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Smart Ports Design Features Analysis: A Systematic Literature Review

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ABSTRACT: *Ports and port areas' (the hinterland and the logistics corridors) development involves innovative technological solutions. These solutions are at both levels of instrumentation and information systems : instrumentation that has become highly communicating (sensors, RFID, Internet of Things, etc.) and new information systems integrating the complexity of large amounts of data (the Big Data and its semantic processing for detection and machine learning). In this framework, this article aims first at highlighting the Smart concept, second at presenting a modeling a smart port concept by determining its main activities as well as the essential elements that lead to the success of each activity. Third at presenting a systematic literature review specifying the activities, tools, technologies, software and offers research tracks related to smart ports, this is done through a littérature review analysis of more than 50 articles published during the (2003-2020).*

Our objectives are to move from traditional port supply chains (port of Rades, TUNIS "Who suffers from problems in using modern technology") to smart ports in order to make informed decisions. and optimize logistics and transport processes. However, the integration of the IOT into the port infrastructure requires new technologies (sensors, wireless communications, cloud computing, etc.) to ensure the reliability of the connected system.

KEYWORDS: *Smart concept, Smart port, smart port modeling, systematic literature review*

1 INTRODUCTION

The volatility of the last decade's economic condition and the increase in global competitiveness have led to strong innovation trends, particularly among developed countries. However, the integration of communication and information technology in the port's infrastructure has required new technological solutions such as the Internet of Things and Big Data, which create development opportunities, not only for the sector, but also contribute to the development of the management of port chain activities.

The term "intelligence" had existed since the dawn of humanity. Intelligence, according to the theory of Franz E Weinert (Stampfli and Collaros, 2010), is divided into 50% of genetic disposition, 25% of environmental factors and 25% of factors related to personality. Intelligence remains a delicate subject tackled in the vast field, it varies according to times, cultures and fields of application, among others.

This paper is articulated around 4 sections. Section I presents an overview of Smart concept and the modeling of the concept of intelligent port by determining its main activities. Section II presents background and taxonomy of smart concept. Section III and IV introduce smart ports and the essential elements for the success of its

activities. Section V presents a review specifying some attributes and suggested lines of research related to smart ports. The paper will be summarized with concluding remarks.

2 BACKGROUND AND TAXONOMY OF SMART CONCEPT

Currently, the term "Smart" is at the center of research concerns: different studies aim to track, monitor and predict the evolution of technology of such terms as 'smart grid'. The smart grid can be considered as a modern power grid infrastructure for increased efficiency and reliability through automated control, high power converters, modern communication infrastructure, sensing and counting technologies and modern energy management techniques

Based on optimization of demand, energy and consumption (Gungor et al., 2011). According to (Petric, 2010) and (Lund et al., 2017), the smart grid is considered the greatest technological invention.

(Postránecký and Svíték, 2017) defined smart City is as: "The concept of smart city appears because of the mobilization of populations in the cities". In addition, a smart city can be considered as a contextualized interaction between technological innovation, managerial and organizational innovation and political innovation (Nam

and Pardo, 2011). In the same vein, (Su et al., 2011), (Qin et al., 2010) and (Hall et al., 2000) have defined "smart city" as the use of information and communication technologies to detect, analyze and integrate key information from the central systems of cities in activity. Indeed, in smart systems, most electronic devices will communicate with the basic system of the software and, in this way, they will allow the user to access the information where the user is and at any time, (Arsan, 2016). Furthermore, 'Smart Logistics' is a key approach for a more efficient organization of physical logistics and information logistics in cross-society and international transport chains and networks. It integrates existing logistics technologies, such as material handling systems, and enables them to respond and act accordingly, (Uckelmann., 2008), (Oonk et al., 2013). Hence, Intelligent Logistics uses Internet of Things (IoT) integrated technologies, such as Smart Contracts, Machine Learning, Wireless Sensor Network (WSN) and Big Data based on the Blockchain in order to improve the traceability of logistics processes in real time, (Arumugam et al., 2018).

In recent years, many coastal countries, have actively started building smart ports and have achieved significant results. Smart ports in the port chain are inevitably indispensable for a fast, flexible and collaborative response to customer demand. Therefore, facing the changing environment of the port chain, the application of IoT technology to the intelligent management of the port chain to build the port chain of happiness becomes the development trend of modern companies (Xisong et al., 2013).

3 SMART PORTS

3.1 The complexity of the port chain

Modern technological systems include a societal component due to the impact of users. These systems are said to be complex when there are subsystems whose actors have divergent or even opposing objectives. Considered as an evolution of today's intelligent port platform, the Smart port is a perfect example of a complex system. This term refers in particular to an optimized port platform integrating the behavior and actions of users. According to (Beugin, 2006) a system is said to be complex when the relationships linking the components are multiple, interdependent and looped. In the same aspect, (Guérard, 2014) asserts that the science of complex systems studies systems with many components by nature independent, highly interconnected and interacting. Next, (Bittencourt et al., 2016) presented a complex model as an emergent phenomenon resulting from interactions within a network of determinants; methodological implications of using a complex systemic approach and the application of a complex model. We say that a complex system is "A system that involves many interacting agents whose aggregated behaviors must be understood.

Smart ports have many properties common to complex systems such as the heterogeneity of the elements, the impact of internal and external factors on port management and the need for a measurement and control tool to solve the problem of behavior and dynamics at any scale. In addition, they interact with their environment. The complexity of the port systems remains a vague and subjective notion, it characterizes the systems whose mastery of design, maintenance and evolution pose significant problems, related to their size and the number of technologies used, which makes the whole difficult to apprehend. In this instance, complex port systems are being distinguished from other technically complicated systems.

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3.2 Increased competition between port terminals

In a context of increased competition between port terminals, the port reform deployed worldwide since 2008 aims to give major maritime ports the opportunity to

become directly involved in the design of sustainable supply chains.

The emergence of smart ports across Europe requires the integration of innovative technologies from the TIC, transport and energy sectors to become the benchmark for sustainability. The Intelligent Platform for Smart Port consortium (IPaSPort) is initiated by transport and energy to become the benchmark for sustainability.

4 SMART PORT ACTIVITY SYSTEM

4.1 Smart port taxonomy

The port logistics system includes a regional environmental system, an infrastructure system, a logistics information system, a business coordination support system, a well-defined distribution system and a system that is close to the port industry, see Figure.1. They complement each other, are closely related, and form together a port logistics system (Li, 2017).

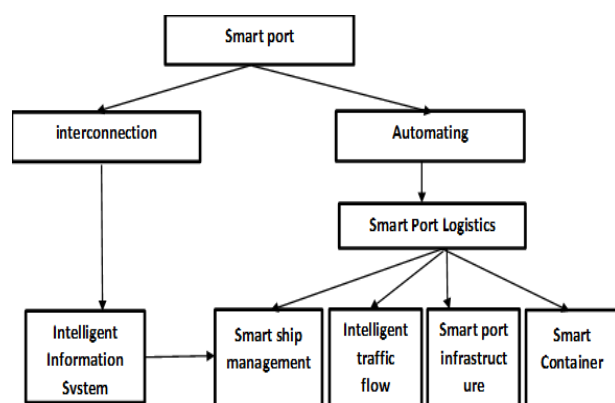


Figure 1: Smart Port Activity System

4.2 Intelligent Information System

Smart ports aim to adopt modern information technologies to enable better planning and management within and between ports. When we talk about a connected port, we are referring to all the technologies that make it possible to lighten administrative procedures and better manage freight traffic. All this requires optimal management of physical flows and information for perfect control of the port chain (Deiss, 2011).

Hence, their role has changed in recent years to fit into an integrated logistics world. An issue that all parties have seized for several years, from port authorities to operational. The management information system would finally become coherent; it would give the decision maker better legibility of activity flows and a much more accurate simulation capability, (Rowe, 2016a).

On the other hand, (Rowe et al., 2018b) introduced the information system that reduces the asymmetry of information between transactional organizations and there-

by moderates the effect of the supply environment on supply chain integration (SCI).

Besides, (Rai et al., 2006); (Song and Panayides, 2008) and (Rowe et al., 2018b) defined the Intelligent Information System as "the use of intelligent and seamless communication systems that facilitate the efficient maintenance of supply chain operations between companies".

4.3 Smart ship management

Nowadays, the time of the intelligent ship is at the door. This is the result of the new fourth industrial revolution that is fast approaching. The fourth industrial revolution is the result of a huge increase in the amount of information acquired, stored, processed and transmitted. This has resulted in intelligent home appliances, robots, telephones, production machines and other objects, visible throughout everyday life. It is now debated whether intelligent ships would be fully autonomous, remotely controlled or crewed, who would be responsible for the vessel in question, and how smart ships would affect shipping. The recent trend to design more efficient and versatile vessels allows for a variety of intelligent port architectures. To improve performance with these architectures, intelligent control strategies are needed.

In fact, the smart ship connected with the smart port to collaborate automatically in the planning of docks, in the preparation of cargo handling operations and work and materials handling and in the organization of truckers to the hour. The thing that improves the management of fleets and minimizes the waiting time of vessels at the dock and also the time of inactivity. This collaboration between the ship and the port has a considerable market impact for the port to become a smart port (Douaioui et al., 2018).

The ship design typically includes three to four phases: design, fabrication, preliminary design and operation of vessels. These design processes are extremely complex processes and consume large amounts of energy throughout their life cycle, (Ang et al., 2016a), (Ang et al, 2017b). Moreover, Information technology (IT) and sensor technology have made many new steps possible in ship automation. Furthermore, Intelligent ship design is qualified that has interconnected capabilities that can potentially elevate and expand the entire shipbuilding process using computer intelligence techniques. Designing smart ships, i.e. making ships with built-in intelligent capabilities (Ang et al., 2016a).

In the same aspect, (Kobyliński, 2018) has defined the smart ship 'According to the general understanding the smart ship is a ship that is either: remote controlled or fully autonomous. In both cases the ship could be unmanned or manned with a skeleton crew'. This applies to collecting, processing, and transmitting the data from

sensors and appliances on board the ship and transmitting it to the shore station, to a unified bridge for remote-controlled unmanned ships, to effective autonomous collision avoidance systems, and to advanced sensor technology.

4.4 Intelligent traffic flow

The objective of traffic management systems is to make use of this information infrastructure so as to interpret the different states of traffic flow and react accordingly in order to maintain or improve the overall performance of the supervised network. This kind of activity obviously requires an intelligent behavior of the system. An effective way of achieving this kind of intelligent behavior, is to endow the system with knowledge about the structure and the dynamics of controlled network. This knowledge is supplied by the human operators and is used to identify critical traffic situations as well as to decide on the most appropriate control actions to be taken. (Hernández et al., 2002) argues in favor of the concept of intelligent traffic management systems (ITMS) as a means of integrating the increasingly complex and heterogeneous traffic control infrastructure and providing a means of strategic support for traffic management.

In traditional traffic detection, infrared detection systems are most commonly used for their ability to count traffic. However, when vehicles are traveling either too closely to each other or in parallel at high speed, such a traffic detection system can easily make a misjudgment, resulting in the failure of a supposedly intelligent traffic signal system to adjust the timing of traffic signals (Chao and Chen, 2014). However, in (Zhou et al., 2010), the controller incorporates the Traffic System Communication Algorithm (TSCA) and the Traffic Signal Time Algorithm (TSTMA) using the WSN technology proposed. Moreover, in (Ngoduy, 2013), The author aims to derive analytical conditions describing the instability of heterogeneous intelligent traffic flow using an extended (microscopic) multi-class Intelligent Driver Model (IDM) with different time delays

4.5 Smart port infrastructure

Smart ports urgently need to be tightly integrated within IoT to ensure efficient data sharing and stability of port services. In other words, smart ports are a new generation of ports, with new intelligent port infrastructure and integrated, intelligent management and service. So, establishing intelligent infrastructure is imperative to ensure smooth and efficient traffic flows and, ultimately, trade flows in the Port of Hamburg. Intelligent information technology consists of elements such as Bluetooth, hotspots or WLAN, cloud, mobile end devices, Internet of Things and Big Data. Moreover, ports are regional multimodal intersections of global supply chains. They function in the context of complex infrastructure, business transactions, and regulations. With the global economy demanding maritime transpor-

tation, ports have faced increasing pressure to optimize their performance in terms of economic, environmental, energy, and functional challenges that impact their sustainability (Molavi et al., 2019).

A smart port has all the information technology's infrastructure and information structure, the latest technologies in the fields of telecommunications, electronics and mechanics, all the information technology infrastructure and the information structure and the latest technologies in the fields of telecommunications, electronics and mechanics. Consequently, a stepping-stone is necessary for the software infrastructure to allow us to rapidly prototype intelligent, or context-aware, services within such an environment (Dey et al., 2000). In addition, according to (Skopik et al., 2012), these three pillars, namely i) confidentiality, ii) integrity and iii) availability, constitute the basis of the concept of smart meter infrastructures.

The infrastructure must support interoperability of context widgets and applications of computing and programming languages on heterogeneous platforms environment (Dey et al., 2000).

4.6 Smart container

For many years, one of the major goals for reaching a smart port is container evolution. The concept of the "Smart Container" is to make the container intelligent so that it can communicate useful, targeted and real-time information. It allows all actors (carriers, freight forwarders or end customers) to have value-added information reflecting the actual progress of a transport and the status of the goods. This information is essential for carriers to improve their services, but also for their customers to help them manage their supply chain. Smart Container as a data sharing facilitator. In summary, the smart container is a key element of multimodal coordination and exception process management. It can detect and communicate real-time information for multimodal transport and improved logistics. Several researches work and approaches have been presented to treat the methods that apply the smart container. We will mention some works encountered in the literature; because containers are densely distributed in a port, it is difficult to identify and transmit the data effectively. To protect the cargo from damage, theft and terrorist threats, businesses and governments are turning to wireless sensors and RFID tags. The Tradition container is replaced by a smart container.

(Zhang et al., 2008) used RFID electronic seals that have both commercial and security interests by tracking commercial container shipments from their point of origin, en route to their destination and at the point of clearance. Their main purpose was to protect the cargo from damage, theft and terrorist threats. In 2010, (Brackmann et al., 2010) showed that the intelligent container system includes universal "crates-pallets", audible, sealable, stackable, traceable and can be scanned. Then,

they were applied to electronic locks, sensors and sophisticated alarms powered by battery were provided, as well as an RF communication and GPS location module that transmits to a base station the time, location and status of the inventive Smart Cargo Container, as well as any abnormal events, including unauthorized attempts of opening or penetrating the container, or any potential damage. On the other hand, (Jurenoks, 2015) presented ICON, intelligent container abbreviations, which are self-managed entities providing applications or service infrastructures, they showed the novelty of ICON in the ability of containers to adapt to their environment, to target near-optimal service delivery and to require only high-level advice from application management. They used IT facilities provided by the Independent Edge Providers (IEPs). As for (Jakovlev et al., 2018), they proposed a WSN (wireless sensor networks) technology that can be very useful when it is used to acquire and send data collected over large areas, and they have used ICT to quickly pre-select high risk and to develop secure and "smart" containers, but the results showed that this technology is not able to direct communications between multiple containers.(Ruckebusch et al., 2018) also proposed the WSN technology. They established a wireless link between containers and a cellular network, i.e. an extra-container communication and intra-container communication in order to communicate from the outside to the inside of the container and vice versa. In addition, they created an ad hoc network of communication between stacked containers. The challenge is to find innovative solutions to balance service requirements while integrating automated and non-automated cargo handling equipment into container terminals to ensure sustainability, safety and security.

5 CLASSIFICATION OF ARTICLES

After presenting the different works dealing with port activities in the maritime transport sector since 2003, in this section, we will try to classify these various works according to different criterion such as activities, methods, new technologies and the most representative software commonly used in the academic and industrial world.

Several authors have used different port activity with different methods have proposed the intelligent container as a port activity such as: (Ruckebusch et al., 2018), (Tang and Dai, 2008), (Moccia et al., 2008),(Arango et al., 2011), (Laganá et al., 2006), (Ślaczka et al., 2017), and (Anwar, 2019). However each author has used a method or the technology different from the other. For example (Ruckebusch et al., 2018) has proposed the smart container as a port activity and they have used intelligent container overlays technology. In the same aspect (Zhao, 2014) has proposed the smart container as a port activity, but they have used wireless sensor network technology. In (Najib, 2014), (Jakovlev et al., 2018) and (Castilla et al., 2020) authors have treated the container terminal problem. As the problem is NP-Hard,

they have presented an innovative mathematical formulation as a Linear Programming (Zavodovski et al., 2018), (Jakovlev et al., 2018), (Khatiashvili et al., 2006),(Najib, 2014). In (Arango et al., 2011), (Wang et al., 2006), and (Cortés et al., 2007), they have tackled the Ship loading and unloading problem. They have solved this problem as Simulation in (Cortés et al., 2007), (Arango et al., 2011), and Metaheuristic in (Wang et al., 2006). In (Zhao, 2014), (Mondragon et al., 2015a), (Mondragon et al, 2012b), (Ślaczka et al., 2017),(Tang and Dai, 2008),(McGinley, 2014) ,(Layaa and Dullaert, 2014),(Laganá et al., 2006), (Kim and Moon, 2003) they have introduced the intelligent transportation system problem. To solve the problem, they have proposed two method, the first one is the simulation method and the second one is the linear programming.

5.1 Port activities

According to the research discussed in this paper, the port activities can be treated under different activities which are presented in Figure 2: container terminals, Ship loading and unloading, intelligent transportation system, smart container and customs.

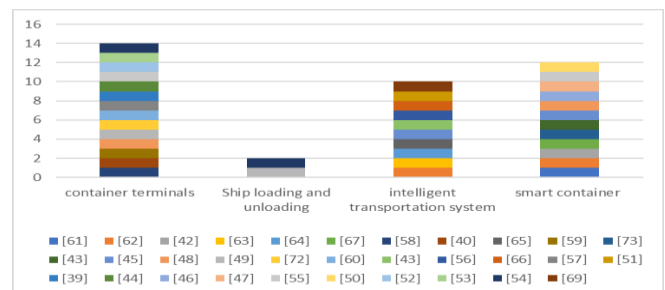


Figure 2: Port activities (see annex for key description)

From of the figure 2 we can note a significant number of container terminals and an almost total lack of work of the Customs.

5.2 The methods

Referring of the Figure 3, we notice that most of the researchers have used the simulation method, while others choose to use different ones noting: the metaheuristic method, the linear programming, etc.

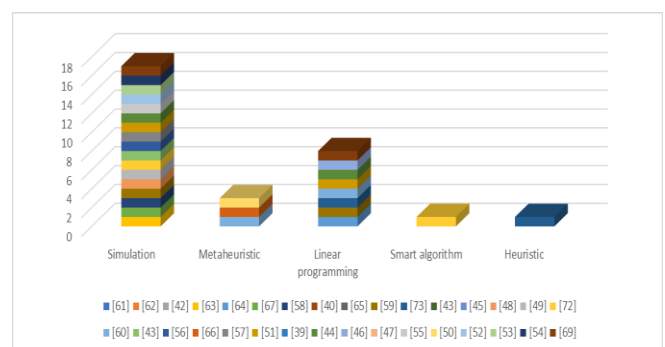


Figure 3: Used methods (see annex for the key description)

5.3 Technologies

According of the Figure 4, we conclude that the WAN (wireless sensor network) is the most recent and used technology, meanwhile, despite being an innovative technology, the vehicular environment is not the most used.

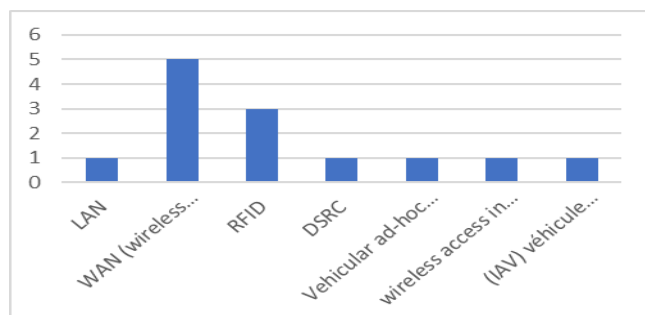


Figure 4: Used technologies

5.4 Softwares

From of the Figure 5, we note that the CPLEX and ARENA Softwares are the most used ones even though they are regarded as old Softwares

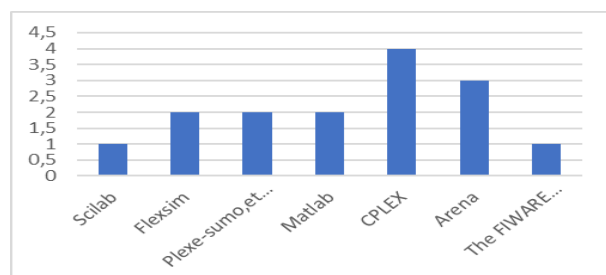


Figure 5: Used Softwares

6 CONCLUSION

In this work, we have presented a reference paper for the recent literature review treating the smart port activities. To further develop Tunisian port research a solid academic field, new conceptualization and modeling are in high demand. Within the methodology followed, an intelligent port relies on the interconnection of port activities actors, the automation of the equipment and the operations of the port terminal to improve the fluidity, the reliability, the security of information exchange and to take real-time decisions. These practices also increase the productivity of the smart port and improve its energetic efficiency. Based on our effort, we point out that: the activities, methods, new technologies and the most representative Software. We have noticed that most of the authors have used the container terminal as a port activity.

For the future, we can envisage two stimulating research directions. The first consists in proposing resolution methods for the problem with instances and parameters of much larger size and in proposing a new concept of

smart port with the use of the concept of artificial intelligence, bigdata, Data Mining and Blockchain technology. in a Tunisian container terminal in Radès.

A second avenue of interesting research would be to minimize the planned transfer times between storage locations and container berths by using AGV vehicle with new technology.

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ANNEX

Key description for **Figure 2 and Figure 3:**

[39] (Jakovlev et al, 2018), [41] (Zhao, 2014), [42] (Zhang et al, 2009), [43] (McGinley, 2014), [44] (Tian et al, 2009), [45] (Tan and Dai, 2008), [46] (Najib, 2014), [47] (Benghalia, 2015), [48] (Moccia et al, 2006), [49] (Arango et al, 2011), [50] (Wang et al, 2006), [51] (Khatiashvili et al, 2006), [52] (Laganá et al, 2006), [53] (Cortés et al, 2007), [54] (Kofjac et al, 2013), [55] (Almaz et Altiok, 2012), [56] (Al-Dhaheri et al, 2016), [57] (Zehendner et al, 2015), [58] (Zeinebou and Benabdelhafid, 2013), [59] (Zavodovski et al, 2018), [60] (Jakovlev et al, 2018), [61] (Aramrattana et al, 2019), [62] (Alrawi, 2017), [63] (Mondragon et al, 2015a), [64] (Mondragon et al, 2012b), [65] (Ślącza et al, 2017), [66] (Layaa and Dullaert, 2014), [67] (Barceló et al, 2005), [69] (Neal et al, 2019), [72] (Anwar, 2019).