Research Article

Malaysia Seaport Development towards Embracing Industrial Revolution 4.0: Enhancing the Quality and Competitiveness of Seaport Industry

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Abstract: Seaport industry is a dynamic industry which is experiencing a rapid growth. Industrial Revolution 4.0 merges the digital, physical and biological system to enhance the capabilities of the industry. It creates a platform which enables the seaport industry to build its effectiveness, reliability and governance towards improving the quality of seaport services. Accordingly, the evolution of seaport services entails the application of technologies so that the industry can fulfil its customer satisfaction goals. In line with this notion, the purpose of this research is to examine the relationship between Industrial Revolution 4.0 and the quality of seaport services. This research employed the quantitative content analysis, covering seaport effectiveness, seaport reliability and seaport governance. The respondents of this research comprised expert individuals within the seaport industry cluster. The results revealed that there is a significant correlation between the adaption of IR 4.0 and seaport quality. This research offers a truly novel policy innovation towards achieving seaport competitiveness.

Keywords: seaport, Industrial Revolution 4.0, effectiveness, reliability, governance, competitiveness

1. Introduction

The advancement of technology has played an important role and has become a key factor in the development of industries. The recent Industrial Revolution 4.0 is one of the key issues that has gained much attention at conferences and forums on industrial development at the global level. Industrial Revolution 4.0 refers to the revolution that focuses on cyber-physical production systems (CPSS) that merge the real and virtual worlds.

The first industrial revolution began around the end of 18th century with Industrial Revolution 1.0 which centred on mechanical facilities powered by water and steam. This was followed by Industrial Revolution 2.0, which began in the 20th century and focused on electrical energy. Later on, Industrial Revolution 3.0, which commenced in 1970s and lasted till the 20th century, saw the focus being shifted to the application of electronics and IT to further automation.

In line with the focus of Industrial Revolution 4.0, this research focuses on Malaysian Seaport development in the context of seaport industry towards achieving the goals of Industrial Revolution 4.0. Specifically, this research examines the perspectives of quality and competitiveness attributable to Industrial Revolution 4.0. Before focusing on Industrial Revolution 4.0, the performance of seaport systems needs to be improved, in line with the dynamic nature of maritime business. The inefficiency of transportation systems, the lack of effective container management, the high level of competition among seaports, the inadequacy of infrastructure and the problems of bottlenecks and low accessibility capacity (e.g. due to traffic congestion) are the common issues found in seaport systems and they need to be addressed by the seaport industry (Jeevan *et al.*, 2015 & Heilig *et al.*, 2016). The use of IoT as one the information management tools of digital transformation may help to overcome the constraints caused by traffic congestion or delay of time etc. frequently faced by the seaport industry.

1.1. Literature Review of Research on Seaport Industry in the Context of Industrial Revolution 4.0 (IR 4.0)

Industrial Revolution 4.0 (IR 4.0) covers crucial issues that have been vigorously discussed throughout the world, with the specific focus on development of world-class industries. IR 4.0 is viewed as one of the drivers that sustain economic growth and employment, namely in the field of manufacturing by providing added values through the transformation of materials into products (William, 2014). Moreover, IR 4.0 aims to achieve the ubiquitous connectivity of people, things and machines by the Internet of Things, Internet of Services and Internet of Data (Kagermaan *et al.*, 2014, Hussain et al., 2020 & Crnjac *et al.*, 2017). Since its introduction in

2011 by Germany's federal government as one the key initiatives for high-tech strategy implementation, the subject on Industrial Revolution 4.0 has become popular among companies, research centres and universities. The topic is discussed in numerous academic publications and conferences (Hermann *et al.*, 2015). IR 4.0 also focuses on information technology platforms used by people to communicate in this era, involving devices and machines powered by the Internets of Things (IoT).

IR 4.0 also mobilises the smart factory which facilitates the development of the virtual copy of the physical world and decentralised decision-making (Morrar *et al.*, 2017; Dutton, 2014 & Buhr, 2015). In this sense, IR 4.0 focuses more on creating intelligent products, processes and procedures to make employees, machines and resources communicate easily by using the IoT (Kagermann, 2014). IR 4.0 is also discussed at the global level, namely in the world economic forum by highlighting the preparations and challenges faced by industries. The arguments or discussions on IR 4.0 tend to centre on the global impact caused by the intense growth of digitalisation, internet of things (IoT) and smart knowledge things.

For example, in 2016, the issues discussed revolved around the challenges industries would be facing in tackling the inevitable problem of unemployment if the use of IoT cyber-physical strategy is adapted through the application of machines and equipment (Emmanuel, 2016). The arising question is, can this problem be overcome when the Industrial Revolution 4.0 is implemented.

While IR 4.0 indicates a clear trend of using more extensive technologies and online platforms to make the seaport industry more efficient by making it safer, more environmentally friendly and more cost efficient, the industry still has far to go in moving forward to achieve the goals of Industrial Revolution 4.0. These include reassessing areas such as cargo tracking, maritime supply chain security, environmental protection, navigating safety, planning, operations, administration and monitoring. Nowadays, seaport industry is rapidly growing, and seaport competitiveness is highly intense among the industry's players. In relation to this, IR 4.0 demands a crucial reform that would ultimately improve seaport competitiveness and foster the development of the industry. This notion is supported by a previous research which claimed that latest technologies contribute to seaport competitiveness (Bichou, 2009 & Lee, 2016). This finding is an evidence that the seaport industry needs to embrace Industrial Revolution 4.0.

1.2. Perspectives on Seaport Quality and Competitiveness towards Adapting to Industrial Revolution 4.0

Industrial Revolution 4.0 prioritises the implementation of digital technologies by merging the real and virtual worlds. Before seaport industry moves towards implementing Industrial Revolution 4.0 goals, the element of quality must be addressed to meet the high level of competitiveness in the industry. Quality is the key component in measuring the degree of inherent characteristics to fulfil the requirement of the Industrial Revolution 4.0.

Elements such as effectiveness, reliability and good governance must be highlighted as priority criteria in ensuring seaport quality. In a systematic literature review (SLR) (Transfied *et al.*, 2003), seaport quality is categorised into three elements: seaport effectiveness, seaport reliability and seaport governance (see Figure 1). A preliminary database was established in the SLR by exploring Scopus publications to find related journals on seaport quality (see Table 1). In Stage 1, a total of 110 journals that focused on a broad scope of research on seaport was identified. In the next stage, the journals were filtered until 70 journals focusing on attributes of quality, seaport service quality, seaport management, seaport competitiveness, seaport safety and security, seaport environment and seaport performance were selected. Finally, up to 30 journals on seaport quality was shortlisted, covering seaport effectiveness, seaport reliability and seaport governance.

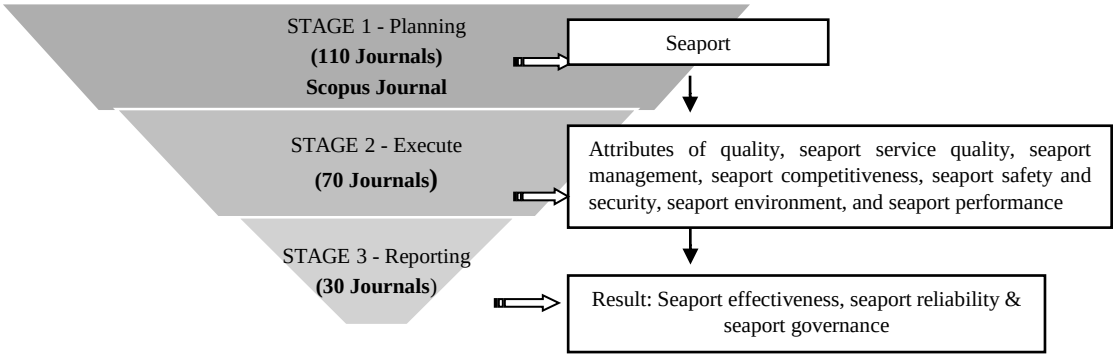

Figure 1. Application of SLR Methodology
Source: (Noralam *et al.*, 2017)

The elements of seaport effectiveness and seaport reliability were developed in previous studies to establish a benchmark to gauge the improvement of seaport quality. The elements and definitions pertaining to seaport effectiveness such as timeliness, price acceptability, safety and security, infrastructure, management and operations depict the effectiveness and the quality of seaport operation (Cuadrado *et al.*, 2004; Brooks *et al.*, 2015; Lee *et al.*, 2013; Yeo *et al.*, 2016).

Meanwhile, seaport reliability depicts the quality of performance or productivity of a seaport by including the elements of resources, responsiveness, cooperation and outcome (Yeo *et al.*, 2015). Seaport governance covers the quality of seaport policy and elements of structure (implementation regulatory framework) action (degree of coordination among seaport users) and elements (the efficiency in flows of giving the information) (Geiger *et al.*, 2011). Enhancing these elements of seaport quality can improve seaport competitiveness. The improvement in seaport competitiveness would then enable the seaport industry to easily tackle the challenges of Industrial Revolution 4.0.

Table 1. Preliminary database of academic journals on quality and seaports
Source: Noralam *et al.* (2017)

	Academic Journals	*1990-1999*	*2000-2009*	*2010-2016*	*Number of paper*
Journal on definition of quality	Journal of Quality Management	8			8
	Journal of Quality and Technology	17	8		25
	Journal of Total Quality Management	1			1
	Journal Quality Improvement	1			1
	International Journal Quality & Science	1			1
	Journal of Retailing	4			4
	Journal of Quality Science	1			1
	Journal of Marketing	10	3		13
	Asia Pacific Journal of Marketing Logistics		1		1
	European Journal Marketing			1	1
	Journal of Services Marketing	1			1
	Journal Business Economics Studies		1		1
	Journal of Business Research	1			1
	Journal of Business Strategy	1			1
	International Journal Services Industry Management		1		1
	Journal of Services Theory & Practices		2		2

	Journal of Management History (Archive) Merged Management Decision	1		1
	Annals of Tourism Research	1		1
Journal on seaports	Social Behavioural Sciences	1		1
	Transport Record	1	4	5
	Transportation Economics	4	1	5
	Transportation Business and Management		1	1
	Transportation Policy		1	1
	Transportation Geography		1	1
	Transportation Research : Part A	1		1
	Transportation Review		1	1
	Transportation Research : Part E		2	2
	European Transport	1		1
	Industry Cluster & Transportation		2	2
	International Journal Logistics Research & Application	1		1
	Asian Journal Shipping & Logistics		2	2
	International Journal Shipping & Transport Services		1	1
	Journal Shipping & Trade		1	1
	Maritime Economics		2	2
	Maritime Policy Management	1	3	4
	Review Network Economics	1		1
	Journal of Policy, Administration & Institution		2	2
	American Political Science Review		2	2
	Pakistan Journal of Commerce & Social Science		2	2
	Social Behavioural Science		1	1
	Competitiveness Review		2	2
	International Journal of Scientific & Research Publications		1	1
	Opening Journal Accounting		1	1
	Recent Advances in Environment, Energy Systems & Naval Science	1		1
	Journal Mechanical Science and Technology	1		1
	Total			110

1.3. Preparation and Challenges of Malaysian Seaports in Facing Industrial Revolution 4.0

The evolution of global the seaport industry has now reached the fifth generation, creating dynamic seaport centric logistics which help lead the industry towards providing world-class-customer-centric services where all the processes—from the initial stages like loading and unloading of cargo to customer to delivering to end users—are centred in only one place. However, despite having the advantage of strategic locations, namely as significant passageways or stopover points connecting the whole world, the question arises as to whether Malaysian seaports are ready to face the fifth-generation challenges and also to move forward towards meeting the goals of Industrial Revolution 4.0.

The statistics of seaport world ranking in 2017 revealed that Malaysia's Port Klang is ranked 11th among the world's ports, while Port of Tanjung Pelepas is ranked 19th (International Association Port and Harbors, 2017). The data show that only 2 major ports of Malaysia were listed among the top twenty ports of the world, raising the question of the status of other seaports in Malaysia, especially the major ones. In addressing this question, the present research seeks to provide a guideline to help Malaysia's seaports improve their quality so that they can persevere and meet the challenge of maintaining a high-level competitiveness in global seaport industry domain.

The current issue facing the seaport industry in the country is its preparedness to face Industrial Revolution 4.0 within the framework of cyber-physical system. This implies the use of the IR 4.0 via the Internet of Things as a medium to facilitate operational management at the global, industry or organisational level. The evolution of the seaport industry from the 1950s to date reveal that IoT has not been fully utilised in the seaport industry as it uses more tangible methods or automations to smoothen the operation of seaports. For example, seaports apply IoT to plan the process of loading and unloading cargos and for tracking containers at the terminal. The question that arises here is whether seaport operations that employ traditional or real-time methods are more effective, efficient and time-saving compared to those that apply digital technology. To clarify this, the first step that Malaysian seaports must take to improve their performance is to gather more data through in-depth studies on seaport operations.

In meeting Industrial Revolution 4.0, Malaysia's seaports can take Singapore's seaports as models as they apply more advanced technologies to overcome the problem of congestion in their terminals. In 1997, the Port of Singapore Authority adapted the flow-through gate system which automatically picks up signal from trucks' transponders and this helped to shorten the gate processing time to 25 seconds (Lee *et al.*, 2000).

In addition, the Singapore seaport began to implement harnessing technology and introduced the Remote Crane Operations and Control (ROCC) system at Pasir Panjang Phase 1 and Phase 2 Terminals in 2000 (Port of Singapore Authority, 2016). The latest technological breakthrough also increased the turnaround rate for containers bound for transhipments, which helped to save the amount of space needed to temporarily house containers within the seaport area. Overall, technologies can help to improve seaports' quality and also increase their competitiveness.

At the global level, Hamburg Port Authority has adopted a cyber-physical system in its seaport operations. Hamburg Port Authority has been using the term 'SmartPort' as part of its strategy to adapt to Industrial Revolution 4.0. Table 2 specifies the adaption made by Hamburg Port Authority to implement Industrial Revolution 4.0's goals.

Table 2. Adaption made by Harmburg Port Authority in line with IR 4.0
Source: Hamburg Port Authority

Subject	Description
Navigation in real-time	• SmartInformation: Seaport users have access to information on parking and infrastructure, closures of the moveable bridges as well as the latest information on important operations. • Benefit: To ensure an efficient traffic flow
Shore power from renewable energies	• SmartEnergy: These ocean-going giants are supplied with electricity via a transformer station and mobile transfer mechanism at the Altona cruise ship terminal. • Benefit: Significantly reduces the environmental impact in Hamburg
Intelligent railway point	• SmartRailways: Frequently used points on the harbor railway are fitted with sensors that transmit data to a central IT system in real-time. • They collect a variety of data by moving or passing over the switching points, thereby providing information about the condition and wear of essential operational intersections. • Benefit: Identify maintenance work or repairs at an early stage to avoid down-time

Mobile all-purpose sensor	• SmartMobile: A mobile GPS sensor is currently being developed, which wirelessly forwards data to the HPA IT system. Along with intelligent fleet management, the sensor is also used to perform other measurements such as temperature, wind speed and direction, air pollution and the flow of the Elbe. • Benefits: To identify floating cranes, emergency vehicles closest to an incident as well as wind speed, direction, air pollution etc.
Smart maintenance	• SmartMaintenance: The infrastructure in Hamburg Port is monitored using mobile end devices, such as tablets or smartphones. When controlling roads, bridges and tracks, these devices automatically send measurements to the down-stream IT systems, where the data is processed, stored and edited. • Benefits: Renders the maintenance processes more effective and efficient and improves the quality of notifications
Virtual depot	• SmartVirtual Depot: The virtual depot is developed to optimize the movement of empty containers between packing companies. The cloud-based system informs participating operators which containers are to be delivered back to the depot. The packing company then requests these directly. • Benefits: Eliminates unnecessary vacant trips to the depot.
Port monitor	• SmartPort Monitor: Information is centrally gathered and can be accessed remotely such as electronic cards, vessel positions, water level data, berths, current construction sites, planned dives and bridge heights and widths. • Benefits: Important information is therefore always accessible to all those involved on land and on the water
E-Mobility in the port	• SmartE-Mobility: Electric vehicles are becoming increasingly common place in road transport. The port is reviewing ways of extending e-Mobility to passenger and freight traffic in the harbour area. • Benefits: Optimize space and time management in the seaport
Parking for professionals	• SmartPort Logistics app for trucks • Benefits: Its comprehensive parking management guarantees optimum utilization of existing and future truck parking spaces within the port. The system's features include the detection and management of parking spaces, especially with a view to relieving the pressure in neighbouring city districts.
Renewable energies	• SmartEnergies: By focusing on innovative technologies, the HPA is adopting a pioneering role in Germany to address the issue of a turn-around in energy policy. • Benefits: At the centre of this is the efficient use and expansion of the existing networks, and above all, the option of generating renewable energies

By taking development strategies implemented in Hamburg Port Authority as an example, Malaysian seaports should move forward by taking the necessary steps to become smart seaports, in line with Industrial Revolution 4.0. To cope with the Industrial Revolution 4.0's guidelines, the seaport industry in Malaysia needs to look deeper into the capabilities of the internet networking systems in Malaysia to determine whether it can accommodate the overall requirements of its seaports' operations. Moreover, the capability of managing the issue of cyber-security must also be emphasised in facing the challenges of Industrial Revolution 4.0. Preparedness towards updating the quality of information technology is imperative to improve the capabilities of internet networking systems to address the requirements of Industrial Revolution 4.0 strategies.

2. Methodology

This research employed quantitative content analysis which refers to a family of procedures for the systematic, replicable analysis of text. This analysis involves the classification of parts of a text through the application of structured, systematic coding scheme, from which conclusions can be drawn about the message of the content (Susan *et al.*, 2015). Content analysis can also be used to investigate either the substantive or content and form or formal features of text. Substantive refers to what is being said in a message, while form features refer to how it is being said (Schreier, 2012). The quantitative content analysis approach is a tool for the interpretation of usually written (corporate) communication.

The approach is rooted in communication science and may help in understanding and interpreting the manifest as well as the latent contentof communication regarding a corporation's ethical understanding, conduct and behaviour (Irina, 2017).

2.1. Application of Quantitative Content Analysis

This research adapted the existing theory of Port Service Quality Model (PSQ) by Thai (2008) as a guideline to develop the study's questionnaire. Based on the theory, this research also developed the research question: "What are the criteria that enhance seaport quality (SQ) and seaport competitiveness (SC) towards realising Industrial Revolution 4.0 (IR 4.0)?". The next step taken was to develop the objective or formulate the conceptual research on ways to enhance seaport quality (SQ) and seaport competitiveness towards realising Industrial Revolution 4.0. The sampling unit employed was purposive sampling involving a seaport cluster. The coding scheme applied in this research was Likert scale, ranging from 1, referring to 'strongly disagree' to 5, referring to 'strongly agree'. This research employed a questionnaire as a data collection tool, and it was developed based on previous journals on seaport quality. For the analysis of data in this research, the Cronbach's alpha reliability test was carried out to measure the reliability of the data. Finally, the results for this research for this data was obtained (refer Figure 2).

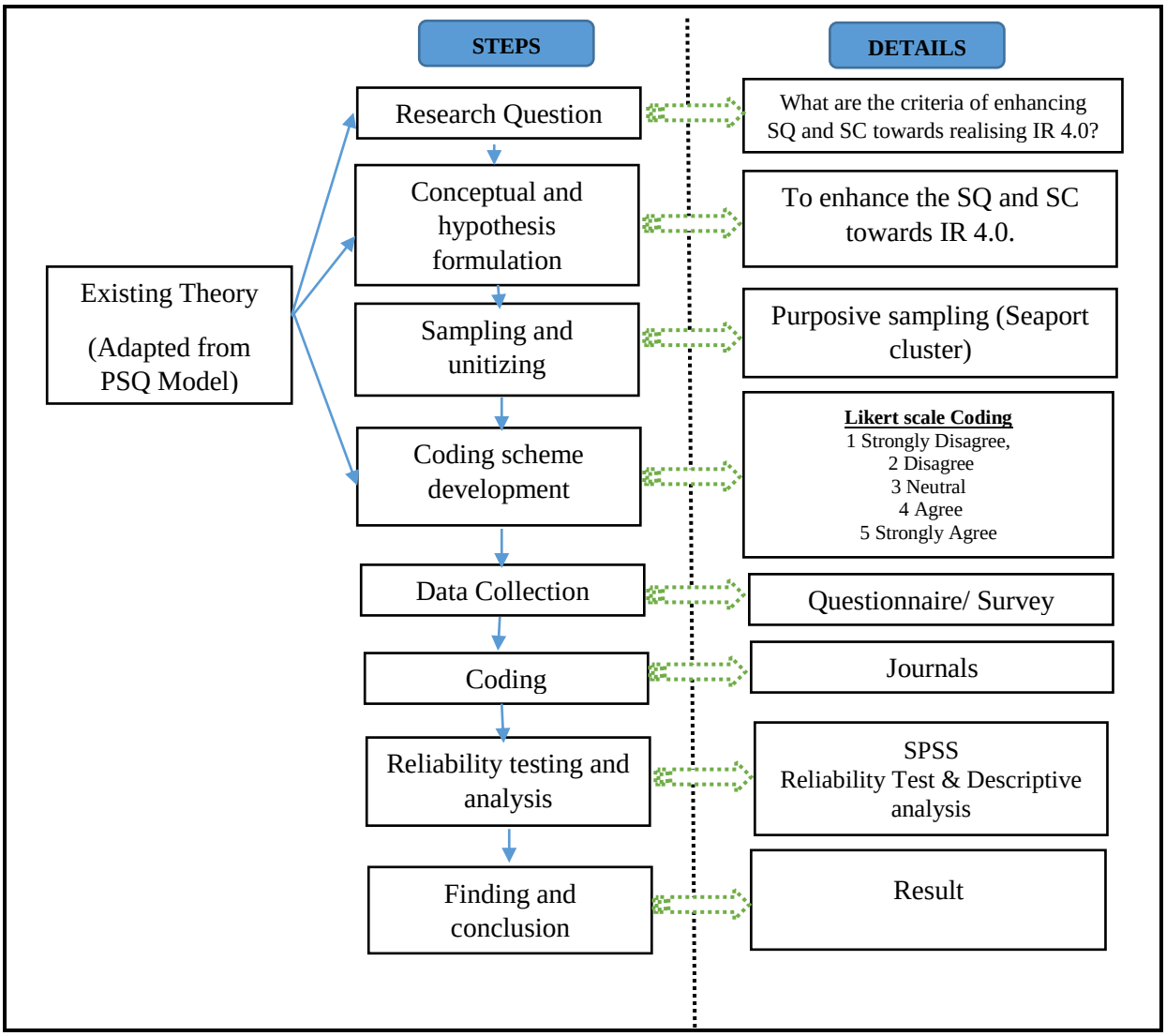

Figure 2. Quantitative Analysis Process
Source: (Susan *et al.*, 2015)

3. Results and Discussion

The result for the Cronbach's alpha reliability test in this research was **0.958**, indicating a high level of internal consistency for the scale used in the questionnaire for this specific sample.

Table 3. Results of reliability test

Subject	Result : Reliability Test
Cronbach's Alpha	0.958

The second analysis carried out in this research was correlation analysis, which aimed to determine the significance of seaport quality by considering three categories: seaport effectiveness, seaport reliability and seaport governance with the seaport competitiveness. The elements of seaport quality and seaport competitiveness are related to the features of Industrial Revolution 4.0. The final results showed that seaport effectiveness (refer Table 4), seaport reliability (refer Table 5), seaport governance (refer Table 6) and seaport competitiveness (refer Table 7) were significant because the correlation values of these elements were within 0.05. These results revealed that these elements of seaport quality are significant in influencing Malaysia seaports' move towards realising the goals of Industrial Revolution 4.0.

Table 4. Seaport effectiveness – Pearson correlation analysis

Variable	1	2	3	4	5	6	7
Seaport Effectiveness							
Seaport safety	1	r = 0.623 p = 0.003	r = 0.523 p = 0.016	r = 0.533 p = 0.016	r = 0.176 p = 0.459	r = 0.356 p = 0.128	r = 0.426 p = 0.061
Decrease in delays	-	1	r = 0.703 p = 0.001	r = 0.518 p = 0.019	r = 0.295 p = 0.207	r = 0.464 p = 0.039	r = 0.553 p = 0.011
Safety in accessing seaport	-	-	1	r = 0.510 p = 0.022	r = 0.152 p = 0.522	r = 0.326 p = 0.160	r = 0.535 p = 0.015
Security compliance	-	-	-	1	r = 0.560 p = 0.010	r = 0.678 p = 0.001	r = 0.705 p = 0.001
Physical design	-	-	-	-	1	r = 0.726 p = 0.000	r = 0.524 p = 0.018
Systematic arrangement	-	-	-	-	-	1	r = 0.632 p = 0.003
Effective accessibility	-		-	-	-	-	1

Table 5. Seaport Reliability – Pearson Correlation Analysis

Variable	1	2	3	4
Seaport Reliability				
• Effective resolution for ship and cargo	1	r = 0.649 p = 0.002	r = 0.554 p = 0.011	r = 0.584 p = 0.007
• Quick response	-	1	r = 0.440 p = 0.052	r = 0.479 p = 0.033
• Effective response to regulator body	-	-	1	r = 0.911 p = 0.000

• Ancillary services	-	-	-	1

Table 6. Seaport Governance – Pearson Correlation Analysis

Variable	1	2	3	4	5	6	7	8	9
Seaport Governance									
• Strategic planning of structure and organisation	1	r = 0.882 p = 0.000	r = 0.399 p = 0.081	r = 0.190 p = 0.423	r = 0.340 p = 0.142	r = 0.562 p = 0.010	r = 0.609 p = 0.004	r = 0.375 p = 0.104	r = 0.695 p = 0.001
• Changes of regulations	-	1	r = 0.452 p = 0.045	r = 0.358 p = 0.121	r = 0.496 p = 0.026	r = 0.637 p = 0.003	r = 0.690 p = 0.001	r = 0.425 p = 0.062	r = 0.502 p = 0.024
• Connection between seaport cluster	-	-	1	r = 0.889 p = 0.000	r = 0.524 p = 0.018	r = 0.484 p = 0.031	r = 0.593 p = 0.006	r = 0.792 p = 0.000	r = 0.370 p = 0.109
• Systematic guidelines	-	-	-	1	r = 0.636 p = 0.003	r = 0.563 p = 0.010	r = 0.623 p = 0.003	r = 0.861 p = 0.000	r = 0.137 p = 0.566
• Easy understanding	-	-	-	-	1	r = 0.885 p = 0.000	r = 0.533 p = 0.016	r = 0.688 p = 0.001	r = 0.415 p = 0.069
• Good Governance	-	-	-	-	-	1	r = 0.800 p = 0.000	r = 0.697 p = 0.001	r = 0.435 p = 0.055
• Expertise in managing	-	-	-	-	-	-	1	r = 0.698 p = 0.001	r = 0.277 p = 0.237
• Efficient flow	-	-	-	-	-	-	-	1	r = 0.350 p = 0.131
• Application of IT governance	-	-	-	-	-	-	-	-	1

Table 7. Seaport Competitiveness – Pearson Correlation Analysis

Variable	1	2	3	4	5
Seaport Governance					
• Hinterland	1	r = 0.817 p = 0.000	r = 0.484 p = 0.031	r = 0.690 p = 0.001	r = 0.682 p = 0.001
• Port centric logistics	-	1	r = 0.593 p = 0.006	r = 0.427 p = 0.060	r = 0.590 p = 0.006
• High operational efficiency	-	-	1	r = 0.436 p = 0.055	r = 0.793 p = 0.000
• Enough capacity	-	-	-	1	r = 0.850 p = 0.000
• Extension of port area	-	-	-	-	1

4. Conclusion

As a nation that is moving towards achieving the status of developed country, Malaysia needs to emulate advanced Asian countries like China, Hong Kong, Japan and Singapore in facing the challenges of Industrial Revolution 4.0. In line with this, seaport quality elements should be given priority to improve and enhance the competitiveness of the country's seaport industry, both at the national and international levels. This is because the elements of seaport quality are essential in improving seaport services in Malaysia as well as improving its performance and contributing to the development and growth of the country's economy. When Malaysia's seaports can attain a steady level of competitiveness, they will be able to keep up with the rapid development of the seaport industry in the global arena. With that, Malaysia's seaports will also be able to navigate Industrial Revolution 4.0 efficiently and easily. From the academic point of view, the research on seaport itself must be

enhanced as more exploration and research are needed to provide further insights into fields related to seaport quality, namely the weaknesses or deficiencies found in the industry. To achieve this, researchers must work together with the industry to gain more exposure and understanding on the current issues that the seaport industry is facing. This research can offer a truly novel policy innovation towards achieving seaport competitiveness.

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