to SPM's warehouse for unstuffing and restuffing to be transported by SL2 to Guangzhou port. A second shipping line (SL2) offers transportation to Guangzhou at a higher charge; a difference of \$210 per TEU.
- Case 4: Containers stayed at finished goods warehouse for 15 days then trucked to PSA. PSA is closed due to port strike, and SPM decides to wait, containers are retrucked from PSA to SPM's warehouse. However, the crisis escalated and the issues remain unresolved after 10 days. SPM decides to transport the containers through Jurong Port instead. As SL1 does not call at Jurong Port,

containers are then retrucked from PSA to SPM's warehouse for unstuffing and restuffing to be transported by SL2 to Guangzhou port. SL2 offers transportation to Guangzhou at a higher charge; a difference of \$210 per TEU.

The expression of total costs comprises three components – production cost, warehousing cost and transportation cost incurred. A breakdown of each type of costs in Table J.1 shows the costs components involved. Figure J.4 shows the cargo flow as each cost component is incurred. Costs for the four cases will be calculated and a comparison will be made to examine the amount of savings generated should PDM be implemented. The assumptions of the supply chain system are as follows:

1. Disruptions at the port are the only disruptive event encountered from the time finished product enters warehouse till it reaches customer's choice of port.
2. Information is shared truthfully among all involved parties.
3. Lead time and customers' orders are independent.
4. Finished products are left in warehouse for additional 10 days, after which alternative plans will be activated by SPM.
5. Alternative plans are executed without disruptions.
6. All involved ports and transportation service entities are willing to accept cargo.
7. Cargo handling rates are the same at all involved ports.
8. No berthing and cargo handling constraints at all involved ports.
9. Tariffs and port charges of all involved ports are the same.
10. Sea freight and inland transportation costs do not fluctuate due to the crisis/disruption.
11. Transportation on alternative routes does not encounter further disruptions.

12. Customers are infinitely patient and will not switch to other suppliers.

13. All months have 30 days.

Table J.1: Costs Involved in Simulation

Components of Costs Involved:		
1. Production Cost	2. Warehousing Cost a. Storage - <i>Packaging bags</i> - <i>Forklift handling</i> b. Container stuffing c. Manpower - <i>Normal working hours</i> - <i>Over time charges</i> d. Miscellaneous services - <i>Restacking of palletized cargoes (when applicable)</i> - <i>Supply of labors & material for stretch wrapped</i> - <i>Cleaning of empty pallet</i> e. Inventory holding	3. Transportation Cost a. Trucking to port b. Port charges c. Sea freight d. Stuffing/unstuffing at port (when applicable)

Source: Author, synthesized from interviews with SPM's employee

Figure J.4: Processes that Incur Costs

Source: Author, synthesized from interviews with SPM's employee

In addition, the following symbols and notations of parameters will be used in the calculations:

1. PC = Production cost
2. WC = Warehouse Cost
3. W_s = Warehouse storage cost
4. $W_{s.PB}$ = Cost of packaging bags
5. $W_{s.FH}$ = Forklift handling cost
6. W_{CS} = Container stuffing in warehouse
7. W_{MP} = Manpower charges
8. W_N = Normal working hours
9. W_{OC} = Overtime charges
10. W_{MS} = Miscellaneous warehouse charges

11. $W_{MS,R}$ = Restacking of palletized cargo
12. $W_{MS,SW}$ = Supply of labor and materials for stretch wrapped
13. $W_{MS,C}$ = Cleaning of empty pallet
14. W_{IH} = Inventory holding cost
15. T = Transportation costs
16. T_T = Trucking
17. T_{pc} = Port charges
18. T_{SF} = Sea freight
19. $T_{S/US}$ = Stuffing/Unstuffing
20. X = Customer order (TEU)
21. X_{MT} = Customer order (MT)
22. N = Number of pallets in each 20' container
23. w = Number of days product spent at warehouse
24. t = Number of days from production completion to delivery to destination

The exact rate for each cost component is not shown as the company has requested not to release the figures. According to the data provided by SPM, the parameters follow the formulae below:

$$N = 16,$$

$$PC = 1650X_{MT},$$

$$X_{MT} = 16X,$$

Total Costs

$$\begin{aligned}
&= \sum_{i=1}^X (\text{PC}_i + \text{WC}_i + \text{TC}_i) \\
&= \sum_{i=1}^X \left([1650(\text{X}_{\text{MT}})_i + (\text{W}_{\text{s.PB}})_i + (\text{W}_{\text{s.FH}})_i + (\text{W}_{\text{CS}})_i + (\text{W}_{\text{N}})_i + (\text{W}_{\text{OC}})_i + \right. \\
&\quad \left. (\text{W}_{\text{MS.R}})_i + (\text{W}_{\text{MS.SW}})_i + (\text{W}_{\text{MS.C}})_i + (\text{W}_{\text{IH}})_i + (\text{T}_{\text{T}})_i + (\text{T}_{\text{pc}})_i + \right. \\
&\quad \left. (\text{T}_{\text{SF}})_i + (\text{T}_{\text{S/US}})_i \right]
\end{aligned}$$

Figures J.5, J.6 and J.7 depict the graphical comparison of the costs of total costs, warehousing costs and transportation costs incurred respectively of the four cases, while Table J.2 shows costs in exact figures. As can be observed from Figure J.5, the gaps between total costs of each case become larger when the order increases in size and Case 4 incurs the highest total costs. The large difference between Case 3 and 4 is mainly due to the additional 10-day inventory holding costs experienced in Case 4. The graphs of Case 1 and Case 2 lie very close to each other because of the similarities in circumstances shared by both. The only difference between the two cases is that there is a 12-hour delay in Case 2 and this gives rise to higher inventory holding costs and higher warehouse storage costs as shown by the figures in Table J.2. The graphs for total costs are broken down into graphs for warehousing costs and transportation costs for a closer look to account for the observations in Figure J.5.

The graphs for warehousing costs are shown in Figure J.6. The graph of Case 4 shows that highest warehousing costs are incurred mainly due to the additional 10-day storage at warehouse while the lowest occurs in Case 1. The differences among Cases 1, 2 and 3 are due to whether unstuffing and restuffing processes are required and these in turn involve manpower which constitutes additional charges as the order size increases. While it is not apparent in Figure J.6, the figures in Table J.2 show that warehousing costs of Case 2 are higher than that of Case 3 for the first two TEUs. For orders with three TEUs or more, the warehousing costs of Case 2 become lower than that of Case 3. This trend is attributed by the unstuffing and restuffing rates experienced in Case 3 and the duration of delays in Case 2. Therefore, the warehousing costs for different duration

of delays were investigated in Table J.3, with those that are higher than that of Case 3 highlighted. This sets the boundary at which warehousing costs of Case 2 exceeds that of Case 3.

On the other hand, the graphs for transportation costs as displayed in Figure J.7 show that there are only two lines. Cases 1 and 2 share the same graph as the transportation means and plans for these two cases are the same. Due to the deviation in transportation routes and shipping lines from the initial plan, the graphs of Cases 3 and 4 lie on each other. The higher transportation costs of Cases 3 and 4 as compared to Cases 1 and 2 is explained by the extra unstuffing and restuffing of products at the port as well as two additional trucking legs (from PSA to warehouse and from warehouse to Jurong Port).

Figure J.5: Total Costs of Each Case

Source: Author

Figure J.6: Warehousing Costs of Each Case

Source: Author

Figure J.7: Transportation Costs of Each Case

Source: Author

The results of this section reiterate the significance of port resilience in supply chain continuity. The marginal costs differences as depicted by the graphical representations show that the increase in costs in an undesirable event is mainly attributed to higher warehousing storage costs, inventory storage costs, manpower costs as well as transportation costs. The duration of delays encountered will likely affect the management decision to stay put or deploy alternatives as the costs incurred involves the amount of additional work and rework to be carried out and the charges of alternative plans. In summary, assuming no other types of disruptions are encountered in the supply chain, a port user will experience additional costs when a PSCD threat results in undesirable consequences ranging from a slight delay to loss of port service. This numerical example is simulated from the perspective of the port user and since the capacity of a port is much higher than the limit imposed in the simulation, that is 20 TEUs, the impact on all industries involved and users alike is expected to be comparatively dire. The limitation of this simulation exercise is that the outcome of the model in numerical simulation exercise is predetermined and hypothetical. Future research can be conducted to carry out simulation to validate the model by using realistic inputs and output to determine whether the desired outcome is achieved, such that the cost impact of port users and port operators can be more realistically portrayed.

Table J.2: Summary of Costs

TEUs	Warehousing Costs				Transportation Costs				Total Costs			
	Case 1	Case 2	Case 3	Case 4	Case 1	Case 2	Case 3	Case 4	Case 1	Case 2	Case 3	Case 4
1	\$12,661.83	\$13,074.09	\$12,908.06	\$21,153.14	\$706.88	\$706.88	\$1,723.75	\$1,723.75	\$15,431.21	\$15,843.46	\$16,694.31	\$24,939.39
2	\$25,323.67	\$26,148.18	\$25,912.30	\$42,402.48	\$1,413.75	\$1,413.75	\$3,447.50	\$3,447.50	\$30,862.42	\$31,686.93	\$33,484.80	\$49,974.98
3	\$37,985.50	\$39,222.26	\$39,012.74	\$63,748.01	\$2,120.63	\$2,120.63	\$5,171.25	\$5,171.25	\$46,293.63	\$47,530.39	\$50,371.49	\$75,106.76
4	\$50,647.34	\$52,296.35	\$52,209.38	\$85,189.73	\$2,827.50	\$2,827.50	\$6,895.00	\$6,895.00	\$61,724.84	\$63,373.85	\$67,354.38	\$100,334.73
5	\$63,309.17	\$65,370.44	\$65,502.20	\$106,727.65	\$3,534.38	\$3,534.38	\$8,618.75	\$8,618.75	\$77,156.04	\$79,217.32	\$84,433.45	\$125,658.90
6	\$75,971.00	\$78,444.53	\$78,891.22	\$128,361.76	\$4,241.25	\$4,241.25	\$10,342.50	\$10,342.50	\$92,587.25	\$95,060.78	\$101,608.72	\$151,079.26
7	\$88,632.84	\$91,518.62	\$92,376.43	\$150,092.06	\$4,948.13	\$4,948.13	\$12,066.25	\$12,066.25	\$108,018.46	\$110,904.24	\$118,880.18	\$176,595.81
8	\$101,294.67	\$104,592.71	\$105,957.84	\$171,918.55	\$5,655.00	\$5,655.00	\$13,790.00	\$13,790.00	\$123,449.67	\$126,747.71	\$136,247.84	\$202,208.55
9	\$113,956.50	\$117,666.79	\$119,635.43	\$193,841.24	\$6,361.88	\$6,361.88	\$15,513.75	\$15,513.75	\$138,880.88	\$142,591.17	\$153,711.68	\$227,917.49
10	\$126,618.34	\$130,740.88	\$133,409.22	\$215,860.12	\$7,068.75	\$7,068.75	\$17,237.50	\$17,237.50	\$154,312.09	\$158,434.63	\$171,271.72	\$253,722.62
11	\$139,280.17	\$143,814.97	\$147,279.21	\$237,975.19	\$7,775.63	\$7,775.63	\$18,961.25	\$18,961.25	\$169,743.30	\$174,278.10	\$188,927.96	\$279,623.94
12	\$151,942.01	\$156,889.06	\$161,245.38	\$260,186.45	\$8,482.50	\$8,482.50	\$20,685.00	\$20,685.00	\$185,174.51	\$190,121.56	\$206,680.38	\$305,621.45
13	\$164,603.84	\$169,963.15	\$175,307.75	\$282,493.91	\$9,189.38	\$9,189.38	\$22,408.75	\$22,408.75	\$200,605.71	\$205,965.02	\$224,529.00	\$331,715.16
14	\$177,265.67	\$183,037.24	\$189,466.31	\$304,897.56	\$9,896.25	\$9,896.25	\$24,132.50	\$24,132.50	\$216,036.92	\$221,808.49	\$242,473.81	\$357,905.06
15	\$189,927.51	\$196,111.32	\$203,721.06	\$327,397.40	\$10,603.13	\$10,603.13	\$25,856.25	\$25,856.25	\$231,468.13	\$237,651.95	\$260,514.81	\$384,191.15
16	\$202,589.34	\$209,185.41	\$218,072.01	\$349,993.44	\$11,310.00	\$11,310.00	\$27,580.00	\$27,580.00	\$246,899.34	\$253,495.41	\$278,652.01	\$410,573.44
17	\$215,251.18	\$222,259.50	\$232,519.15	\$372,685.66	\$12,016.88	\$12,016.88	\$29,303.75	\$29,303.75	\$262,330.55	\$269,338.88	\$296,885.40	\$437,051.91
18	\$227,913.01	\$235,333.59	\$247,062.48	\$395,474.08	\$12,723.75	\$12,723.75	\$31,027.50	\$31,027.50	\$277,761.76	\$285,182.34	\$315,214.98	\$463,626.58
19	\$240,574.84	\$248,407.68	\$261,702.00	\$418,358.70	\$13,430.63	\$13,430.63	\$32,751.25	\$32,751.25	\$293,192.97	\$301,025.80	\$333,640.75	\$490,297.45
20	\$253,236.68	\$261,481.77	\$276,437.72	\$441,339.50	\$14,137.50	\$14,137.50	\$34,475.00	\$34,475.00	\$308,624.18	\$316,869.27	\$352,162.72	\$517,064.50

Source: Author

Table J.3: Warehousing Costs for Case 2

TEUs	Delays (Hours)											
	2	4	6	8	10	12	14	16	18	20	22	24
1	\$12,730.54	\$12,799.25	\$12,867.96	\$12,936.67	\$13,005.38	\$13,074.09	\$13,142.80	\$13,211.51	\$13,280.22	\$13,348.92	\$13,417.63	\$13,486.34
2	\$25,461.09	\$25,598.50	\$25,735.92	\$25,873.34	\$26,010.76	\$26,148.18	\$26,285.59	\$26,423.01	\$26,560.43	\$26,697.85	\$26,835.27	\$26,972.69
3	\$38,191.63	\$38,397.76	\$38,603.88	\$38,810.01	\$39,016.14	\$39,222.26	\$39,428.39	\$39,634.52	\$39,840.65	\$40,046.77	\$40,252.90	\$40,459.03
4	\$50,922.17	\$51,197.01	\$51,471.84	\$51,746.68	\$52,021.52	\$52,296.35	\$52,571.19	\$52,846.03	\$53,120.86	\$53,395.70	\$53,670.53	\$53,945.37
5	\$63,652.71	\$63,996.26	\$64,339.81	\$64,683.35	\$65,026.90	\$65,370.44	\$65,713.99	\$66,057.53	\$66,401.08	\$66,744.62	\$67,088.17	\$67,431.71
6	\$76,383.26	\$76,795.51	\$77,207.77	\$77,620.02	\$78,032.28	\$78,444.53	\$78,856.78	\$79,269.04	\$79,681.29	\$80,093.55	\$80,505.80	\$80,918.06
7	\$89,113.80	\$89,594.76	\$90,075.73	\$90,556.69	\$91,037.65	\$91,518.62	\$91,999.58	\$92,480.55	\$92,961.51	\$93,442.47	\$93,923.44	\$94,404.40
8	\$101,844.34	\$102,394.02	\$102,943.69	\$103,493.36	\$104,043.03	\$104,592.71	\$105,142.38	\$105,692.05	\$106,241.72	\$106,791.40	\$107,341.07	\$107,890.74
9	\$114,574.89	\$115,193.27	\$115,811.65	\$116,430.03	\$117,048.41	\$117,666.79	\$118,285.18	\$118,903.56	\$119,521.94	\$120,140.32	\$120,758.70	\$121,377.08
10	\$127,305.43	\$127,992.52	\$128,679.61	\$129,366.70	\$130,053.79	\$130,740.88	\$131,427.97	\$132,115.06	\$132,802.16	\$133,489.25	\$134,176.34	\$134,863.43
11	\$140,035.97	\$140,791.77	\$141,547.57	\$142,303.37	\$143,059.17	\$143,814.97	\$144,570.77	\$145,326.57	\$146,082.37	\$146,838.17	\$147,593.97	\$148,349.77
12	\$152,766.51	\$153,591.02	\$154,415.53	\$155,240.04	\$156,064.55	\$156,889.06	\$157,713.57	\$158,538.08	\$159,362.59	\$160,187.10	\$161,011.60	\$161,836.11
13	\$165,497.06	\$166,390.28	\$167,283.49	\$168,176.71	\$169,069.93	\$169,963.15	\$170,856.37	\$171,749.58	\$172,642.80	\$173,536.02	\$174,429.24	\$175,322.46
14	\$178,227.60	\$179,189.53	\$180,151.45	\$181,113.38	\$182,075.31	\$183,037.24	\$183,999.16	\$184,961.09	\$185,923.02	\$186,884.94	\$187,846.87	\$188,808.80
15	\$190,958.14	\$191,988.78	\$193,019.42	\$194,050.05	\$195,080.69	\$196,111.32	\$197,141.96	\$198,172.60	\$199,203.23	\$200,233.87	\$201,264.51	\$202,295.14
16	\$203,688.69	\$204,788.03	\$205,887.38	\$206,986.72	\$208,086.07	\$209,185.41	\$210,284.76	\$211,384.10	\$212,483.45	\$213,582.79	\$214,682.14	\$215,781.48
17	\$216,419.23	\$217,587.28	\$218,755.34	\$219,923.39	\$221,091.45	\$222,259.50	\$223,427.56	\$224,595.61	\$225,763.66	\$226,931.72	\$228,099.77	\$229,267.83
18	\$229,149.77	\$230,386.54	\$231,623.30	\$232,860.06	\$234,096.83	\$235,333.59	\$236,570.35	\$237,807.12	\$239,043.88	\$240,280.64	\$241,517.41	\$242,754.17
19	\$241,880.32	\$243,185.79	\$244,491.26	\$245,796.73	\$247,102.21	\$248,407.68	\$249,713.15	\$251,018.62	\$252,324.09	\$253,629.57	\$254,935.04	\$256,240.51
20	\$254,610.86	\$255,985.04	\$257,359.22	\$258,733.40	\$260,107.58	\$261,481.77	\$262,855.95	\$264,230.13	\$265,604.31	\$266,978.49	\$268,352.67	\$269,726.86

Source: Author