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Enhancing productivity of ship chandlers' trucks at the port for sustainability

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Abstract

Purpose – Ship chandlers' trucks are now facing challenges owing to their job characteristics, which will lead to low productivity of trucks, congestions and pollutions at the port. The aim of this paper is to identify important causes and the effects of low truck productivity at the port under the demand of sustainable development.

Design/methodology/approach – Based on the literature review, potential causes and relevant analysis are developed and carried out by using a systematic approach, incorporating in-depth interviews with experts, cause analysis and risk management process.

Findings – Results from the research framework showed that a lack of communication with the port, late arrival of ships, truck congestion and fragmented deliveries are the most important factors that led to low truck productivity at the port. A solution that combines an integrated system that shares real-time information with the port, a consolidation hub and a truck-pooling platform is proposed to comply with green port concepts, together with factors considerations.

Originality/value – Although the operation of ship chandlers' trucks is a derived business in overall port operations, it is an indispensable element at the port. The findings present a new insight to the relationship between ship chandlers' trucks productivity and port operation efficiency for industry practitioners and port policymakers.

Keywords Productivity, Cause analysis, Port congestion, Ship chandlers' truck, Risk management

Paper type Research paper

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1. Introduction

The productivity of ship chandlery services has become an important aspect of port operations (Chopra, 2019). A ship chandler can be defined as a maritime service company that deals with supplying commodities, such as provisions, marine supplies, spare parts and personal items for ships and its crew (Chopra, 2019). In other words, it can be described as a goods retailer that provides a niche service to ships which require the purchase of necessary equipment and supplies from a single supply source before leaving the port. Although ship chandlers work closely with ships, they do not have an accurate berthing schedule of the ships at the port. As a result, ship chandlers are required to be operational 24 h daily, which means they have to be well equipped and staffed to be able to deliver the large quantity stocks and supplies via its truck to the port terminal when they are called for.

At the Port of Singapore, ship chandlers can deliver the supplies directly either via supply boats to ships that are at anchorage in Singapore waters, or by trucks at the container terminal for ships that are berthed. Especially for liner container ships, the ship chandlers have to send their trucks to the port cranage area for delivery. These trucks would arrive early at the port to wait for their turn in a first come first serve basis. However, the time spent waiting in the queue depends on how soon the ship they serve completes its loading and discharging operations.

Although ship operations are commonly regarded as one of the bottlenecks at the port owing to shortage of terminal resources (Sharif *et al.*, 2011), it has the highest priority (Phan and Kim, 2015). Thus, the delivery of supplies onboard the ship can only be done after the last loading or discharging movement and before the ship leaves for the next port of call. Furthermore, there can be unforeseen circumstances at the port which lowers the productivity of ship chandlers' trucks, leading to truck congestion. Such congestion occurs when there are more than two resource users interfering with one another, leading to the increment of operational times (Talley and Ng, 2016). Hence, these will cause a negative effect not only to the ship chandlers alone but also have impact on sustainable port development strategies. On one hand, one of the embodiments to measure port sustainability is the efficiency of port's loading and discharging operations. Considerable delays resulting from such operations will increase the number of trucks staying at the port simultaneously, which may be co-responsible for the delay of overall port operations. On the other hand, as the function of ship chandlers' truck is to serve the ships at the port, once delayed, it may also produce a negative impact on the ships that are at berth or at anchorage, which are considered to be the main sources of vessel emissions (Weng *et al.*, 2020). In a word, port sustainability and ship chandlers' trucks productivity are closely related. One of the main concerns that can affect port's efficiency and sustainability is the congestion factors.

Aligning with above concept, the aim of this study is to improve the productivity of ship chandlers' trucks at port based on empirical studies, in order to reduce congestion, thereby resulting in less pollution and greater efficiency. In general, productivity is treated as a tool to measure the efficiency of inputs when outputs are produced (Obed, 2013). In this study, the productivity of trucks refers to the time taken for each truck to deliver the supplies and its turnaround time at the port. This determines the number of trips each of the trucks could make in a day.

Thus, this study intends to find out the behaviors that led to the low productivity which are happening within the premises of the port terminal and seeks to provide alternatives to ship chandlers to improve truck productivity and port sustainability. This study seeks to answer the following research objectives:

- identify the important causes of low productivity of ship chandlers' trucks that lead to port congestion;
- identify possible approaches to increase the productivity of ship chandlers' trucks in an effort to minimize congestion and maximize port efficiency; and
- identify the factors that would influence ship chandlers in order to ensure successful implementation of the proposed approaches.

Particularly, this study will focus on the Port of Singapore, a global city that relies heavily on its port for economic development. The findings in this research serve as a basis to facilitate studies on a larger scale to ascertain the relationship between ship chandlers' trucks productivity and port operation efficiency for quantitative analysis. The remainder of the paper is organized as follows. Section 2 provides a literature review of relevant background to this study. Section 3 details the methodology with the source of data. Section 4 contains research results and discussion about practical and managerial implications. Finally, conclusions of this study are given in Section 5.

2. Literature review

To identify the potential causes that affect the normal operations of ship chandlers' trucks at the port, this section reviews the literature related to port congestion, port sustainability and measures on addressing port-related problems.

2.1 Port congestion

The term "port congestion" is often referred to a situation where ships, trucks or other players have to queue outside or inside a port while waiting for their turn to be operated. According to the trend of port integration, there have a number of studies on port congestion on conceptual levels in the past decade. A study by Talley and Ng (2016) has defined two kinds of port congestion: port single-service congestion and port multi-service congestion. Gidado (2015) applied the concept of variations in the turnaround time of ships and cargo in comparison with the port's capacity to identify the active factors that caused the congestion in the context of Africa ports. The study showed that there are six prevalent types of congestion in African ports, including the ship berth congestion, ship work congestion, vehicle gate congestion, vehicle work congestion, cargo stack congestion and ship entry or exit route congestion. Meersman *et al.* (2012a) have categorized the levels of congestion into eight categories, namely, maritime access routes, locks, berths, loading and unloading, storage, customs inspection, hinterland loading and unloading and hinterland connections.

Although many factors can trigger congestion at ports, it has been widely accepted that the concentrated arrivals of road truck at the highest congested time windows is the main reason. This, reflects the operation modes of ship chandlers' trucks. Moreover, there are many other reasons for truck congestions such as growing container volume, improper planning and time loss (Meersman *et al.*, 2012b; Gidado, 2015; Cordero, 2014; Kwateng *et al.*, 2017). However, the causative factors for port congestion vary in different ports. After conducting a survey among five major ports in Africa, Gidado (2015) found that port congestion in Africa is unavoidable as it occurs seasonally. This is largely owing to improper planning, inadequate equipment or shortage of ancillary infrastructure that is required to support the port. According to Cordero (2014), the issue of port congestion in America was mainly because of the growth of container volume. Furthermore, based on the development of containerization at port, Kozan (2000) found that there are six main factors that contribute to the low efficiency of the seaport container terminals in Australia and presented a decision support system to address the issues.

2.2 Port sustainability

There are three pillars of sustainable development, namely, environmental sustainability, economic sustainability and social sustainability (AAPA, 2007). Indeed, the goals of each of the three pillars in the context of ports have attracted many attentions these years. Ignaccolo *et al.* (2020) have developed an A-S-I (Avoid Shift Improve) port sustainable framework to improve the operation efficiency at two ports of Catania and Augusta. In their research, using the port infrastructure to minimize congestion and information campaign were both considered as the "SHIFT" modes about environmental and social sustainability, which are in line with this study. Without exception, port congestion could affect port sustainability through different stakeholders. Meersman *et al.* (2012a) indicated that from the shipping companies' perspectives, congestion increases the time both staffs and ships spent at port, leading to a higher cost. In addition, this causes problems to terminal operators, as they have to adjust their schedule for the ships which are affected by congestion. As a result, Meersman *et al.* (2012a) further concluded that the delays from port congestion may cause a chain effect which will be felt by other actors elsewhere in the maritime transport chain, such as the hinterland transportation. According to Saharidis and Konstantzos (2018), truck operation is also exposed to the effects of port congestion as delays create a long line of queue for the arriving trucks to load the containers, which will emit greenhouse gases owing to frequent stop and go motions at the port. Based on above observations, it is appropriate to take the realities and stakeholders' needs into consideration on the development of marine sustainability (Hai and Speelman, 2020).

2.3 Measures on addressing port-related problems

As discussed above, with the continuous growth in container volume, many ports are facing congestion in the terminal. Nowadays, the port activities have reached a degree of complexity that there are many solutions regarding port congestion (Gidado, 2015). To reduce port congestion, some researchers have investigated this phenomenon, using different time-varying methods. For example, Chen and Jiang (2016) conducted a truck congestion study at the port and proposed a framework for managing truck arrivals with a time window based on truck vessel service relationship. The framework outlines the use of vessel-dependent time window (VDTW) method, which not only can be used to minimize air pollution and congestion but also can improve the planning collaboration between the land and seaside operations in a seaport. Based on the truck's time-dependent queuing characteristic, Chen *et al.* (2011) studied the best pattern of time-varying tolls at the port. A nonlinear programming model was developed with the objectives to minimize the total truck turnaround time and discomfort due to shifted arrival times. Another approach for managing port congestion explored by researchers is adopting the truck appointment system (TAS), which is now a common IT system used by many ports, such as ports of Mexico and Italy (Caballini *et al.*, 2020) and Port of Los Angeles (Torkjazi *et al.*, 2018).

Port congestion is one of the bottlenecks in the port-centric supply chain, and majority of the papers use the mathematical optimization techniques such as the VDTW or TAS to tackle this problem. However, to our best knowledge, there are very few studies using management tools to solve other port related problems at the operational level. For example, a six-sigma framework proposed by Nooramin *et al.* (2011) was used to reduce truck congestion in marine container terminals, with the objective of minimizing the average number of trucks in queue and waiting time in the container terminal. Jiang *et al.* (2018)

developed a SCOR-AHP risk management model combines supply chain operation reference model (SCOR), supply chain model and analytic hierarchy process (AHP) method to evaluate enterprise supply chain risk at Qingdao Port.

Addressing the gaps in the current literature, this study applies cause analysis and risk management techniques into the definition of main causes for low productivity of ship chandlers' trucks at Singapore Port. Fishbone diagram will be used in cause analysis to identify the causes of low productivity of ship chandlers' trucks. The "Fishbone diagram" or sometimes referred to as "Ishikawa Diagram" was developed by Kaoru Ishikawa, which is used to show the relationships between causes and effects qualitatively (Luo *et al.*, 2007). As one of the seven tools of quality management, it can help to visualize and indicate the seemingly unrelated factors that result in impacts (Ku and Chen, 2013). Risk management can be defined as the process of taking strategic steps to identify, assess and mitigate the risks involved in a process (Kaplan and Mikes, 2012; Wang and Huang, 2005). There are various kinds of quantitative and qualitative techniques to assist risk management experts to conduct risk assessment research. In the maritime domain, Mokhtari *et al.* (2021) used a security threat matrix to design a security risk management framework in Sultanate of Oman to access its security threats. According to ABS's guide for risk evaluations of marine-related facilities, once the estimated frequency and consequence of each risk are generated, the most intuitive way for risk evaluation and presentation is to multiply the frequency by each consequence value (ABS, 2003).

To summarize, though the topic of port congestion has been covered extensively in the current literature reviews, most of the literature mainly focus on port congestion relating to ships and covers truck congestion caused by container trucks at the port. To date, the study of ship chandlers' trucks supplying marine supplies to ships at the port is still missing, which remains a problem. Although the operation of ship chandlers' trucks is a derived business in overall port operations, it is an indispensable element at the port. Meanwhile, owing to the position of ship chandlers' trucks in the port system, solutions such as off-peak truck deliveries and time-varying methods are not feasible. Hence, this study seeks to fill the gap by investigating how to improve the productivity of ship chandlers' trucks to mitigate the congestion at the port.

3. Methodology

For this study, a systematic method approach has been applied to address the three research objectives. To propose proper solutions, we first identify the causes of port congestion based on the literature review and the outcomes of the interviews with experts in the industry. Then, a Fishbone diagram is developed, and risk management tools are applied to find out the main causes, and after that, solutions are proposed to improve the low truck productivity. The approach also concludes with factors considerations that could ensure its successful implementation.

The Fishbone diagram developed in this study can help to identify all factors that become causes of the problem we need to investigate. Just as its name, the structure of a Fishbone diagram is a complete barbed fish bone. After drawing the accidents or results with accurate language at the right side of the Fishbone diagram, the leading causes can be grouped into different categories in the "ribs."

The risk management techniques that were used in this research comprise of risk matrix and risk score table. The risk matrix consists of a graph in which the likelihood of the occurrence (from unlikely to high likely) is at the y-axis, and the consequence (from very low to very high) is at the x-axis (Duijm, 2015). The purpose of a risk matrix in this paper is to rank the findings of both likelihood and consequences obtained from the questionnaires. In order to get quantitative and exact results, a risk score table was used to calculate the "scores" of each potential cause by multiplying the likelihood and consequences of the risk (Duijm, 2015). Through calculation, these causes were then arranged according to the risk scores in descending order, which helped to determine the most important causes of low productivity.

Through the application of the Fishbone diagram, risk matrix and risk score table, the main causes for low productivity of ship chandlers' trucks were determined. Possible solutions were also discussed to solve the issue based on the interview results and the literature review, along with the factors that would influence ship chandlers to implement such approaches.

4. Results

4.1 Data collection

For this research, both primary and secondary data were collected. Secondary data was collected from literature review to identify possible causes of low truck productivity at the port, and primary data was collected via face-to-face interviews with two groups of participants, including the employees of the ship supplies companies and a maritime industry expert.

Three ship employees (one chief executive officer, a business analysis and an operation executive) of three supplies companies and one maritime industry expert were interviewed. These interviews were semi-structured in which a list of questions was prepared and asked during the interviews. The combined duration of each interview and survey took about 40 min. Table 1 lists the profile of the interviewees in the study.

4.2 Results of the research process

4.2.1 Results of the interview. As described in Section 3, the collected quantitative and qualitative data were combined from the interview and literature review. A summary of the highlights obtained from the interviews with the employees of the ship supplies companies and a maritime expert are illustrated in Table 2.

4.2.2 Causes analysis. The causes of low productivity of ship chandlers' trucks at the port were identified and verified through the in-depth interviews. Figure 1 presents a Fishbone diagram to identify the potential causes of low productivity of ship chandlers' trucks. The potential causes of low productivity of ship chandlers' trucks were broken down into four categories according to the classification criteria of Fishbone diagram: port, ship, ship chandlers' trucks and inspections. Particularly, the category "inspections" includes custom inspections and crew inspection of items, which were inputs recommended by the participants that helped to enhance this study. For easier reference for follow-up analysis, the potential causes have been labeled from A1 to A15, which can be seen in Table 3.

Participant	Company status	Position	Exp. (yrs.)
AA	Ship chandler, major player, operating more than 35 years	Business analyst	7
BB	Digital technology company, new player in the ship industry	Chief executive officer (CEO)	3
CC	Ship chandler, operating more than ten years	Operations executive	3
DD	Polytechnic	Senior lecturer	20

Table 1. Profile of the participants in the interviews

Respondent	Company	Highlights
AA	A: Ship chandler	Impact of low productivity of trucks to operation: – Affects operation cost and fixed cost of maintaining trucks Key factors that lead to low productivity of trucks: – Inaccuracy of vessel ETA, truck congestion – Lack of communication with the port – Fragmented deliveries Productivity of trucks can be improved by: – Consolidation of items into a single truck
BB	S: Digital technology company	Key factors that lead to low productivity of trucks: – Lack of reliable information – Fragmented deliveries Productivity of trucks can be improved by: – Integrating systems with the port and truck- pooling initiative Key considerations to implement: – Cost and reliability
CC	W: Ship chandler	Impact of low productivity of trucks to operation: – Affects the delivery schedule and cost Key factors that lead to low productivity of trucks: – Lack of communication and truck congestion Productivity of trucks can be improved by: – Consolidation hub
DD	Z: Polytechnic	Impact of low productivity of trucks to operation: – Affects the crews' morale, and delays can be costly Key factors that lead to low productivity of trucks: – May limit the capacity of the port to run efficiently, and possibly affect the port's reputation Possible factors that may cause delays at the port: – Crew inspection of items and custom inspection The port can help by: – Giving advice on the best timing to enter the port

Table 2.
Summary of the interview results

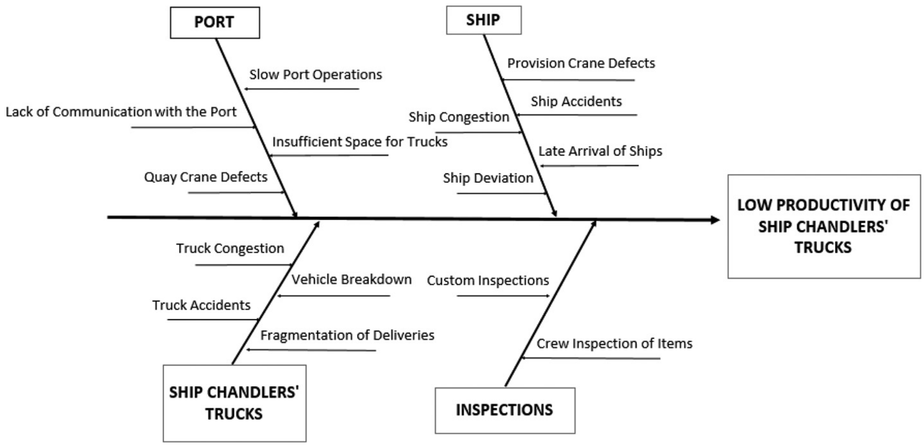

Figure 1.
Fishbone diagram for low productivity of ship chandlers' trucks

To set a priority for the potential causes of low productivity of ship chandlers' trucks, the risk matrix and the risk table have been used. Firstly, from the responses gathered in the questionnaires, the likelihood and consequences of each cause were established. A risk matrix in Figure 2 is used to present the findings.

Results can be seen clearly in Figure 2. Interestingly, there are some causes which rarely happen but may lead to dire consequences. For example, Truck Accident (A3) resulted in the highest consequence score to a ship chandler with regards to time and financial losses, but the likelihood of its occurring is one of the lowest. In fact, these phenomena have practical interpretations. Truck Accident (A3) rarely occurs because the port is a regulated area with a safe speed limit. However, if an accident happens, there would be different types of costs involved to the ship chandler owing to the damaged vehicle and goods. Thus, this explains why Truck Accident (A3) has a low likelihood of occurrence, but high consequences.

Categories	S/N	Potential causes
Ship chandlers' trucks	A1	Truck congestion
	A2	Vehicle breakdown
	A3	Truck accident
	A4	Fragmented deliveries
Port	A5	Lack of communication with the port
	A6	Slow port operations
	A7	Quay crane defects
	A8	Insufficient space for trucks
Ship	A9	Late arrival of ships
	A10	Provision crane defects
	A11	Ship congestion
	A12	Ship accident
	A13	Ship deviation
Inspections	A14	Custom inspections
	A15	Crew inspection of items

Table 3. Potential causes of low productivity of ship chandlers' trucks

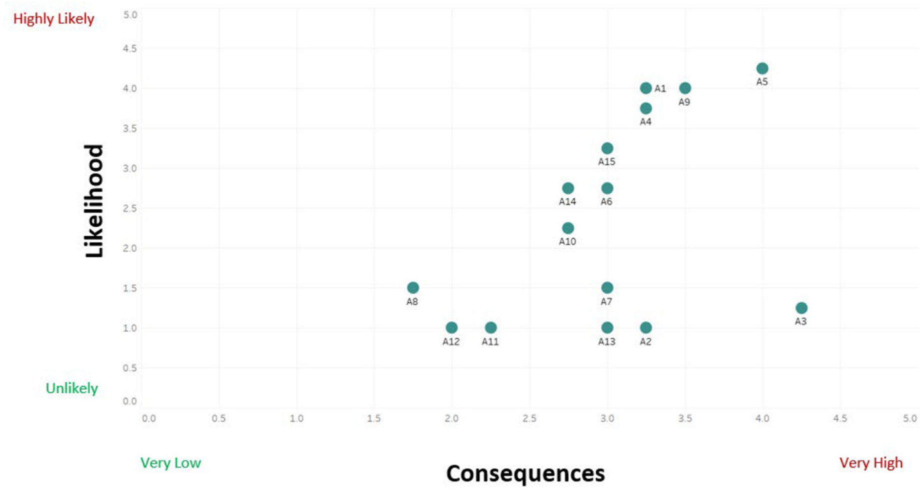

Figure 2. Risk matrix of the potential causes

Secondly, the likelihood and consequence are multiplied to give the risk scores shown in Table 4. The risk scores help determine the most important causes of low productivity of ship chandlers' trucks. According to the risk score table, the causes with risk scores greater than 10.0 are Lack of Communication with the Port (A5), Late Arrival of Ships (A9), Truck Congestion (A1) and Fragmented Deliveries (A4). It appears that all the respondents have agreed that A5, A9, A1 and A4 were the more important factors, with A5 being the most important. It can also be concluded that these factors are interlinked with each other and largely attributed to the lack of communication with the port.

Thus, A5, A9, A1 and A4 are set as the main problems to be solved in this research. The following section explains the reasons behind these four main causes and their impacts on overall port operations.

Lack of communication with the port. Currently, the ship chandlers in Singapore take reference of ship's berthing timings through PORTNET (www.portnet.com/). PORTNET is an online network portal provided by the port that shares information about the ship to its authorized clients. Although PORTNET provides information to the ship chandlers, the data provided could be inaccurate because the port is not releasing real-time information, which may cause information asymmetry between the port and ship chandler companies. Once the ship chandlers' trucks arrive at the port at inappropriate times, they will not only cause port congestion but also reduce the overall port operation efficiency by occupying the terminal space and get in the way of on-going operations at the terminal.

Late arrivals of ships. Late arrivals of ship could be because of many reasons, such as bad weather conditions and detours. For example, stormy weather and rough seas hinder the movement of the ship. To avoid jeopardizing the safety of the crews, the ship must reduce its speed or make a detour to a safer route. However, the relevance of a ship's ETA and its supply trucks has made this process to be a huge system; a slight delay at one part may see effects cascading down the entire network. As a result, late arrivals of ships could lead to a domino effect in overall port operation efficiency, such as increasing trucks' waiting time, generating more emissions at the port and hindering the arrival of other ships.
Truck congestion. As the port does not reveal the schedule for port operations as well as does not provide information on when other ship chandlers' trucks are coming, often of times, there would be a clash of timings between ship chandlers' trucks because all the

Rank	S/N	Cause of low productivity of ship chandlers' trucks	Likelihood	Consequences	Risk score
1	A5	Lack of communication with the port	4.25	4.00	17.00
2	A9	Late arrival of ships	4.00	3.50	14.00
3	A1	Truck congestion	4.00	3.25	13.00
4	A4	Fragmented deliveries	3.75	3.25	12.19
5	A15	Crew inspection of items	3.25	3.00	9.75
6	A6	Slow port operations	2.75	3.00	8.25
7	A14	Custom inspections	2.75	2.75	7.56
8	A10	Provision crane defects	2.25	2.75	6.19
9	A3	Truck accident	1.25	4.25	5.31
10	A7	Quay crane defects	1.50	3.00	4.50
11	A2	Vehicle breakdown	1.00	3.25	3.25
12	A13	Ship deviation	1.00	3.00	3.00
13	A8	Insufficient space for trucks	1.50	1.75	2.63
14	A11	Ship congestion	1.00	2.25	2.25
15	A12	Ship accident	1.00	2.00	2.00

Table 4.
Risk score table

trucks would arrive at the port at the same time. As a result, this forms a queue, which causes truck congestion thus low productivity. Figure 3 illustrates the congestion of ship chandlers' trucks at the port. The container trucks and ship chandlers' trucks have their own separate truck lanes where the containers will be carried using a quay crane and the pallets will be carried using a provision crane, which could not be operated simultaneously, otherwise they will collide with each other. As a result, owing to safety precautions, ship chandlers' trucks can only position itself next to provision crane after the quay cranes are cleared from that area. Moreover, if ship chandlers' trucks are congested at the port, the cargo movement will be obstructed as the movement of quay cranes would be restricted.

Fragmented deliveries. Ship chandlers' trucks at the port are often not fully used. For instance, a truck could hold up to ten pallets, but only load two pallets for delivery. Therefore, truck capacity is underutilized because the remaining truck space could be used to load more pallets. Furthermore, ship owners always order supplies from various ship chandlers due to several reasons, such as product exclusivity and costs. Thus, fragmented deliveries occur because each company delivers a portion of the total pallets to the port for delivery, which may increase ship's waiting time at the port, thereby increase other ships' operation time indirectly.

In conclusion, when more ship chandlers are involved, there would be many trucks at the port arriving at the same time. After that, the port would be congested, and long queue occurs. Owing to lack of communication with the port, the idling time would be further extended because trucks arrive at the port at the wrong time, which lowers the productivity of each truck significantly. Therefore, this explains why these four causes are correlated and why lack of communication with the port is the most important factor that contributes to low productivity of ship chandlers' trucks.

5. Discussion and industry implications

5.1 Proposed solutions

To address the abovementioned issues, the following initiatives can be implemented.

5.1.1 Integrated platform with the port. As mentioned previously, all the respondents have consensus that communication with the port is crucial. An integrated platform with the port helps enhance such communication, providing more reliable information that is real time

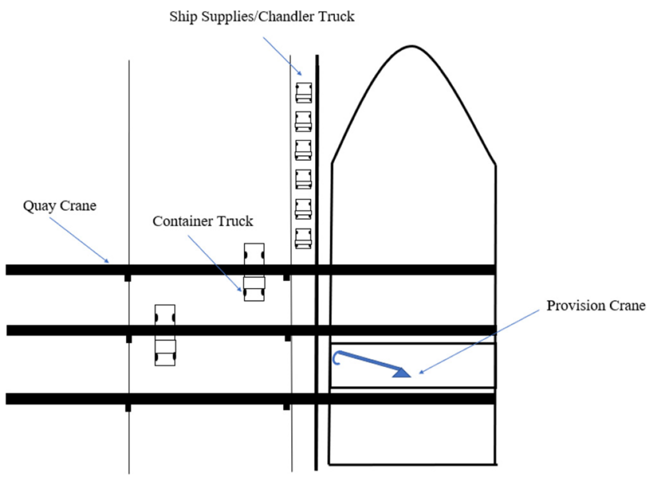

Figure 3.
Congestion of ship chandlers' trucks

and in the form of push notifications. Push notifications refer to pop-up messages that instantly alert the users when information from the port changes, without the need for them to physically login to the system to check for updates. Further enhancements to this platform such as sharing real-time schedules of quay cranes and ship's berthing time would help ship chandlers gauge the best time for making deliveries. This helps trucks reduce waiting time during the loading and discharging operations.

If the entire platform has adopted the above functions, not only the ship chandlers will be benefited, the port would also stand to gain. On one hand, it would be useful if the platform can send out notifications to ship chandlers and obtain their preferred window period, similar to making an appointment booking. With this enhancement, ship chandlers would be able to obtain greater visibility of the port's schedule and avoid clash of timings with other trucks. Thus, communication with the port will be enhanced, which significantly reduces delays and truck idling time at the port. On the other hand, the port can also benefit from this because it enables the port operator to gain better control of the trucks that enter the port. Hence, the port could use the information to manage port congestion and plan supporting infrastructure to avoid undesirable effects in advance, thus indirectly improving the port sustainability.

However, the application of this concept entirely depends on the willingness of the port in revealing the suggested information to ship chandlers, as well as ship chandlers' willingness to change their original delivery plans, which serve as the stumbling blocks in the process of promoting this idea at Port of Singapore. Because of commercial confidentiality considerations, ship chandler companies have no incentive to share their real-time conditions with the port, not to mention compromise with their competitors. Therefore, the suggestions only highlight the possibilities that can be achieved through a collaborative effort between the port and ship chandlers.

5.1.2 Consolidation hub. A consolidation hub refers to an open platform that usually provides professional services, such as packing, storage, loading and unloading in a specific industry (Zhuo, 2014). There is minimal effort to consolidate trips because there is no real consolidator in this industry, which stops the introduction of this concept into the port supply chain thus results in excessive ship chandlers' trucks at the port temporarily. Figure 4 illustrates the scattered model that this industry is adopting currently.

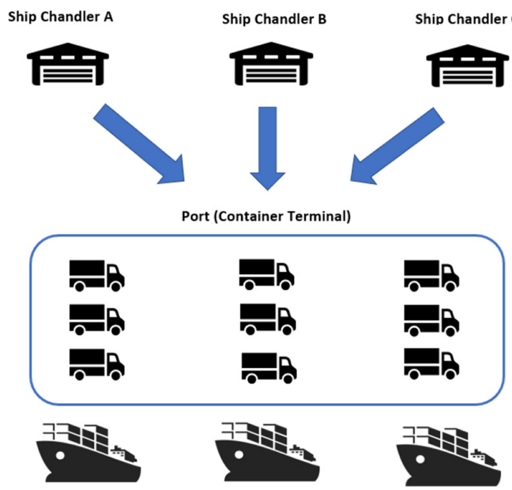

Figure 4.
Scattered model of ship supplies delivery

By having a consolidation hub, the capacity of the truck that is entering the port will be maximized as it makes full use of the space available to consolidate other ship chandlers' pallets into a single truck. Figure 5 illustrates the streamlined model of ship supplies deliveries at the port by consolidating orders.

In this mode of delivery, the respective ship chandlers deliver the pallets to the consolidation hub, where the pallets will be consolidated into one truck and be delivered to the same vessel at the port during the best window period available. Trucks which are available after they sent the pallets to the hub can then be used to fulfill other job orders or any other meaningful activities instead of being congested and idled at the port.

The Port of Singapore has a very wide market prospect on enlarging this business since Singapore has been a reputable free trade port. This, lays a good foundation for the establishment of such consolidation hubs. Currently, the port allows each registered truck to deliver supplies to only one ship per entry. If ship chandlers' trucks could be allowed to deliver pallets to different ships within the same terminal, the benefits of the adoption of consolidation hubs will be fully realized. For instance, if two ships arrive at the port around the same time, the consolidated truck can be used to deliver the pallets for both ships, which will reduce the number of trucks entering the port significantly and in turn, minimize truck congestion. Concurrently, the port can also benefit because the fewer trucks entering and exiting the port, the lower amount of greenhouse gases will be emitted from the trucks.

However, considering that one is willing to assume the responsibility of the consolidator, stakeholders should be wary not to transfer the bottlenecks from the port to the consolidation hub. Although ship chandlers and the port may benefit from consolidation, delays may still happen at the hub. This is because the consolidator must wait for ship chandlers to arrive with the pallets before leaving to the port. If either one arrives late, this will affect the whole delivery schedule and magnify the problem. Furthermore, this may not be suitable for fulfilling urgent orders.

5.1.3 Truck pooling system. Truck pooling system refers to an open community for ship chandlers, which complements the concept of consolidation with the aim of divesting the number of ship chandlers' trucks at port. According to our survey, Company S has developed an online truck-pooling platform for ship chandlers that coordinates the movement of trucks to the port. This concept is similar to "Grab hitch," in which the truck share small job orders with the ship chandler community to maximize truck capacity. By joining in the pool of trucks from the ship chandler community, a ship chandler would be able to generate some revenue by sharing truck

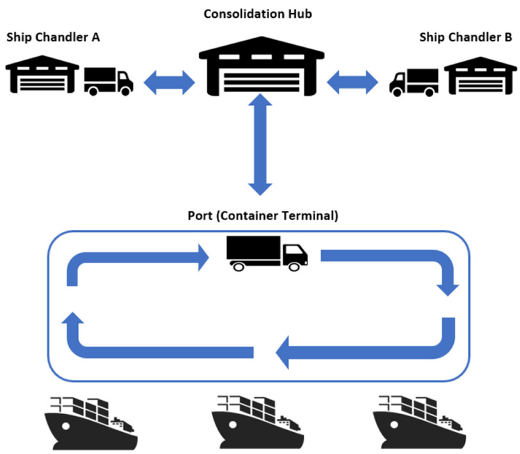

Figure 5.
Streamlined model of ship supplies delivery

space with other companies if the truck has spare capacity. This creates more flexibility to ship chandlers because they can choose to either outsource deliveries to the pool of trucks or take job orders by offering truck space to other companies for deliveries.

By leveraging on this system, ship chandlers could improve truck productivity and reduce delivery cost. However, there are still some issues to consider as this initiative is still fresh in the ship supplies industry.

Firstly, the question of who will be liable if anything happens to the goods that comes into place. As it involves multiple parties. The company who has accepted the job to consolidate the orders has to take unnecessary risk for the reason that the goods may get damaged before and during delivery. As such, there must be some form of evidence to show that the goods are in good condition and nicely palletized before being loaded onto the truck. This evidence must be communicated to the service providers to gain protection from such losses. Secondly, if the ship rejects the goods, it will create additional work for the company that provides the trucks for consolidation. This is because the goods must be returned to the respective ship chandlers or stored somewhere.

5.2 Implications for the industry

Considering that each approach may have some disadvantages, perhaps in industrial practice, by combining all three approaches together into one platform, some of these issues in maritime industry can be resolved. For instance, a platform that shows real-time information of ship's berthing time and port schedules enable ship chandlers to plan for consolidation better, especially for small order deliveries. If orders are rejected, the company that provides the truck can use the space in the consolidation hub to store the goods temporarily, where the respective ship chandlers can retrieve the goods afterwards.

Therefore, there are numerous opportunities for ship chandlers to improve truck productivity. If the above concept works in the future, it can be recommended to other players, such as trucking companies. This initiative would help to provide jobs for trucking companies and concurrently, trucks will also be readily available for ship chandlers to make deliveries at the port. However, the implementation of these initiatives may not significantly improve the situation. Thus, other efforts are required.

Assuming that all three approaches can be integrated together into a single platform, the factors to ensure successful implementation of the approach from the ship chandlers' perspective are reliability, costs and adaptability to changes.

Reliability: This is because a ship chandler may not like the idea of outsourcing deliveries, as the company will not be in full control of its operation. In order to gain confidence in the consolidation initiatives, ship chandlers need to be given the assurance that their goods will be safe and be delivered to the ship on time, without any delivery complication involved. Thus, reliability is one of the considerations.

Cost: This is because IT infrastructure can be costly, challenging and time-consuming. Additionally, the cost involved for having a consolidation hub must be considered. To ensure smooth truck movements within the hub premises, the hub must be able to accommodate enough space for inbound and outbound movements of trucks. For ship chandlers, the cost of delivery will determine whether they will subscribe to the consolidation service. Therefore, the service needs to be priced competitively to ensure that the ship chandler community can reduce delivery cost and benefit from the service. Thus, cost is one of the considerations.

Adaptability to changes: This is because ship chandlers may need some time to adapt this new concept since it involves working with competitors. In practice, there are companies, such as Haulio which helps to match container trucking companies to jobs, enabling the industry to pool and utilize resources in a more efficient manner (Reyes, 2017). However, the concept of truck pooling system for consolidation is similar to Haulio but used in a different context. According to the learning curve, it will be time-consuming for them to acquire new skills, which may disrupt the operations. Furthermore, if there are frequent urgent orders, it will be troublesome for ship chandlers to do consolidation. As such, ship chandlers may still prefer the traditional method of delivery. Thus, adaptability to changes is one of the considerations.

In this study, we have come up with three solutions to improve ship chandlers' trucks productivity for the Port of Singapore. However, this systematic research framework is not only tailored for Singapore. At modern ports, welfare-maximizing port authorities and profit-maximizing stakeholders have to face the same problems about low productivity caused by any participant in a port-centric supply chain. As a part of maritime integrated transportation, ship chandlery service is an indispensable component in the overall port operations, which can influence the port's efficiency. This in turn affects the sustainable strategies at the operational level. Meanwhile, the Fishbone diagram and risk management techniques used in this study can be easily understood and moved to other researches according to the actual situation. By conducting such an empirical research, port managers could have deeper insights on the relationship between ship chandlers' trucks productivity and port operation efficiency so as to better fulfill the needs of port sustainable development.

6. Conclusions

This paper presents a comprehensive risk evaluation method to identify the causes that led to low productivity of ship chandlers' trucks and proposes ways on how to improve the situation for sustainability under the Singapore context. A mixed-method approach by conducting interviews, creating Fishbone diagram and applying risk management tools showed that there are four main causes as follows:

(1) lack of communication with the port;

(2) late arrival of ships;

(3) truck congestion; and

(4) fragmented deliveries.

These factors were found to be interlinked and largely attributed to the lack of communication with the port.

Furthermore, possible improvement solutions were discussed based on the most important causes identified. Given the position of different stakeholders in the supply chain, businesses, societies and governments can work out some initiatives to improve truck productivity and port sustainability. The proposed solutions were discussed, namely:

- an integrated platform with the port that shares real-time information on ship berthing and quay crane operation timings, in the form of push notifications;
- a consolidation hub to consolidate pallets from various ship chandlers into a single truck; and
- a truck-pooling system that shares truck space with the ship chandler community for delivery.

It was concluded that these approaches could be integrated together and provide a well-rounded service to the ship chandler community that help to improve truck productivity, as well as the port sustainability. Based on the assumption that these approaches could be integrated together, the factors to ensure successful implementation of this initiative from the ship chandlers' perspective were also discussed: (i) reliability, (ii) cost and (iii) adaptability to changes. If these considerations can be addressed, more ship chandlers will subscribe to the concept of consolidation in future. Hence, through a collaborative effort between various stakeholders, ship chandlers can improve truck productivity and minimize delays together with sustainable development considerations at the port.

For the implementation of the proposed approaches in this research, it is still in the early stages of development, this study has some limitations and needs further research. Most importantly, this research focused more on the ship chandlers' perspectives and the results lack strong quantitative justifications. Therefore, for future studies in this area, more companies can be interviewed from the ship supplies industry. Future studies could include data collection from other groups of stakeholders, such as the port and liner shipping companies to gather responses from different perspectives. In addition, it is recommended that quantitative data, such as the average time each truck stays at the port and how much time can be reduced from the enhancement, should be included for future research to provide a more comprehensive perspective. Future studies could also compare the effectiveness of the approaches proposed in this study against the traditional method. This would help the ship chandler community to improve truck productivity through collaborations with various stakeholders.

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