SMART PORTS: THE FUTURE OF MARITIME TRANSPORTATION

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Abstract

Modern ports function in the context of complex infrastructure, business transactions, and regulations and have a broad range of stakeholders including but not limited to port operators, port authorities, haulers, and shipping companies. There is a recent trend in the ports toward adopting technology-based solutions as well as new approaches to port operations planning and management. Ports are becoming increasingly interested in smart solutions to optimize operations, promote efficiency, enhance sustainability, and avoid safety and security incidents. The adoption of such solutions to address recent problems is known to be switching to smart ports. This work attempts to develop a framework for a smart port and a quantitative metric, Smart Port Index (SPI), that ports can use to improve their performance, resiliency, and sustainability. Our proposed SPI is based on Key Performance Indicators (KPIs) that are collected from the literature and measure the port performance with regard to smart port activity domains: operations, environment, energy, and safety & security. Numerical results show how SPI can be used to evaluate the performance of a port. Our methodology provides a quantitative tool for port authorities to develop their smart port policies, assess their smartness, and determine their strengths and weaknesses for potential improvements.

Introduction

A port is a maritime facility which comprises equipment (e.g., wharf cranes and rubber gantry cranes) and space (e.g., storage yard and parking) required for loading, unloading, and moving cargo and passengers. Early ports acted mostly as simple harbors while modern ports are regional multimodal intersections of global supply chains and tend to be distribution hubs with transportation links to sea, river, canal, road, rail, and air. These modern ports function in the context of complex infrastructure, business transactions, and regulations and have a broad range of stakeholders including but not limited to port operators, port authorities, haulers, and shipping companies. According to the review of maritime transport by United Nations Conference on Trade and Development, world seaborne trade as well as large vessels have been growing in numbers during the last decade. In the United States, the coastal port system currently contributes $5.4 trillion to the nation’s economy, this amount has increased by about 17% since 2014 and now forms about 26% of the U.S. GDP. There has also been an 18% increase in the U.S. container traffic and both the import and export handled by maritime transportation have incremented significantly from 2011. This growth in demand for maritime transportation and the high influence of port service on the economy have caused several problems and challenges for the ports.

In response to the recent problems, a new trend has emerged in the ports toward adopting technology-based solutions as well as new approaches to port operations planning and management. Ports are becoming increasingly interested in smart solutions to optimize operations, promote efficiency, enhance sustainability, and avoid safety and security incidents. The adoption of such solutions to address recent problems is known to be switching to smart ports. Our literature review revealed two different perspectives of a smart port. One view is that the smartness of a port relates more to the ideology, policy decisions, and the smart use of resources rather than technologies and physical infrastructure. Another perspective of smartness is related to the utilization of recent technologies in order to improve the port performance or facilitate sustainable development.

A commonly accepted definition of a smart port and its associated activity domains have not been well addressed in the literature. Hence, the objectives of this work include: 1) providing a smart port definition and identifying its activity domains, 2) developing a performance measurement index to evaluate the port performance to meet the smart port objectives, and 3) determining the leading factors of the current smartness state of ports.

Smart Port and Smart Port Index (SPI)

A smart port gathers better-educated individuals, skilled workforces, intelligent infrastructures, and automation to facilitate knowledge development and sharing, optimize the port operations, enhance the port resiliency, lead a sustainable development, and guarantee safe and secure activities [1]. According to the categorized literature review and classified smart port initiatives, a smart port has four main activity domains: operations, environment, energy, and safety and security. The performance of a smart port can be measured by four indices that we present here: Smart Operations Index (SOI), Smart Energy Index (SEgI), Smart Environment Index (SEnI), Smart Safety and Security Index (SSSI). Key performance indicators (KPIs) were collected from the literature ([2], [3], [4], [5]) to enable the quantification of smart port sub-indices. Thus, we have 29 KPIs associated with SOI, 27 KPIs for the environmental performance of the port, 17 KPIs for energy, and 15 KPIs for safety and security. Because the range of measured KPIs can be quite different from one KPI to the next, the values must be rescaled so that the KPI values are comparable in the combined SPI. For rescaling the KPIs, the normalization is used to transform the original data into values between 0 and 1. Then, the KPIs are modified in such a way that if a higher KPI value is preferred, the normalized value can be used as-is. But, if less value for the KPI is preferred, the KPI value can be multiplied by -1). Each of the four indices (SOI, SEgI, SEnI, and SSSI) is calculated as a function of the relevant normalized and modified KPIs (Equations (1)-(4)), and SPI is calculated as a convex combination of these four sub-indices (Equation (5)).

$$SOI = \sum_{i=1}^{n_1} \alpha_i k'_{1i}, \qquad \sum_{i=1}^{n_1} \alpha_i = 1, \qquad \alpha_i \geq 0,\ \forall i = 1,\ \ldots,\ n_1 \tag{1}$$

$$SEgI = \sum_{i=1}^{n_2} \beta_i k'_{2i}, \quad \sum_{i=1}^{n_2} \beta_i = 1, \quad \beta_i \geq 0,\ \forall i = 1,\ \dots,\ n_2 \tag{2}$$

$$SEnI = \sum_{i=1}^{n_3} \gamma_i k'_{3i}, \quad \sum_{i=1}^{n_3} \gamma_i = 1, \quad \gamma_i \geq 0,\ \forall i = 1,\ \dots,\ n_3 \tag{3}$$

$$SSSI = \sum_{i=1}^{n_4} \delta_i k'_{4i}, \quad \sum_{i=1}^{n_4} \delta_i = 1, \quad \delta_i \geq 0,\ \forall i = 1,\ \dots,\ n_4 \tag{4}$$

$$SPI = \lambda_1 SOI + \lambda_2 SEgI + \lambda_3 SEnI + \lambda_4 SSSI, \ \sum_{i=1}^{4} \lambda_i = 1,\ \lambda_i \geq 0,\ \forall i = 1,2,3,4 \tag{5}$$

Numerical Example

Among the busiest ports in the world in terms of annual TEUs, fourteen ports are selected to demonstrate our methodology. The selection of the ports is based on the availability of the data and the diversity of their locations.

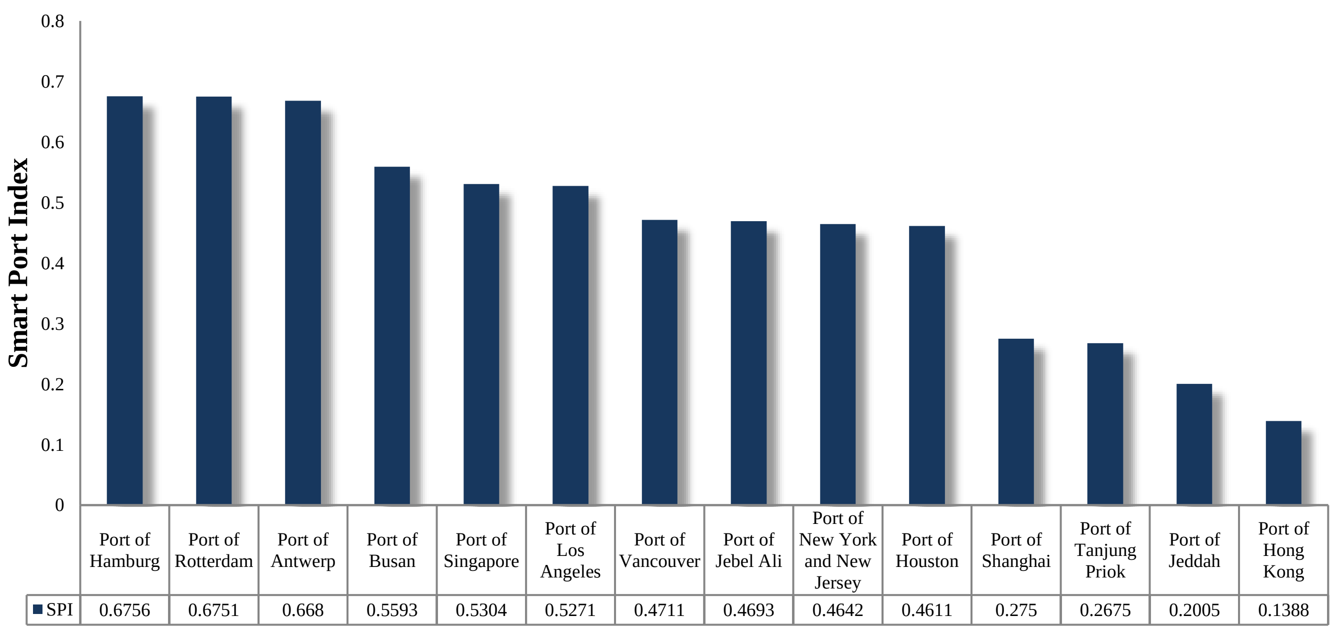


Figure 1. Comparison of Smart Port Index for 14 ports

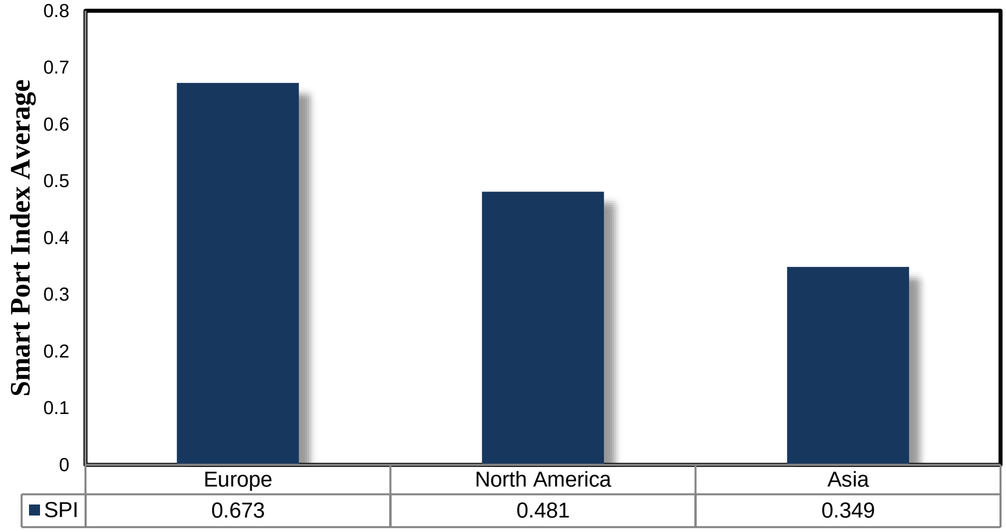
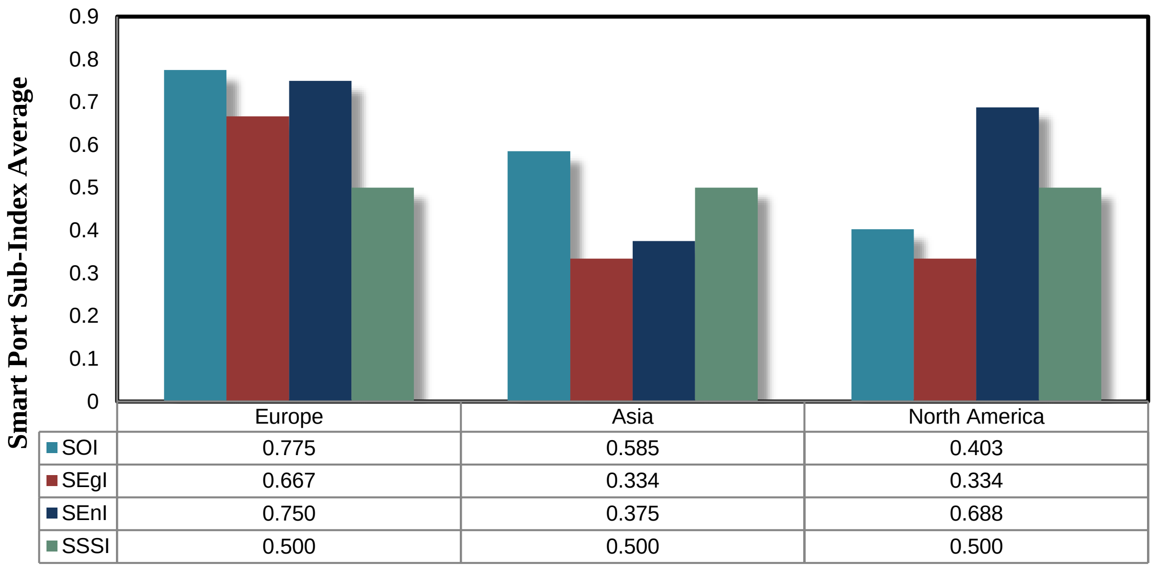


Figure 2. Smart Port Index by region

Figure 3. Smart port sub-indices by region



Conclusion

In this study, we introduced the definition of a smart port by classifying the literature and smart port initiatives and identified smart port main activity domains: operations, energy, environment and safety and security. For evaluating the performance of the port with regard to smart port definition and activity domains, we developed Smart Port Index and four sub-indices by collecting and using the KPIs from the literature. Our study shows that smart port initiatives around the world have different levels of comprehensiveness and smart port penetration into the port activities differ from one port to the next. We show in the result that the government policies and region-specific variables can impact the smart port index value.

References

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