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Fuzzy comprehensive evaluation of port-centric supply chain disruption threats

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ABSTRACT

A port with reliable operations and management plays a pivotal role in ensuring supply chain continuity, given the integral role of ports in supply chains nowadays. As supply chain parties are closely linked to each other in today's globalised trade, any disruption at ports will have negative impacts on other supply chain players. This paper evaluates the likelihood and severity of these port-centric supply chain disruption (PSCD) threats using data collected from port operators worldwide through a survey questionnaire. The PSCD threats were first identified from existing literature and interviews and subsequently structured into the questionnaire for the respondents to rate these threats' likelihood and consequence. The data were analysed using fuzzy comprehensive evaluation method. Each threat was ranked according to the relative risk value assigned to it. The results show that the combined risk level rated by port operators is between low and medium, with threats pertaining to planning and infrastructure having the greatest contribution to the disruptions, and those related to security the lowest. Congestion within terminals, congestion at hinterland transfer, shortage of facilities or equipment, port equipment breakdown and inadequate port cargo-handling equipment are the key factors in causing disruptions. Indicators are then presented to act as early-detection of these threats to manage supply chain disruptions.

1. Introduction

Seaports are critical transport nodes as around 90% of the world trade volumes are transported by sea (International Chamber of Shipping, 2015). With increasing integration of ports into international supply chains, the scale of disruptions that originate from port operations continues to escalate. In many earlier studies, ports are treated as integrated logistics centres that offer multifunctional roles (UNCTAD, 1990; UNCTAD, 1999; Pettit and Beresford, 2009). In essence, ports have become large-scale transport nodes with new functions being introduced by containerisation, inland terminals and supply chain management (Felsenstein et al., 2014).

Ports are susceptible to operational risks due to the nature of their business. For instance, cargo handled at ports includes hazardous substances or dangerous goods (DG), and containerised cargoes which are not physically visible. The handling of DG requires specialised knowledge and effective communication, while non-visibility of containerised cargo means shippers' declarations about the cargo's nature are used to assign the position of containers in the yards and aboard vessels. Ports are also platforms where communications flow across intertwined parties that include the shippers, cargo owners, shipping lines, terminal operators, truckers, stevedores and other logistics service providers. Given the complexities and diverse range of port operations, ports are quite susceptible to operational risks which thus impact on supply chain continuity. In this study, man-made operational risks

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that threaten the supply chain continuity are investigated, with the aim of better understanding such risks so that risk mitigation methods can be devised accordingly. These risks are referred to as port-centric supply chain disruption (PSCD) threats in this paper. A PSCD threat has the potential of disrupting supply chains. Given that business competition is very much about supply chains nowadays and ports are an integral player in the supply chains, the scope of this study is on the threats that have an impact on supply chains. The term "port-centric supply chain disruption threats" is to add more clarity to the assumption that many port-related incidents may disrupt supply chains. The consequences of PSCD threats have worsened in light of changing roles of ports, and the impacts of PSCD threats remain relatively uncharted. Herein, it is clearly of strategic value to establish clear triggers for PSCD threat detection so that actions can be in place to avoid or reduce disruptions.

In this study, the PSCD threats and their potential effects on supply chain continuity are first identified from the existing literature. The validation was done through in-depth interviews with seven experts from port management in Singapore, Vietnam and Australia. Subsequently, the PSCD threats were then assessed through survey questionnaire answered by port operators worldwide. To handle the complexities in port operations, fuzzy comprehensive evaluation based on fuzzy mathematics theory could be used which, according to Cui (2012), describes the uncertain states of things in a quantitative way. Indicators of PSCD threats are established which can serve to enhance port resilience and provide a reference for risk analysis and risk management at ports. The paper is organised as follows. First, related literature is reviewed to determine the PSCD threats and their potential impact. Next, the data collection process is explained with details on the procedures. The results are then analysed using fuzzy comprehensive evaluation to reveal the risk level of PSCD threats as well as the relative risk value for each threat. Indicators of the PSCD threats are then presented for the management of disruptions. The paper concludes with research limitations and future research areas.

2. Literature review

Port risks can come from the peripheral environment, internal operations and through incongruous communications during the interaction between internal and external parties. This section highlights the outcome of the literature review on PSCD threats and their continuity on supply chain; they are subsequently grouped into the following four main themes of port risks – infrastructure, planning, manpower and security.

There are deficiencies that are directly affecting the functionality of the port. Table 1 provides a list of supply chain disruptions resulting from port-centric events. These are threats that tend to be infrastructure-related, such as the physical equipment, facilities and information and communication devices, which play an essential role in facilitating port services.

Over-aged, defective or inadequate cargo handling equipment at the ports reduces productivity and efficiency of port operations and exposes cargo to possible damage and loss (Igbokwe, 2001). Marsh and McLennan Companies (2008) pointed out that cargo loss and damage can be due to cargo handling accidents, effects from equipment failure, mishandling of equipment, among other direct and indirect causes such as terrorism and theft. As port accidents reduce efficiency at the port and incur accident costs, safety level at the port affects total transport cost borne by the supply chain parties (Hassanzadeh, 2013). The Mumbai Port and Jawaharlal Nehru Port Trust had to be shut down and missing containers were reported due to an oil spill caused by a vessel collision (NDTV Correspondent, 2010). In another accident involving vessel collision, a wharf at Port Lincoln had to be closed to contain oil spill after it was damaged (Pedler, 2010). To better manage vessel entry and departure in order to avoid such accidents, information and communications technology has been applied in the traffic monitoring at ports and this initiative has yielded positive results in reducing accident rates and improving vessel movement in the waterways (The World Bank, 2004).

With the increasing types of services assumed by ports, a port is required to manage a diverse range of processes, on top of overseeing the maintenance of physical infrastructure. Operational activities within the terminals include positioning of containers at the yard space, loading and discharging of cargo onto berths, transportation and storage of cargo in the terminals (Burns, 2015). These are closely linked to the space planning at the yard, berths and warehouses (Kim and Lee, 2015). The planning of existing infrastructure and resources will affect the availability of equipment and workforce. The presence of congestions can be an indication of insufficient resources or facilities and are typical results of improper planning and forecasting. In recent years, vessel sizes have been increasing at a rate faster than ports can accommodate. With the growth of vessel sizes built to save costs and achieve greater economies of scale, ports have been struggling to serve these mega-ships, resulting in rising supply chain risks related to mega-ships as well (OECD, 2015). When a port system fails to change to adapt to high volume growth, cargo cannot be cleared in time for new incoming ones (Igbokwe, 2001) and it can cause port congestions which adds uncertainties to the supply chains (Suwannakij and Javier, 2011). When a port is under-equipped and lacks the adequate links to multi-modal transport corridors, cargo have to undergo extra packing and handling at the port (Igbokwe, 2001; Ocean Shipping Consultants, 2008). This greatly hampers the movement of cargo and rate of clearance, resulting in shipment delays. An estimate by The World Bank indicates delays and inefficiencies arising from inadequate infrastructure amount to 10% of the cost of imported goods (Mooney, 2016). Similarly, resource shortages can also directly result in cargo handling delays (The Journal of Commerce Online, 2010).

Port business is very labour intensive, hence human factors play a crucial role in port accidents. These manpower threats are related to the soft skills of workers throughout the port and are also affected by governmental policies. In late 2014 and early 2015, the massive disruptions caused by the US West Coast port strikes once again brought to attention the importance of ports in supply chains of international freight. As nearly 50% of the United States' cargo are handled at the West Coast ports (LLamasoft, 2016; Stevens, 2015), the disruptions caused retailers to lose billions of dollars in inventory holding costs and lost revenue (Reagan, 2015). Port strikes in Australia is also not uncommon and had left supply chain entities unable to fill orders, resulting in severe breach of contractual obligations (Burgess, 2011). Port operations are also influenced by human factors such as work experience, age, staff training, and the adaptability to new skills and technologies (Fabiano et al., 2010). Fabiano et al. (2010) reported that port accidents tend to occur during the summer months and suggested that accidents are related to workload and productivity increase borne by the port workers. Similarly, Horck (2008) discussed the importance of communication among the workers at the port, maritime education and staff motivation among other soft attributes of individuals in a port.

The importance of incorporating resilience in a port and other supply chain links has been emphasised in many studies ever since the 11 September 2001 attack in New York which brought attention to the exposed vulnerabilites apparent in many systems (e.g. Siggerud, 2007; Price, 2007; Salleh, 2006; Bichou, 2008; Pinto and Talley, 2006). Darbra and Casal (2004) found that there are four