CHALMERS
UNIVERSITY OF TECHNOLOGY

Exploring seaport - dry ports dyadic integration to meet the increase in container vessels size

Citation for the original published paper (version of record):
Jeevan, J., Roso, V. (2019)
Exploring seaport - dry ports dyadic integration to meet the increase in container vessels size
Journal of Shipping and Trade, 4(8): 1-18
http://dx.doi.org/10.1186/s41072-019-0047-4

Jeevan and Roso Journal of Shipping and Trade (2019) 4:8
https://doi.org/10.1186/s41072-019-0047-4

Journal of Shipping and Trade

ORIGINAL ARTICLE Open Access

Exploring seaport - dry ports dyadic integration to meet the increase in container vessels size

Jagan Jeevan[1] and Violeta Roso[2*]

* Correspondence: violeta.roso@chalmers.se
[2]Department of Technology Management and Economics, Division of Service Management and Logistics, Chalmers University of Technology, Vera Sandbergs Alle 8, SE-412 96 Gothenburg, Sweden
Full list of author information is available at the end of the article

Abstract

This paper explores the implications of vessel enlargement on seaport competitiveness and investigates the dyadic integration between seaports and dry ports to address drastic vessel size acceleration in the Malaysian seaport system. Therefore, this paper aims to reveal the seaport/dry port dyadic relationship to improve seaport competitiveness in light of the increase in vessel size in the arena of global trade. To achieve this aim, mixed methods were applied by conducting qualitative and quantitative approaches concurrently. The outcome of this paper indicates that vessel enlargement has caused several problems in seaports including reduction in operational efficiency, congestion, limited capacity and infrastructure support, outdated policies for existing seaport development, urgent needs for additional investment in spatial development, as well as requirements for new structure in manpower training. Furthermore, the integration of dry ports in the seaport system to deal with vessel size enlargement is expected to improve seaport accessibility through improved infrastructure and service quality as well as increased capacity and efficiency.

Keywords: Vessel size increase, Mega-vessel, Seaports, Dry ports, Competitiveness, Malaysia, Mixed method

Introduction

Ideal X (1956, capacity of 500 TEUs), Fully cellular (1970, up to 2500 TEUs), Panamax (1980, capacity of 3000–4500 TEUs), Post Panamax (1988, up to 6000 TEUs), New-Panamax (2014, up to 12,500 TEUs), and Ultra Large Container Ship (2013, capacity of up 21,000 TEUs) are some generations of container ships from the 1950s (Rodrigue et al. 2017). This evolution shows that the size of vessels is increasing to ensure economies of scale in the maritime transportation of containers. For the last 20 years, the mission to achieve economies of scale has become the driving factor behind the development of vessels with capacities exceeding 18,000 TEU (Parola et al. 2016). Key components of economies of scale (EOS) include efficient production, the spread of risk, cheaper capital, and reduction in logistics costs. In this paper, EOS has become a key motivation to enlarge vessel size to provide substantial benefits to all players in the supply chain. However, at the same time, it has imposed extraordinary operational constraints in the seaports. Each subsequent generation of container vessels faces a shrinking number of seaports that are able to handle the vessels by placing pressure on port infrastructure and equipment (Rodrigue et al. 2017; Tran and Haasis 2015). Large vessels benefit from economies of scale at sea but create diseconomies of scale at seaports (Tran and Haasis 2015). EOS is the main outcome resulting from vessel size enlargement. However, this enlargement and the enormous volume of containers to be handled create diseconomies of scale (DOS) at seaports due to space limitation and unavailability to respond to changes in a timely manner. Consequently, the EOS of vessel enlargement creates pressure on seaports due to their physical limitations, rigidity of business practices, and insufficient integration with inland components.

Significant benefits gained from economies of scale indicates that the growth of container vessels shows no sign of ending (Monios 2017). Besides the enhancement of vessel size, the shipping alliances that began in the 1990s constitute a cooperative operational arrangement between two or more non-arms-length ocean carriers to combine their assets with the goal of implementing a mutually beneficial strategy (Tang and Sun 2018). In enlarging vessels, individual organisations or combinations of a few organisations are pursuing similar objectives of achieving economies of scale and scope for trading. For example, the establishment of a few mega alliances, especially the P3 Alliance in 2014, the Ocean Alliance and The Alliances, as well as the 2 M Alliances between 2016 and 2017, allowed them to control almost 77% of global container ship capacity, leaving the remaining percentage to other container liners (Tang and Sun 2018). It is important for every shipping organization to sustain itself in the competitive environment as well as to compete with gigantic alliances that already exist in the maritime sector. Substantial demand for economies of scale and concerns about greenhouse gas emissions have justified the existence of mega-vessels in the maritime trade. For example, emissions generated by a vessel of 20,000 TEUs are 50% lower per unit than emissions released by a vessel with 8000 TEUs (Notteboom et al. 2017).

Despite providing a huge advantage to shipping companies due to economies of scale and environment, the growth of mega-vessels generates demanding and costly implications for seaports. Those implications include the need for development of new infrastructure for seaports, restructuring land-side operations, and stressing the whole logistics chain of containers. In addition to that, terminal operators and seaport authorities are pushed into making significant investments in equipment and nautical accessibility in view of reducing or eliminating potential diseconomies of scale of such large units in the seaports (Notteboom et al. 2017). Furthermore, seaports need to collaborate with their inland terminals to improve their flexibility through recuperated inland access. Jeevan et al. (2018a) and Roso (2013) have indicated that the implementation of dry ports in the seaport transportation system can have significant implications for seaport competitiveness. Based on these arguments, this paper explores the issues faced by seaports due to vessel enlargement and investigates the role dry ports play in assisting seaports to face these issues. The research question is: "*What role can dry ports have in supporting seaports to maintain their competitiveness due to the container vessel enlargement trend?*" Information on the ability of dry ports to assist seaports in coping with the trend of vessel enlargement is still vague and needs extensive exploration.

Methodological approach

This paper employs a mixed method approach to address the research problem. A triangulation design has been adopted to concurrently collect both qualitative and quantitative data and merge both sets, then to use the outcome to address the research question. A qualitative approach is used by conducting interviews with key experts from seaport and dry port operators. During the interview session, two main questions were answered by the participants, and they address issues faced by seaports due to vessel enlargement and how dry ports can play a role in assisting seaports in facing vessel enlargement.

Concurrently, in the quantitative phase, Exploratory Factor Analysis (EFA) has been employed to analyse the data. EFA is exploratory in nature, and it investigates the main dimensions to generate a concept, theory, or model from a large set of items (Williams et al. 2010). In this paper, EFA has been utilised to validate the implications of vessel enlargement on seaport competitiveness. The next stage is to examine the relationship of vessel enlargement to dry port/seaport competitiveness, i.e., to examine how dry ports assist seaports in facing the vessel enlargement issue to preserve and improve seaport competitiveness.

A triangulation mixed method (see Fig. 1) approach has been implemented in this study because it involves different perspectives including issues regarding the effect of vessel enlargement on seaport competitiveness, the possibility of dry ports assisting seaports in handling mega-vessels, and the implications for seaport competitiveness. Further, the mixed method triangulation strategy has been implemented due to the specific strength of this method. For example, it answers broader research questions; it is able to integrate qualitative and quantitative approaches to overcome the weaknesses and utilise the strengths of each approach; and it improves insights into and understanding of the data that might be missed when using a single method approach. It also integrates qualitative and quantitative data to provide strong evidence for conclusions, and triangulating the data from different methods increases the validity of the results and the conclusions (Creswell and Clark 2007).

According to Cooper and Schindler (2011), sampling strategy is crucial as a selecting element for a population related to the research topic in order to draw a significant conclusion about the topic. In general, the sampling strategy depends on the methods chosen and the availability of resources (Kemper et al. 2003). In the qualitative phase, non-probability sampling is used with different sizes of samples depending on the research question and the unit of analysis. The focus of the qualitative phase is to derive depth and extensive information across both phases to address the research questions (Teddlie and Tashakkori 2009, p. 181). Convenience sampling is carried out by locating potential respondents who meet the criteria and selecting them on a first come, first served basis until the sample size is full (Robinson 2014).

Meanwhile, in the quantitative phase, a list-based, stratified sampling technique was applied to increase the sample's statistical efficiency to above that of simple random sampling, and it is suitable for use with a survey when the respondents' organisations are scattered (Cooper and Schindler, 2014). This sampling technique is very accurate compared to simple random sampling, keeping a record of the availability of respondents and generating more representatives in each stratum (Biffignandi and Bethlehem 2012). Hence, in this triangulation design, two different sampling strategies have been employed

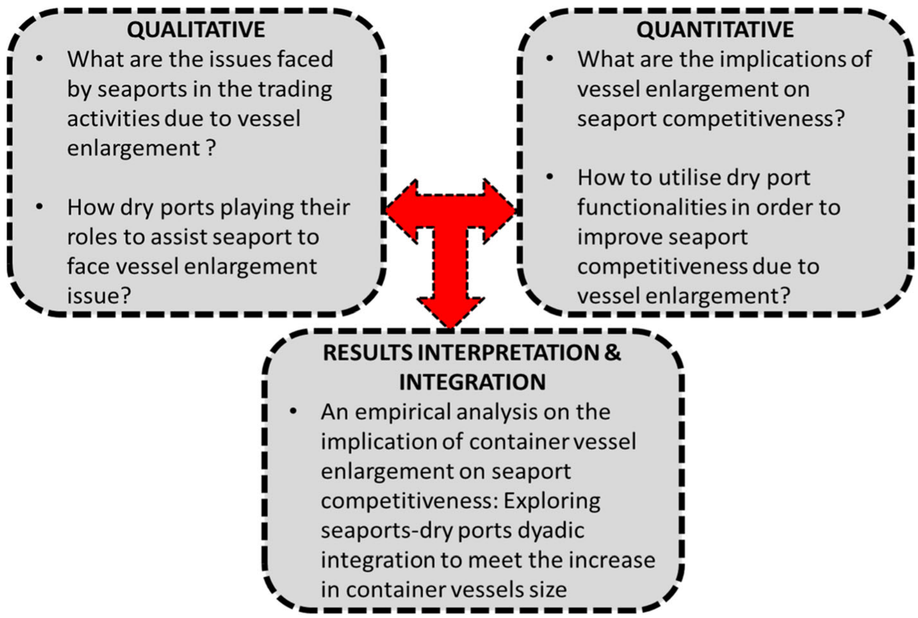

Fig. 1 A mixed method triangulation strategy. Source: Adapted from Creswell and Clark (2007)

to obtain significant results, and the results from the qualitative method can be expanded into quantitative results (Klassen et al. 2012). Table 1 shows the sampling frame for both phases.

Frame of reference

This section addresses the concept of seaport competitiveness and the impact of vessel enlargement on that competitiveness. In addition, this section explains the role of dry ports in seaport competitiveness.

Seaport competitiveness

Seaport competitiveness is changing frequently due to the significant impact of technological advancement, changes in institutional functionalities, significant involvement of seaports in regional and international competition, dramatic spatial development, improvement of seaport services, and changes in the business environment (Bichou and Gray 2005). Furthermore, the changes in seaport competitiveness are highly connected to the nature of the maritime business, which is greatly affected by continuous and productive activity or change. Hence, the criteria for seaport selection among users are changing accordingly.

The concept of competitiveness is widely used to analyse strategic behaviour of firms and later was used to refer to competition among nations (Porter 1990) and business ecosystems (Moore 1996). Bichou and Gray (2005) have defined seaports as networks in which the success of each business is firmly connected to the whole system's competitiveness. Tongzon and Heng (2005) proposed eight key determinants of port competitiveness: port (terminal) operation efficiency level, port cargo handling charges, reliability, port selection preferences of carriers and shippers, depth of the navigation channel, adaptability to the changing market environment, landside accessibility, and

Table 1 Sampling frame for qualitative and quantitative phase

Participant in qualitative phase	Convenience sampling strategy	Population	Sampling size
Dry port operators	Selecting from dry port operators in Malaysia	4	4 (FIP* 1,2,3, and 4)
Ministry of Transportation	Selecting from Port Division	1	1 (FIP 5)
Marine Department	Selecting from Maritime Transportation Division	1	1 (FIP 6)
Seaport authorities	Port Klang Authority, Penang Port Commission, and Johor Port Authority (major seaport authorities)	6	2 (FIP 7 and 8)
Seaport operators	Westport, Northport, Penang Port, and PTP (seaport operator administered by main seaport authorities)	11	2 (FIP 9 and 10)
TOTAL		23	10
Stratum in quantitative phase	Stratified Sampling frame	Population	Sampling size
Shippers	Key shippers listed in Port Klang, PTP, and Penang Port.	20	20
Rail operators	Samples selected from 5 regional branches of Malaysian Railway that handled containers.	10	10
Seaports	Selecting operational, container, and logistics executives in all seaports including their branches.	21	21
TOTAL		51	51

FIP (Face-to-face interview participant)

product differentiation. These components slightly differ from Seung (2015), who emphasis efficiency, attractiveness to major liners and shippers, extension of networks, and development of hinterlands.

Kim et al. (2004) investigated the concept of seaport competitiveness in northeast Asia, and the results show that seaport competitiveness is normally based on local cargo volume (economic size), port facilities utilization (business infrastructure), proximity (to the import/export area, market, and host city), preferences of shipping liners and the relevant industries, a port's physical capacity to accommodate additional volume, hinterland development, terminal productivity, cargo handling speed, supply chain cooperation, simplification of procedure, total transport costs per container, trans-shipment costs, port charges, port service costs, reliability of service performance, safety and security, application of IT, quick response to port users' needs, and low congestion at the seaport.

Parola et al. (2016) rank the key drivers of port competitiveness such as port costs, hinterland proximity, hinterland connectivity, port geographical location, port infrastructure, operational efficiency, seaport service quality, maritime connectivity, nautical accessibility, and port site. In addition, Kim and Chiang (2017) reveal that the determinants of port competitiveness have focused on the aspect of sustainability while serving the customers' expectations, which include operational efficiency, port availability, port costs, and service quality.

In general, the criteria for seaport selection differ among researchers and keep changing. Seaports need to be prepared to face these changes in order to stay or become attractive to users. The focus of seaport competitiveness on various segments including seaport operation, ability to adapt to the current environment, hinterland networks, services, and charges indicates that seaports will not operate in the same mode for a long time, and any changes in the seaport system will probably have implications for seaport competitiveness.

Impact of vessel enlargement on seaport competitiveness

According to Imai et al. (2006), the major hindrances faced by seaports in accommodating these mega-vessels are their drafts, i.e., channels not deep or wide enough (Prokopowicz and Berg 2016). For example, the combined beam of two ships plus a safe separation zone between vessels is required for safe passing in a channel; this may be a significant problem for two large vessels. To accommodate most large vessels, one-way traffic would have to be imposed, and this would cause delays for other vessels in the queue. Therefore, other seaports that handle feeder vessels will be more attractive to shipping lines compared to the seaports that handle a substantial number of mega-vessels. In addition, quay cranes capable of faster handling for quick turnaround times would be required in the selected mega-hub ports (Damas 2002). In order to ensure the smooth flow of cargo to and from vessels, significant investments are required to certify the compatibility of facilities for the volume of cargo handled by mega-vessels.

Terminal operators and seaport authorities are pushed into making big investments in equipment and nautical accessibility in view of reducing or eliminating potential diseconomies of scale of such large units in port (Notteboom et al. 2017). This is important to improve the efficacy of vessels (less turnaround time) as well as seaports (fast transloading procedure). Hence, to achieve these milestones, seaports and terminals have been forced to make large and rapid investments in infrastructure to cope with new vessel sizes and to preserve their competitiveness with other seaports. Regarding seaport competitiveness, this trend strongly affects the ship/port relationship as operational bottlenecks and port inefficiency bring about insufficient infra- and supra-structures at seaports.

Efficiency can be provided by extensive usage of information technology (IT) solutions by terminals, stevedores, freight forwarders, and logistics and transport companies. Uniform IT platforms for all participants in the port logistics process may be necessary to ensure the necessary capacities to serve VLCSs (Prokopowicz and Berg 2016). Another challenge is the synchronisation of seaports in terms of landside operations (Rodrigue and Notteboom 2010). The significant growth in vessel size has forced gateway ports to have a higher degree of synchronisation with their hinterlands through specialised high-capacity transport corridors serviced by rail or barges, often including dry ports (Roso and Lumsden 2010). This is necessary to transfer huge volumes of containers from vessel to hinterland and vice versa in a very short time to reduce demurrage, which eventually will affect the attractiveness of seaports. Hence, the inland transportation system must be well connected to and from seaports to shorten the dwelling time of containers.

Seaports face congestion due to a surge of internal and external traffic (Tran and Haasis 2015), and this congestion may generate a ‘knock-on’ effect. For example, a delay caused by congestion can in turn cause the lay time to expire which eventually results in a delay in reaching the next port of call (Jiang et al.

2017). According to Prokopowicz and Berg (2016), the emergence of mega-vessels will increase the requirements for storage capacity expansion to provide additional space for more containers. Therefore, intermediate container storage space, marshalling yard space, plug-ins for cooling and refrigerated containers, and warehouse space will be essential for smooth transloading and transhipment procedures. Besides space capacity, a large quantity of skilled labour, equipment, and involvement of autonomous vehicles will be necessary to improve productivity at seaports.

According to Nur Anis'sa et al. (2019), seaports need to face new challenges to accommodate mega-fleets, for example, effects on quay cranes and yard productivity, significant requirements for additional yard space, utilization issues regarding quay cranes, and rampant increments in operational costs. In detail, the presence of mega-vessels might increase the dwelling time of containers, which in turn might affect the productivity of seaports and eventually reduce their attractiveness among users. In that case, significant support is required from dry ports to reduce the burden on seaport operations. Existence of seaport-based, city-based, and border-based dry ports may assist seaports from various directions to reduce operational pressure and increase productivity.

Meng et al. (2017) indicate that the current layouts of container terminals will be unable to meet the demand from larger container vessels because of high utilization rates and the long stay times and wait times for most vessels. The implications of vessel enlargement will put pressure on seaports to preserve their competitiveness. In general, the implications of vessel enlargement can be classified into four main themes: seaport infrastructure, operational efficiency, hinterland network, and service quality (see Table 2).

Role of dry ports in seaports competitiveness

An increase in maritime flow usually creates an almost proportional increase in inland flow, and, therefore, advancements and improvements only in the maritime link in the transport chain are not enough to make the entire chain function properly (Roso, 2007; Bask et al. 2014. Dry ports have become a solution to increase seaport productivity due to movement of containers via high capacity means to and from seaports to achieve an effective supply chain solution in the hinterland as well as in the entire transport chain (Roso, 2007; Khaslavskaya and Roso 2019). The advancement in supply chains increased the pressure on seaport operations and inland freight distribution. Therefore, inland accessibility becomes an important component in determining seaport competitiveness (Notteboom and Rodrigue 2005; Roso et al., 2019).

The rising number of container flows from and to seaports caused congestion in terminals and increased container dwelling times, which affected the competitiveness of the seaports as a whole (Roso et al. 2009; Black et al. 2018). The emergence of dry ports as a connecting node with different players facilitates container traffic in the supply chain and increases the competitiveness of seaports as a result (Notteboom and Winkelmans 2001; Roso 2013). Access to the seaport hinterland became critical for competitive advantage as container volumes increased. Implementation of dry ports has impacted seaport competitiveness, especially by enhancing seaport performance and increasing service variations for seaport customers (Andersson and Roso 2016),

Table 2 Vessel enlargement and the effect on seaport competitiveness

Factor of vessel enlargement	Effect on seaport competitiveness	Reference
Port infrastructure	Draft restrictions in seaports such as low water depth in access channels and berths to accommodate deep-draft ships	Imai et al. 2006
	Normal quay cranes are not effective with gigantic container ships.	Tran and Haasis 2015
	Storage capacity is not sufficient for massive volume of containers.	Jeevan et al. 2018a
	Operational bottlenecks and port inefficiency cause of unavoidable and insufficient infra- and supra-structures	Notteboom et al. 2017
	Issue of vessel breadth and channel passing which may be a significant problem for two large vessels.	Prokopowicz and Berg 2016
Operational efficiency	The container mega-ship raises issues concerning container-handling operational needs at ports.	Imai et al. 2006
	Economies of scale have driven towards increased vessel size (above 18,000 TEU). However, at the same time, it has imposed unprecedented operational constraints in ports.	Parola et al. 2016
	Low capability of faster handling for quick turnaround time required in the selected mega-hub ports.	Imai et al. 2006
	The productivity of container yard will be affected.	Tran and Haasis 2015
	The call of mega ships possibly causes rush and off-peak hours in ports. It is expected that the ports will face congestion due to a surge of internal and external traffic.	Tran and Haasis 2015
Hinterland network	Need for high synchronisation with hinterlands through specialised high-capacity transport corridors serviced by rail or barges, often including dry ports.	Roso and Lumsden 2010
	Inland transportation system must be well connected to deliver cargo on time as well as shorten dwell time of containers in port.	Tran and Haasis 2015
Service quality	The current container terminal will unable to meet the larger container demand in the distant future because of high utilization rates and the long stay times and wait times for most vessels.	Meng et al. 2017
	Uniform IT platforms for all participants in the port logistics process are necessary to ensure capacities to serve VLCSs.	Prokopowicz and Berg 2016
	Unavoidable an insufficient 'info-structure' (e.g., Port Community Systems)	Notteboom et al. 2017

improving seaport-hinterland connectivity, increasing seaport trade volume, and increasing seaport capacity. This indicates that the implementation of advanced intermodal terminals like dry ports in the seaport transport system can improve the attractiveness of the seaport itself.

The ability of dry ports to manage and optimise a large share of the container transportation chain helps to establish the seaport's function in the inland region (Roso et al. 2009). The introduction of a dry port in the seaport system increases seaport competitiveness by providing additional capacity, increasing the accessibility to and from the seaport, increasing speed and frequency of container clearance, acting as a relieving zone for seaport congestion, and increasing throughput without physical seaport expansion (Ng and Gujar 2009). The seaport community consisting of shippers, freight forwarders, shipping lines, terminal operators, and transport operators consider that dry ports reduce disturbance in the supply chain, which in turn saves money and time during the container transfer process (Beresford et al. 2012). In general, dry ports increase consistency in sourcing containers from inland destinations, improving inland access, reducing seaport congestion, and providing better customer service (Roso and Lumsden 2010; Andersson and Roso 2016). Dry ports strengthen transport capability by introducing various foreign and domestic stakeholders to the network (Beresford et al. 2012), and they have good potential to generate competitiveness in container seaports from various dimensions, namely, seaport performance (Roso 2013), seaport capacity (Ng and Gujar 2009), seaport hinterland (Bask et al. 2014; Roso et al., 2019), information systems (Notteboom and Rodrigue 2005), seaport services (Andersson and Roso 2016), and maritime trade (Rodrigue and Notteboom 2010).

Results and analysis

This section will interpret the findings from the interview sessions and the EFA. Section 4.1 presents the outcome of interviews with 10 participants from dry port operators, Ministry of Transportation, Marine Department, seaport authorities, and seaport operators. The aim of this section is to explore two main questions addressing issues faced by seaports due to vessel size enlargement and how dry ports play a role in assisting seaports in overcoming this issue. Second, the outcome from the EFA is presented in section 4.2. The input for this section was derived from 51 responses from shippers, rail operators, and seaports. This section mainly focuses on the implications of vessel enlargement for competitiveness and the strategy of using dry port functions to preserve seaport competitiveness in light of vessel size enlargement. Triangulations of results from both phases have been done in the discussion and the conclusion.

Vessel enlargement impact on seaports and the role of dry ports

During the interview session, two main questions were asked of the participants regarding major issues faced by seaports due to vessel enlargement and the role of inland terminals/dry ports in assisting seaports to overcome these issues. One of the interviewees (FIP 1) responded that '*[t]he efficiency of seaports will be affected, and at the same time the supply chain from seaport to hinterland will be severely affected. Furthermore, congestion will be another issue that seaports will face*'.

'*I believe the current capacity of seaports is not sufficient to accommodate large vessels with massive volumes of containers*' (FIP 2). Further, FIPs 7 and 8 stated that '*the arrival of larger vessels may cause congestion at seaport gates with more external trucks entering and exiting the seaport area*'. These participants believe that Malaysian seaports need additional infrastructure support to be prepared to receive larger vessels. For example, FIPs 9 and 10 agree that infrastructure support, especially from quay cranes, prime movers, and gantries, needs to be upgraded immediately to preserve the competitiveness of seaports. FIPs 1 and 2 agree that '*[t]he current policy is not suitable because it highly reflects on new seaport development rather than improving the existing capacity and infrastructure of the seaport itself*'.

On the other hand, FIP 3 considers the draft to be insufficient in some of the seaports in this region, especially in the northern region and the east coast of peninsular

Malaysia; the drafts are less than 14.5 m, and to receive the mega-vessels, drafts of more than 15–16 m are required. Again, the facilities need to be upgraded in order to serve these larger ships. In regard to this, FIPs 4 and 5 agree that seaports need to channel additional financial aid for dredging activities, which need to be done frequently. In addition, FIPs 6, 7, and 8 declared that additional investment is required for seaport spatial development, especially in wharf areas, to support and accommodate double or triple the volume of containers from larger vessels compared to feeders. Furthermore, additional training needs to be provided to the pilots in order to assist larger vessels to the seaport area (FIP 3 and 5). In that case, seaports also need to provide additional budgeting for pilot training. It can be summarized that the emergence of larger vessels in Malaysian seaports may cause several problems including decline in operational efficiency, congestion, limited capacity and infrastructure support, outdated policies for existing seaport development, requirements for additional investment in spatial development, and the need to introduce a new syllabus for manpower training.

After identifying the issues that arose from vessel enlargement, the next question addressed how these dry ports may assist seaports in overcoming issues of vessel enlargement. First, FIPs 3, 4, and 7 responded by stating, '*The connectivity between seaport and dry ports is expected to improve the efficiency of seaport operations by providing appropriate modal shift between transportation modes to ensure the freight movement to and from seaport will be faster than single mode transportation*'. Also, FIPs 1 and 3 mentioned that '*the existence of dry ports may expand the seaport capacity and subsequently reduce the congestion issues at seaports*'. Immediate movement of containers from seaports to dry ports will reduce congestion at seaports because haulers will divert their attention to dry ports for cargo collection, transfer, and distribution. This will reduce the need for additional investment by seaports to provide more space for a larger volume of containers; consequently, transloading activities and dwelling time at seaports could be reduced.

In general, there are four major functions carried out by Malaysian dry ports: transport, administration, logistics, and value-added functions. Some of these can be utilised by dry ports to assist seaports in reducing the negative consequences of vessel size enlargement. For example, FIPs 3, 4, and 7 responded by stating, '*The connectivity between seaport and dry ports is expected to improve the efficiency of seaport operations by providing appropriate modal shift between transportation modes to ensure the freight movement to and from seaport will be faster than single mode transportation*'. In that case, the transportation function of dry ports can be exploited to reduce container dwelling time in terminals, decreasing inland transportation costs, and increasing shippers' connectivity to the seaports. Second, FIPs 1 and 3 mentioned that *'the existence of dry ports may expand seaport capacity and subsequently reduce the congestion issues at seaports'*. In this regard, logistics functions of dry ports can be utilised by providing warehousing, storage, and de/consolidation functions at various locations.

The integration of dry ports into the seaport system provides additional facilities and infrastructure without massive investment (FIPs 4, 8, and 9). In Malaysia, some of the dry ports such as Nilai Inland Port (central region) and Segamat Inland Port (southern region) have additional space for future development. This indicates that seaports are able to cooperate with dry ports to ensure the ability of seaports to serve larger vessels and prepare for the future. In contrast, lack of additional space for future development reduces the possibility of these dry ports (Padang Besar Cargo Terminal-PBCT and Ipoh Cargo Terminal-ICT) to cooperate with seaports to resolve the vessel enlargement issue. Although these dry ports (PBCT and ICT) have no space for future development, their connectivity with other dry ports provides another alternative solution for their clients. For example, collaboration via location pooling with other dry ports or container depots in the region could provide a bright opportunity for PBCT and ICT to increase their capacity and accommodate laden and empty containers simultaneously. PBCT, and especially ICT, utilized space by location pooling with other dry ports, generating a network between them, reducing competition, and enhancing the performance of the dry ports (see Fig. 2).

The nature of Malaysian seaports as transshipment seaports may also allow the use of dry ports to serve larger vessels. For example, transshipment containers can be 'pushed' immediately to dry ports to provide more space at seaports to locate immediate containers for transloading procedure. This indicates that dry ports may effectively assist the performance of gateways in this region.

Padang Besar Cargo Terminal (PBCT), which began operating in 1984, was the first Malaysian seaport. This border-based dry port encourages domestic and international container transactions, especially in southern Thailand and the northern region of peninsular Malaysia; it contributes 40% of container traffic to Peneng port and 10% to port Klang (Jeevan et al. 2015). The capacity of the container yard at PBCT is around 800 TEUs, and, unfortunately, this dry port has no space for locating empty containers or land for future development. Perishable goods, rubber, wood, timber, and raw materials are the main cargo handled at PBCT. Ipoh Cargo Terminal (ICT) is a city-based dry port that started their operation in 1989. This dry port connects to all major seaports in Malaysia by contributing 35%, 10%, and 5% of containers to Port Klang, Penang Port, and PTP, respectively. This dry port has a capacity of 800 TEUs in its container yard and space to accommodate empty containers, but it has no land for future development. The main cargo handled at this dry port are raw materials and manufacturing goods (Jeevan et al. 2015).

Third, Nilai Inland Port (NIP) started operations in 1995 and is located strategically in the centre of Malaysia. This dry port contributes 60% of containers to Port Klang and 10% to PTP. Current yard capacity of this city-based dry port is about 1200 TEUs, but it has no space for empty containers. For future development, this dry port possesses land to accommodate additional containers. The main cargo handled at this dry port includes raw materials and manufacturing goods (Jeevan et al. 2015).

Finally, Segamat Inland Port (SIP) is the latest border-based dry port in Malaysia. It started operations in 1998 by providing 20% of the containers to both Port Klang and PTP. The total capacity of SIP's container yard is 3500 TEUs, and it has ample space for empty containers and future development. The main cargo handled at SIP are agricultural products and raw materials. Figure 3 maps the locations of dry ports and seaports in Malaysia and the availability of multimodal transport networks and logistics providers throughout the region.

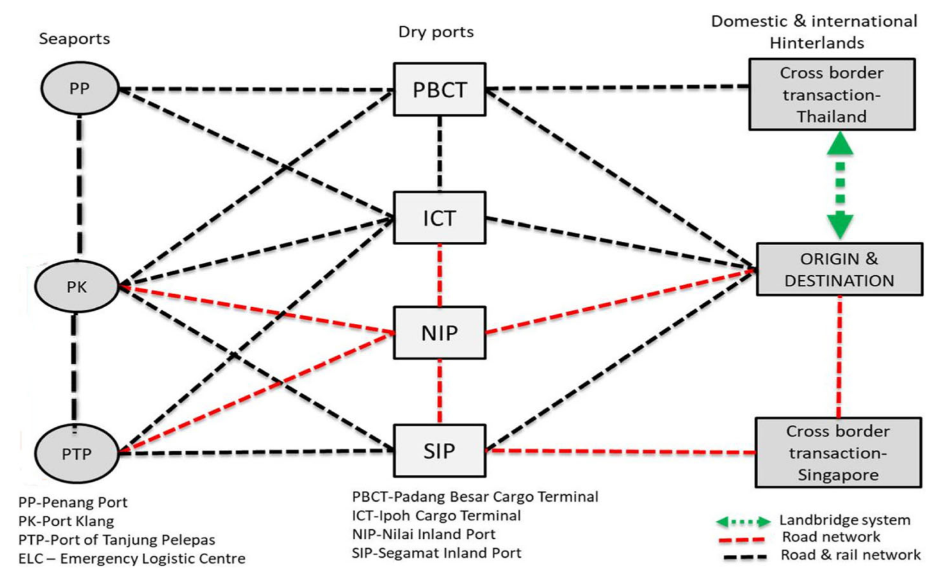

Fig. 2 Framework of the Malaysian intermodal freight system. Source: Authors

Dry ports/seaports dyadic integration to improve seaport competitiveness

In this section, quantitative data were gathered via EFA to validate the implications of vessel size enlargement on seaport competitiveness as well as the effects of dry ports on seaport competitiveness resulting from dry port integration into the seaport system. Seventeen out of 19 items have been extracted to identify the impact of ship enlargement on seaport competitiveness, and these results have been divided into five major dimension scales: seaport accessibility, seaport infrastructure, seaport service quality, seaport capacity, and seaport efficiency (total variance is 69.88%). Intercorrelation items for contributing factors were assessed; the KOM measure of sampling adequacy (0.603)

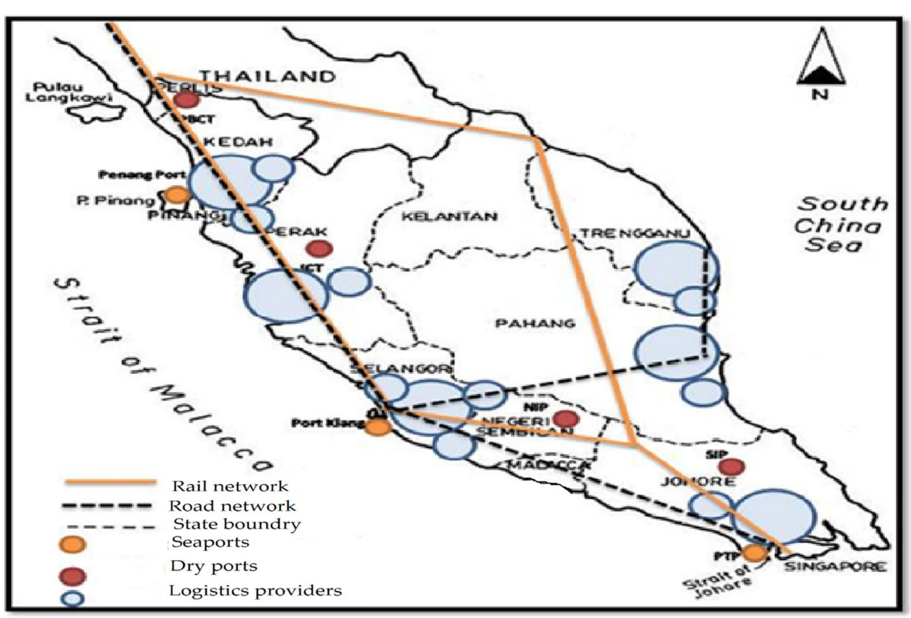

Fig. 3 Mapping the location of seaports and dry ports in Malaysia. Source: Authors

indicates that variables are acceptable, and Bartlett's test was significant where the *p* value was < 0.05 for all variables (Kumar et al. 2013). The Cronbach's Alpha coefficient for each dependent variable was used for the reliability test, as recommended by Garver et al. (2008). An acceptance coefficient value of 0.6 or above has been indicated as acceptable (Yurdugül 2008). In this paper, the alpha values are between 0.634 and 0.830, reflecting significant reliability of the outcome.

The first implication is labelled as 'seaport accessibility' (Cronbach $\alpha = 0.830$). Basically, accessibility is defined as the ability to reach, or the ease of reaching, a destination (Rosenberg 2018). The expansion of fleet size obviously will affect the accessibility at Malaysian seaports because two of these ports have drafts of less than 12 m (Table 3). On the other hand, this indicates that three major seaports—PTP, West Port, and North Port—are able to receive these mega-vessels as their drafts are more than 15 m, the necessary depth for these vessels (OECD 2015). Since the drafts at Penang port and Kuantan are not suitable for mega-vessels, congestion may occur at the other three seaports and eventually affect accessibility via foreland (due to vessel waiting time) as well as inland (delays in freight transportation from seaports due to limited multimodal options).

Due to the limited draft at Penang and Kuantan ports and the congestion at the remaining three seaports, these container terminals will be unable to meet the larger container demand in the future because of the long waiting time for most vessels. Hence, this trend will affect the ship and seaport relationship because insufficient infra- and supra-structures, e.g., nautical accessibility, quay walls, etc., will degrade the attractiveness level of these seaports. Mooney (2017) indicates that at key seaports such as Busan, Tanjung Pelepas, Yangshan, Ningbo, Hong Kong, Jebel Ali, Yantian, Rotterdam, Hamburg, Qingdao, Antwerp, and Bremerhaven, recorded average crane movement is around 27 moves for vessels 7000–10,000 TEUs and 24 moves for vessels 14,000–18,000 TEUs. This clearly indicates that the smaller vessels provide high productivity compared to larger vessels. Hence, welcoming larger vessels at Malaysian seaports will cause significant delays, limiting seaport activities, creating additional unsafe territories and congestion, and causing long dwelling times for containers.

The second implication is related to seaport infrastructure (Cronbach $\alpha = 0.752$). Large quantities of equipment and skilled labour must be available to serve large ships. Providing maximum manpower to one ship will cause fatigue and reduce the workers' concentration when working on the following ship, eventually reducing their focus during task execution. Hence, this situation could lead to accidents and create safety issues at seaports, leading to further downgrading the seaports' attractiveness from the perspective of safety and security.

Inland access/connection to the hinterland is one of the crucial components of seaport competitiveness. The enlargement of vessels will eventually—and should—result in the synchronization of inland components and seaports. This integration has become an important factor in shaping the performance and competitive strategies of seaports. However, in Malaysia, limited transport connectivity, limited capillary transport connection within the states, underutilised dry ports, and congested road facilities that are in bad shape reduce the synchronization between seaports and hinterland. Hence, the presence of mega-vessels at Malaysian ports will worsen the situation by causing heavy congestion during transloading both at yard and seaport gate.

Table 3 Malaysian seaports draft

Seaports	Draft (current depth in meters)
PTP	18.5
West Port, Malaysia	17.5
North Port, Malaysia	15.5
Penang Port	11.0
Kuantan Port	11.2

Source: Authors developed based on the interviews

According to Parola et al. (2016), seaport service quality refers to the quality of seaport facilities and to the capacity for differentiating the services supplied by their competitors. In this paper, the third implication of mega-vessels is labelled as 'seaport service quality' (Cronbach $\alpha = 0.745$). In order to serve mega-vessels, intermediate container storage space, yard space, plug-ins for cooling and refrigerated containers, and warehouse space are essential. However, at the current stage, two major seaports in Malaysia are approaching optimum utilisation level (Port Klang and PTP), and two of them are exceeding the optimum utilization rate (Penang Port and Johor Port) as depicted in Table 4. At this stage, a container seaport needs to turn to new investments as a solution when the utilization rate exceeds 70%, as this implies the seaport is becoming congested (Ilmer et al. 2018). In this case, mega-vessels selecting Malaysian seaports as ports of destination will cause issues regarding the seaports providing a high quality of services to their clients.

A uniform IT platform for all participants in the seaport logistics process is needed to ensure necessary capacities for serving large vessels (Prokopowicz and Berg 2016). Information sharing can encourage effective inland-based freight distribution (Monios 2017). In this region, the ability of seaports and inland components to compete has become a major reason for the reluctance of this major node to share information with their co-players in the freight network. In that case, if a large vessel starts to enter Malaysian seaports, the interoperability between seaports and other players will not be well connected and eventually will affect the competitiveness of seaports and encourage customers to choose a seaport in the neighbouring regions as their port of destination instead of Malaysia.

Seaport capacity and seaport efficiency are the fourth and fifth implications of vessel enlargement at Malaysian seaports; they recorded 0.634 and 0.708 Cronbach α values, respectively. In general, major container seaports need to implement or increase the number of cranes and other facilities including gantries and prime movers to meet the larger volume. In addition, some seaports face limited space and need to undergo land reclamation to build additional facilities as mentioned. Hence, the emergence of larger vessels at Malaysian seaports could lead to additional investment and create environmental issues due to seaport land reclamations.

Jeevan et al. (2015) indicated that many seaports in Malaysia have undergone land reclamation processes within the past decades, especially Port Klang and Penang Port. In 2018, Kuantan Port joined the group performing reclamation. Slow turnaround time and lower container yard productivity are the two primary problems that hamper seaport efficiency. Every vessel demands fast turnaround time, however, it will be impossible for seaports to accommodate these vessels due to the level of complexity. Limited

Table 4 Container throughput and capacity in major Malaysia container seaports in 2017

Year	2017		
Ports	Container volume (TEUs)	Seaport capacity (TEUs)	Utilisation rate
Port Klang	11,978,166	17.6 million	68%
PTP	8,137,905	12.5 million	65.1%
Penang Port	1,507,266	2 million	75.4%
Johor Port	900,682	1.2 million	75%
Kuantan Port	147,041	600,000	24.5%

Source: Authors developed based on the primary and secondary data

modal shift, less integration with inland components, long dwelling times due to limited space in the seaport area, and low productivity of crane movement for larger vessels all cause delays in transloading activities and eventually increase vessel turnaround time. Again, this situation will affect the attractiveness of Malaysian seaports among their clients (see Table 5).

Discussion and conclusion

Basically, the presence of larger vessels at Malaysian seaports raises several issues regarding seaport efficiency: congestion, limited capacity and infrastructure support, outdated policies for existing seaport development, requirements for additional investment for spatial development, and the need for manpower training. Therefore, this paper has proposed the implementation of dry ports to reduce the negative effects of larger vessels on the Malaysian seaport system. Initially, research by Jeevan et al. (2018b) indicated several implications of dry ports in the container seaport system due to general changes in maritime logistics, including enhancing seaport performance, increasing seaport service variations, reducing seaport-hinterland proximity, and increasing seaport trade volume and capacity (see Fig. 4).

The implications of dry ports at seaports due to changes in vessel size remain unexplored. Hence, this paper has established that dry ports may assist these seaports in several ways, and as an outcome, seaport accessibility, seaport infrastructure, seaport service quality, seaport efficiency, and seaport capacity are expected to improve. For example, as indicated by FIPs 3, 4, and 7, the connectivity between these nodes and availability of modal shifts at most of the dry ports enhance efficiency, accessibility, and service quality during the presence of larger vessels. Further, as indicated by FIPs 1 and 3, limitations in seaport capacity (most of the seaport approaching and exceeding optimum utilisation rate) may lead to calls for immediate assistance from dry ports to support capacity, especially from the spatial perspective.

Functional cooperation may lead to capacity enhancement at seaports involving a minimum amount of financial implications and without them needing to undergo seaport reclamation. This outcome is aligned with the answers from FIPs 4, 8, and 9, which indicate that the involvement of dry ports may prevent the need for significant investments by seaports and encourage the utilisation of existing assets. It is important to meet this goal, especially regarding the improvement of seaport capacity, efficiency, and infrastructure. With this symbiotic nexus between sea-based and inland-based nodes, additional investments could be attracted from shipping lines at these dry ports to improve their (the shipping lines') performance during the presence of larger vessels

Table 5 Impact of vessel enlargement on seaport competitiveness

No	Factors	Items	Factor Loading	Cronbach Alpha
1	Seaport accessibility	Long total stay times	0.877	0.830
		Waiting times for the majority of vessels	0.757	
		Insufficient infra- and supra-structure (such as nautical accessibility, quay wall, etc.)	0.655	
		Unsafe passing channel at the port	0.628	
		Limitation of operations in port	0.579	
2	Seaport infrastructure	Large number of skilled labourers	0.782	0.752
		Inland transportation system must be well connected	0.704	
		Draft limitation to accommodate deep-draft ships (such as low water depth access channel and berth)	0.653	
		Large quantity of equipment	0.588	
3	Seaport service quality	Demand plug-in for cooling and refrigerated containers	0.754	0.745
		Face congestion from surge of internal and external traffic	0.752	
		High utilization rates	0.613	
		Insufficient information sharing	0.564	
4	Port capacity	Quay cranes outreach capable serving	0.816	0.634
		Expended storage capacity	0.791	
5	Seaport efficiency	Slow/quick turnaround time	0.720	0.708
		Affecting productivity of container yard	0.665	

in this region. In addition, the availability of dry ports reduces total stay time, limits waiting time for major vessels, improves the efficiency of seaport operations, reduces internal traffic, provides sufficient information sharing, allows faster turnaround time, and increases productivity at the container yard.

The growing presence of larger vessels in Malaysian seaports may cause several problems including reduction in operational efficiency, congestion, limited capacity and

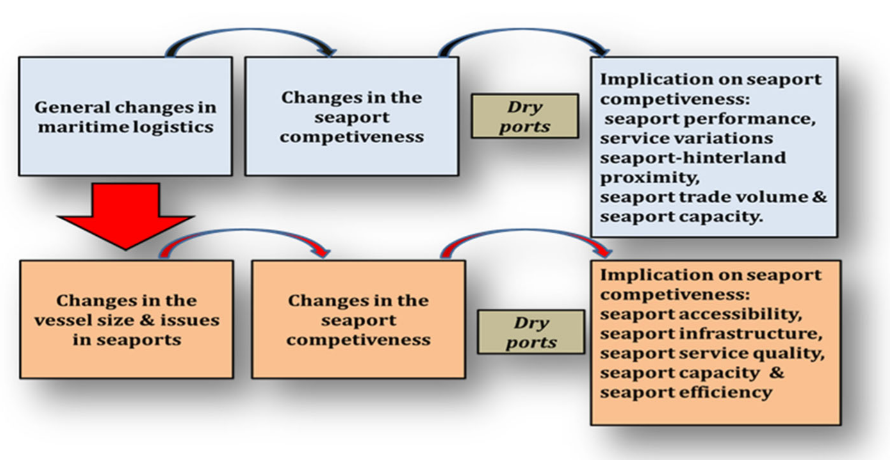

Fig. 4 Implications of dry ports for seaport competitiveness (adapted from Jeevan et al. 2018b)

infrastructure support, effects on current seaport policy for seaport development, requirements for additional investment for spatial development, as well as the need to restructure manpower training. Therefore, the assimilation of dry ports into the seaport system is urgently required to overcome these problems, especially regarding operational efficiency, congestion, limited capacity, and infrastructure support. Quantitatively, the existence of dry ports in the seaport system results in an improvement in seaport accessibility, enhancement of seaport infrastructure, as well as improvements in seaport service quality, capacity, and efficiency.

The development of mega-vessels provides significant benefits to traders. In Malaysia, the presence of larger vessels is not yet common at seaports, but it may bring about significant financial implications in the future. Malaysian seaports should adapt to this change in order to gain a competitive advantage. Besides focusing on the collaboration between seaports and dry ports, a seaport system consisting of seaports, inland terminals, transport networks, and freight corridors needs to be implemented to ensure these seaports are prepared to accommodate larger vessels. This is important in developing Malaysian seaports with their existing underutilised capacity and transforming them to be competitive with other world-ranked seaports.

Abbreviations
EFA: Exploratory Factor Analysis; FIP: Face-to-face Interview Participant; ICT: Ipoh Cargo Terminal; IT: Information Technology; PBCT: Padang Besar Cargo Terminal; TEU: Twenty-feet Equivalent Unit; VLCS: Very Large Container Ship

Acknowledgements
No acknowledgements

Authors' contributions
JJ collected and analyzed the data and was a major contributor in writing the manuscript. VR contributed to the writing. Both authors read and approved the final manuscript.

Funding
No specific external funding.

Availability of data and materials
The datasets used and analyzed during the current study are available from the corresponding author on reasonable request.

Competing interests
The authors declare that they have no competing interests.

Author details
[1]School of Maritime Business and Management, Universiti Malaysia Terengganu, 21030 Kuala Nerus, Terengganu, Malaysia. [2]Department of Technology Management and Economics, Division of Service Management and Logistics, Chalmers University of Technology, Vera Sandbergs Alle 8, SE-412 96 Gothenburg, Sweden.

Received: 29 April 2019 Accepted: 20 August 2019
Published online: 03 September 2019

References
Andersson D, Roso V (2016) Developing dry ports through the use of value-added services. Commercial Transport. Springer, Cham, pp 191–203
Bask A, Roso V, Hämäläinen E, Andersson D (2014) Development of seaport – dry port dyads: two cases from Northern Europe. J Transp Geogr 39:85–95
Beresford A, Petit S, Xu Q, Williams S (2012) A study of dry port development in China. J Marit Econ Logis 14(1):73–98
Bichou K, Gray R (2005) A critical review of conventional terminology for classifying seaports. Transp Res A Policy Pract 39(1):75–92
Biffignandi S, Bethlehem J (2012) Web surveys: methodological problems and research perspectives. In: Advanced statistical methods for the analysis of large data-sets. Springer, Berlin, pp 363–373
Black J, Roso V, Marušić E, Brnjac N (2018) Issues in dry port location and Implementationin metropolitan areas: the case of Sydney, Australia. Trans Marit Sci 7(01):41–50
Cooper DR, Schindler PS (2011) Qualitative research. Business Research Methods, pp 160–182
Cooper DR and Schindler, P.S (2014) Business Research Methods, McGraw-Hill.
Creswell JW, Clark LP (2007) Designing and conducting mixed methods research, 1st edn. SAGE publication, USA, Thousand Oaks
Damas P (2002) Global terminal operators' rule. American Shipper

Garver MS, Williams Z, Taylor GS (2008) Employing latent class regression analysis to examine logistics theory: an application of truck driver retention. J Bus Logist 29(2):233–257
Ilmer M, Wang J, Renz B, Ormanns S, Weniger M, Horst D, D'Haese J, Werner J, Bazhin A (2018) Feedback loops of canonical WNT regulate stemness traits in pancreatic cancer cells. Pancreatology 18(4):S 125
Imai A et al (2006) The economic viability of container mega-ships. Transp Res E 42:21–41
Jeevan J, Chen SL, Cahoon S (2018a) Determining the influential factors of dry port operations: worldwide experiences and empirical evidence from Malaysia. Marit Econ Logis 20(3):476–494
Jeevan J, Chen SL, Cahoon S (2018b) The impact of dry port operations on container seaports competitiveness. Marit Policy Manag 46:1–20
Jeevan J, Chen SL, Lee ES (2015) The challenges of Malaysian dry ports development. The Asian Journal of Shipping and Logistics 31(1):109–134
Jiang C, Wan Y, Zhang A (2017) Internalization of port congestion: strategic effect behind shipping line delays and implications for terminal charges and investment. Marit Policy Manag 44(1):112–130 Routledge
Kemper EA, Springfield S, Teddlie C (2003) Mixed methods sampling strategies in social science research. Handbook of mixed methods in social and behavioural research, pp 273–296
Khaslavskaya A, Roso V (2019) Outcome-driven supply chain perspective on dry ports. Sustainability 11(5):1492
Kim DH, Sohn BJ, Nakajima T, Takamura T, Takemura T, Choi BC, Yoon SC (2004) Aerosol optical properties over East Asia determined from ground-based sky radiation measurements. J Geophys Res Atmos 109(2)
Kim S, Chiang BG (2017) The role of sustainability practices in international port operations: an analysis of moderation effect. J Korea Trade 21(2):125–144
Klassen M, Peters T, Pudritz RE (2012) H II region variability and pre-main-sequence evolution. Astrophys J 758(2):137
Kumar M, Talib SA, Ramayah T (2013) Business research methods, 1st edn. Oxford Fajar Sdn Bhd, Shah Alam Available at: https://cw.oxfordfajar.com.my/businessresearchmethods
Meng Q, Weng J, Suyi L (2017) Impact analysis of mega vessels on container terminal operations. In: Transportation Research Procedia. Elsevier B.V., pp 187–204
Monios J (2017) Cascading feeder vessels and the rationalisation of small container ports. J Transp Geogr 59:88–99 Elsevier Ltd
Mooney, T. (2017). Midsize vessels outpace mega-ships in berth productivity. https://www.joc.com/port-news/data-show-berth-productivity-highest-midsize-ships_20171130.html. (Accessed 29 Oct 2018)
Moore JF (1996) The death of competition: leadership and strategy in the age of business ecosystems. Harper Business, New York, p 297
Ng AK, Gujar GC (2009) Government policy, efficiency and competitiveness: the case study of ports in India. J Transp Policy 16(5):232239
Notteboom T, Rodrigue J (2005) Port regionalization: towards a new phase in port development. Marit Policy Manag 3(32):297–313
Notteboom TE, Parola F, Satta G, Pallis AA (2017) The relationship between port choice and terminal involvement of alliance members in container shipping. J Transp Geogr 64:158–173
Notteboom TE, Winkelmans W (2001) Structural changes in logistics: how will port authorities face the challenge? Marit Policy Manag 28(2):71–89
Nur Anis'sa I, Nurul Haqimin MS, Jeevan J (2019) Emergence of mega vessels and their influence on future Malaysian seaport expansion requirements, Universiti Malaysia Terengganu. J Undergrad Res 1(1):58–67
OECD (2015) The impact of mega-ships, case-specific policy analysis. International transport forum https://www.itf-oecd.org/sites/default/files/docs/15cspa_mega-ships.pdf. 2 rue André Pascal, 75775 Paris Cedex 16, France. (Accessed 29 Oct 2018)
Parola F, Risitano M, Ferretti M, Panetta E (2016) The drivers of port competitiveness: a critical review. Transp Rev 37(1):116–138
Porter R (1990) What was the enlightenment? In: The enlightenment. Palgrave, London, pp 1–11
Prokopowicz AK, Berg J (2016) An evaluation of current trends in container shipping industry, very large container ships (VLCSs), and port capacities to accommodate TTIP increased trade. Transport Res Procedia 14:2910–2919
Robinson O (2014) Sampling in interview-based qualitative research: a theoretical and practical guide. J Qual Res Psychol 11(1):25–41
Rodrigue J-P, Comtois C, Slack B (2017) The geography of transport systems. Routledge, New York, p 440 ISBN 978-1138669574
Rodrigue JP, Notteboom T (2010) Foreland-based regionalization: integrating intermediate hubs with port hinterlands. Res Transp Econ 27(1):19–29
Rosenberg M (2018), Defining accessibility and mobility in transportation and geography. 1500 Broadway, New York, NY 10036. https://www.thoughtco.com/accessibility-definition-geography-1434629. (Accessed 29 Oct 2018)
Roso V (2007) Evaluation of the dry port concept from an environmental perspective: A note. Transportation Research Part D: Transport and Environment 12(7):523–527.
Roso V (2013) Sustainable intermodal transport via dry ports - importance of directional development. World Rev Intermodal Transport Res 4(2/3):140–156
Roso V, Lumsden K (2010) A review of dry ports. Marit Econ Logist 12(2):196–213
Roso V, Woxenius J, Lumsden K (2009) The dry port concept: connecting container seaports with the hinterland. J Transp Geogr 17(5):338–345
Tang O, Sun PW (2018) Anti-competition of ocean shipping alliances: a legal perspective. Marit Bus Rev 3:4–19
Teddlie C, Tashakkori A (2009) Foundations of mixed methods research
Tongzon J, Heng W (2005) Port privatization, efficiency and competitiveness: some empirical evidence from container ports (terminals). Transp Res A Policy Pract 39(5):405–424
Tran NK, Haasis HD (2015) An empirical study of fleet expansion and growth of ship size in container liner shipping. Int J Prod Econ 159:241–253
Williams B, Osman A, Brown T (2010) Exploratory factor analysis: a five-step guide for novices. Australasian J Paramed 8(3):1-13
Yurdugül H (2008) Minimum sample size for Cronbach's coefficient alpha: a Monte-Carlo study. Hacettepe Üniversitesi eğitim fakültesi dergisi 35(35):1–9

Publisher's Note