Smart Ports from Theory to Practice: A Review of Sustainability Indicators

Silvia Battino[1](✉) and Maria del Mar Muñoz Leonisio[2]

[1] DiSea - University of Sassari, 07100 Sassari, Sardinia, Italy
sbattino@uniss.it
[2] University of Cádiz, 11003 Cádiz, Spain
mar.leonisio@uca.es

Abstract. About 70% of the Earth's surface is covered by water. A "blue planet" whose essential driving force is represented by the ports that ensure the connection also of the most peripheral and insular areas. The activities of ports are configured as an element of economic development and creation of new employment. In Europe, according to the last report of 2020, maritime transport was fundamental to import and export 74% of goods, to generate employment for 1.5 million workers and to move about 420 million passengers.

At the same time, port activities are responsible for several negative externalities that are often not considered in business strategies. In recent decades the port industry has undergone a profound transformation because of different technical, commercial, and legal aspects. The smart port concept is based on the ability of new technologies to transform port services into interactive and dynamic businesses, more efficient and transparent. Its objective is to satisfy the needs of customers and users without forgetting its responsibility to the city and the citizens.

The digitization combined with careful planning and management of port operations allows us to find smart solutions to optimize logistics and environmental impacts, to promote efficiency and to enhance the safety of both seaports and coastal regions involved.

This paper, after a review of the literature on smart port studies, aims to build a matrix of indicators of the sustainability of port ecosystems which will allow the measuring and ranking of ports in its Smart Port category.

Keywords: Seaports · Smartness · Sustainable indicators

1 Introduction

The policies and strategies dedicated to the transport sector are regularly updated by many multidisciplinary contributions that analyze and elaborate solutions to reduce the

This study is developed in the context of "Programma di Sviluppo Dipartimenti di Eccellenza 2018–2022 BES - Benessere Equo Sostenibile", Department of Economics and Business – University of Sassari. This paper is the result of the joint work of the authors. In particular: Sects. 1 and 2 have been written by Silvia Battino and Sects. 3 and 4 by Maria del Mar Muñoz Leonisio.

© The Author(s), under exclusive license to Springer Nature Switzerland AG 2022
O. Gervasi et al. (Eds.): ICCSA 2022 Workshops, LNCS 13381, pp. 185–195, 2022.
https://doi.org/10.1007/978-3-031-10548-7_14

negative impacts resulting from the use of transport means (land, air, and sea) and to improve the mobility of people and goods [1].

The concept of sustainable mobility first appeared in Europe in 1992 within the "Green book", which highlighted the impact of transport on the environment and the common strategy to improve the negative effects of the sector on the economic and social life of the Member States. Subsequent documents including the 2030 Agenda (2015), the 7th and 8th Action Programs (2018 and 2021), the European Green Deal (2019) and the Next Generation EU (2021) bring to the attention of all stakeholders the need to implement actions for cohesive and inclusive growth [2]. The plan to reach the goal of climate neutrality in 2050 is ambitious: by this date a 90% reduction in emissions from the transport sector is expected [3]. According to recent statistics, climate neutrality still seems far away. Indeed, this sector has recorded a constant increase in the production of Green House Gases (GHG) from 2013 to 2019: road transport is responsible for 72% of all GHG, followed by aviation (13%) and maritime (14%) [4]. The emissions of the latter two means of transport have increased by more than 50% since 1990. In this panorama of documents and policies, we will focus on the strategy that perceives the future of ports considering the combination of four elements: port operations, environment, energy and safety and security. This combination will allow more efficient and sustainable ports along with improvements in the accessibility and safety.

The remainder of the paper is organized as follows. Section 2 presents a brief re-view of the literature. Section 3 which is divided into three parts explores the key findings on smart port indicators. The first part explains the port model in order to establish responsibility in terms of sustainability. The second part explores the initiatives and regulations that have been implemented in ports to reduce environmental impact and improve port operations. The third part is based on the development of a set of indicators that will allow the comparison of the degree of compliance with smart port objectives.

We summarize our main conclusions and future lines of research in the fourth section.

2 Related Works

The ports have traditionally been defined according to three different classifications: hierarchical, generation and functional. The first classification is based on the hub and spoke system without considering possible horizontal relationships with the hinterland. The second classification (generation) highlights ports in their evolutionary history from a primitive system (e.g., fishing village) to a global hub. This view also considers the development of port-city integrations. Finally, the functional classification emphasizes the regionalization of the port system considering logistics integration as the final step of development [5].

In 1990, the proposal of a theoretical model, carried out during the United Nations. Conference on Trade and Development (UNCTAD), helped to understand the evolution of seaports. The model considers locally adopted strategies, services provided, and information technology to distinguish five generations of ports (Fig. 1) [6–9].

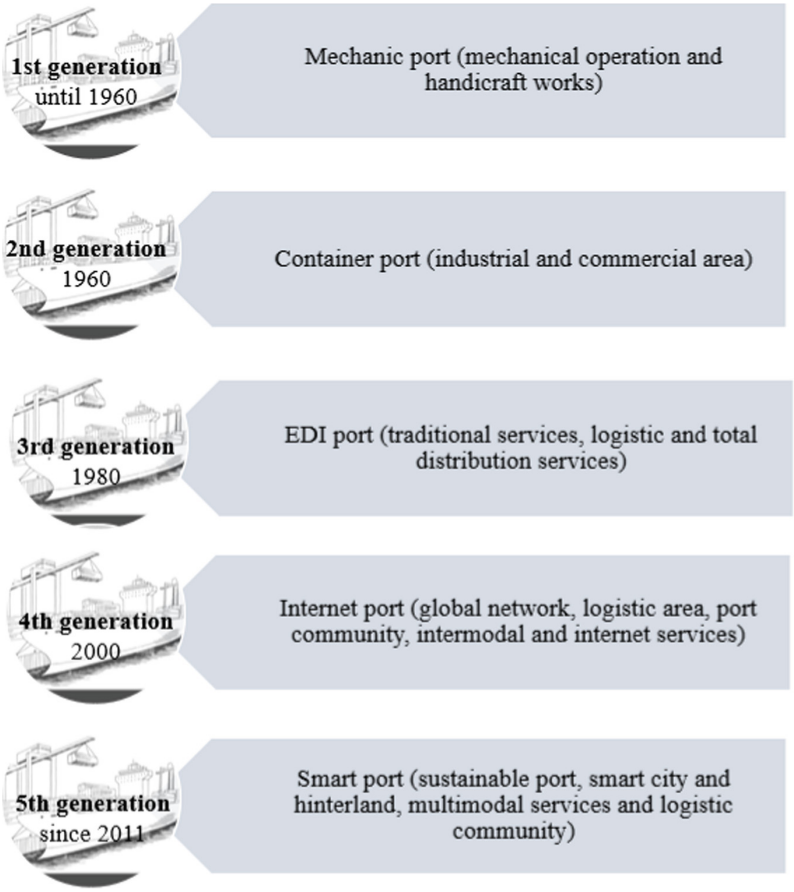

Fig. 1. Evolution of seaport. Source: own elaboration based on [6, 7, 9, 10].

Ports in their evolutionary process have produced numerous changes in various operational areas such as productivity, infrastructure and governance. Also, the adoption of modern technologies and the activation of new business partnerships/strategies have been important. Thus, increasingly sophisticated networks are working to make all port activities sustainable and more interconnected. This trend, accompanied by the evolution of digitization, marks the way for the realization of the Smart Port [11–13]. For a port to reach the definition of smart, it must achieve certain requirements. Among these requirements are the provision of high quality infrastructure; the operational integration with the other port operators and the territories that gravitate towards it; the ability to process significant amounts of data; the achievement of competitive advantages and at the same time having the ability to implement practices that are respectful of the environment and citizenship [8]. The most important ports in the world have taken steps to equip themselves with the most modern and sophisticated technologies to improve their functions in a competitive context and at the same time careful not to cause irreversible negative impacts [14]. However, not all ports start from the same situation regarding

the implementation of smart port strategies. Smart ports are those that use intelligent technologies together with sustainable commercial mechanisms. One of main challenges that the port sector has to face is the one related to the use of Information Technology (IT) and cybersecurity. To guarantee success in the transition process, it is important that the interests of the government, shareholders and stakeholders follow the same direction [11, 13].

For this reason, it is necessary to identify the structure of a smart port and to measure in quantitative terms the different levels of efficiency and sustainability. These Key Performance Indicators (KPIs) are based on the fundamental goals that characterize a smart port, such as the relevant operations, environment, energy and safety [14, 15].

The Research and Innovation Strategies for Smart Specialization (RIS3) plays a key role in the port smartification process. This tool is fundamental in helping port systems achieve the right degree of smartness and fit into the strategies of the Green Deal and Blue Growth [16]. This emphasizes the need for a participatory involvement of all the stakeholders that revolve around a port system to address in holistic terms the process of sustainability in its social, economic, environmental, and temporal dimensions [17].

In this context, it seems appropriate to highlight the historical relationship between port and city. Port cities, together with the countries in which they are located, owe their growth to the increase in port activities. However, a crisis in this relationship became evident in the second half of the 20th century due to the acceleration of the globalization process that led to significant changes in transport systems and location choices. In this sense, it must be remembered that the containerization and inter-modality have caused a significant territorial and social disaggregation. This has challenged the complex relationship between ports, cities and their hinterlands [18–25]. The complex city-port relationship is characterized by multiple contradictions and problems arising from current planning and design processes. In port cities there is now an important debate around the role of the urban waterfront. Many port cities are engaged in urban waterfront conversion processes with the intention of creating new spaces, uses and future port scenarios and more sustainable economic growth [26, 27]. The growth of port activities can help revive the city's economy thanks to an increase in the flow of goods, new investments and passenger arrivals, as well as from a tourist perspective linked to cruise tourism. Together with these projects, value-added services will increase and the construction/renovation of road and rail infrastructures will be encouraged, which will also boost the city's economy. Hence the need for sustainable and integrated logistics, which is embodied in the creation of a Smart Tunnel. This is an intelligent platform of logistics services for port cities and is aimed at maximizing the safety and efficiency of the port-retroport corridors. It essentially means increasing the value of the port terminal within supply chain management [28–31].

A digitally-supported network and IT strategy aimed at managing land and sea traffic are helping to maintain the economic viability of the port city. City residents can get around easily and port operations become more efficient. Thus, transportation planning is combined with urban planning promoting the improvement of the quality of life of the port city [32]. The integration between the urban and port system represents the connection between the local and global economy. The application of Data Envelopment Analysis (DEA) on the whole city/port allows to measure and compare the level of

sustainable development achieved by the above-mentioned indissoluble pair (port city) [33]. It is to assess and constantly monitor the degree of sustainability of port cities, using, also, methods of classification of different plans and long-term port visions to be compared with a set of social, economic, and environmental KPIs [34]. Finally, it can be said that the study of the economic-territorial organization of a port facilitates the required interventions of territorial planning and economic programming [35].

3 Smart Port Indicators

3.1 Port Organization Model

Globalization and technological developments have not only affected the design and operations of port facilities, but also the organizational and institutional relationships between members of the port community [47, 48]. The characteristics of the demand for port services and the technology of the offer determine the economic structure of the ports and their management. The search for efficiency in maritime transport leads to the introduction of certain mechanisms to encourage internal competition in the provision of port services. Ports face competition between ports and also competition between port terminals. Most of the activity of a port is carried out by private companies that operate in it through licenses, authorizations or concessions granted by the Port Authority (PA). These agreements enable companies to operate in the port under certain conditions of use. The private terminal operator can build and maintain its own buildings, purchase and install its own equipment on port land and hire workers. Port public-private partnerships are considered a very effective tool in the hands of public agencies for port development and performance, while maintaining strategic control over the asset in the long term [36–38]. In fact, landlord port model is the most common organization of the main ports of North America, Europe and Asia. The main strength of a landlord port is that a private operator adapts more quickly to changes in the market than public agencies. It must be taken into account that the survival of private terminals depends on the existence of profits. PAs and the private operators must respond to the demands of society and the ports users.

The management of the PAs should be characterized by a double objective: to make the port attractive for users through a competitive offer of services, and on the other hand to increase the well-being of its citizens [39]. Shareholders consider the financial position and return on investment as well as the reputation of the port in terms of the legal and transparent competitive allocation of port terminals. At the same time, the performance of a high use of information and communication technologies and the use of environmentally friendly procedures, are gaining weight in investors' decisions [40–42].

Table 1 summarizes the configuration of the landlord port model in regard to the ownership and management of resources and commercial activities.

Although the influence of the PA is in many cases indirect, all PAs are called to proceed and operate effectively to implement the Environmental Management System (EMS) of the ports under their jurisdiction. PAs not only have administrative regulations to promote better environmental management but also economic incentive mechanisms

Table 1. Landlord port model. Source: own elaboration.

Administrative management of the port space Enabling private operators through licenses, concessions or authorizations	PORT AUTHORITY
Organization of the activity Management, surveillance and control of port activity	
General services Cleaning of common areas, cleaning of floats, etc	
Basic Infrastructure: shelter dikes, dredging Complementary Infrastructure: development of docks, berths, roads, service networks	
Superstructure: Loading, unloading, handling and storage equipment	PRIVATE PORT OPERATORS
Port services (provided by licence) Handling of merchandise, passenger services, technical nautical services and reception of ship waste	
Commercial services (provided by concession) Storage, activities of added value to the merchandise, etc.	

such as discounts on activity rates or extensions to the concession term for those operators who comply with Good Practice agreements.

3.2 Smart Port Initiatives

The increase in social and economic demands is causing that ports around the world to incorporate initiatives to reduce environmental impact and improve port operations. In this context, the Good Practice Guides developed by the Spanish State Ports aim to provide a common frame of reference. These guides provide initiatives to promote better environmental performance of operations within the entire port system. Two guides are currently available:

- Guide to good practices in the implementation of environmental management systems. It provides recommendations for implementing environmental management systems in port companies. The purpose of these recommendations is to adapt the management systems to operations in the port and to the needs for verifying the good practice agreements.
- Guide to good practices in the handling of solid bulk. This guide provides recommendations on both good practices in operations and in the provision of equipment. The objective is to help control the environmental impacts linked to the handling of solid bulk through a wide variety of operating schemes.

There are some international regulations related to the prevention of marine pollution and greenhouse gas emissions. Some of them are the protocols of the International

Convention for the Prevention of Marine Pollution from Ships (MARPOL) 73/78/97. The Eco-Management and Audit Scheme (EMAS) is a tool developed by the European Union that recognizes those organizations that have implemented an EMS.

In addition, the European Sea Port Organization (ESPO) supports environmental protection in European ports and emphasizes the importance of adopting programs that include actions to control and monitor green practices. The Environmental Product Declaration (EPD) is a comprehensive, internationally harmonized report created by a product manufacturer that documents the ways in which a product, throughout its lifecycle, affects the environment.

In the social sphere, ISO 45001 standard recognizes the organization's commitment to corporate responsibility and the development of a preventive culture in the organization.

ISO 50001, an international standard for energy management systems, specifies the requirements for designing, applying, maintaining and enhancing an Energy management system.

In addition to the risks inherent to the activity itself, ports are exposed to threats of terrorist attacks and cyber security. International Ship and Port Facility Security (ISPS) code is a set of measures to enhance the security of ships and port facilities.

These are only some of the most popular guides and recommendations, but the transition to smart port is an ever-evolving process.

3.3 Smart Port Indicators

The smart definition finds application in all human activities, from production and management activities to mobility of people and goods. The use of indicators is aimed at monitoring the operational, managerial, and environmental performance of seaports. For this reason, academic research needs a continuous confrontation with maritime transport professionals to ascertain, choose, estimate, and confirm plausible, achievable, and feasible indicators for the sector [43]. The involvement of multiple actors in the determination of Port Sustainability Indicators (PSI) seems to be becoming more attractive and decisive. In fact, the scientific work carried out thanks to the confrontation with the experts of the PAs is associated with the experiential points of view of local political/administrative powers, of companies that manage other transport systems (air, rail, and road) and, finally, of citizens. The involvement of citizens in the process, who may lack specific knowledge but "gravitate" to or "live" in the port, highlights a decision-making approach with social implications [44].

A smart port is based on the implementation of behavior strategies that can be classified into four main activity domains: Operations, Environment, Energy and Safety and security [14]. Recent research [45, 46] has determined a rank of smartness achieved by the most important (10) Spanish ports, both for each of the four pillars considered (economic operational, social, institutional political, natural environment).

Based on the related Works and previously mentioned guidelines and standards management system (SMS) we have established a set of performance indicators that will allow ports to be classified within the Smart category. Smart port performance indicators are defined on measurable and realistic objectives. Each PA establishes its own objectives regarding the transition to smart ports through the implementation of the

best available practices and their own resources. Table 2 shows a matrix of Smart Port KPIs classified into four categories and a brief description.

Table 2. Smart port key performance indicators. Source: own elaboration.

Description			Key performance indicators
Smart port operations	Operational	Operational efficiency	Total cargo moved in relation to seaport equipment
	Economics	Economic efficiency	Investments and returns
	Political & Institutional	Management transparency Private operators (%) Quality private services SMS	Open data system Concession area Index Number of private operators with discounts for the quality of their services ISO 9001
	Social	Health & Safety. SMS Labor inclusion and equality in the workforce	ISO 45001 Number of female workers of total workers Gender diversity in the Board of Administration
	Mobility	Optimize the mobility of heavy vehicles Boost rail traffic	Existence of railway tracks inside the port
Environment	Water quality Water consumption management Noise pollution		EPD ISO 14001 EMAS III
Energy	Renewable energy production Energy management systems		Use of renewable (wind energy, solar power) ISO 50001
Safety and security	Actions to improve cybersecurity		ISPS

We have established four categories of measures related to easily identifiable indicators. These measures are not the only ones possible nor do they exclude the possibility of adding other alternatives. It is important to mention the fact that this is voluntary behavior on the part of the PAs. This analysis will permit us to investigate which are the most accepted and applied indicators.

The objective pursued is to monitor the implementation of KPIs and at the same time detect which of the dimensions of smart port requirements are not met. The comparison between ports will allow the establishment a smart port ranking.

4 Conclusions and Future Lines of Research

Smart port is a broad concept that encompasses different organizations and requires a long-term commitment. Although the term is relatively recent, the interest shown by researchers reveals the importance of the topic throughout the world. National governments and PAs are interested in the implementation of good practices that combine economic growth and social responsibility.

In this work, three relevant topics have been observed. First, the ability of seaports to evolve under the sustainability and smart paradigm principles was presented. Second,

the port city relationship is analyzed through the evolution of technology and global networks and the ports´ contribution to the creation of incomes in their hinterland. Third, possible mechanisms are studied to reduce the undesirable output of port activity. The best way to improve harmony between the port and its citizens is the implementation of transparent management that incorporates the requirements of all stakeholders. At the same time, studies and researches seem to confirm that implementing smart strategies improves both the operational efficiency and port city relationships. Taking into account that some practices are mandatory, the true scope of the smart port category is in the implementation of voluntary actions. This behavior will lead the way for other ports in the future.

The first step for the design of quantifiable SMIs consists in the identification of responsible behaviors within each port environment. In this sense, this work is a starting point to measure the reality of progress in the implementation of smart development goals. The second step of this research will consist of the application of KPIs to Spanish and Italian ports to check the level of commitment of their PAs. Additionally, it should be interesting in the future to contrast the use of KPIs and port economic or operational performance.

References

1. Holden, E., Gilpin, G., Banister, D.: Sustainable mobility at Thirty. Sustainability **11**(1965), 1–14 (2019)
2. Madau, C., Battino, S.: Trasporti e innovazione per “ripensare” gli spazi. L’approccio smart della Regione Sardegna. In: Dini, F., Martellozzo, F., Randelli, F., Romei, P. (eds.) Oltre la globalizzazione – Feedback, Società di Studi Geografici. Memorie geografiche NS 19, pp. 67–73 (2021)
3. Di Marco, L.: Obiettivi di sviluppo sostenibile e politiche europee. Le sfide del futuro dell’Europa. Quaderni dell’ASviS. **5**, 1–156 (2021)
4. European Environment Agency: Greenhouse gas emissions from transport in Europe (2021). https://www.eea.europa.eu/ims/greenhouse-gas-emissions-from-transport
5. Kanellopoulos, J., Mininel, S., Daems, F., Nikolopoulou, A.: Port of the future challenges, enablers and barriers. In: COREALIS Consortium 2018–2021 (2021)
6. UNCTAD: Port Marketing and the Challenge of the Third Generation Port. Trade and Development Board Committee on Shipping ad hoc Intergovernmental Group of Port Experts (1994)
7. UNCTAD: The Fourth Generation Port. UNCTAD Ports Newsletter **19**, 9–12 (1999)
8. Karaś, A.: Smart porto ad a key to the future development of modern ports. TransNav **14**(1), 27–31 (2020)

9. Kaliszewski, A.: Fifth and sixth generation ports (5gp, 6gp) evolution of economic and social roles of ports. Retrieved **5**, 1–31 (2018)
10. Flynn, M., Lee, P., Notteboom, T.: The next step on the port generations ladder: customer-centric and community ports. In: Notteboom, T. (ed.) Current Issues in Shipping, pp. 497–510. Ports and Logistics, University Press Antwerp, Brussels (2011)
11. Jović M., Kavran N., Aksentijević S., Tijan E.: the transition of Croatian seaports into smart ports. In: MIPRO 2019, 20–24 May, Opatija - Croatia, pp. 1.386–1.390 (2019)
12. Hossain T., Adams M., Walker T.R.: Sustainability initiatives in Canadian ports. Marine Policy **106**, 11 (2019). (103519)
13. (de la) Peña Zarzuelo, I.: Cybersecurity in ports and maritime industry: reasons for raising awareness on this issue. Transp. Policy **100**, 1–4 (2021)
14. Molavi A., LKaras G. J, Race B.: A framework for building a smart port and smart port index. Int. J. Sustain. Transp. **14**(9), 686–700 (2020)
15. Makkawan, K., Muangpan, T.: A conceptual model of smart port performance and smart port indicators in Thailand. J. Int. Logist. Trade **19**(3), 133–146 (2021)
16. Meyer, C.: Integration of baltic small and medium-sized ports in regional innovation strategies on smart specialisation (RIS3). J. Open Innov. Technol. Mark. Complex **7**(3), 184, 16 (2021). https://doi.org/10.3390/joitmc7030184
17. Lozano, R., Carpenter, A., Sammalisto, K.: Analysing organisational change management in seaports: stakeholder perception, communication, drivers for, and barriers to sustainability at the Port of Gävle. In: Carpenter, A., Lozano, R. (eds.) European Port Cities in Transition. SS, pp. 205–224. Springer, Cham (2020). https://doi.org/10.1007/978-3-030-36464-9_12
18. Vallega, A.: Nodalité et centralité face à la multimodalité. Élements pour un relais entre théorie régionale et théorie des transports. In: Muscara, C., Poli, C. (eds.) Transport Geography Facing Geography, pp. 69–88. Dipartimento di Pianificazione Urbanistica e Territoriale, Rome (1983)
19. Vallega, A.: Cityports, coastal zones and sustainable development. In: Hoyle, B.S. (ed.) Cityports, coastal zones and regional change, pp. 295–306. Jhon Wiley & Sons Ltd., Hoboken (1996)
20. Hoyle, B.S.: The port-city interface: Trends. Problems and examples. Geoforum **29**(4), 429–435 (1989)
21. Hoyle, B.S. (ed.): Cityports, Coastal Zones and Regional Change. John Wiley & Sons Ltd., Hoboken (1996)
22. Hoyle, B.S., Pinder, D.A.: European Port Cities in Transition. Belhavwen Press, London (1992)
23. Musso E.: Città portuali: l'economia e il territorio. FrancoAngeli, Milano (1996)
24. Ducruet, C.: Approche comparée du développement des villes-ports à l'échelle mondiale: problèmes conceptuels et méthodologiques. Les Cahiers scientifiques du transport AFITL **48**, 59–79 (2005)
25. Ducruet, C.: The port city in multidisciplinary analysis. In: Alemany, J., Bruttomesso, R. (eds.). The Port City in the XXIst Century: New Challenges in the Relationship Between Port and City, pp. 32–48. RETE, Venezia (2011)
26. Giovinazzi, O.: Citta' portuali e waterfront urbani: costruire scenari di trasformazione in contesti di conflitto. Méditerranée: Revue géographique des pays méditerranées **111**, 69–74 (2008)
27. Gras, P.: Storia dei porti. Declino e rinascita delle città portuali, pp. 1940–2010. Odoya, Bologna (2013)
28. Carbone, V., Martino, M.: The changing role of ports in supply-chain management: an empirical analysis. Marit. Policy Manag. **30**(4), 305–320 (2003)
29. Shan, J., Yu, M., Lee, C.Y.: An empirical investigation of the seaport's economic impact: evidence from major ports in China. Transp. Res. Part E **69**, 41–53 (2014)

30. Mazzarino, M., Battino, S.: Lo sviluppo di servizi di trasporto innovativi a supporto della mobilità dei crocieristici: una valutazione di fattibilità strategica per il porto di Ragusa (Dubrovnik). Boll. della Soc. Geogr. Ital. **2**(2), 29–48 (2019)
31. Amaro García A., Battino S.: Turismo de cruceros en Las Palmas de Gran Canaria (España): reflexiones territoriales. In: Parreño Castellano J.M., Moreno Medina, C.J. (eds.) La reconfiguración capitalista de los espacios urbanos: transformaciones y desigualdades, pp. 19–39. ULPGC editores, Las Palmas de Gran Canaria (2021)
32. Gurzhiy, A., Kalyazina, S., Maydanova, S., Marchenko, R.: Port and city integration: transportation aspect. Transp. Res. Proc. **54**, 890–899 (2021)
33. Chen, C., Lam, J.S.L.: Sustainability and interactivity between cities and ports: a two-stage data envelopment analysis (DEA) approach. Marit. Policy Manage. **45**(7), 944–961 (2018)
34. Schipper, C.A., Vreugdenhil, H., de Jong, M.P.C.: A sustainability assessment of ports and port-city plans: comparing ambitions with achievements. Transp. Res. Part D **57**, 84–111 (2017)
35. Carpenter, A., Lozano, R. (eds.): European Port Cities in Transition. SS, Springer, Cham (2020). https://doi.org/10.1007/978-3-030-36464-9
36. Vining, A.R., Boardman, A.E.: The potential role of public–private partnerships in the upgrade of port infrastructure: normative and positive considerations. Maritime Policy Manage. **35**(6), 551–569 (2008)
37. Siemonsma, H., Van Nus, W., Uyttendaele, P.: Awarding of Port PPP contracts: the added value of a competitive dialogue procedure. Marit. Policy Manage. **39**(1), 63–78 (2012). https://doi.org/10.1080/03088839.2011.642314
38. Panayides, P.M., Parola, F., Lam, J.: The effect of institutional factors on public–private partnership success in ports. Transp. Res. Part A: Policy Pract. **71**(C), 110–127 (2015)
39. Musso, E., Benacchio, M., Ferrari, C.: Ports and employment in port cities. UME **1**(4), 283–311 (2000)
40. Ferretti, M., Schiavone, F.: Internet of Things and business processes redesign in seaports: the case of Hamburg. Bus. Process Manag. J. **22**, 271–284 (2016). https://doi.org/10.1108/BPMJ-05-2015-0079
41. Botti, A., Monda, A., Pellicano, M., Torre, C.: The re-conceptualization of the port supply chain as a smart port service system: the case of the port of Salerno. Systems **5**, 35 (2017). https://doi.org/10.3390/systems5020035
42. Yang, Y., Zhong, M., Yao, H., Yu, F., Fu, X., Postolache, O.: Internet of things for smart ports: technologies and challenges. IEEE Instrum. Meas. Mag. **21**, 34–43 (2018). https://doi.org/10.1109/MIM.2018.8278808
43. Puig, M., Wooldridge, C., Darbra, R.M.: Identification and selection of environmental performance indicators for sustainable port development. Mar. Pollut. Bull. **81**(1), 124–130 (2014)
44. Shiau, T.A., Chuang, C.C.: Social construction of port sustainability indicators: a case study of Keelung Port. Marit. Policy Manage. **41**(1), 1–17 (2015)
45. Rodrigo, G.A., González-Cancelas, N., Molina, S.B., Camarero, O.A.: Preparation of a smart port indicator and calculation of a ranking for the Spanish port system. Logistics **4**(9), 1–22 (2020)
46. Rodrigo, G.A., González-Cancelas, N., Molina, S.B., Camarero, O.A.: Smart ports: ranking of Spanish port system. World Sci. News **144**, 1–12 (2020)
47. Haezendonck, E., Dooms, M., Verbeke, A.: A new governance perspective on port–hinterland relationships: The Port Hinterland Impact (PHI) matrix. Maritime Econ. Logist. **16**, 229–249 (2014). https://doi.org/10.1057/mel.2014.10
48. González-Laxe, F., Martín-Bermúdez, F., Martín-Palmero, F., Novo-Corti, I.: Sustainability at Spanish ports specialized in liquid bulk: evolution in times of crisis 2010–2015. Marit. Policy Manage. **46**(4), 491–507 (2019)