Integrated solution based on innovative digital technologies for smart ports

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***Abstract*— Ports are at present engaged strongly on capital and international funding for the purpose to generate more income, essentially through enhancing efficiency and limiting expenses related to labor. Smart ports represent a great method to achieve these capabilities due to the way they incorporate technologies for communication and information within innovative applications, which eventually contributes to superior port governance. It culminates in enhanced efficiency and reduced operational expenses. The paper is based on one of the use cases, the one in the Port of Galati in Romania, which is part of the European project FOR-FREIGHT, which aims to optimize the application of intermodal freight transport resources, establish affordable resilience with superior levels of performance, and decrease common transport shipping expenses through the establishment of innovative approaches and implementing them with legacy logistics infrastructures.**

Keywords—Smart Port; FOR-FREIGHT; Autonomous Vehicles; Internet of Things

I. INTRODUCTION

Worldwide ports are currently experiencing the fourth industrial revolution as they embrace cutting-edge innovations that include Artificial Intelligence (AI), digitalization, Internet of Things (IoT), and many more to fortify the supply and demand environmental systems. Docks became "Intelligent" in their third-generation phase and have become "Smart" in its fourth-generation phase. Numerous demands have fallen on harbors in current maritime sector [22]. As a result, ports around the world face new obstacles on a daily basis. In recent years, more products and services have been shipped, leading to an increase in vessel traffic. Ports are becoming overcrowded as the worldwide population grows, especially is exacerbated by industrialization and the expanding maritime sector in general. International trade, sustainable development, and technological advancement have all had an impact on the nautical world thus far [21]. All nautical issues existing nowadays, and many more, might be lessened or eliminated by continuing to emphasize the remedies provided through emerging technology that turn all disadvantages into possibilities.

THE SMART PORT CONCEPT

The idea of smart ports, which follows the idea of smart cities and is predicated on the notion that everyone should have access to information about their city, effective communication, and environmental awareness, is now ready for exploration. A "smart port" is more of an abstract idea than a "smart city," which is not a brand-new concept. This is one of the more recent perspectives on the development of ports and shipping where everyone gets a say. The concept of "Smart Ports" calls for digitizing while also managing technological processes, improving the efficiency of port operations, connecting ports with cities, and obtaining energy from other sources. The new management approach known as Smart Port makes extensive use of cutting-edge organizational and technological tools [3].

In 2019, a smart port followed the law, met environmental regulations, and used automation to increase output and safety [6].

According to Lacalle et al. [7], the smart port uses cutting-edge technology to improve predictive decision-making and assess and reduce environmental impacts. Some experts define a smart port as a sustainable port that uses ICT, automates processes and equipment, and efficiently uses energy [8].

The smart port was imagined as a networked, automated port that exchanged real-time stakeholder data [10].
The smart port, a sustainable port, collaborates with its stakeholders to make investments in cutting-edge, environmentally friendly infrastructure and equipment in order to set itself apart from the competitors. The port offers a secure working environment, protection from vulnerabilities and cyberattacks, and assistance with environmental sustainability. These writers claim that Rotterdam, Singapore, and Antwerp are examples of creative smart ports. Finally, it enables effective intermodal integration, which together with scheduling planning and predictive decision making helps to reduce accidents [12].

In 2020, the smart port was included in the concept of the "smart city," which is made up of a number of businesses and ecosystems based on digitalization and the deployment of cutting-edge, environmentally friendly technology. It encouraged continuous growth, created value, and improved the effectiveness and efficiency of port operations. A variety of political, environmental, economic, and port-specific difficulties impacted the transition to a smart port, depending on the port's stakeholders and makeup [3].

Adepoju [13], suggests that significant public and private investments are needed to implement the smart port. According to Yau [14], in order to compete on a global scale, develop value-added services, boost national competitiveness, and promote sustainability, a smart and efficient port mobilizes ICT and innovative infrastructure. On the other hand, smart ports have elements like automation and digitalization. The main goals are to boost citizens' standard of living while improving

economic and sustainability performance and forging a city-port synergy [15].

SMART PORT REVIEW

A. *Port Development*

On a global basis, ports serve as the multimodal intersection of regional supply networks. They work in a complex infrastructure, business environment, and set of regulations [1]. Due to the demand for maritime transportation in the global economy, ports are under increasing pressure to perform at their best in terms of economic, environmental, energy, and operational challenges that affect their sustainability [2].

There are essentially three generations of port development. The first-generation port is a loading and unloading port (until the 1960s). The second-generation is an industrial port (until 1980s). The third-generation port is a logistics and supply-chain port (post 1980s) [3].

Every generation has a unique focus and purpose. The third generation of conventional knowledge asserted that a port's role was less one of service provider and regulator and more one of landlord and facilitator (or cluster manager). We now see that, in response to the increased demand for digital integration, a port is narrowing its focus as a service provider, but not in tangible services like towage and crane operations but rather by transitioning to become a data service provider. This suggests that phase four, which encompasses the digitalization of port activities and the replacement or addition of existing port services with new ones, really follows phase three as shown in Fig. 1 [4].

If a port wishes to truly become a smart port that fully utilizes an IoT network and smart data solutions, it must be able to recognize and take advantage of new economic models within the larger ecosystem.

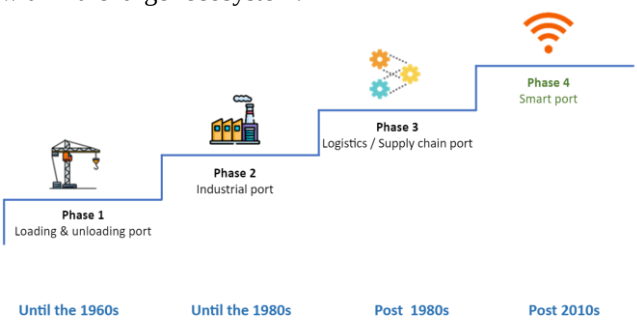

Fig. 1. The port development phases

Technology has changed how ports are categorized, and as a result, ports of the fifth and sixth generations are more frequently recognized. There are a few possible ways in which ports of the 5th or 6th generation differ from those of the 4th generation.

To begin, they might provide higher data transmission speeds, which would make it possible to transfer files more quickly and charge devices more quickly.

Second, they might feature more advanced power delivery capabilities, which would make it possible to charge at greater wattages and manage electricity in a more efficient manner.

Thirdly, it is possible that they may support new capabilities such as video output, which will make it possible to set up displays with a better resolution and multiple monitors. 5th-Generation Ports offer the greatest handling services available anywhere in the world. Such ports include those in Shanghai, Singapore, Hamburg, and Rotterdam. Stakeholders in ports anticipate that fifth-generation ports will focus primarily on enhancing the effectiveness and caliber of their services. This kind of port serves as a logistical hub and has unlimited capacity to handle megaships. Another element driving the creation of fifth generation ports is the use of cutting-edge Technology systems [5].

The specifications for sixth-generation ports are currently not met by either port that is currently in use. When comparing the characteristics of the first, second, third, fourth, and fifth generation ports to the sixth-generation ports, the service of container boats with a capacity of 50 000 TEU (Twenty-foot Equivalent Unit) and a maximum draft of more than 20 meters should be used to separate them [5].

The challenge of increasing the surface area of storage yards will also be faced by the sixth generation of ports. This challenge can be overcome by developing modern storage methods, automating terminals, and developing and implementing technological and organizational innovations. Conversations with port stakeholders and adhering to their demands, as well as planning and predicting loading capabilities, are among the responsibilities of 6GP ports.

B. *Smart Port Domains*

A smart port's four core activity domains are operations, environment, energy, and safety and security. Containerships, cruise ships, tankers, RoRo ships, vehicle carriers, bulk carriers, and refrigerated vessels are just a few of the vessel types that enter ports (reefers). The port's main duties include managing the process of conveying the cargo to storage facilities or other destinations as well as loading and unloading these boats. A smart port employs technology as well as cutting-edge management strategies to increase port operations' productivity and lower associated expenses. Intelligent infrastructure, productivity, and automated port operations are all parts of the smart port operations sector [16].

The environmental domain encompasses all procedures, tools, and fixes that have been implemented to adhere to laws and regulations at both the national and international levels. Protecting the environment from potential harm caused by port activities that harm human and animal welfare is the aim of this sector. In order to do this, the intelligent port uses a perfect environmental management system (EMS) and a reduction in atmospheric emissions. The domain also takes steps to reduce noise pollution, effectively manage trash, and offer techniques for evaluating and minimizing wastewater [17,18]. The port and its logistics utilize a lot of energy. With the development of ports, the demand for maritime transportation, and the rise of port-based industrial activities, there is an increasing need for energy. Smart ports consider strategies to lower energy use while taking into account the constraints of the energy sources that are currently available and port budgets [3]. The subdomains of the energy domain are the use and production of renewable energy, efficient energy use, and the adoption of energy management systems.

Lowering workplace accidents and protecting residents and staff from both internal and external dangers are the two main objectives of safety and security. It complies with local,

state, federal, and international laws, rules, and regulations pertaining to safety and security. Additionally, it has an asset and threat identification system for both internal and external use, a safety management system that satisfies International Maritime Organization (IMO) standards and requirements. These measures increase security and fortify the security system [19].

II. FOR-FREIGHT PROJECT

A. An overview of the project

FOR-FREIGHT is going to deploy the "smart-port" model using dynamic places of employment, based on novel information and communication technology solutions that provide enhanced process digital transformation (data ingestion, storage processing, documentation) and allow automation of vehicles.

The architecture of the system would deliver a dependable and outstanding performance communications network that can facilitate a variety of intelligent and unmanned operations (for example, controlling autonomous vehicles/cranes and remote examination). As a result, autonomous automobiles and drones will be examined in scenarios that are realistic. Various IoT devices are put in the area surrounding the port accompanying operators for gathering data related to the environment. Processes for automatically processing and analyzing data will be provided, resulting in insights for novel policies to drive the Smart Port concept. A different approach is to develop an open data gateway that allows automation and digitalization of port data processing, as well as to provide a reliable information safety and security platform for logistical activities. Third-party ecosystem companies will be able to establish and verify novel information technology services for intermodal transportation as a result of approach. Also, mobile applications are going to be designed that enable personnel to move throughout the port area while completing their duties.

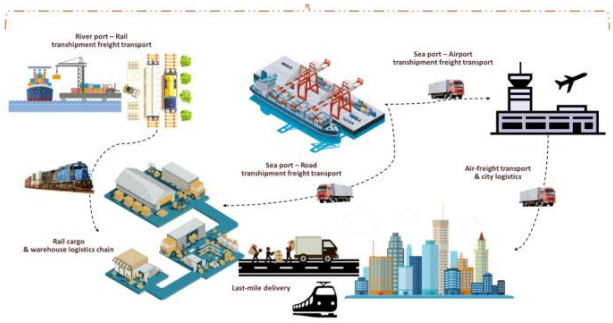

Fig. 2. FOR-FREIGHT platform architecture and general concept (source: https://www.for-freight.eu/concept-and-methodology/)

The solutions defined previously will be carried out implemented as a component of the FOR-FREIGHT project's Romanian use case in order to improve awareness of the situation (data collection with IoT), minimize manual management or examination, and upkeep costs, enhance automation of ports (AI-based systems combined with fast/reliable wireless network), enhance port productivity, that will contribute to a decrease in operation expenses, as well as increase the number of smart devices and intelligent applications.

B. Romanian Use Case

The use case of the FOR-FREIGHT project in Romania will be located in the seaport of Galati. The last mentioned, Galati port *(Fig. 3)*, a vital part of the REN-Danube TEN-T corridor, functions as a starting point for significant shipping from the Black Sea to continental Europe. This is the most significant port on the Danube and Romania's second largest harbor. Numerous worldwide and national enterprises are engaged in shipbuilding, nautical and river development, merchandise for consumer use transit, agricultural goods, cereals, metals, and metallurgical commodities.

The railway transport of commodities accounts for a significant portion of port activities. Currently, the movement of products from maritime vessels to railroads is a decentralized procedure conducted by various operating systems of the numerous parties engaged. As a result, there are misalignments involving unloading/loading and dealing tasks, resulting in severe delay and inefficient resource consumption. These flaws cause waits in the railway's operating schedule, the payment of additional costs, and delays in delivery to recipients. Furthermore, there is no way to trace the products in real time, which allows for illicit trades of assets. Moreover, considerable physical effort is still required for the transfer of goods, resulting in inefficient resource consumption. In addition, given there is minimal digitalization and historical data available, neither immediate time unified functional view is conceivable [26]. Furthermore, there is no plan for sustainable transportation or action on climate change.

Fig. 3. Galati port – the location of the Romanian use case

The FOR-FREIGHT consortium's objective remains to supply capabilities using cutting-edge IoT and data analyzing techniques (5G, Smart Containers) that integrate data collected from each of the company systems for management (supplier, shipping agent, port authority, terminal operator, warehouse, railway operator, beneficiary) allowing the use of comfortable and comprehensible transportation flow data. This will additionally allow previous planning and use of resources throughout the chain [26]. We will be able to monitor activity using the Internet of Things (IoT) system for the purpose to effectively utilize supplies, prevent traffic congestion, and meet the period of operation target.

By implementing the proposed solution in the Romanian use case, the following points will be considered:

1) Integrated and adaptable intermodal freight transportation concept to enhance rail-to-port transportation.

2) 5G connectivity to minimize interference issues and limited IoT applicability

3) ITU real-time location and environmental influences

4) Innovative smart mobility options will be introduced, providing novel transportation methods (autonomous vehicles, light electrical vehicles)

III. CONCLUSIONS

Naval transportation solutions are critical to increasing worldwide commerce, that is delivered by conducting maritime ports over eighty per cent of the entire time [20]. In order to handle this amount of assets, it is now important to enhance both the productivity and effectiveness of these terminals. The aim becomes feasible using the implementation of intelligent harbors that automate every process. Smart ports rely on contemporary technological advances for achieving the optimum degree of administration and planning both within and across ports, reducing administrative procedures and improving maritime circulation [22]. Numerous investigators are at present engaged in identifying intelligent logistical solutions and proposing strategies to attain them.

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REFERENCES

[1] Bessid, Sahbia, Ala Zouari, Ahmed Frikha, and A. Benabdelhafid. "Smart ports design features analysis: A systematic literature review." In *13ème CONFERENCE INTERNATIONALE DE MODELISATION, OPTIMISATION ET SIMULATION (MOSIM2020), 12-14 Nov 2020, AGADIR, Maroc*. 2020.

[2] Molavi, Anahita, Gino J. Lim, and Bruce Race. "A framework for building a smart port and smart port index." *International journal of sustainable transportation* 14, no. 9 (2020): 686-700.

[3] Karaś, A. "Smart port as a key to the future development of modern ports." *TransNav: International Journal on Marine Navigation and Safety of Sea Transportation* 14, no. 1 (2020).

[4] Deloitte Port Services (2017) Smart Ports Point of View.

[5] (Kaliszewski A., Porty piątej oraz szóstej generacji (5GP, 6GP) -ewolucja ekonomicznej i społecznej roli portów, Studia i Materiały Instytutu Transportu i Handlu Morskiego, 2018).

[6] Sari, Y. A., & Pamadi, M. (2019). Current Situation of Wastewater Treatment Plant for Sewage in Batam City. In Paper presented at the Journal of Phys- ics: Conference Series.

[7] Lacalle, I., Llorente, M. Á., & Palau, C. E. (2019). Towards environmental impact reduction leveraging IoT infrastructures: the PIXEL approach. In Paper presented at the International Conference on Internet and Distributed Computing Systems.

[8] [Chen, J., Huang, T., Xie, X., Lee, P. T. W., & Hua, C. (2019). Constructing gov- ernance framework of a green and smart port. Journal of Marine Science and Engineering. https://doi.org/10.3390/jmse7040083].

[9] Jovic, M., Kavran, N., Aksentijevic, S., & Tijan, E. (2019). The transition of Croatian seaports into smart ports. In Paper presented at the 2019 42nd International Convention on Information and Communication Technology, Electronics and Microelectronics, MIPRO 2019 - Proceedings.

[10] Lesniewska, F., Ani, U., Carr, M., & Watson, J. (2019). In the Eye of a Storm: Governance of Emerging Technologies in UK Ports Post Brexit.

[11] Durán, C. A., Córdova, F. M., & Palominos, F. (2019). A conceptual model for a cyber-social-technological-cognitive smart medium-size port. In Paper presented at the Procedia Computer Science.

[12] Frazzon, E. M., Constante, J. M., Triska, Y., Dos Santos Albuquerque, J. V., Martinez-Moya, J., De Souza Silva, L., & Valente, A. M. (2019). Smart port-hinterland integration: Conceptual proposal and simulation-based analysis in Brazilian ports. International Journal of Integrated Supply Management, 12(4), 334–352. https://doi.org/10.1504/IJISM.2019.103197].

[13] Adepoju Olusegun, O. (2020). New seaport development-prospects and challenges: perspectives from apapa and calabar seaports. Nigeria Logistics, 4(2), 8. https://doi.org/10.3390/logistics4020008.

[14] Yau, K.-L.A., Peng, S., Qadir, J., Low, Y.-C., & Ling, M. H. (2020). Towards smart port infrastructures: Enhancing port activities using information and communications technology. IEEE Access, 8, 83387–83404.

[15] López-Bermúdez, B., Freire-Seoane, M. J., Pais-Montes, C., & Lesta-Casal, E. (2020). Port-city development: the Spanish case. Transactions on Maritime Science, 9(01), 82–89.

[16] Kalmar Global. (2018). Kalmar SmartPort Automation. Retrieved from https://www.kalmarglobal.com/automation/kalmar-smartport/.

[17] Al-Fatlawi, Hayder Ali, and Hassan Jassim Motlak. "Smart ports: towards a high performance, increased productivity, and a better environment." International Journal of Electrical and Computer Engineering 13, no. 2 (2023): 1472.

[18] Belmoukari, Basma, Jean-François Audy, and Pascal Forget. "Smart port: a systematic literature review." European Transport Research Review 15, no. 1 (2023): 1-12.

[19] Molavi, A., Lim, G. J., & Race, B. (2020). A framework for building a smart port and smart port index. International Journal of Sustainable Transportation, 14(9), 686–700. https://doi.org/10.1080/15568318.2019.1610919

[20] Leclerc, Y., Ircha, M. (2023). Canada's Rapidly Evolving Smart Ports. In: Johansson, T.M., Dalaklis, D., Fernández, J.E., Pastra, A., Lennan, M. (eds) Smart Ports and Robotic Systems . Studies in National Governance and Emerging Technologies. Palgrave Macmillan, Cham. https://doi.org/10.1007/978-3-031-25296-9_9

[21] E. Idrissi Ayoub, H. Abdelfatteh, A.-A. Abdelmoula, D. Aziz, and A. Abdelhak, 'Mapping the Applications of Vehicular Communications in the Context of Smart Maritime Ports', Vehicular Networks - Principles, Enabling Technologies and Perspectives [Working Title]. IntechOpen, Mar. 24, 2023. doi: 10.5772/intechopen.110086.

[22] Bodewig K. Shaping the Future Policy of the European Maritime Space Motorways of the Sea Detailed Implementation Plan of the European Coordinator: Report EU Mobility and Transport. Brussels, Belgium: European Commission; 2020

[23] Brew, Liam, Logan Drazovich, and Susanne Wetzel. "The Impact of COVID-19 on the Security and Resilience of the Maritime Transportation System." 2021 IEEE International Conference on Cyber Security and Resilience (CSR). IEEE, 2021.

[24] Suciu, G., Pasat, A., Balanescu, M., & Poenaru, C. (2020). WINS@ HI–WEARABLE TECHNOLOGIES FOR MONITORING CRITICAL SITUATIONS IN HAZARDOUS ENVIRONMENTS. International Multidisciplinary Scientific GeoConference: SGEM, 20(2.1), 433-438

[25] Qin, Kongjian, Bongtong Wang, Hui Zhang, Wenbo Ma, Menghua Yan, and Xinming Wang. Research on Application and Testing of Autonomous Driving in Ports. No. 2020-01-5179. SAE Technical Paper, 2020

[26] https://www.for-freight.eu/ accessed on April 12th, 2023