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## Conceptualization of Smart Ports

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**Abstract:**

**Purpose:** The main purpose of the article is to analyze how smart seaports are presented in the literature and source materials, as well as the existing discrepancy in the interpretation of this concept in terms of imprecision, arbitrariness in assigning characteristics to them, and the lack of a conceptual framework for this definition.

**Design/Methodology/Approach:** A literature review was used to generate a representative pool of definitions of the Smart port concept from among searches in electronic scientific databases. In addition, a content analysis of the definitions was conducted to identify activities, tools, technologies and key attributes associated with smart ports.

**Findings:** The presented review of literature and source materials confirmed the lack of a standard and documented definition of smart ports, which at the same time makes it impossible to establish indicators for assessing the degree of implementation of the smart port concept in seaports and their evaluation to date is subjective.

**Practical Implications:** The literature review showed how important it is to systematize knowledge and definitions of smart ports in order to be able to create a common tool for assessing the level of maturity of smart seaports.

**Originality/Value:** To date, there is no extensive research on the conceptualization of smart ports, and case studies of ports implementing the smart port concept in their assessment appear in the literature.

**Keywords:** Innovations, intelligent port, new technologies, smart port.

**JEL classification:** O32, O44, Q55.

**Paper Type:** Review article.

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## **1. Introduction**

Smart ports represent the current trend of port development. Transformation is not only today's trend, but also a reality. Ports could not be excluded from this change. The port industry is undergoing a transformation into a "smart port" as a result of technological advances and changing customer expectations. This transformation is a necessary step to move the port industry into a new era of reliability, sustainability, efficiency and energy dependence, which will further contribute to sustaining economic growth and spreading prosperity around the world.

A set of features related to smart port definitions can be found in the literature on smart ports, ports 4.0 or 5th generation ports. These terms generally refer to ports with increased efficiency (Skiba and Karaś, 2022), new technological capabilities, better resource efficiency, characterized by sustainability, and integrating port stakeholders and users.

Adopting the classification of the United Nations Conference on Trade and Development (UNCTAD) which presents a taxonomy of port generations, smart ports are 5th generation ports. In the 1960s, ports had fairly limited operations and were mainly used for loading and unloading. Later, from the 1960s to the 1980s, ports integrated with their surroundings through transportation, industrial and commercial functions. The expansion of port activities to include industrial and commercial functions created the conditions for an increase in the added value created at ports (Marek, 2012). In the 1980s, ports combined the scope of activities of 1st and 2nd generation ports, and also represented the integration of the port into the transport and –commercial chain. The characteristics of 3rd generation ports also include the relationship between the port and the city for the rational use of resources and joint spatial planning (UNCTAD, 1992). After 2010, ports evolved towards the concept of "smart port" and entered the next stage of evolution, characterized by their digital transformation to follow the revolution of Industry 4.0 (Fig. 1). The concept of smart ports that has emerged from the classification of seaports is certainly not the last, the first mentions of the 6th generation of ports are appearing in the literature, but the literature currently lacks research results and forecasts that would allow predicting the classification of future seaports based on the current criteria of a fourth or fifth generation port and locating a 6th generation port within it. (Kaliszewski, 2017). Currently, the establishment of criteria for sixth-generation ports is difficult to predict, as technological advances in the maritime industry, changes in the environment of seaports, new methods of business management are overtaking the development of ports and seaport generation classifications are being created as a reaction to the occurring and continuous changes in the global economy.

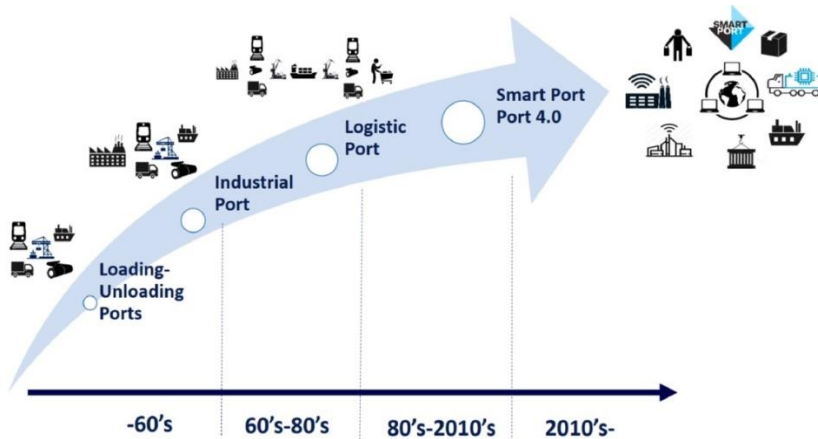


Fig. 1 Port function evolution. Source: De La Peña Zarzuelo I., Freire Soeane M. J., López Bermúdez B., 2020.

## 2. Literature review

A review of the literature has shown that there are different interpretations of the smart port concept and different characteristics are attributed to it. In addition, there is no internationally accepted and unified definition of "smart port." It also does not exist in the context of ports and the maritime industry. Tracing the various definitions of "smart port" in the literature presents the rationale for why the term has appeared in the literature. In the first stage of the literature review, searches were performed. The first search for "smart port" using Google generated about 360,000,000 results, but the results came from both the port, medical and electronics industries. The second search used Google Scholar, this one generated 2,690 results with many of them also coming out of the port area. The third search was conducted using the Scopus database search engine. This generated 184 results, from which the search was narrowed to articles containing the keyword "smart port" or "intelligent port." The Scopus database generated 73 articles, of which only 1 was excluded because the articles were on the topic of smart port from the field of computer science and electronics. For each article selected from among 72, the title, abstract, keywords and bibliography were analyzed. For the purposes of the article, the words smart port and intelligent port are used interchangeably.

## 3. Defining Smart Port

The term "smart port" has received a lot of attention in recent years, both in practice and in attempts to establish a clear and consistent definition of the concept. One of the first attempts to define the concept of smart ports can be found in a study by authors Yang et al. who described the vision of a smart port as a fully automated port in which devices are connected via IoT, and a network of smart sensors, actuators, wireless devices and data centers enables port authorities to provide basic services in a faster and more efficient manner. According to the authors, the main drivers of smart ports are increased productivity and efficiency (Yang et al. (2018). The

element of automation also appears in a study by authors Douaioui et al. According to the authors, an intelligent port relies on interconnectedness within information systems, data service center, cyber security and equipment automation and automation of terminal operations to improve their fluidity, reliability and security of information exchange and real-time decision-making (Douaioui et al., 2018).

The United Nations Economic and Social Commission for Asia and Pacific in its study Smart ports development policies in Asia and the Pacific also points to the element of automation, as the authors emphasize that intelligent port should be understood as those types of ports that strive to automate port facilities and process port operations in such a way, as well as optimize logistics flow through the use of new and advanced technologies. As a consequence of these activities, the port is becoming an autonomous port with integrated information management, rational decision-making and efficient use of resources through technology. Smart ports also mean improving business processes, reducing costs and processing time, increasing port productivity and efficiency, and minimizing the port's environmental impact. A smart port is also a focus on the data it can produce, manage and share (ESCAP, 2021; (Skiba, 2013).

Yen et al. also portray intelligent port as automated, and their development is seen as one of the key factors in economic development. According to the author, governments are committed to transforming ports into smart ports because of the potential benefits they can reap, such as more efficient operation of information and communication technologies, the Internet of Things, energy savings and the pursuit of sustainable development (Yen et al., 2022).

Port Technology International defines smart ports as "ports that leverage automation and innovative technologies, including artificial intelligence (AI), Big Data, the Internet of Things (IoT) and Blockchain, to improve their efficiency" (Port Technology International, 2021).

Marine Insight portal defines smart ports as „Smart Ports are essential infrastructure that uses automation, integration of services, digitization and data-driven techniques for functioning as ports dedicated for management of cargo, mainly using technologies such as the Internet of Things (IoT), Big Data, Block-chain technologies, augmented reality and other smart and data-science based interfaces” (Marine Insight, 2021).

Ki Jun et al. consider a smart port as a port seeking to improve productivity and efficiency by adopting an automated system using a high level of technology - IoT, ICT, Big Data, and environmentally friendly technologies (Ki Jun, 2018). Meanwhile, Cho and Won defined a smart port as a port characterized by automation, high productivity, and having a system of port operations, port logistics equipment, and port logistics infrastructure (Cho and Won, 2014).

In contrast, authors Chen et al. define an intelligent port as follows "a smart port is based on systematic, strategic and social thinking, incorporating the integrated application of cloud computing, Big data, Internet of Things, mobile Internet, intelligent sensing and other next-generation information technologies to achieve comprehensive perception, ubiquitous connectivity, intelligent integration, deep processing and sharing of various elements of connected resources in the ecosystem

of a port organization, so as to ultimately create a modern port that is smarter, safer, more efficient, more flexible, more green" (Chen et al, 2019).

Molavi et al. define the smart port concept as a port that also leverages technology with innovative and efficient management models to increase the efficiency of port operations and minimize associated costs. According to the authors, intelligent ports encompass factors such as productivity, automation and smart infrastructure containing a range of advanced digital technologies consisting of control systems, automation and smart equipment based on sustainability and security (Molavi et al., 2019).

Another proposal is presented in his considerations by Philipp R., who believes that a smart port is completely connected through communication networks and fully integrated with port stakeholders surrounding the port, as well as with other ports and logistics entities around the world. According to the author, a characteristic of ports is the optimization of various modes of transportation and the ability to track cargo in real time (Philipp, 2020).

Toward a completely different understanding in their publication, the authors Henríquez et al. The authors present their concept of smart ports as a concept to be understood in the context provided by the division of seaports into generations, more specifically, the fifth generation port (5GP). The authors compare the smart port with the innovative concept of Port 4.0 (Henríquez et al., 2022).

According to Sakty, the smart port concept is even more different, the author believes that a smart port is a port presented as a combination of three elements - environment, operations (operations) and energy consumption (Sakty, 2016).

A completely different view of smart ports is taken by Chen et al. who combine the smart port concept with the green port concept. The authors believe that these are inseparable elements that reinforce and develop each other. According to the authors' considerations, green port development is the main goal of low energy consumption, low emissions and low pollution, while smart port development is based on smart high-tech technology to improve efficiency and strengthen competitiveness. The authors believe that green development is an important concept for smart port development. Without the concept of green development, the smart port mode would be difficult to realize and at the same time, the application of technological innovation in the smart port is a key means to achieve a green port (Chen et al., 2019).

The smart port and smart city concepts are combined by Yau et al. defining a smart port as one that is part of a smart city and aims to use technological innovation to improve its operations and port services. In turn, when combined with a smart city, a port provides a boost to cities and regions by improving the competitiveness of international trade. A smart port ecosystem also means reducing energy consumption and traffic congestion. The authors distinguish 5 characteristics of smart ports:

- 1) "smart port services and applications such as vessel and container management;
- 2) technologies such as data centre, networking and communication, and automation;

- 3) use of sustainable technology to increase energy efficiency and reduce greenhouse gases emission;
- 4) cluster management such as a shipping cluster that consists of geographically proximate companies and stakeholders with their main activity being shipping; and
- 5) development of hub infrastructures to foster collaboration among different ports” (Yau et al., 2020).

The Asian Development Bank, in its study *Smart ports in the Pacific Asian* Development Bank defines smart ports as ports that prioritize operational efficiency, are managed by technology, are resilient to change and crises, enhance security of operations, are energy efficient, and pursue a sustainable development strategy (ADB, 2020).

Riedl et al. defines smart ports as those based on digital technology, and thus becoming more productive, efficient and user-friendly, and meeting environmental and safety requirements. Smart port technologies include a range of digital-based services, including embedded sensor networks, truck appointment systems, and platform-based information exchange (Riedl et al., 2018).

For Wang et al. “Smart port uses innovative technologies such as “Digital Twin” (DT) in its management, it can help the port industry make better performance of digitalization and move to a new era”. In their discussion, the authors point out that becoming a smart port means developing solutions that address the challenges that ports face, e.g., limited space, productivity pressures, fiscal constraints, environmental stringency requirements, security risks (Wang et al., 2021).

Technological aspects are emphasized in their definition by Rajabi et al. considering that a smart port is a port that is adequately equipped with technologies such as sensors, cloud computing, fog computing, Internet of Things (IoT), robots, radio frequency identification (RFID) and big data management and analysis. An intelligent port is a port that has the ability to quickly and efficiently deal with the challenges of previous generations of ports. "In general, it helps port authorities and terminal operators adapt well and quickly to changing port conditions. For example, by monitoring analyzed data from the Automatic Identification System (AIS), they can make better decisions in real time. This also has some advantages for shipping companies, as they can reduce their costs, for example by reducing waiting times. Finally, a smart port takes into account its environmental impact and reduces it through an energy-conscious approach," Fig. 2. (Rajabi et al., 2018).

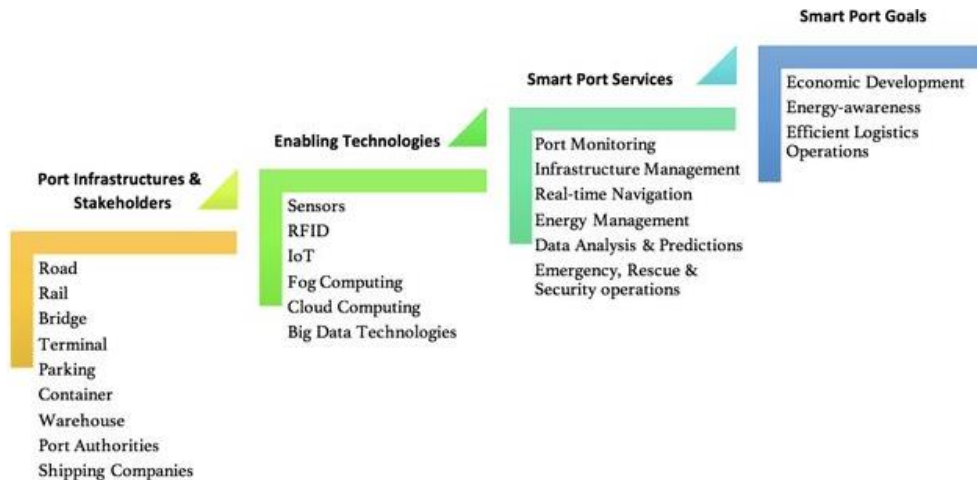


Fig. 2 The proposed architecture of smart port Source: Rajabi A., Saryazdi A., Belfkih A., Duvallet C., 2018.

#### 4. Conclusions

Smart port, intelligent port, or fifth-generation port are terms that give names to today's highly technologically advanced ports. Smart port encompasses various aspects of port operations to enhance port competitiveness, increase the efficiency of port operations, digitize and automate, provide cyber security, energy and environmental efficiency, and integrate port stakeholders. Intelligent ports use elements such as Big data, artificial intelligence, Internet of Things, automation, digitalization, Digital Twins, Block chain, 5G, sensors. However, despite a number of emerging studies on smart ports, there is no clarity on what a smart port is and what indicators and tools would need to be used for ports to be objectively evaluated on the degree of implementation of the concept. Despite the proven benefits of implementing innovations and modern technologies in ports, the conceptualization and implementation of the smart port concept remains a challenge for ports. In the literature, one can notice a divergence in the interpretation of this concept in terms of imprecision, arbitrariness in assigning characteristics to seaports, and the lack of a conceptual framework for this definition. At present, ports themselves are making the transformation to implement the Smart Port concept based on their own defined characteristics and goals.

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