Maritime Business Review

Preliminary study on new container stacking/storage system due to space limitations in container yard

Noorul Shaiful Fitri Abdul Rahman Alisha Ismail Venus Y.H. Lun

Article information:

To cite this document:
Noorul Shaiful Fitri Abdul Rahman Alisha Ismail Venus Y.H. Lun , (2016),"Preliminary study on new container stacking/storage system due to space limitations in container yard ", Maritime Business Review, Vol. 1 Iss 1 pp. 21 - 39
Permanent link to this document:
http://dx.doi.org/10.1108/MABR-03-2016-0004

Preliminary study on new container stacking/storage system due to space limitations in container yard

Noorul Shaiful Fitri Abdul Rahman
Department of Maritime Management, School of Maritime Business and Management, Universiti Malaysia Terengganu, Malaysia
Alisha Ismail
Department of International Business, School of International Studies, COLGIS, Universiti Utara Malaysia, Sintok, Malaysia, and
Venus Y.H. Lun
Department of Logistics and Maritime Studies, The Hong Kong Polytechnic University, Kowloon, Hong Kong

Abstract

Purpose – The purpose of this study is to introduce a new innovative means of container stacking/storage as a potential solution for overcoming the lack of container yard space.

Design/methodology/approach – A qualitative methodology that incorporates questionnaires and interview sessions as the tools is utilised together with an application of new innovation concept.

Findings – The proposed system not only allows increased efficiency and effectiveness in handling containers, but also increases the profit margin of ports, as container stacking/storage is tripled in height.

Research limitations/implications – This is just the beginning of a preliminary research study that proposes a new container stacking/storage system to address the lack of space in container yards. Therefore, much more work needs to be done in future studies before a solid and concrete decision on the application of this innovative system can be carried out.

Practical implications – The practicality of the proposed model means that it can be easily implemented to address space limitation problems in ports.

Social implications – The benefits of the results to the local community around ports are a healthier environment, with cleaner air, so that there will be less health issues of the residents and therefore reduced burden on the local health system. This is due to the use of technology that will prevent the expansion of ports that ultimately could lead to deforestation and environmental damage. This technology will also help to preserve the greenery of the area around ports.

Originality/value – An innovative model of a container stacking/storage system is presented in this study as a possible solution to the problem.

Keywords Container ports, Logistics and supply chain, Maritime business, Maritime operations and innovation, Space limitations, Stacking/storage yard

Paper type Research paper

The authors extend their appreciation to the Universiti Malaysia Terengganu for providing the research facilities and support.

Maritime Business Review
Vol. 1 No. 1, 2016
pp. 21-39
Emerald Group Publishing Limited
2397-3757
DOI 10.1108/MABR-03-2016-0004

1. Introduction

Over the years, the maritime industry has experienced tremendous growth and provided economic benefits for many countries. One of its domains is the shipping and port industries, which have proven to be the most important economy activity because they are essential contributors in facilitating trade. The total container throughput has gradually increased every year. A statistical report from the United Nations Conference on Trade and Development (UNCTAD, 2013) indicated that there has been a significant growth in seaborne statistics during a period of 42 years from 1970 to 2012. Each commodity handled through maritime transportation is continuously increasing in number, even after the economic recession of the financial crisis in 2008 to 2009.

Due to the volume of commodities handled, the containerisation sector has demonstrated exponential growth, from 102 million metric tonnes in 1970 to 1,578 million metric tonnes in 2013 (UNCTAD, 2013). It appears that the Transpacific route is the most busiest route with 20.2 million twenty-foot equivalent units (TEUs) of traffic volume in 2012 (from Asia to the USA: 13.3 and from the USA to Asia: 6.9; total is 20.2), and the euro-Asia routes have a total traffic volume of 20.0 million TEUs in 2012 (from Asia to Europe: 13.7 and from Europe to Asia: 6.3; total is 20.0) (UNCTAD, 2013). Furthermore, the intra-Asia short sea shipping routes have more container traffic volume than any of the three major deep-sea routes in 2012. This was due to the economic boom in Asia, particularly in China and India, and the South American countries, which are the main sources of imports from the European and North American regions. This is not surprising, given that the top 20 container ports in the world are located and dominant in Asia, including China (9), Singapore (1), South Korea (1), Taiwan (1), Japan (1) and Malaysia (2) (Table I). The rest of the top container ports are located in Europe (Rotterdam, Hamburg and Antwerp), the USA (Los Angeles) and Middle East regions (United Arab Emirates). These ports have shown tremendous growth in the volume of containerisation traffic in the past few years.

Although the development in international trade commodity has increased containerisation activities, this has led to the problem of the lack of space in container port areas. Many seaports worldwide are now facing the problem of capacity shortage and the result is space constraint at the container ports (Paul and Maloni, 2010). The Port of Klang, for instance, is in the progress of building a third port terminal to accommodate the growing demand, as the current Northport and Westport are only capable of catering to port users until 2016, and the two ports are nearing their maximum capacity (Teh, 2011). Table II shows the annual capacity available at Port Klang in the past five years and clearly demonstrates that the annual TEU received is nearly reaching annual capacity, and in particular the Westport. This indicates that the expansion is necessary to handle the growing container traffic. Even though this is the case, there is now little or no space available at Port Klang (Nazery, 2013). This situation may lead to higher stacking of containers in the storage yard to utilise the limited space available in the port area.

When dense stacking is greater than the overall throughput of a terminal, the port operator needs to identify any possible mechanism or system to manage the high volume of container demand, so as to continue to offer excellent service performance to its customers (Nico, 2000). The purpose of this paper is therefore to introduce a new innovative means of container stacking/storage as a potential solution for overcoming the problem of limited container yard space.

Table I. Container throughput of the top 20 world container ports (2011-2013)

Rank	Port	Volume 2013 (million TEUs)	Volume 2012 (million TEUs)	Volume 2011 (million TEUs)	Website
1	Shanghai, China	33.62	32.53	31.74	www.portshanghai.com.cn
2	Singapore	32.6	31.65	29.94	www.singaporepsa.com
3	Shenzhen, China	23.28	22.94	22.57	www.szport.net
4	Hong Kong, S.A.R., China	22.35	23.12	24.38	www.mardep.gov.hk
5	Busan, South Korea	17.69	17.04	16.18	www.busanpa.com
6	Ningbo-Zhoushan, China	17.33	16.83	14.72	www.zhoushan.cn/english
7	Qingdao, China	15.52	14.50	13.02	www.qdport.com
8	Guangzhou Harbour, China	15.31	14.74	14.42	www.gzport.com
9	Jebel Ali, Dubai,	13.64	13.30	13.00	www.dpworld.ae
10	Tianjin, China	13.01	12.30	11.59	www.ptacn.com
11	Rotterdam	11.62	11.87	11.88	www.portofrotterdam.com
12	Dalian, China	10.86	8.92	6.40	www.dlport.cn
13	Port Kelang, Malaysia	10.35	10.00	9.60	www.pka.gov.my
14	Kaohsiung, Taiwan	9.94	9.78	9.64	www.khb.gov.tw
15	Hamburg, Germany	9.30	8.89	9.01	www.hafen-hamburg.de
16	Antwerp, Belgium	8.59	8.64	8.66	www.portofantwerp.com
17	Keihin ports, Japan	8.37	7.85	7.64	www.city.yokohama.lg.jp/en/
18	Xiamen, China	8.01	7.20	6.47	www.portxiamen.gov.cn
19	Los Angeles,	7.87	8.08	7.94	www.portoflosangeles.org
20	Tanjung Pelepas, Malaysia	7.63	7.70	7.50	www.ptp.com.my

Source: World Shipping Council (2015)

2. Review of related studies

The inbound and outbound of a container at a container terminal go through two important areas: the quayside and the landside (Zhang *et al.*, 2003). The quayside area is where vessels berth, and quay operations (loading and unloading activities) of quay cranes and transporters take place. Meanwhile, the landside area is where arriving and departing containers will be temporarily stored in the storage yard before the final shipment is carried out through the terminal gate. In the container terminal area, the storage yard is the most important area, given that the most complicated operations take place when both import and export flows are concurrently handled.

The increasing traffic in ports has basically increased the demand for storage space by both port users and operators. A combination of increasing container throughput and the lack of storage yard capacity have created serious and complex operational challenges for port operators in providing efficient services (Carlos *et al.*, 2014). With this situation, the common practice is to stack containers to multi-levels to store the containers. However, Jiang *et al.* (2012) argued that the practice of stacking containers to multi-levels in storage yards not only causes the unproductive reshuffling of containers but also results in a high concentration of activities in a small area, which may cause traffic congestion from transporters if activities in the storage yard are not properly coordinated.

Ports that lack space struggle to manage increasing traffic regardless of whether at sea or on land. Notteboom and Rodrigue (2005) indicated that ports, especially large gateways, are facing a wide array of local constraints that impair their growth and efficiency. The lack of availability of land for expansion among other problems is one of the most acute issues of large gateways. This is perhaps due to the extensive expansions that have been previously done to address the increases in traffic volume. The continuously increasing traffic at the major ports and the lack of space for further expansion may eventually lead to severe problems not only at sea but also on land. Although some ports are adopting ways to increase container terminal capacity, others are under pressure due to issues that pertain to capacity shortages (Chao and Lin, 2011).

The imperativeness of container storage planning for port operational efficiency has been highlighted and discussed in the literature. Several academics have offered potential solutions that could be implemented prior to container storage yard planning at container terminals. Bazzazi *et al.* (2009), for instance, proposed a genetic algorithm approach to solve the extended storage space allocation problem at container terminals. Meanwhile, to overcome both limited space and hardware equipment of the storage yard, Laih and Chen (2013) introduced a queuing pricing model for export containers

Year	Northport annual capacity	Northport real annual TEUs	Westport annual capacity	Westport real annual TEUs
2014	6.0	2.5	9.05	8.4
2013	5.0	2.8	9.0	7.5
2012	5.0	3.1	6.0	6.9
2011	5.0	2.4	6.0	6.4
2010	4.4	1.6	6.0	5.6

Source: Port Klang Authority (2015b)

Table II. Annual capacity of Port Klang (million TEUs) which eliminates the waiting time outside of the storage yard area. Similarly, Sharif and Huynh (2013) addressed the storage yard problem by using an ant-based control method where the routes for individual import and export containers are assigned to provide balance among yard blocks and minimise the distance travelled by trucks between yard blocks and berths.

Although these studies have focused on the allocation of space for the operations of container yards, the focus should actually be more on the yard layout and space planning in the existing storage yard. To the best of our knowledge, there are no innovative solutions that can be used to address the lack of storage space capacity for the long term that could be implemented in port areas and benefit port users. Therefore, to optimise the effective and efficient use of container storage space in port areas, an automatic parking system (ASP) is proposed in this study. This system is a mechanical system that was designed to minimise the space required to park cars by vertically stacking cars to maximise the number of vehicles that can be stored. The concept of the ASP is mainly driven by two factors: the need for parking space and lack of space and storage capacity. Given that there are similarities in terms of the scarcity of space for parking vehicles and storing containers in ports, it is envisaged that the adoption of a similar system would bring about positive impacts to container ports.

3. Overview of Port Klang container handling

Port Klang is the main gateway by sea into Malaysia and comprises two main ports called Northport and Westport. It is the busiest container port in Malaysia. Port Klang was ranked as the 12th busiest container port (in 2012) worldwide. Port Klang is ideally placed to capitalise on the domestic and international markets. In 2012, the port handled a total capacity of 10 million TEUs (Table III), which is double or about 5.5 million greater than that of the total throughput in 2005, or nearly half or 48.5 per cent of the total number of containers handled by all Malaysian ports (Lian, 2010). It is also anticipated that Port Klang will handle between 15 and 20 million TEUs by 2020 (Port Klang Authority, 2013).

Table III shows the number of containers handled by Port Klang from 2005 to 2014 in millions of TEUs. The trend of the total container throughput is a linear relationship, as the container volume continues to increase every year, except for a slight decrease in

Year	Import	Export	Transshipment	Total
2005	1,342,901	1,276,661	2,923,965	5,543,527
2006	1,403,946	1,367,625	3,554,724	6,326,295
2007	1,527,893	1,474,193	4,116,628	7,118,714
2008	1,629,977	1,598,544	4,745,058	7,973,579
2009	1,515,743	1,478,354	4,315,682	7,309,779
2010	1,716,304	1,718,845	5,436,596	8,871,745
2011	1,794,508	1,720,542	6,088,876	9,603,926
2012	1,872,867	1,821,995	6,306,633	10,001,495
2013	1,907,497	1,860,613	6,582,299	10,350,409
2014	1,962,431	1,942,773	7,040,600	10,945,804

Source: Port Klang Authority (2015a)

Table III. Total number of containers handled by Port Klang: 2005 to 2014 (million TEUs)

2009, which was due to the world economy recession. The total container volume is computed by adding the total of three types of containers handled by Port Klang, which are import, export and transshipment containers. The total transshipment container volume handled by Port Klang increased by 25 per cent in 2010 in comparison to that in 2009. The total export containers have also increased by about 16 per cent for the same period, along with an increase in the total import containers of 13 per cent.

According to Westport officers, the container volume throughput, which is mainly from transshipment and indigenous boxes, exceeded expectations and registered increases of 22 per cent and 13 per cent, respectively, in 2011. This type of robust performance has made Westport one of the fastest-growing ports in the world (ASEAN Port Association Malaysia, 2012). Furthermore, the increment of the total number of container volume handled by Port Klang also increased, due to the recent boost of trade between China and the intra-ASEAN market in 2013.

More containers as result of containerisation and hinterland development will be needed to enhance port competitiveness to cater to a larger number of container throughput and larger vessels. Globalised markets and the outsourcing and changing of production bases have boosted trade and demand for maritime services. More trade means that more investment in ports is needed to increase the capacity to facilitate greater trade volumes (Nazery, 2005; Nazery and Ibrahim, 2007).

In addition, this phenomenon is considered to be the result of increase in the increment of the total number of containerships that have entered Port Klang from 2005 to 2014. Based on the statistical data of containership calls at Port Klang (Port Klang Authority, 2015a), in 2005, 10,266 units of containerships were reported to berth at the port and the number steadily increased to 11,543 units in 2006 and 12,019 in 2007, before slightly declining to 11,675 in 2008 and 11,080 in 2009 during the global financial crisis. Nevertheless, the number of containership calls at Port Klang then rebounded to 12,332 and 12,387 units in 2010 and 2011, respectively. However, following that, Port Klang once again experienced a drastic decline in containership calls, and in 2012, the number of units was reduced to 11,241, and then further reduced to 10,933 in 2013, and finally, yet another reduction to 10,551 units in 2014.

The decrease in containership calls at Port Klang from 2012 to 2014 was due to the increase of ship size with the use of larger container ships, which explains the declining number of container volume handled. Due to the growth of containerisation traffic, shipping liners are now acquiring ships that are larger in size to gain economies of scale where the unit transportation cost can be significantly reduced (Stopford, 2009), while also attracting powerful shippers who have a large amount of products to be shipped (Nam and Song, 2011). The following illustrates the evolution of containership size since the introduction of Ideal X, which is a converted tanker: www.agcs.allianz.com/assets/Infographics/ContainerShipGrowthInfographic2015_1000X1125.jpg

The container ship size has rapidly increased from 1,500 TEU in 1968 to 19,000 TEU in 2014/2015 for a single voyage. It is expected that the size of the containership will grow, although there have been debates over the Malaccamax size of ships, which is the largest ship size currently able to fit through the Strait of Malacca.

However, the significant development in ship size comes with a downside, particularly the size of the current terminals which require proper port facilities and competitive ship-to-shore performance such as crane outreach at the terminals. The increasing size of container ships to date has contributed to declines of port calls from

4.9 to 3.35 from 1989 to 2009, and this reduction is due to the concentration of the primary and larger shipping lines that call at transshipment hubs (Ducruet and Notteboom, 2012). This is also another reason that possibly explains for the decline in containership calls at Port Klang for 2012 to 2014 despite the growth in containerisation traffic.

Table IV shows the current container facilities provided by the two Klang ports of Northport and Westport. In the past few years, the facilities at Port Klang have increased, in particular the berths, storage and equipment. The increase in international container traffic, high volume of vessels enter the ports and the increase in vessel size are some of the factors that have contributed to additional facilities at these two ports. For instance, in 2009, the total number of berths for both ports was 23, which increased to 28 in 2015. Similarly, the container storage capacity has increased and equipment added. In recent years, the Port of Klang has shown increases in berth productivity up to 69 moves per hour per vessel (Tan, 2016). Although investments have been made to upgrade the facilities at Port Klang, the rapid growth of international container traffic has witnessed the increasing demand of more space for storage. This indicates that more space is needed for future expansions to accommodate more containers. However, as mentioned earlier, there is little or no space available now in the vicinity of the Port of Klang.

In general, the container yard is used for the temporary storage of containers. If there is sufficient land available, it is possible to put every container on a separate chassis, which will allow faster and easier movement of containers among different terminal locations (Islam and Olsen, 2011). Moreover, to cater to increases in demand for containers, Port Klang needs more space, which has resulted in the expansion of the port. However, due to environmental factors, such as limitations in space, environmental concerns and marine ecosystem issues, Port Klang cannot undertake any further expansions which will address the need for more space at the port.

		Port Klang	
Container	Northport	Westport	Total
Berths			
Number of berths	12	16	28
Length (m)	3,029	4,600	7,629
Draft (m)	11.0-15.0	15.0-17.5	11.0-17.5
Storage			
Annual capacity (million TEUs)	5.6	11	16.6
Reefer points	1,111	2,428	3,539
Equipment			
Quay cranes	32	53	85
Rubber tyre gantry cranes	84	160	244
Straddle carriers	26	16	42
High stackers	11	27	38

Sources: Northport (2015); Westports (2015)

Table IV. Port Klang container facilities

4. Methodology

In this study, a qualitative methodology that incorporates questionnaires and interview sessions as the tools is utilised. First, the factors that have led to the lack of space are determined based on the literature. There are 13 factors that have led to this problem: lack of space in the container yard area, high volume of containers, high volume of vessels that are entering at one time, increased ship size, poor port management, environmental issues, GDP growth rate, cranes, manufacturing in lower-cost countries, inland waterways, gates, manufactured products from China and labour (Ortiz *et al.*, 2007; Islam and Olsen, 2011; Robinson, 2003). These factors are considered to be critical in this study because each contributes to the problem of lack of space in container yards.

A set of questionnaires were developed in accordance with the 13 factors listed above. The questionnaires solicited the assistance of ten experts, comprising Port Klang decision-makers (six individuals, three each from Northport and Westport) and four academic members from a higher education institution, to classify the level of severity of each factor in affecting the problem of limited space at Port Klang. A scale of 1 to 10 was provided as guidance for the experts to express their views, with "1" as not at all serious, "5" as moderately serious and "10" as very high serious in contributing to the problem. The rating from each expert was totalled in accordance with each factor and then divided by 10 to obtain the mean score. The same process was used for the rest of the factors. Table V summarises the mean score for each factor that has been ranked accordingly. From the feedback obtained, the most serious factor in contributing to the lack of space at Port Klang is identified, and then recommendations for improvement could be suggested accordingly.

According to the mean score in Table V, the top three factors that most affect the lack of space at Port Klang are:

(1) limitations of the container yard area (87 per cent);

(2) high volume of containers (85 per cent); and

(3) high volume of vessels that are entering the port at the same time (72 per cent).

Factor	Level of severity (from 10 experts)	Mean score
Limitations of the container yard area	(10 + 10 + 9 + 9 + 9 + 8 8 + 8 + 8 + 8)	(87/10) = 8.7
High volume of containers	(10 + 9 + 9 + 9 + 8 + 8 + 8 + 8 + 8 + 8)	(85/10) = 8.5
High volume of vessels entering port at same time	(8 + 8 + 8 + 8 + 8 + 7 + 7 + 6 + 6 + 6)	(72/10) = 7.2
Increasing ship size	(8 + 8 + 8 + 7 + 7 + 7 + 7 + 6 + 6 + 5)	(69/10) = 6.9
Poor port management	(7 + 7 + 7 + 6 + 6 + 6 + 6 + 5 + 5 + 5)	(60/10) = 6.0
GDP growth rate	(6 + 6 + 6 + 6 + 6 + 5 + 5 + 5 + 5 + 5)	(55/10) = 5.5
Environment	(6 + 6 + 6 + 6 + 5 + 5 + 5 + 5 + 5 + 5)	(54/10) = 5.4
Labour	(6 + 6 + 6 + 5 + 5 + 5 + 5 + 5 + 5 + 5)	(53/10) = 5.3
Manufactured products in China	(6 + 6 + 6 + 5 + 5 + 5 + 5 + 5 + 5 + 4)	(52/10) = 5.2
Manufacturing in lower-cost countries	(6 + 6 + 5 + 5 + 5 + 5 + 5 + 5 + 4 + 4)	(50/10) = 5.0
Cranes	(6 + 6 + 5 + 5 + 5 + 5 + 5 + 4 4 + 4)	(49/10) = 4.9
Gates	(6 + 6 + 5 + 5 + 5 + 5 + 4 + 4 + 3 + 3)	(46/10) = 4.6
Inland waterways	(5 + 5 + 5 + 4 + 4 + 4 + 4 + 4 + 3 + 3)	(41/10) = 4.1

Table V. Level of severity of contributing factors to lack of space at Port Klang

The three least relevant factors are cranes (49 per cent), gates/trucks (46 per cent) and inland waterways (41 per cent). After conducting an analysis, the mean value of each factor was determined by using a spider or radar chart (Figure 1). The chart showed all of the factors for the lack of space and the scores given. In this case, the potential solution would focus on the top two factors due to their level of severity and they are considered as internal factors, while the third factor is considered ambiguous and beyond the control of Port Klang.

5. New innovative idea for container stacking/storage

The top two factors listed in Table V are those that most affect the issue of lack of space at Port Klang, as determined by the sample of industrial and academic experts. A potential solution to overcome the problem is to introduce a new innovative means of container stacking/storage that can accommodate a height of 15 containers instead of 5, which is the current practice. This innovative container storage system is a mechanical system designed to cater to container volumes up to three times the normal practice. The system provides multiple levels of stacked containers on both a vertical (15 container slots) and horizontal (10 container slots) axis, which in total can accommodate up to 150 TEUs for one container stacking block.

In current practices, the container storage arrangement at Port Klang is using a traditional technique in which each container is placed on top of another in the container yard and the maximum height is five boxes (Figure 2). To move the last container at the bottom, the top four containers are required to be moved first, so that more time and work are needed. If the new system is used, more containers can be stored and less work time is required because each container is stored in a different slot and not stacked on top of each other. Also, this system can be either automatically or semi-automatically operated, and thus, human errors that may cause injuries and damage to goods can be reduced. In addition, the efficiency of the new container stacking/storage mechanism is anticipated to have more reliability compared to the current practice in Port Klang.

Stacked container storage is generally carried out by the use of machinery with electric motors or hydraulic pumps in the motor mode that move a container into a selected storage position. The containers that are unloaded from ships are placed into

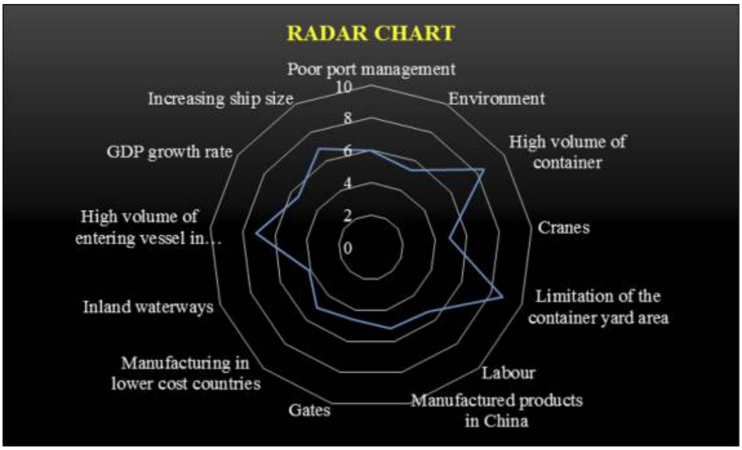

Figure 1.
Factors that have led to space limitations based on interviews

Source: Zaidi and Abdul Rahman (2014)

Figure 2.
Concept of innovative means of container stacking/storage

designated areas. Hydraulic or mechanical container lifters raise the container to another level for proper storage. The container can be moved vertically (up and down) or horizontally (left and right) to a vacant space until the container is needed again. Once the container has been placed in the selected location, then its location identity will be automatically recorded in a barcode system. For instance, if the container barcode is B0703, this means that the container has been stored in Block B, Level 07 (vertical) and Door 03 (horizontal).

Logically, there are tremendous benefits from the use of this container stacking system. First, there is no need to search for container space and at the same time, the natural beauty and greenery of the area will not be damaged by expansion work or building projects. Furthermore, this system not only saves space, but in the long run, will save time and increase profit as well as increase work efficiency. Besides that, it will generate greater revenue for Port Klang, which will boost the economy of the country. The system will also ensure that container movement efficiency exceeds current standards, which will attract more customers in the future who will choose Port Klang as the port of destination and hub port instead of other ports. The improved infrastructure will increase the international market share of Port Klang.

Figure 3 shows a simple design of the container stacking/storage system that could be used as a potential solution to address the space limitation problem of the container yard at Port Klang. The model shows multiple blocks of stacking/storage that consist of 15 stacks and 10 horizontal container slots which are able to automatically move the containers. This is not just a model but incorporates a green technology concept that is also environmentally friendly. Green energy techniques are proposed to reduce high operational costs by using panels that operate on wave energy located along the berth, solar energy panels on the rooftop of the container stacking/storage system and windmills installed around the port limit area.

Figure 4 shows the working concept of the new container stacking/storage system (the term "container hotel" is used in the graphic). There are six steps involved in transporting a container from Port Klang to the customer:

(1) *Step 1*: Truck arrives at the entrance gate of the container yard.

(2) *Step 2*: The truck driver scans the identity barcode of the container that will be loaded by using a barcode searching system at the entry gate of the container yard.

(3) *Step 3*: The identity barcode of the selected container appears on the monitor and will need to be confirmed by the driver. Once confirmed, then the device will deliver the identity barcode information to the container stacking/storage system and find the matching container.

(4) *Step 4*: Once the selected stacked container block in storage receives the barcode information, the intended container will then be automatically retrieved for loading onto the truck.

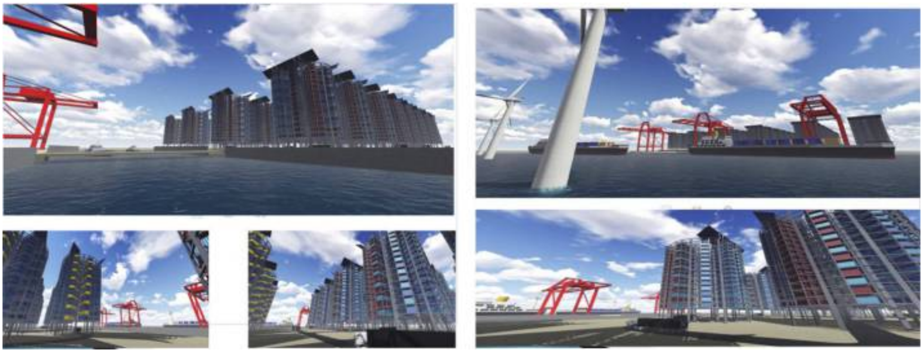

Figure 3. An innovative mechanism for container stacking/storage

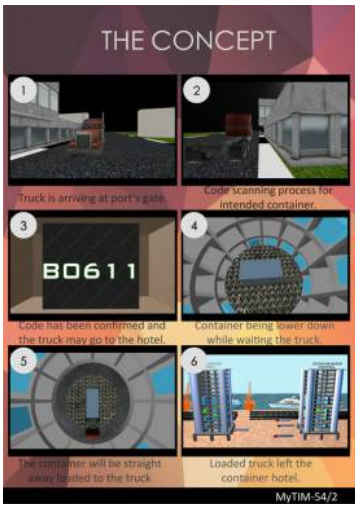

Figure 4. Working concept of the container stacking/storage system

(5) *Step 5*: The truck will move towards the automatic stacked container to load the container without any restrictions.

(6) *Step 6*: Once the process is completed, the truck immediately leaves the respective block of containers and exits the container yard.

Figures 5–8 show the graphics of the new container stacking/storage system when it is in place at the container port. Figure 5 illustrates the front view of the new container storage blocks that are located at the container port together with the slot management system, and the loading and unloading processes onto trucks. The use of alternative energy through wave energy, solar power and wind is also shown. Figure 6 illustrates the top view of two specific container storage blocks together with the direction of entry and exit for trucks to complete the loading and discharge processes. For each container storage zone, for instance, Zone A1, there are two directions for entry and one direction for exiting. Figure 7 shows the top view of the directions for entry and exit for a single container storage block. Finally, Figure 8 shows the overall container yard from a bird's eye view which contains three different zones: Zones A, B and C. Each zone has two sub-zones, for instance Zones A1 and A2. Also, each sub-zone has two columns of container blocks with a length of eight units and two units for each row, which is equal to 16 container storage blocks.

6. Comparative study between traditional and new systems in container handling practices

The implementation of this innovative concept is important in various aspects, especially for the environment. The more intelligent use of space at container ports means there is no longer the need to build more facilities or expand the port, which will damage the environment, such as causing seabed disturbance and changes in coastal processes. Thus, the natural beauty and greenery of the area around a port can be preserved accordingly.

Table VI summarises the differences between the traditional system, which is currently being used in container ports, and the new container stacking/storage system in accordance with ten factors relevant to container handling practices.

Furthermore, the benefits of the results of this study to the local community around ports are a healthier environment, with cleaner air, so that there will be less health issues of the residents and therefore reduce the burden on the local health system. This is due to the use of technology that will prevent the expansion of ports that ultimately could lead to deforestation and environmental damage. This technology will also help to preserve the greenery of the area around ports.

Besides that, port owners or operators will benefit in various aspects, especially financially. The system is anticipated to generate more income to a port and also the nation by handling increased container demand through the enhancement of multilateral or bilateral import and export business trade around the world. The use of this innovative system is anticipated to allow a high degree of efficiency and effectiveness in the container handling process. As a result, the system will attract more customers who will choose Port Klang as their port of calling because this port will be more competitive in terms of cost, operations and management.

Finally, Malaysian residents will benefit too, due to the financial ramifications to the national economy. There will be more income generated for the country, which will

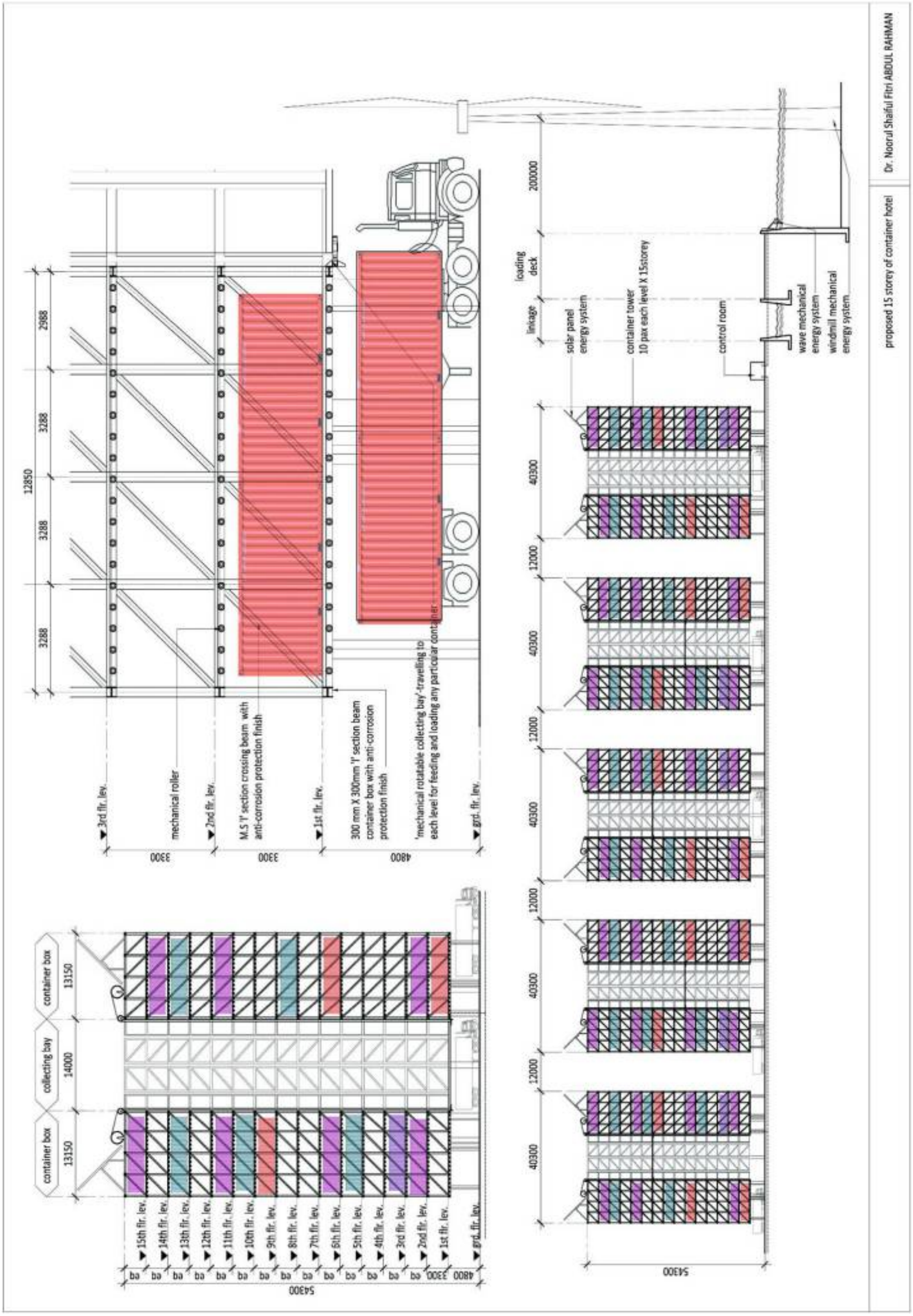

Figure 5.
Front view of new container storage blocks

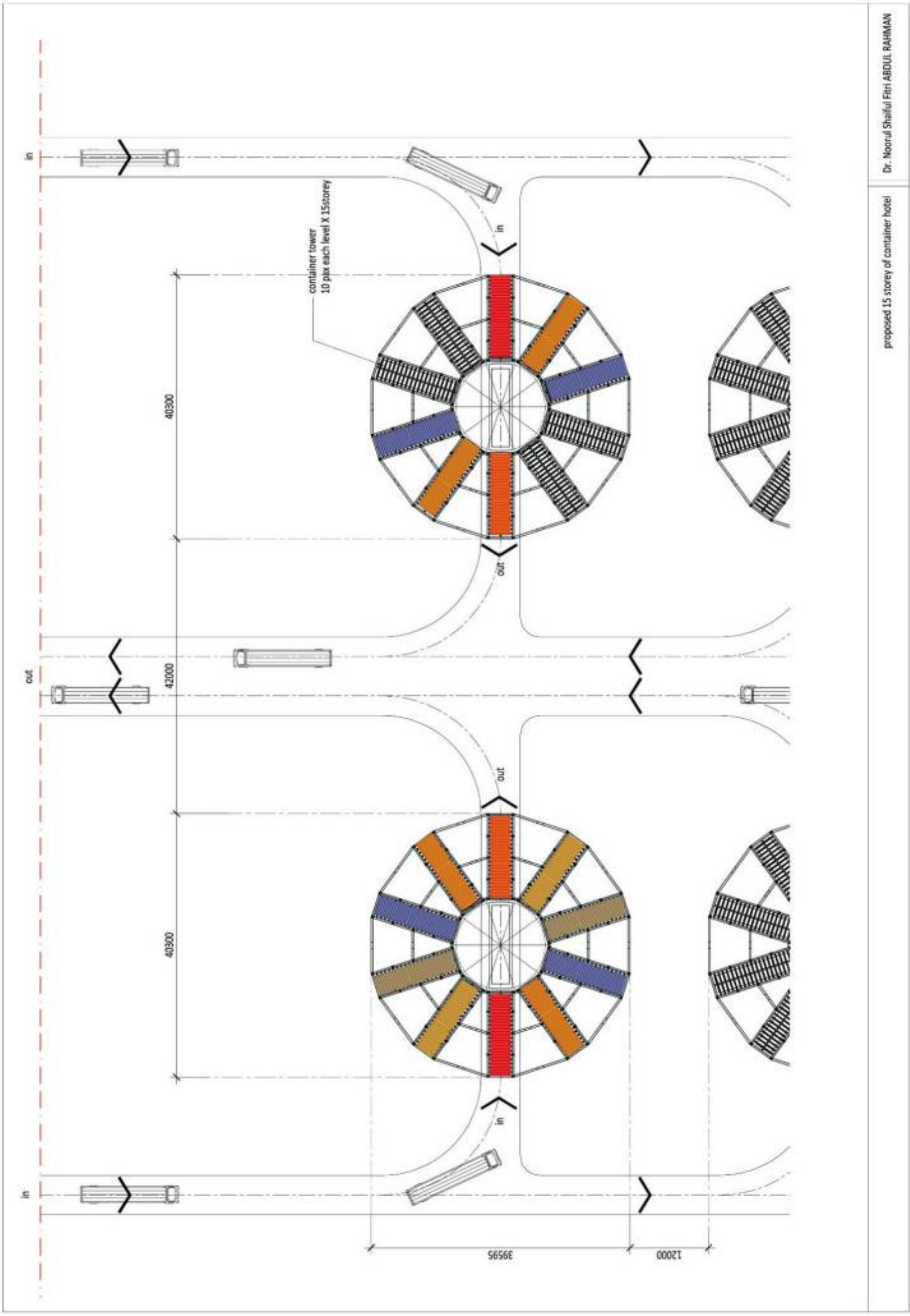

Figure 6.
Top view of two specific container storage blocks

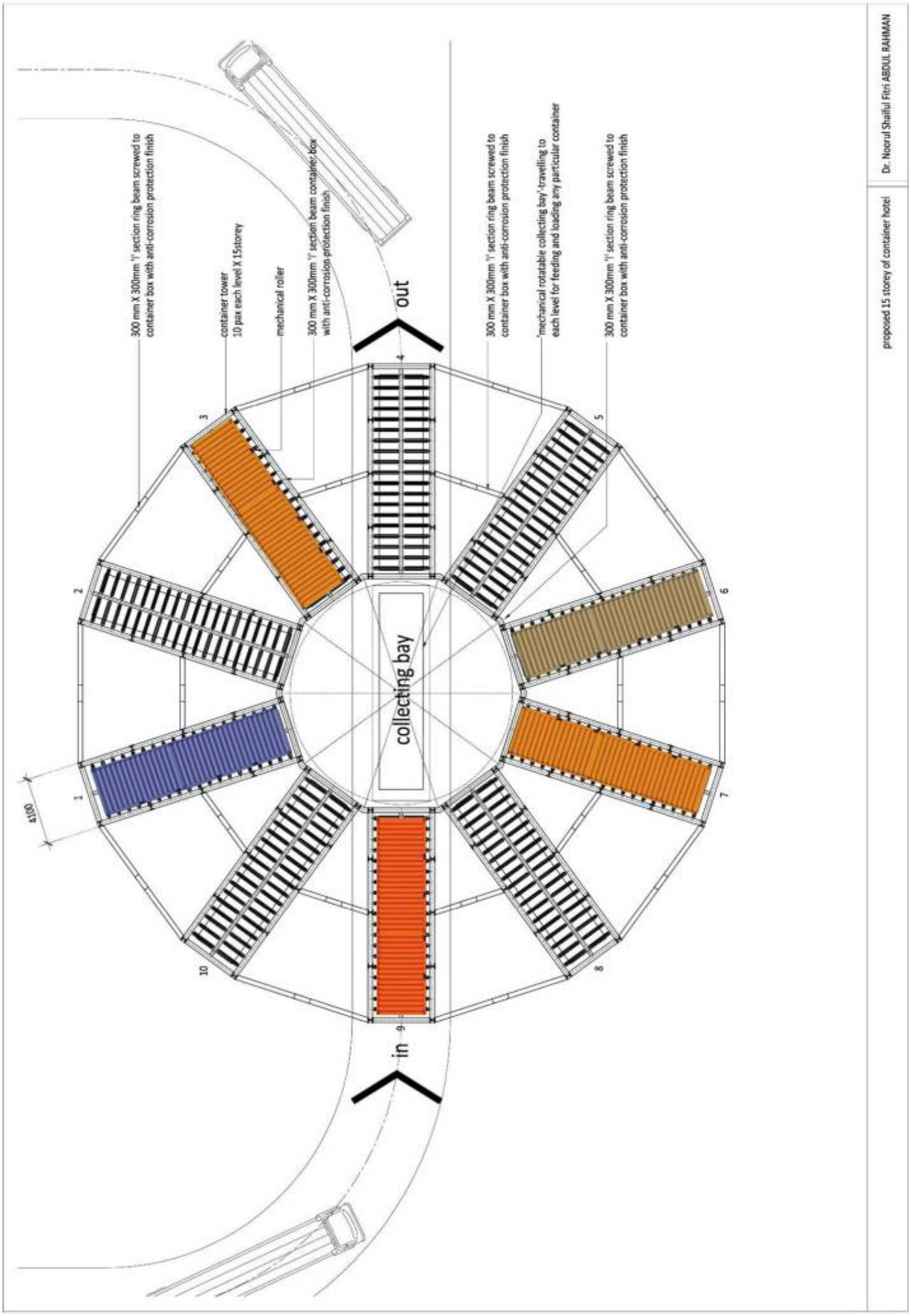

Figure 7.
Top view of entry and exiting

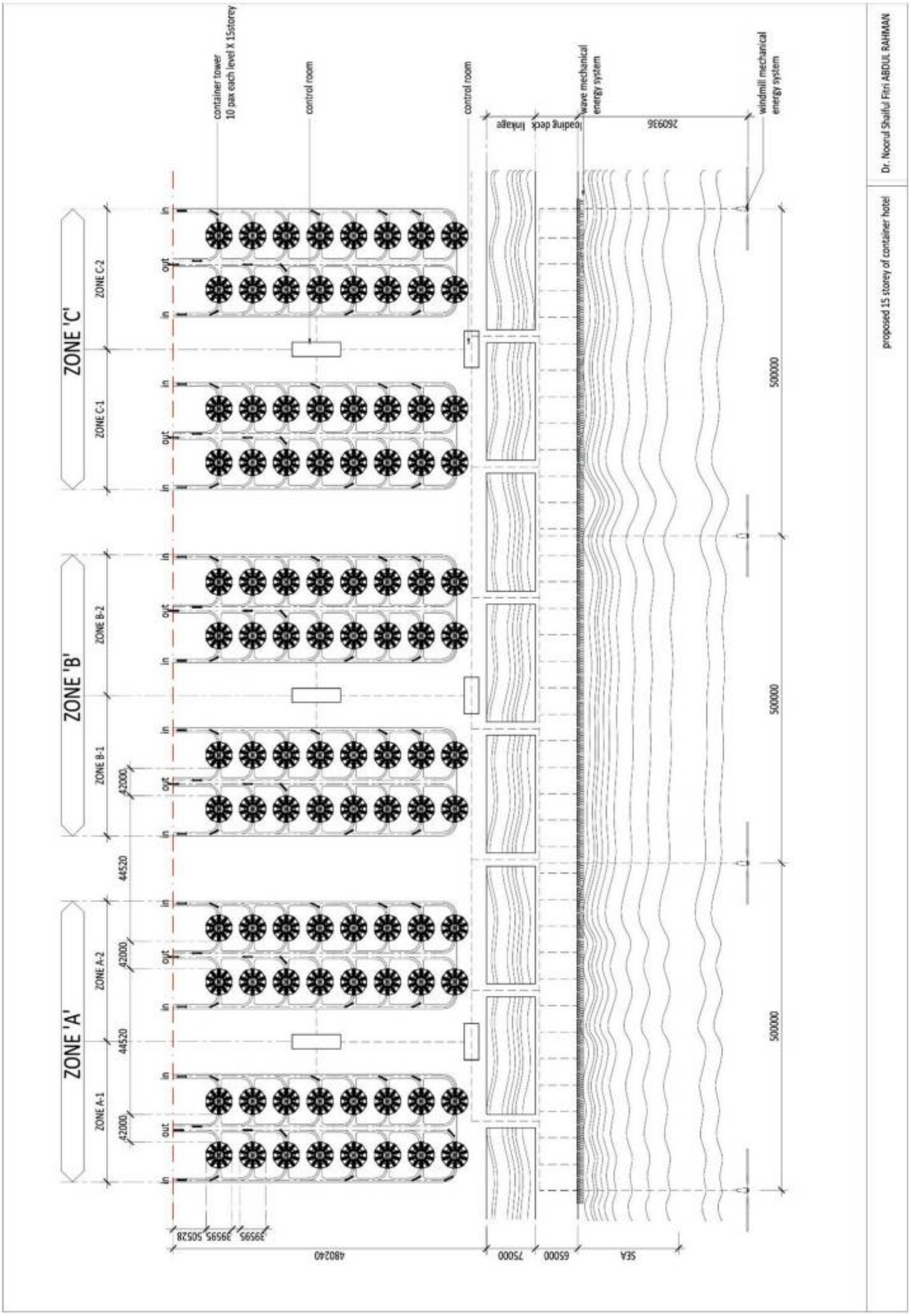

Figure 8.
Overall container yard – bird's eye view

Table VI. Comparison between traditional and new systems in container handling practices

Factor	Traditional system	New system
Storage system	Each container is stacked on top of each other	Each container is placed into a different slot in a container block. A special ID code will be automatically issued for each container
	Normally, five to six containers are stacked high	One block comprises 10 containers in each level × 15 stories = 150 containers
	To obtain the bottom container, the top four or five containers need to be removed first	Each container has its own ID slot number, and there is no need to remove other containers
Time	Wastes time because the other four containers have to be placed back at the same location after selecting the bottom one	No waste of time because this is an automatic system
Efficiency	Less efficient and reliable, sometimes due to human error	Anticipated to be more efficient and reliable because automated
Environmental	No or low green concept	Fully utilises green concept by introducing use of solar energy and wave energy panels, and windmills
		Less emission and maintains greenery in the area
		Less emission or pollution from port means that fewer health problems
Cost and investment	Normal port income	The port income anticipated to triple (high profit margin)
	Less investment cost	High investment cost in the first stage, but countered by anticipated higher profit obtained by the port
	High labour cost	Reduces labour cost
	High operational costs because utilising space capacity and carrying out operations require funds	Less operational cost because adopts green technology
Container volume	Normal total container volume can be handled	Total container volume can increase to three times normal volume
Operations	Manual operations for obtaining a specific container	Can accommodate 40-foot container in full container load
		Hazardous and special containers will be allocated to a special zone
		Applicable for full container loads, less container loads and empty containers
		Can be set to be fully or semi-automatic
Safety	Human errors and accidents in container yard take place frequently	Reduces human errors because system can be fully automatic
Maintenance	Less maintenance is required	Scheduled proper maintenance is required and will incur maintenance costs
Technology	Uses old technology	Uses latest and most updated technology

indirectly benefit society, such as infrastructure improvements, higher incomes, job opportunities, etc.

7. Conclusions

The growth of international seaborne trade is reflected by the increase of container ships, container throughput and container terminals. This shows that the global economy is continuing to grow after recovering from the global financial crisis of 2008-2009. As containerisation continues to increases, it is essential to think of ways that would cater to the increased demand. As existing space at ports becomes inadequate to address the increases in number of container throughput every year, this study has been able to determine the factors that lead to space limitation. It is found that limitations in the space of the container yard area is the most serious issue. An innovative model of a container stacking/storage system is presented in this study as a possible solution to the problem. The trend of container growth can therefore continue to gradually increase in the future without being limited by the need for more space. The use and further development of this innovative system is anticipated to benefit port operators/owners, investors, shipping companies, governments and society in terms of the economy, environmental, technological, operational and safety benefits. Also, the new container stacking/storage system enables container ports to increase their competitiveness and better serve their clients.

References

Asean Port Association Malaysia (2012), *Westports Container Volume Jumps*, available at: www.apamalaysia.com/tag/westports-malaysia/

Bazzazi, M., Safaei, N. and Javadian, N. (2009), "A genetic algorithm to solve the storage space allocation problem in a container terminal", *Computers and Industrial Engineering*, Vol. 56 No. 1, pp. 44-52.

Carlos, H.J., Vis, I.F. and Roodbergen, K.J. (2014), "Storage yard operations in container terminals: literature overview, trends, and research directions", *European Journal of Operational Research*, Vol. 235 No. 2, pp. 412-430.

Chao, S.L. and Lin, Y.J. (2011), "Evaluating advanced quay cranes in container terminals", *Transportation Research Part E: Logistics and Transportation Review*, Vol. 47 No. 4, pp. 432-445.

Ducruet, C. and Notteboom, T. (2012), "The worldwide maritime network of container shipping: spatial structure and regional dynamics", *Global Network*, Vol. 12 No. 3, pp. 395-423.

Islam, S. and Olsen, T.L. (2011), "Factors affecting seaport capacity", *19th International Congress on Modelling and Simulation, 2011*, *Perth, Western Australia*, pp. 412-418.

Jiang, X., Lee, L.H., Chew, E.P., Han, Y. and Tan, K.C. (2012), "A container yard storage strategy for improving land utilization and operation efficiency in a transshipment hub port", *European Journal of Operational Research*, Vol. 221 No. 1, pp. 64-73.

Laih, C.H. and Chen, Z.B. (2013), "The model of optimal non-queuing pricing for Port container yard", *Journal of the Eastern Asia Society for Transportation Studies*, Vol. 10, pp. 280-294.

Lian, Y.K. (2010), *Port Klang Retain Status as Busiest Container Port*, Asean Port Association, Malaysia.

Nam, H.S. and Song, D.W. (2011), "Defining maritime logistics hub and its implication for container port", *Maritime Policy and Management*, Vol. 38 No. 3, pp. 269-292.

Nazery, K. (2005), *The Development of Port and Shipping Sector in Malaysia*, Maritime Institute of Malaysia (MIMA), Malaysia.

Nazery, K. (2013), "Port Klang may have a 3rd port", available at: www.freemalaysiatoday.com

Nazery, K. and Ibrahim, H.M. (2007), *Growing Shipping Traffic in the Strait of Malacca*, Maritime Institute of Malaysia (MIMA), Malaysia.

Nico, B. (2000), "Efficient stacking on container terminals: how to cope with volume fluctuations on a densely stacked terminal, while maintaining terminal performance", *Port Technology International*, Vol. 35, pp. 53-54, available at: www.porttechnology.org/technical_papers/efficient_stacking_on_container_terminals_how_to_cope_with_volume_fluctuati/

Northport (2015), *Container Services: Container Terminal Facilities*, Northport Malaysia, available at: www.northport.com.my/npv2/containerservices.html

Notteboom, T.E. and Rodrigue, J.-P. (2005), "Port regionalization: towards a new phase in port development", *Maritime Policy and Management*, Vol. 32 No. 3, pp. 297-313.

Ortiz, D., Weatherford, B., Willis, H.H., Collins, M. and Mandava, N. (2007), *Increasing the Capacity of Freight Transportation US and Canadian Perspectives*, RAND Corporation, Santa Monica, CA, ISBN: 978-0-8330-4125-8.

Paul, J.A. and Maloni, M.J. (2010), "Modeling the effects of port disasters", *Maritime Economics and Logistics*, Vol. 12 No. 2, pp. 127-146.

Port Klang Authority (2013), *Gateway*, A Publication of Port Klang Authority, Malaysia.

Port Klang Authority (2015a), *Port Klang Statistics: Container Information (TEU)*, available at: www.pka.gov.my/index.php/component/content/article/127-port-klang-statistics.html

Port Klang Authority (2015b), *Gateway Report*, A Port Klang Authority Publication, available at: www.pka.gov.my/index.php/en/download/category/3-gateway.html

Robinson, B. (2003), "Container terminal vehicle booking systems", *Cargo Systems*, Vol. 30, p. 16.

Sharif, O. and Huynh, N. (2013), "Storage space allocation at marine container terminals using ant-based control", *Expert Systems with Applications*, Vol. 40 No. 6, pp. 2323-2330.

Stopford, M. (2009), *Maritime Economics*, Oxon, Routledge.

Tan, M. (2016), Singapore's container port faces a productivity question, *The Business Times*, Companies and Market, available at: www.businesstimes.com.sg/companies-markets/singapores-container-port-faces-a-productivity-question

Teh, K.P. (2011), *PKA Awaiting Cabinet Nod for Third Port*, Asean Port Association, available at: www.apamalaysia.com/pka-awaiting-cabinet-nod-for-third-port/

UNCTAD (2013), "Review of Maritime transport", *United Nation Conference on Trade and Development*, United Nations Publication, New York, NY, Geneva.

Westports (2015), *Container Facilities*, available at: www.westportsmalaysia.com/Container-@-Facilities.aspx

World Shipping Council (2015), "Top 50 world container ports", available at: www.worldshipping.org/about-the-industry/global-trade/top-50-world-container-ports

Zaidi, A.Z.A. and Abdul Rahman, N.S.F. (2014), "Space limitation at container ports: the way to face challenges through new milestones technology", *1st International Maritime Conference (IMC2014)*, Universiti Malaysia Sabah, Malaysia.

Zhang, C., Liu, J., Wan, Y.-W., Murty, K.G. and Linn, R.J. (2003), "Storage space allocation in container terminals", *Transportation Research Part B*, Vol. 37 No. 10, pp. 883-903.

Corresponding author
Noorul Shaiful Fitri Abdul Rahman can be contacted at: nsfitri@umt.edu.my