UiT THE ARCTIC UNIVERSITY OF NORWAY

Department of Industrial Engineering

Onshore and Offshore Coordination of Logistics Services at Seaports

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Abstract

As global trade increases, sizes of vessels and cargo throughputs have also experienced a sudden rise thereby putting excess pressure on ship berths and ports. This is shifting most ports to much smarter technological solutions with the aim of optimizing operations, increasing efficiency and reducing logistics cost without the need for huge infrastructural and equipment investments. Developing the right strategy, lack of data security and inadequate cost-study analysis of the required smart port technology to be adopted remains the major challenge for Small and Medium sized Ports in adopting smart technologies in their operations. Almost all prior smart port researches focuses on larger ports with no attention to small and medium sized ports despite their irreplaceable role in global trade and national development. In this report, a smart port framework focusing on technology, safety and security, sustainable development, and port operations is developed for SMPs, with an integrated implementation plan and a cost benefit analysis. This work will serve as a guide for SMPs in choosing and implementing the right smart initiatives and also lays the foundation for further research in technological innovations for SMPs.

Keywords: *Smart ports, Small and medium sized ports, technology, sustainable development, implementation model.*

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I cant end this section without mentioning my course mates and house mates. Thank you very much for the love and care .

1 INTRODUCTION

Maritime transport represents the most ancient global transportation, whose role in geography discovery, economy development and culture communication in history cannot be replaced [1]. Ports have become a vital part of maritime transport as they serve as hubs for distribution of goods along different routes and connecting nodes among sea, roads and rail. In present times, ports play a significant role in the coordination and management of the flow of information and materials as transportation is a vital part of the entire supply chain [2]. Ports therefore serves as a common business node where terminal operators, shipping agencies, shipping lines, forwarders and other port actors are linked in order to provide an efficient and effective port logistics and trade processing activities [3]. Fig.1 represents the basic cross-view of seaports indicating the various activities and sections of the port.

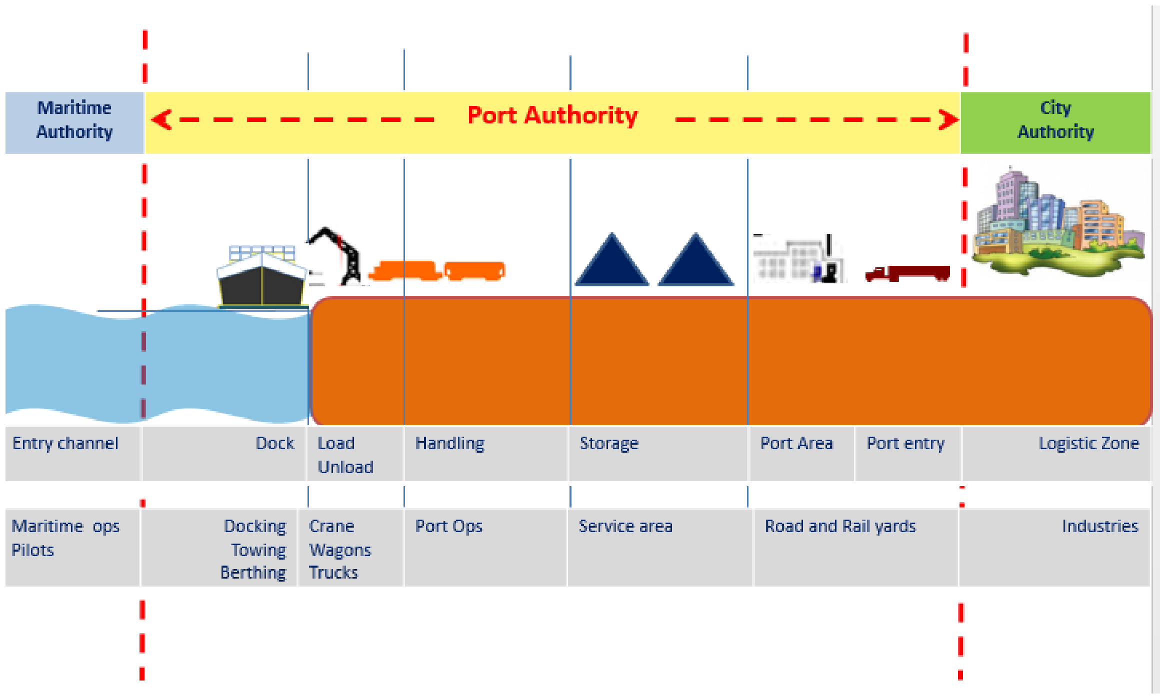

Figure 1. Cross view of a sea port

With several actors and stakeholders operating within the port environment, the complexity of operations and infrastructure utilization also increases significantly. Increasing complexity of the shipping industry has therefore necessitated the need for real-time data sharing among several players including storage providers, cargo and logistics companies, trucking companies, rail and barge operators, and sensor providers for pipelines, berths, cranes and roads [4]. Fig.2 illustrates the complexity and the link between port operations, stakeholders and infrastructure utilization within the port.

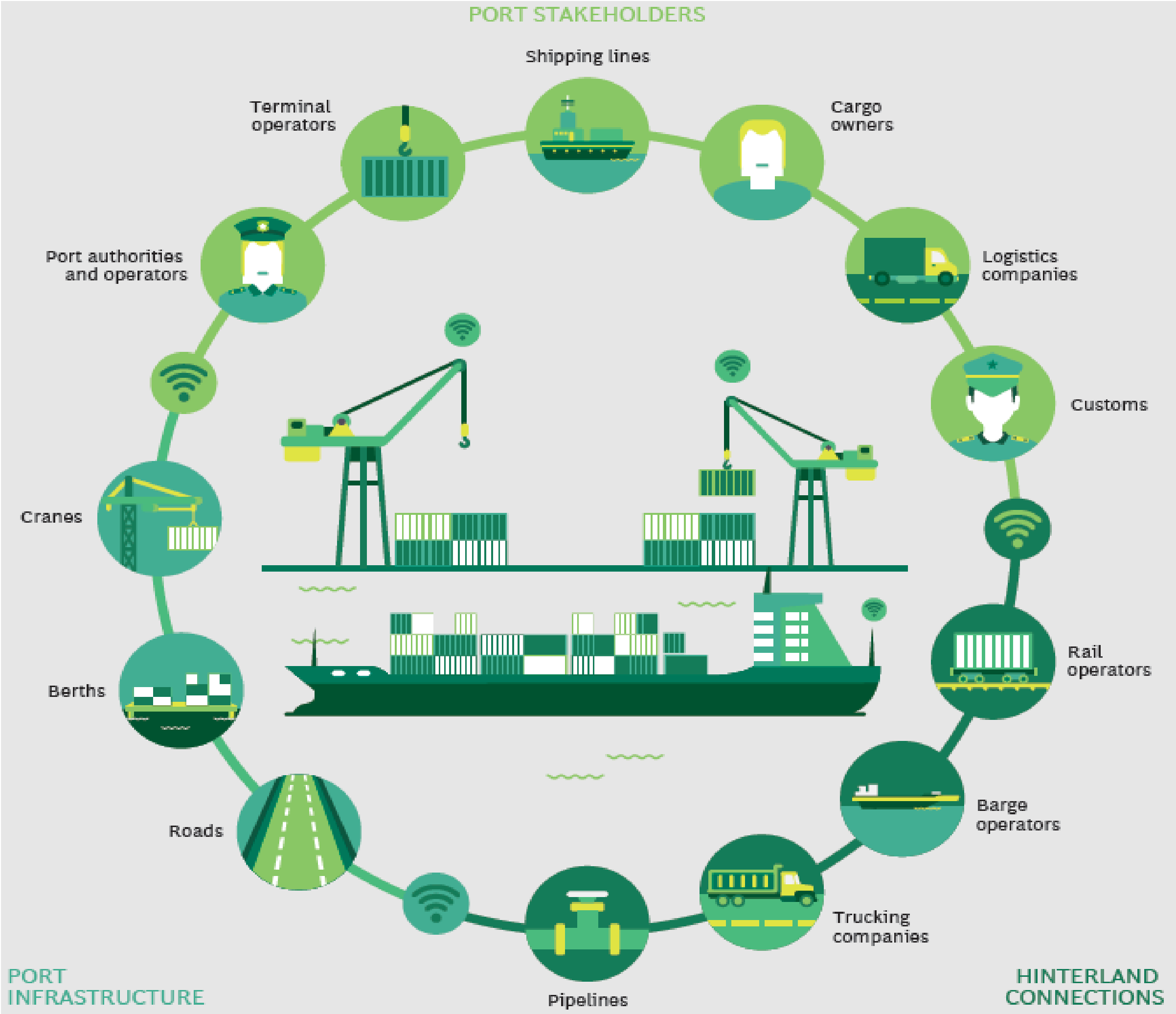

Figure 2. Link between Port Stakeholders, operations and infrastructure *[5]*

Maritime transport represents an extremely large proportion of global trade with approximately 70% of world trade by value and 90% in terms of volume going over sea and through ports [6] [7]. With increasing population, industrialization and standard of living, the demand for increased seaborne trade for both containerized and bulk raw material has also increased significantly [7]. This increase in demand is therefore putting so much pressure on ports, therefore the need for ports to find innovative ways to meet up with these rising demands. Port efficiency is therefore vital in order to stay competitive and to keep the cost low [8]. The large nature of the maritime network confronts SMPs with a large scale of planning problems at the strategic, tactical and operational levels. It has therefore become necessary for maritime logistics to take into consideration a large number of parameters that are liable to change in order to reduce cost, increase service levels and ensure safety [6]. The increasing role of technology and global economic integration is shifting seaports to an era where there is a higher integration in the flow of logistics, capital, and information. This makes the traditional port logistics business model insufficient to meet up with the current demand and growth in the maritime sector [9].

Technological innovation can give a competitive edge and allow SMPs to stay competitive. In recent years, there has been research on shipping 4.0, the fourth industrial revolution in shipping. Shipping 4.0 aims at automating and improving exchange of data within the maritime industry. It places much emphasis on digitalizing and interconnecting industries, business models and value chains which have dependencies on advancements in information technology such as Internet of Things (IoT), cyber-physical systems, cognitive computing, advanced sensor technology, Artificial Intelligence (AI) and Big data [3]. Considering the current trends in ICT advancement, ports are also taking advantage of these technologies in order to improve their operational efficiencies and therefore shifting to a more client oriented port operations and management.

New technology could be used to integrate the logistics at land, sea and railway, increasing the overall efficiency of the processes involved at the port. Mobile applications are already used today to increase the traffic efficiency at ports by enhancing the information flow and using just-in-time principles [10]. A large array of technologies including, sensors, barcodes, mobile applications, RFID, wireless sensor networks, etc. currently play a major role in the supply chain and are more useful in the integration and coordination of the various stages in the chain [11]. Helig and VoB [12] argues that, these sensing systems and actuators are static and are basically for measuring and monitoring purposes despite their huge cost of implementation. In this light, it has become necessary for these sensors to form a network of physical objects that are interconnected and interact with each other in order to create a much dynamic cluster of intelligent sensing systems which can provide real time information and control with minimum or no human involvement. This introduces the ports and their related operations to the era of “smart ports”.

Therefore, this study does not focus only on these sensor technologies, but discusses the concept of smart ports and how SMPs can gain competitive advantage by the implementation of this concept without huge infrastructural investment.

In transportation and logistics sense, smart technologies have resulted in an exponential growth in the sector in the past decades by presenting new approaches to logistics and transportation and also providing optimal supply chain management solutions [13].

1.1 Background and justification of the study

Technological advancement has proven to be a key factor in the modernization of seaports through past developments [10]. This can be traced back to the 1960s where the Maritime industry began to shift from paper-based processes to the electronic data interchange system, which allowed data and documents to be transferred to various actors electronically [10, 14]. In recent years, there has been a research on shipping 4.0, the fourth industrial revolution of shipping. Topics such as internet of things (IoT), big data, cybernetics, etc. are currently in discussion across all fields due the rapid increase in instrumentation and adequate information systems of which the maritime industry is no exception. These technological innovation can give SMPs a competitive edge and allow them to stay as preferred ports by shippers.

As global trade increases, sizes of vessels and cargo throughputs have also experienced a sudden rise thereby putting excess pressure on ship berths and ports. This is shifting most ports to a much smarter solutions with the aim of optimizing operations, increasing efficiency and reducing logistics cost without the need for huge infrastructure and equipment investments [15]. Most smart port technologies currently implemented in ports are referred to as terminal operating systems (TOS) which is basically geared towards container handling ports. Yet, majority of SMPs across Europe handles vast commodities with bulk material as the most commonly handled product on these ports. Dry and liquid bulk accounts for approximately 70% of the total material throughput of SMPs [16]. Fig. 3 represents the proportions of commodity flow at SMPs.

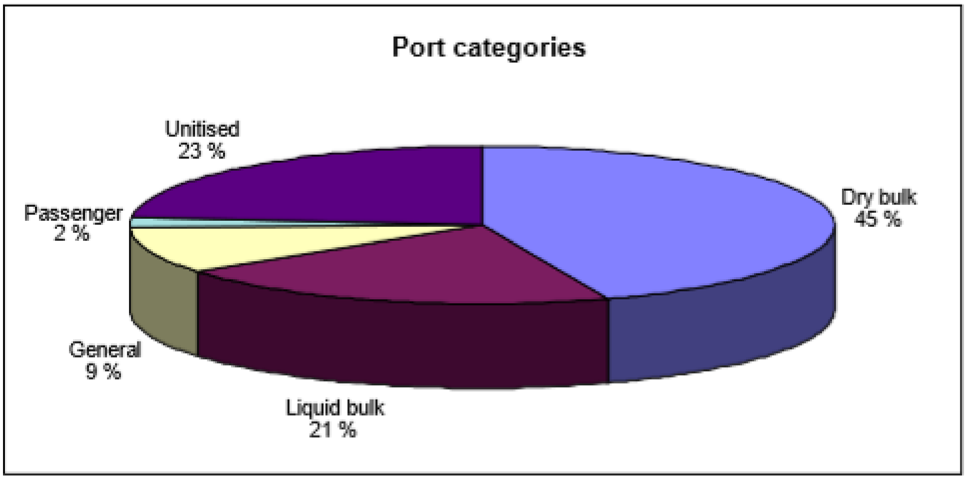

Figure 3.. SMPs categories by their main traffic flow *[16]*

According to Feng [17] most SMPs are much competitive in the bulk cargo market and they are largely driven by domestic trade cargoes.
In order to harness the full benefit of information technology to the industry, the SPHERE project [16] suggests that, SMPs review their existing IT applications and experience and also deploy telematics systems with the other intermodal links to the ports such as road and rail transport.

A large array of technologies exist which are currently being implemented on larger ports across the world with little or no attention to small and medium sized ports. As a matter of fact, no academic publication exist on how SMPs can gain competitive advantage through the implementation of smart port techniques.

1.2 Problem statement

In today's global and fast growing economies, seaborne trade have proven to be the backbone of global trade. Shippers therefore chose their ports based on the logistics cost and the efficiency of the port in handling its operations. Technology has in turn become the baseline through which ports are achieving competitiveness in this present technological age. But the case is different with SMPs, SMPs are more vulnerable than large sized ports and need to stay competitive in order to survive. Identifying which smart port technology to choose from, developing the right strategy, their implementation, aligning the smart port strategy with the overall business need, lack of data security and inadequate cost-study analysis of the required smart port technology to be adopted remains the major challenge for Small and Medium sized Ports in adopting smart technologies in their operations.

In response to these challenges, this study aims at developing a smart port framework tailored to the needs of SMPs. In addition, a smart port implementation model will be developed which will enable SMPs to strategically position themselves in adopting these technological innovations, as well as a cost benefit analysis for implementing these smart initiatives.

1.3 Objectives

As specified in the introduction and background, the aim of this research is to explore the benefits of smart port technology to SMPs and how they will contribute to their overall port efficiency. Based on recent developments in seaports and literature, a reference smart port framework will be defined which will serve as a building block for SMPs in their pursuit for technological innovation.

1.3.1 Specific Objectives

The study is set to achieve the following objectives:

- Make an analysis of port instrumentation and information infrastructure and develop a smart port frame work for SMPs.
- Conduct an analysis on implementing smart technologies and develop a smart port implementation model for SMPs.

1.4 Scope of the study

The main task underlining this study includes:

1. Conduct a literature study on state-of-the-art technologies applying at harbors, generally. And further, that at SMPs, especially.
2. Conduct a literature study on smart port based technologies applying at harbors, generally.
3. Conduct a study on the readiness/maturity level of the smart port technology for SMPs.
4. Conduct cost-benefit analysis on Smart port technology adoption.

As indicated in the introduction, the initial task was focused on the assimilation of sensor-based technologies for SMPs, but this focus change to the concept of connecting these static sensors to form a dynamic network referred to as the smart port initiative. Therefore this study analysis the smart port concept and specifically focuses on SMPs.

1.5 Thesis Structure and layout

This study is structured as follows. In the first chapter, an introduction is made to the research topic and motivated. The second chapter introduces the reader to some common port practices and operations, covers the digital transformation in the maritime industry and discussed some technologies that are currently driving the maritime industry and ports. In chapter three, a smart port frame work for SMPs is developed together with a technology maturity scale. Chapter four discusses a smart port implementation plan. In chapter five, some financial benefits of smart technologies are discussed briefly. Chapter six is the final chapter of this work, and presents the conclusions. In this chapter, a reflection is given on the work done and possibilities for future work is proposed.

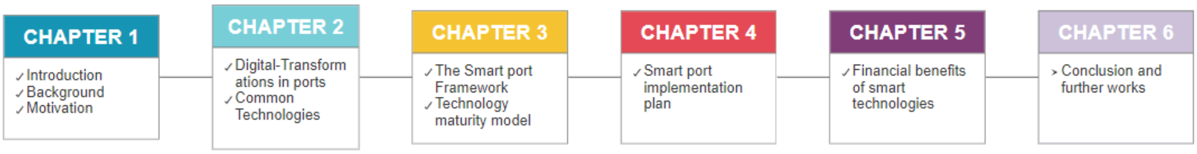

Figure 4. Thesis Layout

Fig. 4 shows a graphical representation of the layout of this study.

2 LITERATURE REVIEW

Although technology is shaping operations and redefining the business strategy of ports, certain traditional practices cannot be undermined. Topics such as port-centric logistics and inter-modality are currently being discussed in literature and these are also ways through which SMPs can gain competitiveness and also generate some revenue. This section therefore throws light on these practices as well as the transformation of seaports in the digital era.

2.1 Maritime logistics systems for SMPs

Maritime logistics can be defined as the process of planning, implementing and managing the flow of goods and information involved in the entire ocean transport system [7, 18]. Since maritime logistics is a concept that was generated from the study of ocean going transportation in the framework of logistics, Radhika [2] identifies three key sections of maritime transportation that makes up the maritime logistics system. This includes port terminal operations, shipping and freight forwarding. Maritime logistics creates a certain amount of value which is known as maritime logistics value. The higher the maritime logistics value, the higher the customer satisfaction which leads to a higher performance of the individual actors and the logistics system as a whole. Logistics systems for SMPs are based on their functionality and this enables the effectiveness of their economic systems. By implementing the general concepts of logistics, it becomes much difficult for small and medium scale ports to maintain a competitive advantage edge in the long term standpoint. Therefore, it becomes important for SMPs to identify new concepts and trends in the logistics frame work in order to maintain a competitive advantage taking into account the distinctiveness of their logistics system [19].

Two logistics systems are currently practiced which includes:

- Regionalization and
- Terminalization (port-centric logistics)

2.1.1 Regionalization

Regionalization is defined as the process where a port evolves into an intermediate transportation hub for the immediate region. This defines how to develop the hinterland and the functionality of the port in order to establish a greater need for the commodities delivered by the port [20]. Under the concept of regionalization, the ports serves as a logistics and distribution centre from which the goods are not distributed directly to the end user, but instead to a small scale distribution centre from where the distribution to the local consumer is much easier [21]. This concept focuses on the port-city development by creating financial incentives and social infrastructure by creating jobs and value-added services in the port city and nearby hinterlands focusing on attracting more cargoes and shipping lines [8].

Successful implementation of regionalization results in the port becoming the primary logistics hub covering a larger geographical area. This makes the entire region more connected to the global trade channels and much competitive [20]. Since smaller ports will never have the same natural attraction of cargo as compared to larger ports, Olesen et al [20] suggests that, SMPs scale down on this concept and instead concentrate on a single product type and device their strategy such that they became a major player in a specific segment within that geographical area.

2.1.2 Port-centric logistics

Port-centric logistics can be defined as the provision of distribution and other value-adding logistics activities at a port [22]. Regarding integrating and developing the port and its immediate hinterland, much emphasis have in recent times been placed on the range of value-added activities that goes through the ports [20]. The primary aim of developing a port-centric logistics system is to identify unused opportunities and disproportions of economic growth and its usage as the basis of developing strategies for the activities of port-centric logistics systems and their interactive modes of transport and types [19].

As shown in fig. 5, the port lies between transport and delivery, and have the opportunity to add value to the supply chain with a series of different activities.

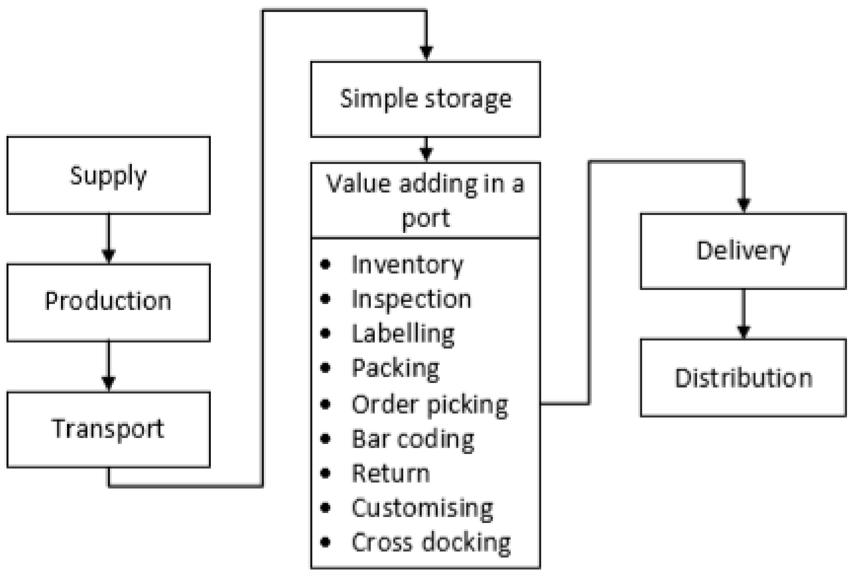

Figure 5. The role of ports in port-centricity *[22]*

In this regard, the ports are not acting solely as points of handling and re-loading goods to their transport routes, but also as logistical and distribution centres that serves as intermodal hubs in the supply chain [21].

Generally, value-adding activities are activities that improves the customer wants which in line with lean principles, is the most desired by customers [20]. From a port's perspective, this doesn't only allow the port to increase their cargo throughput, but also enables them to earn additional revenue by offering extra services to their customers [22].

According to Mangan and Lalwani [23], some ports in UK are actively motivating companies to establish distribution centres at the ports instead of their traditional inland locations. They argue that, since these products pass through the ports before finally arriving at their distribution centres, in-port distribution centres will save them cost in terms of land cost and transportation cost from the port to their in-land DCs.

One advantage of in-port distribution centres is that, it reduces the number of empty containers on the road by emptying them at the port thereby allowing them for faster repositioning to other ports where they are required [23]. By introducing new value-adding activities in the ports, a more competitive situation is created within the port system as there is focus on what the different supply chains benefit from [20]. Many small and medium-sized ports are pursuing port-centric logistics as a way of competing with larger ports.

2.2 Multimodal subsystems in SMPs

Ports have for many years serve as natural sites for trans-shipment by serving as a node for transferring goods from one mode of transport to another. Historically, they have provided the link between maritime transport and inland transport. They have in other words constituted an inter-modal interface between sea and road, and sea and rail transport [7]. Intermodal transportations is another measure of accessing the logistics function of SMPs [17]. The integration of a ports supply chain is characterized by the concept of inter-modalism and organizational integration. Inter-modalism involves the shipment of goods using multiple modes of transport with the aim of reducing cargo handling time, faster transportation and reduction in damages and loses.

A report by the European mobility network [24] identified major bottlenecks that hinder the smooth connectivity of ports and in-land transportation as;

- Rail connection to main network,
- Road infrastructure in port area and port area access,
- Road traffic management,
- Rail operations and related processes.

An integrated port is therefore identified by its ability to facilitate the flow of information, cost reduction and elimination of waste through just-in-time principles and other value adding activities [7, 25].

Sujeta et al [19] differentiate among several terminologies used to describe the interconnectivity of other modes of transportation to the port. These includes; multimodal, intermodal, co-modal, and more recently, Synchro-modal transportation.

2.2.1 Multimodal transportation

Multimodal freight transfer refers to the movement of goods by a sequence of at least two distinct modes of transportation. The regular express delivery system on a regional or national scale, and long-distance pickup and delivery services can be classified as multimodal transportation [19, 25].

2.2.2 Intermodal transportation

Intermodal freight transportation is a particular type of multimodal transportation where goods are transported from one point to another in one and the same intermodal transportation unit without direct handling of the goods themselves when shifting modes. Intermodal terminals around the world give companies the flexibility and the economies of scale of using multiple modes [19].

2.2.3 Co-modal transportation

Co-modality focuses on the efficient use of different modes on their own and in combination. The Commission of the European Communities defines co-modality as the use of two or more modes of transportation, but it can be distinguished from multimodality by two differences:

- it is used by a group or consortium of shippers in the chain, and
- transportation modes are used in a smarter way to maximize the benefits of all modes, in terms of overall sustainability.

2.2.4 Synchro-modal transportation

Synchro-modal transportation is a structured, efficient and synchronized combination of multiple modes of transport. It offers customers or carriers the flexibility to select independently the most preferred mode of transportation based on the needs of the customer [19].

Due to the significant role of ports in the management and coordination of materials and information flow, transportation also serves as an integral part of the entire supply chain. Subsequently, the competitiveness of a port is not only determined by its cargo handling capabilities and hinterland connections, but it is also influenced by its links in the supply chain. Therefore, the competitive position of a port is largely dependent on its ability to externally coordinate and control the entire supply chain [24, 7].

2.3 Digital transformation in ports and port operations

Digital innovation has proven to contribute to the modernization of seaports through past developments. A transformation of both intra- and inter-organizational activities is often required to aid in the achievement of benefits in order to achieve a competitive advantage by the assimilation and use of digital technologies [10]. In the past two decades, the Venkatraman model [26] has received enormous attention in the academic setting. The model differentiates between different levels of digital transformations that extends beyond the perspective of traditional process re-engineering [14].

In general, the model differentiates between five levels of digital transformation. As depicted in Fig. 6, they are arranged based on their overall influence on the organization ranging from minor business activity transformations to a redefinition of business models and scope [14, 10].

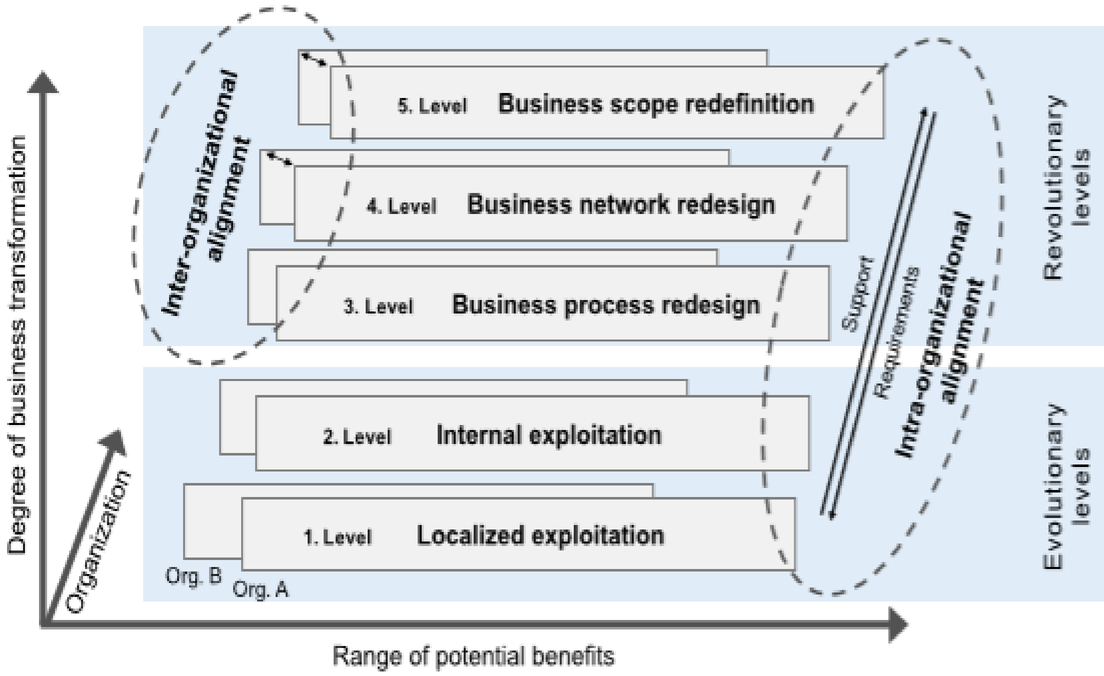

Figure 6. The Venkatraman model of digital transformation *[10]*

The first two lower levels are classified as evolutionary because, they require very little adaptation and they have a considerably low impact on the overall organization and network relative to the remaining higher revolutionary levels. With the first three levels primarily focusing on an intra-organizational perspective, the two highest levels incorporate an inter-organizational perspective [10]. Table 1 summarizes the various levels of digitalization and their implications to an organization.

Table 1. Levels of digital transformation and implications *[10]*

Level	Description and Implications
	•
1. Localized Exploitation	• Deployment of standard IT functionality for supporting individual business activities. • Implies little changes of business activities; low impact on related business processes. • Full potential of deployed IT is not exploited; no long-term competitive advantages. • Examples besides basic IT functionality (e.g. booking, accounting) are production planning and data warehouse management solutions.
2. Internal Integration	• Technical and organizational integration. • Trans-functional process integration builds the basis for business-IT alignment [6]. • Examples are enterprise resource planning (ERP) systems and data warehouses (DW).
3.Business Process Redesign	• A redesign of organizational structures and business processes is necessary to fully exploit new IT/IS capabilities. • The adoption of a DW, for example, may not only change decision making, but also allow to identify new potentials for improvement. • On the other hand, a redesign of business processes may lead to new DW requirements.
4. Business Network Redesign	• Focus on the redesign of business networks from an inter-organizational perspective. • Technical enablers can be common data exchange standards and platforms. • Involves strategic considerations on potential collaborations to benefit from, e.g., shared knowledge and collaborative planning.
5. Business Scope Redefinition	• Includes the modification, elimination, outsourcing, and expansion of former business models and processes given new IT/IS capabilities and transformed processes. • May involve the creation of new strategies, products/services, and partnerships.

In recent years, a broad array of information systems and technologies have been employed in port operations. This has enabled most ports to achieve a competitive edge by ensuring that, most transactions are carried out electronically [14]. An analysis of the digital transformation process at seaports and in the maritime industry is therefore relevant in understanding its impact on ports and to explore the opportunities and barriers it represents.

2.3.1 First generation (1980s): transformation to paperless procedures

In the early 1960s, containerization and intermodal transportation greatly shifted already existing systems of transportation to an integrated transportation system. Container shipping began to experience an extreme growth between 1970 and 1980 which resulted in a drastic reduction in transportation cost and an increasing container volumes [10]. Majority of ports began to shift from their traditional role of conservative loading and discharging hubs for sea and inland transportation to a more intermodal logistics hub that combine transportation systems and offered several range of logistics, distribution, and value added services. Due to the role of ports serving as an intermodal logistics hub, it was not sufficient to focus only on cargo and material flow, but also to ensure efficient flow of information [14].

In the 1960s and the 1970s, the electronic data interchange (EDI) system was developed which made way for the first digital transformation in the maritime industry. However, ports couldn't fully utilize this opportunity due to long standardization process. In 1983, the first EDI based port community System (PCS) was developed. This enabled electronic document transfer between the various stakeholders in port operations, and other important port documents such as the bill of lading were also converted into electronic forms. The first commercial terminal operating systems (TOS) were developed in the late 1980s and served as the basis for data driven planning and automation in ports [10, 14].

2.3.2 Second generation (1990s – 2000s): transformation to automated procedures

Within the 1990s and 2000s, established and new information systems served as the vital basis to largely influence the automation of container handling processes in container terminals. In the early 1990s, laser technologies were used in terminal operations for functions such as profiling, locating, distance detection, damage detection and collision prevention. With these functions, laser technologies were considered as the key technology for enhancing automated and safer handling solutions in automated terminals [10]. Automatic identification and positioning technologies evolved in the 1990s to contribute to the overall efficiency and safety of operations at the ports.

Information systems such as vessel traffic services (VTS) also gained significant benefits from the application of the automatic identification system (AIS) in the late 1990s which made it possible to track vessels as a means of collision avoidance. The first strategic global liner shipping alliance was then formed in mid 1990s to ensure full utilization of the capacity of largely increasing vessels while maintaining service quality [14].

2.3.3 Third generation (2010): Smart Ports

Whiles the first two digital transformation generations were concentrated on building the basis for improved information flows in ports and terminal communities facilitating and improving trading, port automation, and the interface between different actors, the third generation focuses on measuring, controlling and assisting port operations by adopting innovative technologies to better identify new forms and sources of data [14]. The adoption of digital technologies and information infrastructure serves as an indication that ports are extensively moving beyond their traditional scope by operating as port information integrator and provider, which redefines the scope of ports and places them on level 5 of the Venkatraman model [10].

Terms such as internet of things, analytics, big data, cloud computing and mobile computing are currently under discussion by major maritime actors and stakeholders [10]. Several sensors and actuators are attached to the port infrastructure to enhance a better compliance and an eco-friendly utilization of infrastructure. These sensors measures the environmental impact and the states of the infrastructure, process the data in an isolated system and in turn transfer it to a central information system where it is explored, aggregated and propagated over different channels to the various actors and decision makers in the port. In a logistics sense, the analyzing of data could help with the problem of operational disturbances [10, 27]. The maritime industry generates approximately 100 to 120 million sets of data every day from onboard vessel instrumentations and port information infrastructure. These data can be analyzed to help in identifying efficiencies in the port operations and the overall efficiency of the maritime industry [28].

Fig. 7 represents an overview of the three generations of digitalization and summarizes their main events and activities from the 1960s to date.

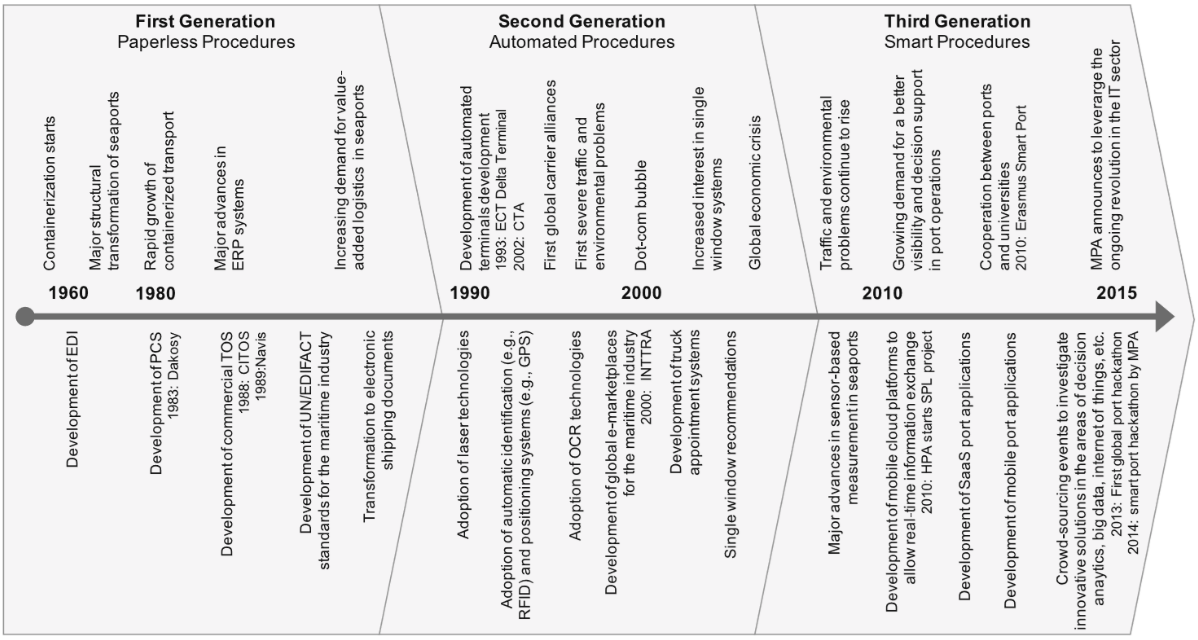

Figure 7. An overview of digital transformation in the shipping industry *[14]*

2.4 Port instrumentation and information infrastructure

With the role of ports as an essential gateway in global supply chains, it is required that ports integrate a variety of networks and include stakeholders to enhance cargo flow, property rights and payments [23]. In this contest, a port can be identified as a part of a group of entities where the performance of the network and the undertaking of value added activities is a collective effort which requires alignment of business procedures and partners [7]. Since the era of containerization, digitalization and integration has been facilitated through the adoption of innovative information technology (IT) and information systems (IS) which has enabled a high degree of automation in port procedures [10].

The SPHERE project 1999 [16] specifies that, the functions that a port's information system has to be able to offer must include:

- speeding up of operations to allow faster loading and unloading of goods
- paralleling of physical and administrative operations to achieve drastic cuts in transit time and, at the same time, provide a service both to users, who can thus speed up their logistics cycle, and to ports, which can thus make optimal use of their infrastructure
- supplying an information support to users; port operators cannot always afford systems or skilled personnel, so the infrastructural information system has to allow them to

access and use general programs and applications, as well as provide a gateway towards external networks

- establishing an interconnection with external data bases (timetables, regulations, bookings)
- handling the information flow, permitting the interconnection of the various users and the common use of specialized resources, while keeping data safe and confidential
- optimizing the cash flow along a faster, simpler invoicing cycle
- managing infrastructure to optimize the use of critical resources such as quays, wharves, yards and specialized machinery.

ICT applications in ports can be subdivided into two parts namely communication systems and information technology infrastructure [29]. The communication systems component includes systems that facilitates the transfer of information and reduces the handling of sensitive data among the various stakeholders at the port. Communication systems seek to integrate several stand-alone systems thereby facilitating information transfer. According to Irwin [30], non-integrated systems and processes poses a lot of disadvantages and threats which includes:

- Error resulting from entering repeated data into different systems
- Inaccurate collation of data on Key performance Indicators (KPIs)
- Inefficient scheduling and planning by customers due to lack of real time and relevant data.
- Different systems by different parties in the supply chain may provide different responses to the same question.

Different ICT systems with the capabilities of communicating with each other and providing precise and real-time information can be integrated to address this problem.

Common communication systems further discussed includes the utilization of the Electronic data interchange (EDI) system in port community systems (PCS) where data can be shared among various port actors in real time thereby facilitating administrative procedures, the port single window regulatory system and the recent introduction of blockchain technology in shipping. The information technology infrastructure sub-component encompasses technologies that enhances port operations and infrastructure. These includes sensor technologies, RFID technology, Internet of Things (IoT), cyber-security systems, big data analytics, etc.

2.4.1 Port Community System (PCS)

To enable efficient handling of inter-organizational information flows, PCS was developed in the mid -1980s by utilizing the standardization of EDI document formats following the first era of port digitalization in the early 1960s [12]. PCS aims at improving logistics and administrative processes by establishing a common information platform for the exchange of relevant operational documents between stakeholders relating to, declaration of imports and exports, customs handling, transport orders, processing of dangerous goods, status information and control, and tracking and tracing through the entire logistics chain [28, 12]. The extent to which a PCS is valued is based on its network effect (the number of individual actors in the network), the quality of shared information, and the benefits derived from the network to the various actors [12]**.** Its main purpose is not to create a new information system but the effective linkage and integration of existing management systems and databases with the capability to convert data of different formats [30]. Fig. 8 illustrates the difference in communication pattern between a traditional port communication process as compared to a PCS. The limitation with PCS is inappropriate data security. This limitation hinders port actors from accepting the adaptation of the PCS leading to the introduction of the port single window which provided a regulatory framework for PCS.

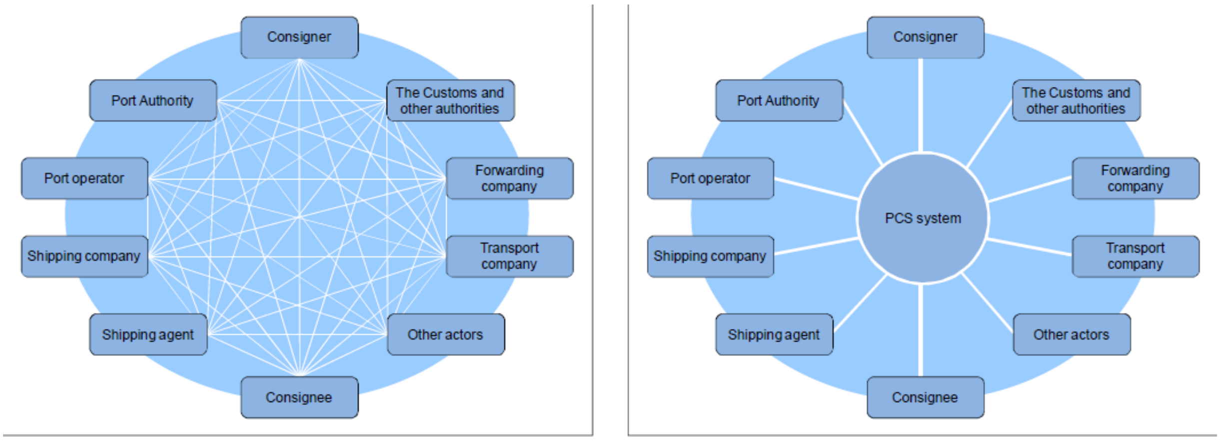

Figure 8. Difference in traditional pattern of Communication and with PCS *[31]*

2.4.2 Port Single Window (PSW)

The primary objective of PSW is to harmonize, streamline, and coordinate reporting procedures, and processes required to fulfil regulatory requirements through electronic means. PCS serves as the foundation on which port single window (PSW) systems can be built. The next step is to merge the PCS with various information systems outside the port environment to create a nationwide and transnational digital commerce and logistics platform to facilitate access to specific information for government authorities and other regulatory bodies [12]. The single window is not really considered as a new IT system but an interface that connects government and ports together [32].

2.4.3 Blockchain

Beyond the efficient moving of cargo within the port, customs collection and processing is one area that data sharing could be used to enhance. Blockchain offers a decentralized registry that enables the multiple storage of data in various locations. Similarly to PCS, this technology eliminates paper-based procedures such as the bill of lading and customs clearance documents. With multiple network nodes (several participating partners) involved in the validation process, there is a greater reduction in the potential of fraud [33].

2.4.4 Blockchain offers secure linkage of isolated systems operated by shippers, port operators and other stakeholders to ensure the efficient record keeping and tracking of goods [34].Global navigation satellite systems

Global Navigation Satellite Systems (GNSS), effectively referred to as Global Positioning Systems (GPS) found their way in ports since the middle of the 1960s [14]. GPS aids in effective position detection and tracking of objects within the port environment. GPS serves as the primary navigational aid for vessels outside the port area [27]. Real time positioning data and status of objects within the port becomes more vital in improving the visibility and to enhance the efficient planning and coordination of activities involving several actors. Beside its position detection capabilities, the retrieved data is also very important for forecasting and for achieving the contextual data of individual objects by combining position data with other relevant data points of interest. Also, GPS can also be used in totally different areas, such as for measuring tides in port areas more accurately [10, 27].

2.4.5 Radio-frequency identification

Radio-frequency identification (RFID) is a contactless automatic identification (Auto-ID) and data sensing technology that makes identification of tagged objects and sharing of information propagated by radio waves without requiring a line of sight [35]. An RFID system consists of a transponder, the RFID tag, and an interrogator (RFID reader). An antenna and an attached microchip which contains an Electronic Product Code (EPC) which allows for the unique identification of each product are embedded in the RFID tag. Advanced RFID transponders have the capability to measure physical variables such as temperature, humidity and motion [27].

Within the interrogation zone formed by the RFID reader, a two way communication between the tag and the reader is automatically established for the transfer of data. The data is then transferred to other systems by the RFID readers for further processing. Due to this, a middleware is employed to filter, convert, correct, and transfer the data to a respective information system. This middleware can be directly installed on the reader or on a separate server [35]. To enhance the integration, the readers have communication interfaces such as Ethernet, WiFi, and USB. RFID tags are considered to be active or passive, based on their source of power supply. Active RFID tags contain a power supply (e.g., on-board battery); passive tags gain electric power from an external RFID reader. Due to the in-built power supply, active tags have the ability to communicate at higher operating frequencies which enables them to travel over longer distances. However, passive tags relatively cheaper in terms of cost [27].

The deployment of RFID technology within a port environment enables the tracking and identification of objects, and improves equipment utilization as well as operational productivity whiles still providing a high level of security of assets and safety of personnel [36]. The efficient use of RFID technologies in sea ports improves cargo security and regulatory compliance, container identification, access control, and identification and tracking of goods [9]. Human associated errors can be reduced up to 70% whiles transaction time can also be reduced by up to 50%. RFID real-time data enables dynamic optimization which enables solving the problem of complexity in cargo handling which leads to higher efficiencies, better planning and improves the overall performance of the port [36].

By utilizing radio waves, RFID technologies are able to provide real-time interaction with several objects at varying distances without the need for direct contact.

These advanced identification and tracing features of RFID can improve the traceability and identification of items within the port environment thereby increasing their efficiency, accuracy and the speed of processes within the port [35]. Application of RFID technology has enormous benefits and thus can be summarized into the RFID benefit tree in fig 9.

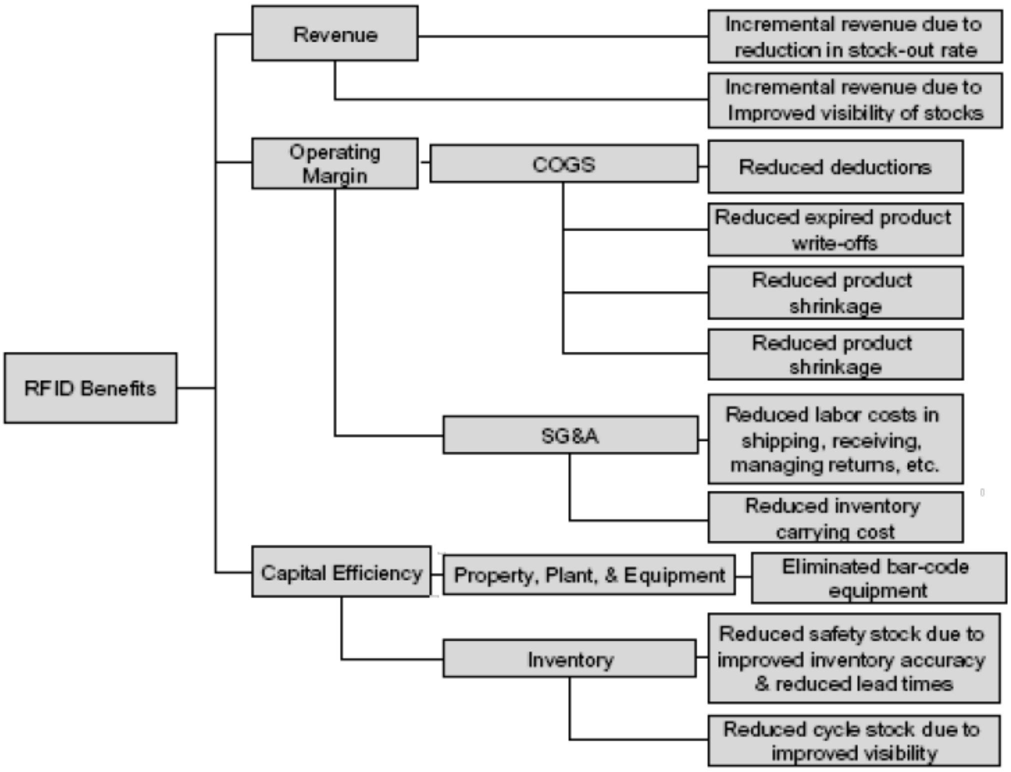

Figure 9. RFID benefit tree *[35]*

2.4.6 Wireless sensor networks

A wireless sensor network (WSN) describes a large-scale system consisting of interconnected wireless sensors deployed within a specified area of interest in order to cooperatively monitor large physical or environmental conditions, such as temperature, humidity, and position. Sensors communicate with each other and with a base station connected to a remote system propagating sensor data for storage, processing, mining, and analysis [27].

2.4.7 Real-time location systems

Real-time location systems (RTLS) enable the identification and constant location tracking of tagged objects located in both indoor and outdoor environments. To enable the detection of object positions, RTLS utilizes RFID technology to establish a communication link between a locally installed base station and the objects of interest. To determine the object position. RTLS readers receive data from the tag and uses the time-of-arrival to determines the respective tag location by forward the data to an RTLS server which. Consequently, RTLS technologies do not depend on satellite systems and can therefore be utilized in confined areas including warehouses and road tunnels. Several techniques are proposed to improve RTLS location estimation [10, 27].

2.4.8 Mobile devices

These days mobile devices such as tablets and smartphones are equipped with powerful computing, communication, and sensing capabilities including GPS, RFID, and mobile data services to receive and transmit data over mobile networks. Different standards are used for communication including GSM (Global System for Mobile Communications), UMTS (Universal Mobile Telecommunications System), and LTE (Long-Term Evolution). The evolution and availability of mobile devices provides many opportunities in the logistics sectors and specifically in the port industry. Yet, the adoption of mobile devices in port communities is still in its infancy, which also applies to research in this area. Other meaningful adoptions may involve the mobile device owner by providing mobile applications that enable not only the exchange of information, but also features to interact with and/or assist the owner, for instance, a truck driver when approaching a port by considering information on the individual position, traffic congestion, parking spaces, etc. Vice versa, individual data from involved actors can be utilized to enhance port operations [27].

3 SMART PORT CONCEPT

Linking the smart port concept to the vision of 5th generation ports (5GP), Lee et al. [29] suggest that five fundaments components must be attained in order to achieve the smart port goal. These includes, Services, technology, sustainable development, cluster and hub ports. The service feature focused on customer satisfaction by performing beyond basic standards by the implementation of advanced technologies. Sustainability describes how ports can efficiently reduce the impact of emissions and pollution on the environment whiles port cluster and hubbing focused on developing the hinterland. Also, In developing a holistic smart port concept for container ports within the Mediterranean, the Mediterranean maritime project [37] defined twenty-three (23) criteria and sixty-eight (68) key performance indicators (KPIs) that aided in assessing ports against the smart port initiative focusing on operations, energy and environment. Some major criteria used in assessing ports towards smart port is depicted in fig 10.

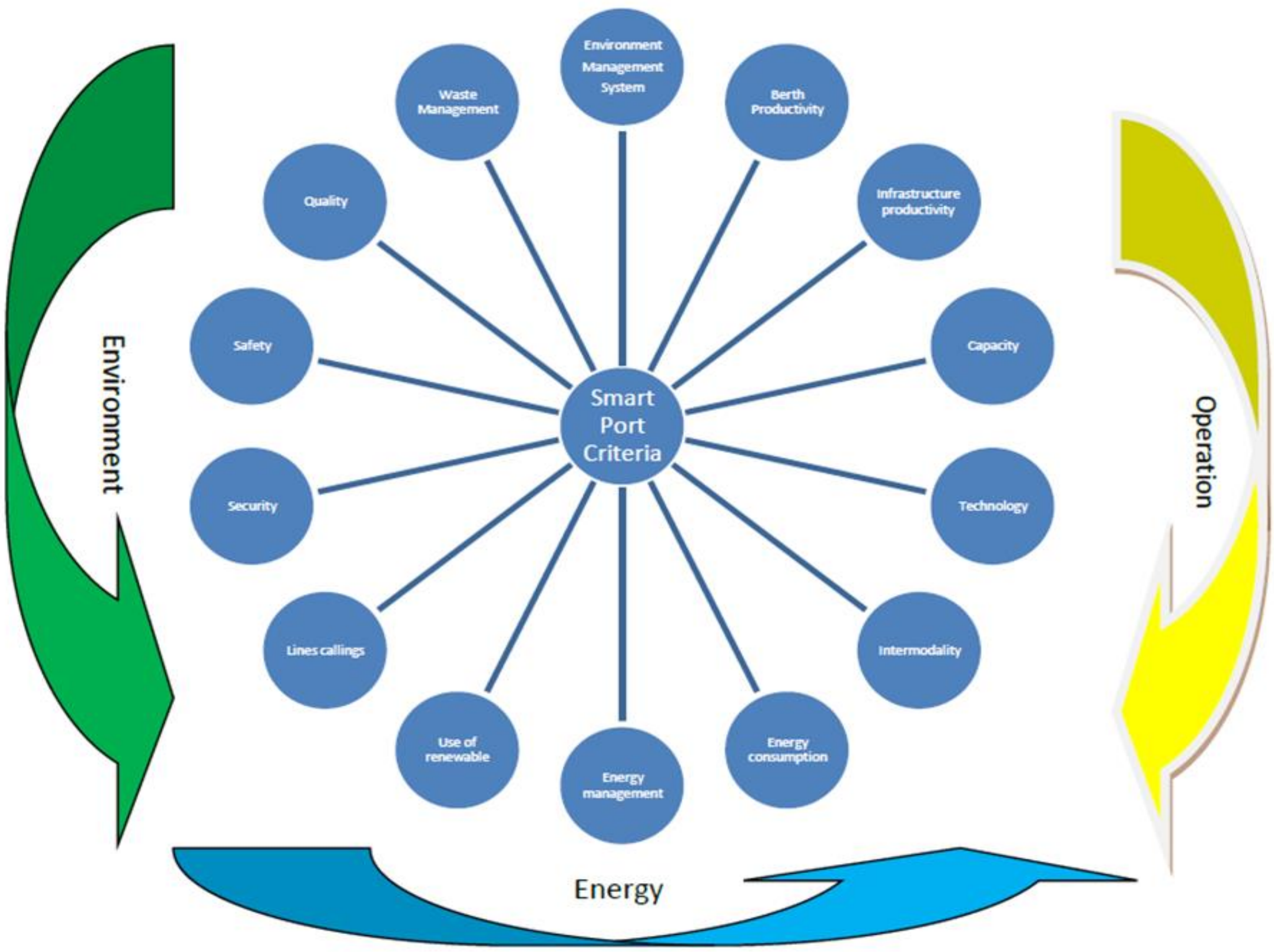

Figure 10. Some KPIs used to asses ports against the smart port concept *[38]*

The implementation of advanced sensor technologies in ports generates data which when not protected, exposes the ports to cyber threats and other failures due to lack of adequate security measures. However, the Lee et al [39] didn't illustrate how various structures and systems must react together to achieve the smart port objective. Moreover, the study underemphasized on the cyber-security factor which in my opinion, a smart port which doesn't have adequate data security measures to protect industry related information is not considered smart enough. Also, assessing SMPs by certain criteria as presented by the Mediterranean project [37] only gives an indication of the extent to which the port has gone in becoming smart and also in judging their performance but does not give a holistic approach to how these ports can fully take advantage of these emerging technologies to enhance their operations in order to achieve smartness.

Due to these gaps in literature, this study develops a smart port framework which serves as a building block for SMPs and also discusses how the efficient integration of these blocks will improve the competitive advantage position of SMPs.

3.1 The smart port framework for SMPs

In becoming smart, SMPs seek to develop solutions to address challenges of the present and future which includes, space restrictions, productivity, safety and security, and sustainability whiles reducing cost and improving efficiency. The proposed smart port framework therefore utilizes four (4) building blocks in order to attain these objectives. The four main components of the smart port framework is illustrated in fig. 11 and it includes technology, port operations, sustainable development, and safety and security measures.

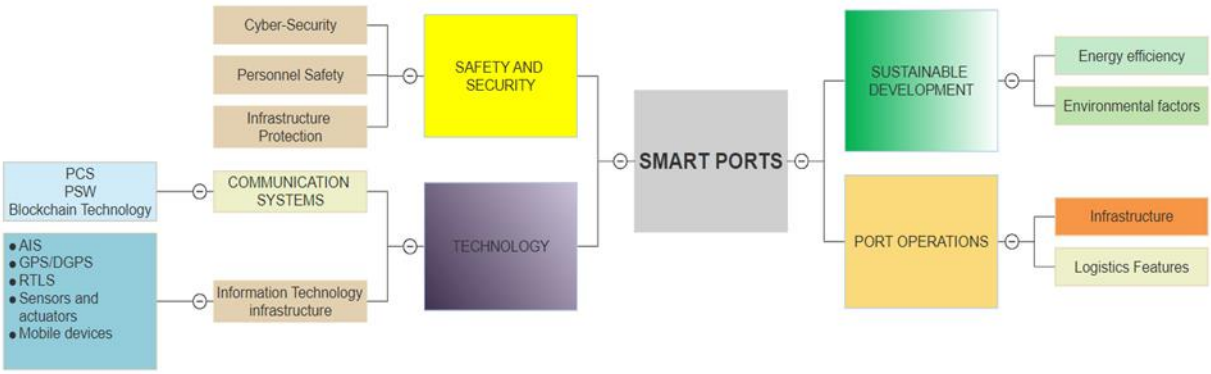

Figure 11. The Smart Port Framework for SMPs

The ultimate smart port is a fully automated and integrated port where both physical and IT infrastructure are connected through IoT platforms. The ability of the adopted smart port technology and smart practices to establish a better coordination in data and information sharing to the benefit of the port and the various stakeholders determines the degree of effectiveness of the smart port concept [36].

However, not all SMPs have the potential to fully integrate these components in order to reach the smart port goal. Some SMPs might not have adequate infrastructure or might not have the required scale in performing these investments and even may lack physical integration with their environment. It is therefore not a must for SMPs to establish a fully advanced IT system in all these areas in order to begin a digital transformation. SMPs can begin this journey by leveraging their existing IT infrastructure and in a stepwise manner, enhance their systems as required.

3.1.1 Technology

The driving force behind the smart port initiative for SMPs is technology. Technology could be used to integrate logistics at sea and land thereby ensuring the smooth flow of logistics and port related activities in a coordinated manner in order to increase their efficiency within the port. There is a wide range of technologies that SMPs can choose from. Srour et al [40] generally classifies ICT applications to trade flows into two basic viewpoints namely exploration and exploitation. Exploration in this case refers to a set of activities undertaken to uncover new opportunities and possibilities that an organization can benefit from through ICT implementation or adaptation. Exploitation on the other hand refers to how organizations can use existing technologies in other to improve their operational efficiency. At present, smart port technologies are tailored towards automation and to consolidate efficient information flows amongst parties operating in the port environment with the primary aim of increasing operational efficiencies. Therefore, smart port designs can be seen as automating existing systems (exploitation) with the aim of discovering advanced port operation techniques in the long term (exploration).

There are several technologies that can be integrated together in enhancing port infrastructure and logistics. These technologies have already being explained in chapter two (2). Their application can thus be summarized in table 2 below.

Table 2. Summary of some Smart port enabling technologies

IT system	*Applications*
Port Community System (PCS)	Improves logistics and administrative processes by establishing a common information platform for the exchange of relevant operational documents between stakeholders relating to, declaration of imports and exports, customs handling, transport orders, processing of dangerous goods, status information and control, and tracking and tracing through the entire logistics chain.
Blockchain Technology	Blockchain offers a decentralized registry that enables the multiple storage of data in various locations. With multiple network nodes involved in the validation process, there is a greater reduction in the potential of fraud.
Global positioning system (GPS)	For location and inventory tracking applications. DGPS could be utilized in port terminals for the identification and tracking of yard positions and for steering unmanned vehicles and equipment [016].
Automatic identification System (AIS)	Uses the unique identification of vessels, their speed, position and course, to track and monitor the movement of vessels thereby assisting in collision avoidance [004, 016].
Radio frequency identification (RFID)	For automatic identification of tagged objects. This technology could be used to track cargo and trucks and also provides security for goods with tamper-resistant RFID seals. Common application in logistics is the warehouse management system.
Mobile devices	Utilizes GPS, RFID and mobile communication services to receive data on mobile devices. Applications includes terminal appointment system for trucks and for parking applications within the port.
Sensors and actuators	Sensors are employed for the monitoring and control of physical objects and port infrastructure, serving as the basis for port automation as well as monitoring environmental conditions within the port. In a smart port environment, sensors form a network of physical objects that communicate with each other. Examples includes laser technologies and camera systems.
Real-time location systems (RTLS)	Employed for the automatic identification and position tracking without reliance on satellite [016]. This makes it suitable for tracking in confined spaces and tunnels.
Optical character recognition (OCR)	For detection of damage on yard cranes and for vehicle and container identification.

3.1.2 Port operations

The operational process of SMPs can be regarded as a large productive procedure in which the end result is not a physical product but a service. Typical operations within a port includes terminal operations, maritime operations, administrative and customs procedures, port-centric logistics, and hinterland and cargo movement operations. Fig. 12 classifies the various port operations and their associated IT enablers.

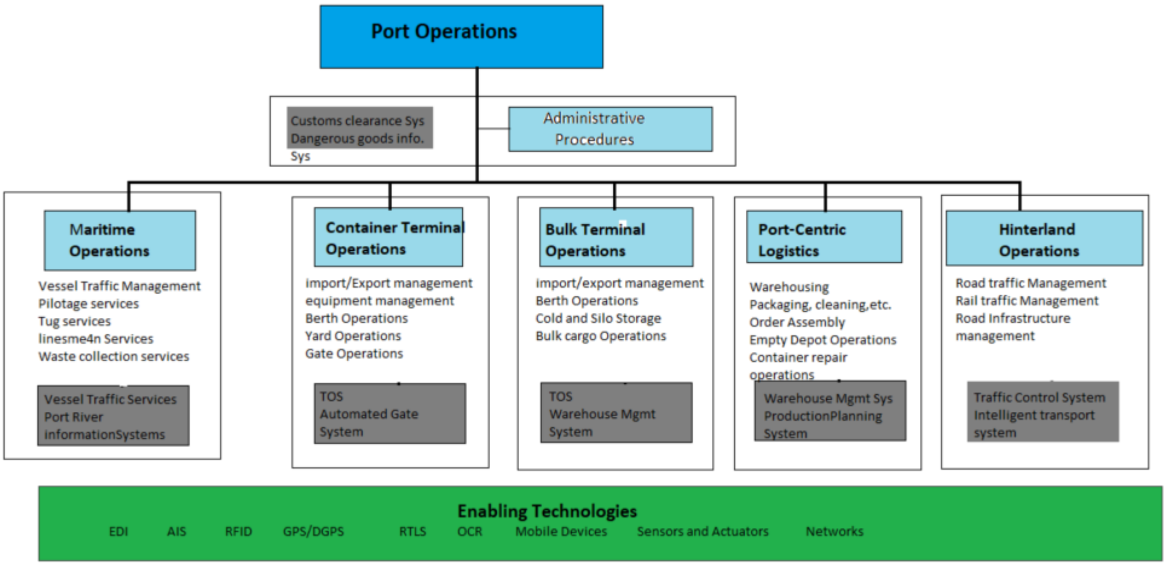

Figure 12. Overview of Port Operations

The aim is to efficiently carry out these operations by utilizing port infrastructure to enhance logistics flow whiles consequently obtaining maximum economic utilization, and energy and environmental efficiency. Therefore, this study classifies port operations based on infrastructure and logistics function.

3.1.2.1 Infrastructure

The implementation of diverse smart sensor devices in the port environment enables real time monitoring and tracking of the state and condition of various port infrastructure such as terminal storage capacity, parking space monitoring and the state of hazardous goods in real time.. Using a base station, data generated from these sensors are quickly transmitted to a monitoring centre thereby providing a quick response time in the event of danger or failure [13].

With smart sensors, terminal operators and port authorities are able to operate, maintain and track the physical infrastructure within the port environment. Fussing sensors on roads, quay walls, bridges, roads and rail lines helps in transmitting real-time information about their operating conditions. This reduces the need for physical inspection and the transmitted data could be utilized by operators to schedule a more accurate maintenance plan [5, 35]. Cranes used for loading and unloading activities at the port are composed of control valves, relays, motors and other moving parts which have the tendency of wearing out and breaking down. Fussing smart sensors to these components eliminates the need for preventive maintenance by providing operators with real time information about their operating conditions. This reduces the down time of the equipment ensuring maximum equipment utilization and also saves cost by ensuring smooth operational flow and eliminates wasted man hours [41].

3.1.2.2 Logistics feature

Smart port logistics refers to the implementation of intelligent logistics solutions to enhance cargo flows and management of goods, traffic flows, parking capacity, etc. This is made possible by the sharing of information between various actors along the supply chain. Retrieval of AIS information prior to the arrival of ships as well as the current state of the port enhances planning and decision making thereby improving loading and unloading times and also minimizes the risk of damage and accidents. RFID and wireless sensors attached to containers enables swift sharing of data about the goods before loading and unloading which results in efficient container management within the terminal. This reduces logistics cost, time and unnecessary moves and also allows for easy tracking of dangerous goods and to also access customs control devices [13].

3.1.3 Sustainable development

Since 1990, there has been an 85% increase in greenhouse gasses emission due to the activities of global trading vessels of which shipping accounts for 3% of the total emissions each year [42]. The EU has therefore made a commitment to decrease its greenhouse gasses (GHG) emission by 20% whiles simultaneously increasing renewable energy sources and their energy efficiency by 20% by the year 2020 [8]. The European 2020 strategy aims at creating a smart, inclusive and sustainable Europe. Based on this strategy, ports are adopting smart initiatives that does not only allow them to do business efficiently, but also aims at energy saving and emission reduction [37].

Since the United Nations agenda 2030 for sustainable development can only be realized by a sustainable transport sector that supports global trade and world economy [43], the International Maritime Organization (IMO) has linked its technical operations with the UN sustainable development goals (SDGs).

Figure 13. Linking IMO's technical Operations with the Sustainable Development Goals *[43]*

Therefore a smart port initiative must have a green strategy for a sustainable operation and development. This can be achieve by limiting their reliance on traditional sources of energy and implementing smarter transportation planning which aims at emission reduction [44]. In becoming smart, SMPs must take into account the possibility of reduced energy consumption and embrace the concept of "green thinking" which only does not reduced the impact of their activities on the environment, but also serves as a cost saving mechanism and also as a revenue generating stream for the ports [42].

3.1.3.1 Energy factor

The port and its related logistics activities results in the consumption of large quantities of energy. Considering the increasing demand for seaborne trade which has led to recent developments in ports and the increasing industrial processes and activities within the port environment, the use of energy have also significantly increase. Therefore, an SMPs' smart port strategy must include steps to not only reduce their energy consumption, but also provide other means of clean energy for vessels waiting at the port. This does not only prevent emissions from the vessels, but generates revenue for the port whiles simultaneously saving fuel cost for fleet operators.

In achieving this goal, the port of Valencia has implemented a motion-sensitive lighting system which has reduced the total energy consumption of the port by 80% and has a payback period of less than two(2) years to recover the investment in this technology [5]. The Port of Valencia is not the only port who has benefitted from implementing smart lighting systems to save a great amount of energy. Portsmouth International Port is also a classic example. The port achieved an impressive 70% energy reduction by replacing its existing flood lights with low energy equivalent LED floodlights [8].

According to the 2 Seas Magazine [8], developing cold ironing (shore electricity for ships in ports) is one perfect means through which SMPs can decrease their energy consumption whiles still reducing emissions. Although the initial investment in this technology may seem high, it pays off for itself in no time and it becomes a revenue generator for the ports in the medium and long term. The authors pointed it out that, cold ironing is practically possible for smaller ports due to the fact that, their national grid in most cases have enough capacity to cope with extra demand [8]. Vessels waiting at the ports can use onshore power supply provided by the ports thereby reducing the impact of emissions on the environment and contributing to a greener eco-system [24].

3.1.3.2 Environmental factors

Although the maritime industry serves as the backbone of global trade, their activities imposes severe environmental impacts. Shipping and its associated hinterland transportation accounts for a large proportion of emissions to air, noise pollution, waste generation and water pollution [42]. According to James et al [45], particulate matter (PM) resulting from shipping activities accounted for over 70,000 lung cancer and cardiopulmonary mortalities in 2007. It is therefore required that, the envisioned smart port initiative by SMPs must take into account measures to control and reduce the impact of these pollutions. One way of accomplishing this is by the adoption of Terminal appointment systems that enables trucks to reserve exact times for picking up and dropping off goods. This reduces the time trucks spend at the port due to turning times and idle waiting times within the port thereby reducing emissions from the truck. A classic example is the GPS- based traffic monitoring system which is currently being tested by the port of Singapore. This system has the ability to track the movement of trucks, notify the terminals when they are approaching and also provide directions for the trucks [5].

Moreover, effective discharge and management of different waste streams at seaports cannot be undermined when SMPs are seeking to embark on the smart port initiative. Major waste streams handled by ports includes; bulk chemical waste, sewage, oily waste, packaged waste and noxious substances. These waste if not properly handled poses severe dangers to the environment and aquatic life. This has made it necessary for all EU ports operating in the Baltic Sea special area to provide reception facilities for these various types of waste and residues from maritime operations [24].

3.1.4 Security and safety

A port can be seen as a complex cyber environment made up of both waterside and inland activities and systems. The port environment utilizes four main asset types namely; buildings, linear infrastructure, plant and machinery, and information and communications systems in carrying out its operations and service provision where the role of technology is very integral [46]. The increasing role of ICT in shifting ports to the smart era gradually by automating its main assets makes ports and logistics vulnerable to cyberattacks and software bugs [47, 48]. As ports are implementing several sensors and smart technologies in their operations, more data is generated which exposes them to cyber-threats [49]. Such attacks could be small-scale attacks which seeks to penetrate the security of the port or major attacks by terrorist who seek to disrupt trade flows as an act of war [47]. Cybersecurity and cyber-resilience therefore becomes an integral part in moving towards a smart port concept. This preparation is not just technological, but requires SMPs to develop a risk aware culture in their activities [49].

Compromising on safety and security within the port may influence on:

- the efficiency and the pace at which the port operates;
- the ports ability to safely carry out specific activities;
- the health and safety of persons within the port environment.

The ports failure to protect its infrastructure and assets may have adverse consequences on their operational procedures and may lead to undesirable situations such as:

a. accidental or unintended exposure of sensitive data, systems or applications to unauthorised persons,

b. System redundancy,
c. Failure modes that may lead to severe system or process failure throughout the entire port.

Not only does these failures poses financial loss to the ports, but also downplays on their reputation [46]. In June 2017, the "NotPetya" cyber-attack compelled Maersk to disrupt most of its terminal operations worldwide which did so much harm to their logistic functions for weeks costing them approximately $300 million [48].

In assessing the security and safety issues within the port environment, H. Boyes et al. [46] uses a six (6) step approach to conduct a cyber security assessment (CSA) of port asset and infrastructure which could assist SMPs in making viable decisions when choosing from a wide range of smart technologies to enhance the security and safety of personnel and property.

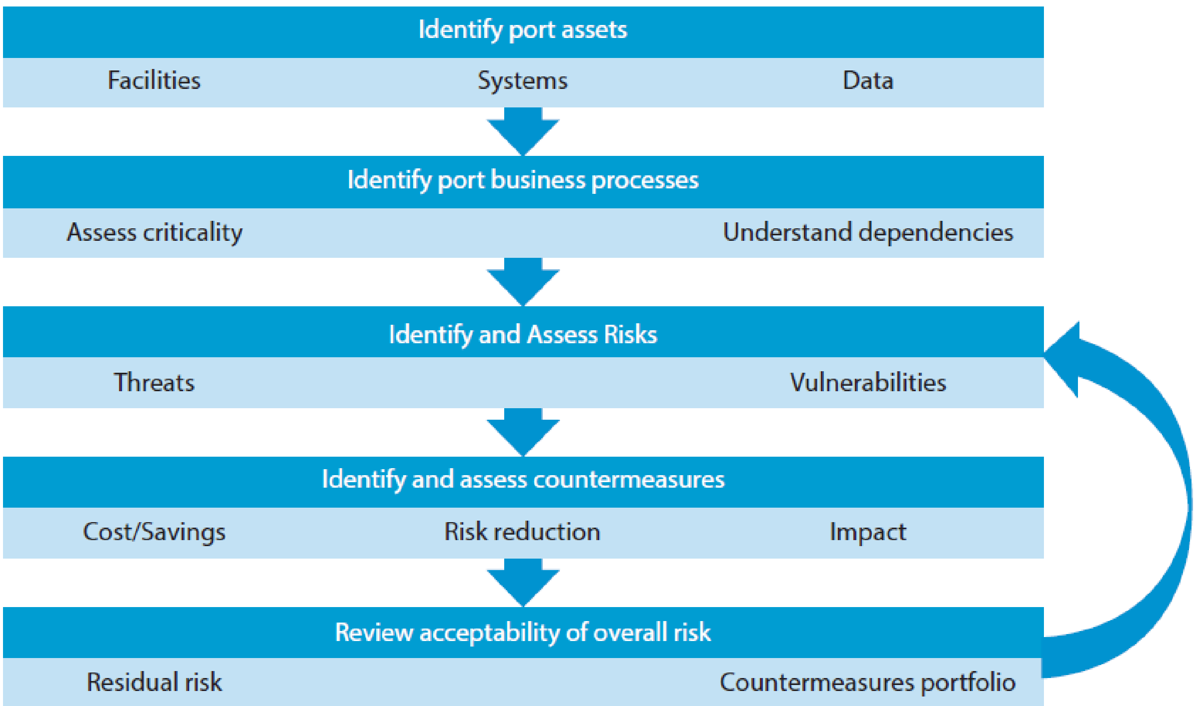

Figure 14. Cyber-Security assessment of ports *[46]*

Meeting the minimum security and safety requirements for the port facilities and assets is the sole responsibility of ports. Smart technologies such as camera and surveillance systems uses advanced video analytics to identify unauthorized access based on movement and pattern recognition and notify security authorities. Smart technologies are also shifting ports from the traditional gate entry system to using networked biometric scanners which require port users and visitors to access the facility via logins [5]. To address the issue of workers health and safety, S. Bauk et al [50] proposed two wireless body area network sensor (WBANS) base models which are attached to the workers protective equipment's and to transmit vital body signals of workers in real time to ensure workers are in the right state of health in carrying out their normal activities.

3.2 Technology readiness of SMPs

According to P. Chwelos et al. [51], an organizations intension to adopt a new IT system is characterised by their perceived benefits, external pressure, and organizational readiness. Perceived benefit refers to the expected advantages that SMPs stand to gain by adopting smart technologies in their operation which can be classified as direct and indirect. Direct benefits may include achieved internal efficiencies and operational cost savings whiles indirect benefits may include improved customer service and a potential for process reengineering. External pressure involves influence from the shipping industry as most larger ports are moving to smart port initiatives and also from SMPs' quest to maintain or increase their competitive advantage.

The organizational readiness factor measures the technological sophistication and financial capability of SMPs in adopting the smart port concept. IT sophistication does not only include the level of technological expertise within the port, but also measures the degree to which management understands and support the adoption of IT in achieving its organizational objectives [51, 52]. This implies that, the technical aspect of readiness which is made up of hardware and software is in this context isolated from non-technical aspect which includes technical know-how, expertise and financial capabilities [52]. The driving factors behind SMPs intensions to adopt smart port initiatives is represented in fig. 15.

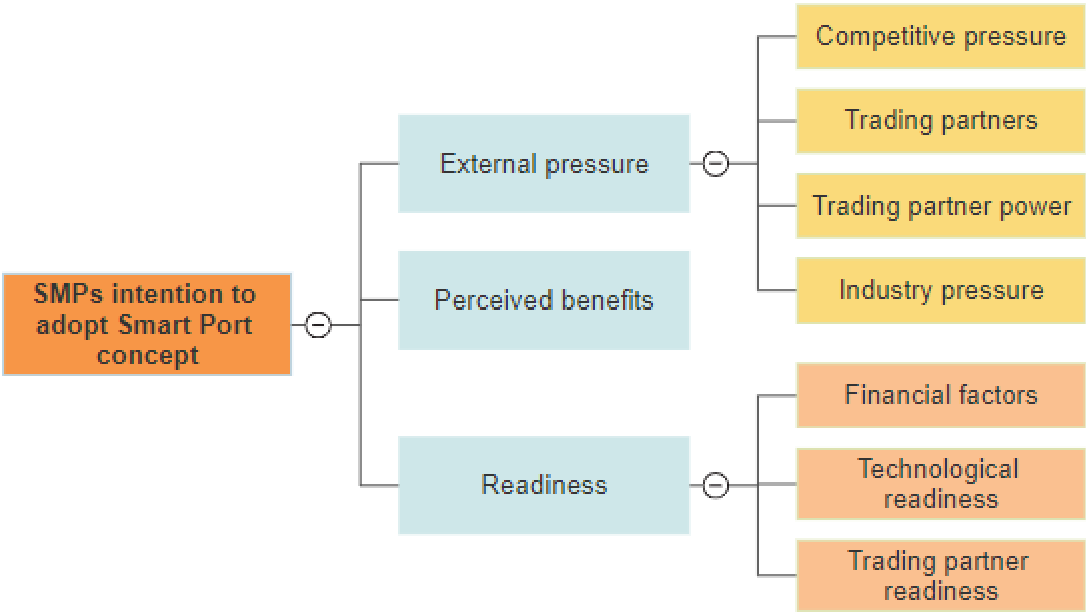

Figure 15. Technology adoption factor tree

SMEs of which SMPs form an integral part are at different levels of technological maturity and it thus becomes difficult to define a holistic approach for SMPs to assimilate these technical innovations [53].

Litchblau et al [54] identifies six levels of readiness of industry 4.0 and smart technologies implementation in organizations. These levels includes;

- Level 0 (outsider): SMPs at this level of readiness demonstrates no knowledge of smart port technology and have not taken any steps towards automation within the port environment.
- Level 1 (beginner): At this level, SMPs have taken steps to pilot a smart port initiative and have made investments and implementation of IT solutions in at least one area of operation whiles infrastructure and existing systems may partially satisfy future integration.
- Level 2 (intermediate): An intermediate level SMP have a strategic orientation towards a smart port initiative and have partially made investments into smart technologies in few areas of operation with an integrated information system, whiles steps to integrate information sharing with other port stakeholders is at its initial stages.
- level 3 (experienced): This level of readiness demonstrates that, an SMP have a formulated smart port strategy and has made investments in multiple areas of operation with a well linked IT system in its operations.

- level 4 (Expert): at this level of maturity, an SMP can be considered as already smart with IT investments in almost all relevant areas of operation. There is also a large integration of information sharing between various port stakeholders and decision making is largely data driven.
- level 5 (top performer): A performer is a fully integrated smart port. An SMP at this level have a comprehensive IT system is its operation where automation and data collection is at its maximum.

For simplicity, the first three higher levels are classified as leaders, whiles the two lower levels are classified as newcomers with ports at the intermediate level of maturity being classified as learners [54]. Most SMPs can thus be classified as new comers with a few of them in the range of learners. Fig. 16 illustrates the various levels of technological maturity and their corresponding features.

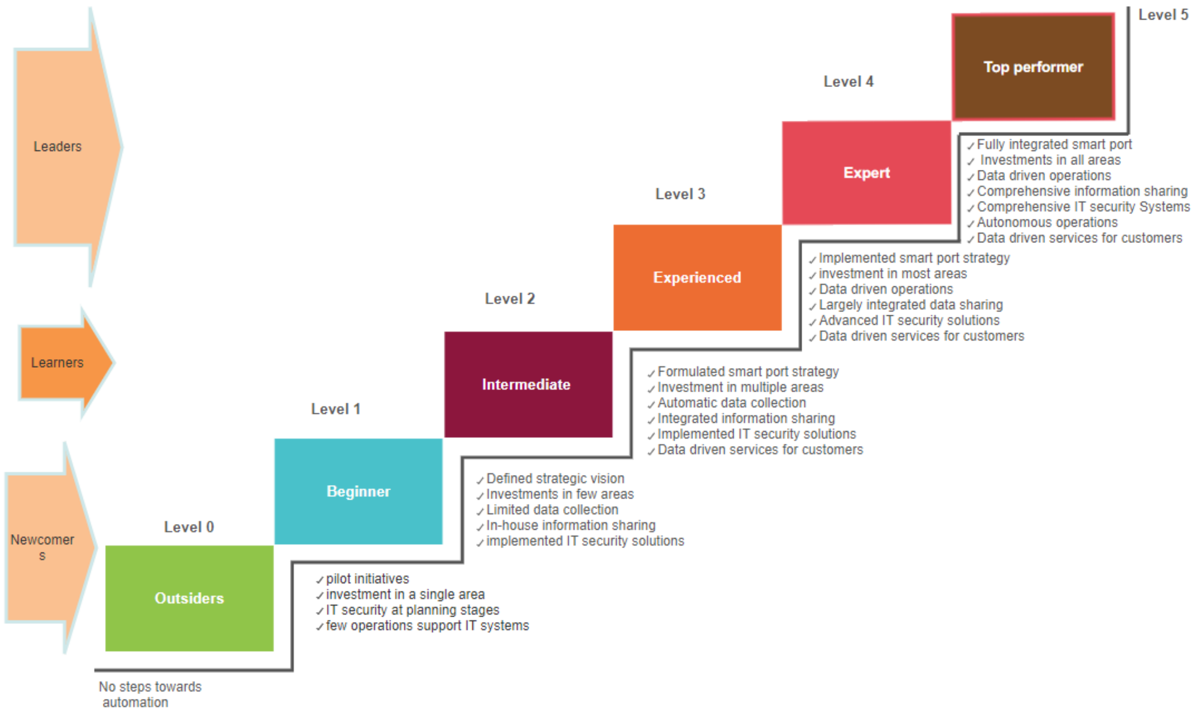

Figure 16. Technology maturity Ladder

To better enable SMPs to make a comprehensive analysis of their digital journey, BCG's Digital Acceleration Index (DAI) [55] can be used which enables port authorities to identify opportunities for adopting a smart port strategy. SMPs can thus determine their starting point by discovering their digital strength and weakness. Next, their digital strength must be compared with other SMPs, larger ports or best-in-class ports who have already implemented smart technologies in their operation. This will enable authorities define an achievable ambition level for their company, develop an integrated roadmap for reaching the targeted digital state, and initiate their digital transformation.

4 Smart Port Implementation

In initiating a smart port project, it is vital to understand the individual needs of SMPs linked to their strategic goals in order to develop a high level requirement plan for the ports [12]. Even though ports serve a basic role as an interface between different modes of transportation, they significantly differ from each other based on their physical location, type of operation and their strategic position in global trade. This means that the associated information flow and systems within each port entity differs significantly and must be clearly defined when choosing a smart port strategy [56]. To gain the full benefit of Smart port technology in delivering a high quality logistics service to their customers, SMPs must take into account the customer needs and requirements in the implementation process in order to create added value and gain competitive advantage [12].

Larger ports such as the port of Antwerp, the port of Hamburg, the port of Barcelona, etc. have the resources and financial strength to migrate to a fully integrated smart port platform as seen today because the economic benefit for such ports is already high. But that's not the case for SMPs. C. Schøder [53] therefore suggests that, the adoption of smart technologies for SMEs should be carried out in a stepwise manner until their operations are fully networked. BCG's report [57] specifies that, establishing a fully advanced IT system is not a must for industries in order to embark on a digital transformation. SMPs can begin this journey by leveraging their existing IT infrastructure and in a stepwise manner, enhance their systems as required.

Fig. 17 illustrates a proposed smart port implementation plan for SMPs. The implementation plan uses seven (7) steps which carefully examines the SMPs specific needs and ensures SMPs undertake the right approach in choosing the right smart port technology relevant to their operation and ensures an agile approach is used to minimize risk.

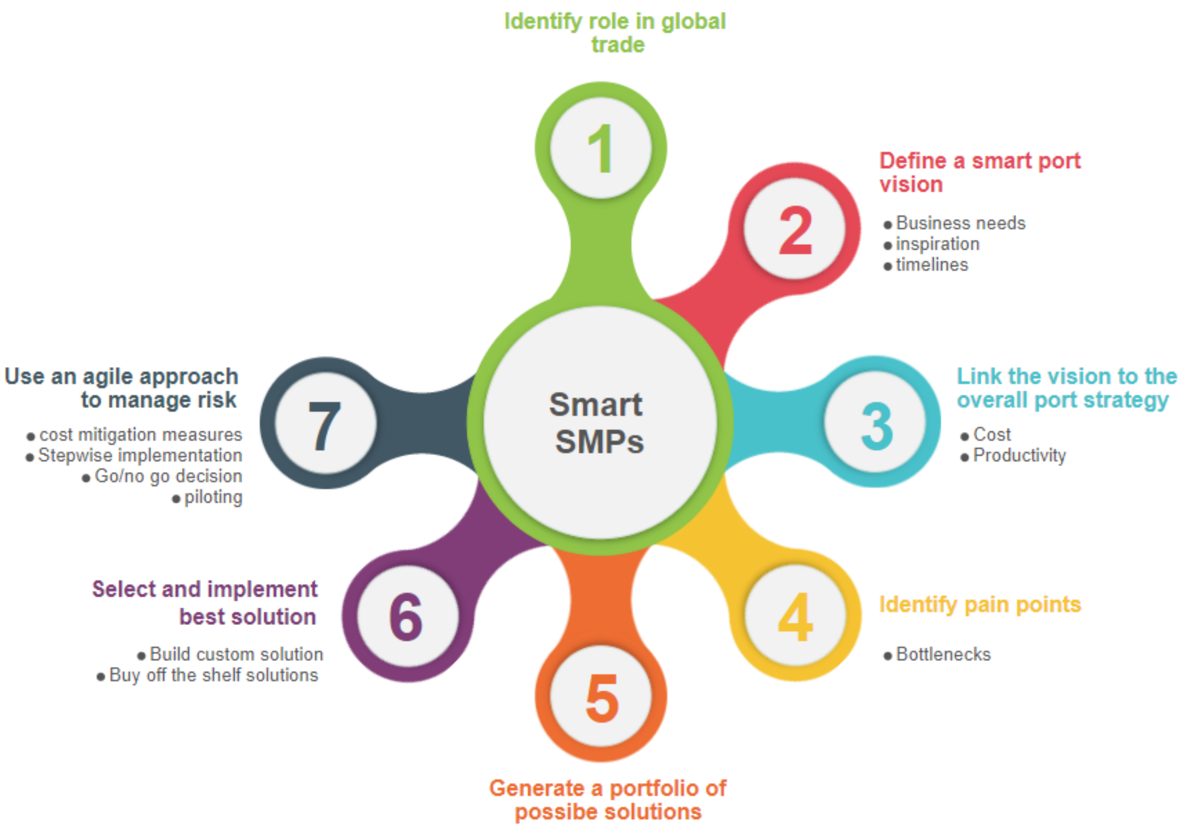

Figure 17. The Smart Port Implementation Plan

4.1 Identifying the role of SMPs in global trade

There are several smart port technologies that SMPs can choose from, but the technology ports seek to adopt should be based on the strategic issue they seek to address. Smart port technology is not a "one size fit all" approach. Based on their location, level of competition and their role in trade, SMPs can adopt different approaches to suit their operations. Based on their role in global trade, BCG report [5] classify SMPs into four (4) main categories namely; emerging ports, local trade hubs, intermodal gateway ports, and city-based ports.

- **Emerging ports**: As economies are rapidly developing, new ports are being built to keep up with high trade growths. The adoption of modern infrastructure presents the opportunity for the ports to offer a much larger capacity and to integrate smart technologies during construction of the facility. Smart port initiatives that enables ports to easily transact business will be much beneficial to emerging ports since their main objective is to attract more cargo [5, 33]. Such technologies may include, port community system (PCS) and single-window customs system that facilitates the exchange of information amongst various port actors, biometric access control systems and RFID technologies that enables easier and faster cargo scanning and enhances customs processing [5].

- **Local trade hubs**: majority of SMPs in Asia, Sub-Saharan Africa and South America predominantly serve as gateways for both local and international trades. These ports seek to keep local exports at competitive levels whiles still keeping cost of operation at minimum. These ports are usually faced with the problem of ever growing cargo volumes and vessel sizes and therefore require technologies that enables them to improve their cargo handling volumes and increase their productivity [5]. Equipment tracking and monitoring systems such as the Smart, Energy efficient and adaptive management system (SEAMS) and the black-box technology could enable the ports to identify and manage bottlenecks in their operation in real-time. Also, since these ports serves as the distribution hub for their geographical regions, smart technologies that enhances smooth hinterland (road, rail) connections to the port are very essential in order to keep trade cost low [33]. Technologies such as gate automation and truck appointment systems can facilitate the flow of traffic in and out of the port.
- **Inter-modal gateway ports**: SMPs falling under this category are usually located on high volume trade routes and carry large amount of cargo in and from far hinterlands [5]. These ports are usually faced with the problem of terminal and intermodal congestions due to the huge quantities of cargo they handle [33]. They could therefore benefit from smart technologies that can assist them in managing intermodal traffic effectively whiles reducing logistics and associated cost. This could be achieved by the implementation of truck appointment system and other combined intermodal systems that manages both rail and road infrastructure [24]. The port of Hamburg has succeeded in implementing a rail logistics system by embedding sensors in their rail infrastructure that monitors their condition.
- **City based ports**: city based ports are primarily faced with environmental issues to the port city such as pollution, noise and congestion on city roads [33]. To ensure the sustainable coexistence of ports and the city, ports must concern themselves with the monitoring and reduction of the environmental impact of their activities on the city [5, 24]. The port of Rotherham has employed a network of sensors that monitors pollution in the air and waters.

Table 3. Classification of Ports according to their role in global trade with applicable smart port solution

TYPE	FOCUS	APPLICABLE SOLUTIONS
Emerging port	Ease of doing business	• Port community systems • Single-window customs • X-ray scanning • Biometric access control systems
Local trade hub	High productivity	• Smart cargo-handling systems • Equipment management and control • Gate automation • Safety management solutions
Intermodel gateway	Optimized traffic across transport modes	• Truck appointment systems • Traffic-monitoring systems • Integrated rail and barge platforms
City-based port	Minimized impact on surroundings	• Asset health monitoring • Environment and energy • Management systems • Port-wide platforms

4.2 Defining a smart port vision

Defining a clear vision for the ports digital identity is vital for developing commitment to a broad and an entire organizational approach. This must address the business needs, backed by an inspiration and with a clear and feasible time frame for success.

- **Business needs**: In defining a vision, SMPs should begin by determining how these technologies could enhance their operations along the entire value chain from the time an initial shipment is made until final delivery of shipment and repositioning of the emptied containers. It is also important for port authorities to identify pain points in their operations where they can recover value that is being lost by the aid of IT infrastructure [57].
- **Inspiration:** In adopting the smart pot concept, it is very important for SMPs to examine the business environment to gain inspirations. They must be abreast with the digital transformations spanning the entire shipping industry [57]. This could be achieved by studying the implementation of similar technologies in larger ports and assessing their benefits and thus, formulating ideas and solutions that fits their business needs [58].

- **Timelines:** The defined vision must be established on the reality of how fast the port can transform. It is therefore important for SMPs to access their readiness in adopting digital technologies in order to define a bold and realistic timeline [57].

4.3 Link the vision to the overall port strategy

The smart port adoption plan must be solidly emphasized to a larger port strategy or goals. Whether the port seeks to find extra capacity in existing assets, increasing market share by increasing efficiency as compared to other ports, operation cost reduction or rendering data-driven services to customers as a new revenue generation mechanism, the smart port vision must be able to support this strategy. At this stage, SMPs can ask stakeholders to define other problems that they think the smart initiative could resolve. This enhances the network effect and gives ports a higher economy of scale.

4.4 Identify pain points

After a smart port vision is well aligned with the overall port strategy, the next step is to identify pain points and gaps in operations that the smart initiative could fix. To uncover structural problems that hinders efficient cargo handling, SMPs must first get a deeper understanding of its existing process set ups. Diagnostic tools such as bottleneck analysis, time and motion studies and process defect analysis can be used to identify operational inefficiencies and suggest ideas for fixing them with a smart port concept.

4.5 Generate a portfolio of possible solutions

When the pain points in port operations have been identified, SMPs must consider and examine available technologies that can address these issues. The availability of possibilities is an indication that, there are several solutions to every problem. In examining the various solutions that exist for a particular problem, SMPs must take inspiration from other ports using smart technologies to address a similar problem. This is to emphasize that, SMPs must not adopt exact same solution for the same problem because, smart technologies are not one size fit all and what might have worked for one port, might not be the best solution for the other.

4.6 Select and implement best solution

After identifying the problem and the best solution identified, SMPs needs to decide whether to purchase off-the-shelf solutions or purchase a custom solution. Off-the-shelf solutions are fast to implement and cheap in terms of cost, but they are limited in implementation such that, they might not integrate very well with existing port systems and applications. To gain the full benefit of adopting a technology, SMPs can partner with technology vendors to develop a custom technology by negotiating with vendors to customize off-the-shelf technologies to suit their needs without huge investments as compared to building a new technology from scratch. This way, it becomes difficult for competitors to replicate the same technology.

4.7 Use an agile approach to manage risk

Adoption of new technology comes with associated risk. Such risk may include software bugs, increased installation cost, and may not present the required return on investment within the stipulated time. Sensor technology and other advance smart port technologies are expensive and disruptive. To mitigate risk, SMPs must implement new systems considering a step wise approach and making a go/no-go decision after each stage. SMPs can also minimize risk by using the concept of minimum viable product to build the smallest possible version of a solution and test it in real time before adding additional features and users [57]. With current technological tools such as simulation software and learning factory tools, ports can run a virtual version of the desired solution to study the operational behaviour before going into a full scale implantation.

5 Cost Benefit Analysis

The analysis of the cost involved and the benefits that can be derived from the implementation of smart technologies for SMPs is of relative importance to aid SMPs make a go/no-go decision when embarking on a digital journey. But as the smart port concept is a new paradigm of digital transformation within the maritime industry, no relevant literature exist which analyses the cost benefit implications of assimilating this technological innovation. Therefore, the analysis made in this chapter is based on assumptions.

Schrøder [53] establishes that, the implementation of industry 4.0 and smart technologies have a positive economic potential in all areas of application. The economic benefit in adopting smart technologies is to some extent difficult to quantify, the author establishes that these technologies have a greater potential of transforming their operations and obtaining higher financial benefits in the long term. In conducting a quantitative cost benefit analysis for the adoption of RFID technology in container ports, Miragliotta et al [59] used four scenarios to model the cost effectiveness of RFID technology. Their results is summarized in table 4.

Table 4. Cost analysis on implementation of RFID technology in a container port

Scenario	Investments	Recurrent cost	Discounted payback period	Net Present Value
A (Active tag)	277,400 €	24,000 €	2years	260,000 €
B (Electronic seal)	312,000 €	25,500 €	2years	680,000 €
C (containers need to be tagged)	154,000 €	5,500 €	-	-341,500 €
D (containers are already tagged)	41,500 €	5,000 €	1year	174,000 €

Their analysis revealed that, containers tagged with RFID experienced a 95% reduction in cost as well as a positive net present value within 2 years of investment in the technology. This is an indication that smart technology doesn't only increase efficiency, but also reduces operational cost significantly.

Also, implementation of the RFID system in the largest port in Taiwan, Port of Kaohsiung port, returned a benefit-cost ratio of 2.5 within an 8year period [60]. The authors then recommended the implementation of this technology in several other ports.

Although these two researches focused only on one technology (RFID), an inspiration can be taken from them to aid in making decisions regarding the adoption of smart technologies.

In becoming smart, SMPs stands a higher possibility of becoming much efficient and more productive by way of optimized logistics flow, decrease in maintenance and logistics cost, and improved information transfer.

Applying smart sensor technologies within the ports produces data which could be utilized by ports as new revenue generating streams. Real time data could be sold to logistics and trucking companies who seek to optimize their trips and schedules [5].

6 Conclusion and Further Work

Conclusion

The smart port concept is much promising and has contributed to the improved efficiencies, cost saving, flexibility and safety in port operations and processes in most larger ports. This giant leap in technology in the maritime industry has a higher potential of improving port related activities in SMPs through an efficient and cost effective application of infrastructure and information. Despite the growing interest in the topic, nothing has been said about how SMPs can also gain competitiveness by implementing smart technologies and practices. In this light, this study can be considered as the first academic work which discusses the smart port concept focusing on Small and Medium size Ports and also serves the theoretical basis for further empirical study.

In this study, a smart port framework focusing on Small and Medium sized Ports have been presented. The framework is composed of technology, sustainable development, port operations, and safety and security which serves ad the building blocks that needs to be well coordinated in order to achieve the perceived smartness by SMPs. Further, a technological maturity scale is also considered which will aid SMPs in identifying their level of readiness in adopting smart technologies with an integrated smart port implementation plan.

The limitations of this work is well understood such that, smart port strategies are not “one size fit all” and the implementation plan developed in this study might not achieve the same results for all ports. Also unavailability of data from ports couldn’t allow for a quantitative analysis, thereby limiting the study to a qualitative research. Nevertheless, the former limitation could be of focus in further works.

Further Works

With this study setting the theoretical basis, it will be of much interest to further validate the developed framework by subjecting it to a real time case study with a cluster of ports, conducting a much detailed empirical analysis on the various blocks and determine how SMPs can achieve the perceived competitiveness.

References

[1] X. J. YANG, J. M. W. LOW and L. C. TANG, "Maritime Trade Evolutions and Port City Developments in Asia," in *Advances in Maritime Logistics and Supply Chain Systems*, Lee Kong Chian School Of Business, 2011, pp. 1-54.

[2] RADHIKA.D, "THE NEW ROLE OF SEAPORTS AS INTEGRAL PARTS OF GLOBAL SUPPLY CHAINS," *International Journal of Multidisciplinary Management Studies,* vol. 2, no. 4, pp. 131-144, 2012.

[3] K. Ono, M. Tanemura and Y. Akakura, "AI PORT INITIATIVES: POSSIBLE MODERNIZATION OF PORT OPERATION AND MANAGEMENT THROUGH CUTTING EDGE ICTs," in *PIANC-World Congress* , Panama City, 2018.

[4] Caroline, "The Rise of Big Data in Ports and Terminals: How the Shipping Industry Is Transforming Port Technology," 16 May 2018. [Online]. Available: https://www.opendatasoft.com/blog/2018/05/16/the-rise-of-big-data-in-ports-and-terminals-how-the-shipping-industry-is-transforming-port-technology. [Accessed 5 February 2019].

[5] J. Riedl, F.-X. Delenclos and A. Rasmussen, "To Get Smart, Ports Go Digital," The Boston Consulting Group, 2018.

[6] M. Mirović, M. Miličević and I. Obradović, "Big Data in the Maritime Industry," *Naše more",* vol. 65, no. 1, pp. 56-62, 2018.

[7] UNCTAD, "Review of Maritime Transport," in *United Nations Conference on Trade and development*, New York, 2016.

[8] *SMALL AND MEDIUM SIZED PORTS AS HUBS FOR SMART GROWTH AND SUSTAINABLE CONNECTIVITY,* 2014.

[9] X. Shi, D. Tao and S. Voß, "RFID Technology and its Application to Port-Based Container Logistics," *Journal of Organizational Computing and Electronic Commerce,* vol. 21, no. 4, pp. 332-347, 7 October 2011.

[10] L. Heilig, E. Lalla-Ruiz and S. Voß, "Digital transformation in maritime ports: Analysis and a game theoretic framework," *Netnomics,* vol. 18, pp. 227-254, 2017.

[11] T. Nguyen, L. ZHOU, V. Spiegler, P. Ieromonachou and Y. Lin, "Big data analytics in supply chain management: A state-of-the-art literature review," *Computers and Operations Research,* vol. 98, pp. 254-264, 2018.

[12] L. Heilig and S. VoB, "Port-centric Information Management in Smart Ports," *Ports and Networks,* pp. 236-250, 2018.

[13] A. Belfkih, C. Duvallet and B. Sadeg, "THE INTERNET OF THINGS FOR SMART PORTS," in *Proceedings of IPaSPort*, 2017.

[14] L. Heilig, S. Schwarze and S. Voß, "An Analysis of Digital Transformation," in *Proceedings of the 50th Hawaii International Conference on System Sciences*, Hawaii, 2017.

[15] J. J.-T. Kim, "SMART IS THE NEW SMALL," CYberLogitec, South Korea, 2018.

[16] "SPHERE Project," SPHERE Final Report, 1999.

[17] L. Feng, "Peripheral challenge by Small and Medium Sized Ports (SMPs) in Multi-Port Gateway Regions: the case study of northeast of China," *POLISH MARITIME RESEARCH,* vol. 20, no. 79, pp. 55-66, 2013.

[18] D.Radhika, "The Role of Knowledge Management as an Innovative Strategy in Maritime Logistics Management," *International Journal of Humanities Social Sciences and Education (IJHSSE),* vol. 1, no. 9, pp. 52-57, 2014.

[19] L. Sujeta and V. Navickas, "THE IMPACT OF PORT LOGISTICS SYSTEMS ON A COUNTRY‘S COMPETITIVENESS (CASE OF SMALL COUNTRIES)," *ECONOMICS AND MANAGEMENT,* vol. 19, no. 1, pp. 44-53, 2014.

[20] P. B. Olesen, I. Dukovska-Popovska, H.-H. Hvolby and K. S. Jensen, "Strategic port development: identifying a development approach for small and medium-sized ports," in *Proceedings from the Annual Transport Conference at Aalborg University,* Aalborg, 2012.

[21] I. JAKOMIN, "NEW FUNCTION OF SEAPORTS: LOGISTICS AND DISTRIBUTION," *Traffic,* vol. 15, no. 1, pp. 1-5, 2003.

[22] J. Monios and G. Wilmsmeier, "Port-centric logistics, dry ports and offshore logistics hubs: strategies to overcome double peripherality?," *Maritime Policy & Management,* vol. 39, no. 2, pp. 207-226, 2012.

[23] J. Mangan, C. Lalwani and B. Fynes, "Port-centric logistics," *The International Journal of Logistics Management,* vol. 19, no. 1, pp. 29-41, 2008.

[24] "Detailed analysis of ports and shipping operations," European mobility network, 2018.

[25] H. Wei, Z. Sheng and P. T.-W. Lee, "The role of dry port in hub-and-spoke network," *Maritime Policy & Management,* vol. 45, no. 3, pp. 370-387, 2018.

[26] N. Venkatraman, "IT-enabled business transformation: From automation to business scope redefinition," *Sloan Management Review,* vol. 35, no. 2, pp. 73-87, 1994.

[27] L. Heilig and S. Voß, "Information systems in seaports: a categorization and overview," *Information Technology Management,* vol. 18, pp. 179-201, 2017.

[28] P. Publications, "The use of Big Data in The Maritime Industry," Port Technology International, 2017.

[29] P. T.-W. Lee and J. S. L. Lam, "Developing the Fifth Generation Ports Model," *Dynamic Shipping and Port Development in the Globalized Economy*, vol. 2, pp. 186-210, 2016.

[30] B. Irwin, "Opportunities for information technology systems to improve port-related supply chain performance," National Transport Commission Australia, 2014.

[31] P. Antti, "E-PORT:Improving the efficiency of Finnish ports with intelligent systems," University of Turku CENTRE FOR MARITIME STUDIES, 2012.

[32] C. Navarro, E. P. García, J. M. L. López, M. G. Sanz, M. L. Escamilla, M. Llop and S. Furió, "Multimodal Innovation for Sustainable Maritime & Hinterland Transport: Best Practice Guide on Single Windows, e-Maritime and Port Community System," Port Integration, 2011.

[33] "Smart ports: increasing efficiency and cutting costs," 19 June 2018. [Online]. Available: https://www.ship-technology.com/features/smart-ports-increasing-efficiency-cutting-costs/. [Accessed 10 February 2019].

[34] M. Hillsdon, "How technology is creating the digital ports of the future," 18 October 2018. [Online]. Available: https://www.raconteur.net/finance/technology-digital-port. [Accessed 5 February 2019].

[35] "A literature review on the impact of RFID technologies on supply chain management," 2009.

[36] T. M. Attia, "Importance of Communication and Information Technology and Its Applications in the Development and Integration of Performance in Seaports," *Journal of Renewable Energy and Sustainable Development (RESD)*, vol. 2, no. 2, pp. 137-146, 2016.

[37] M. M. Projects, *Action Plan towards the SMART PORT concept in the Mediterranean Area*, Med maritime Projects, 2014.

[38] K. EL-SAKTY, "Smart Seaports Logistics Roadmap," *Journal of Renewable Energy and Sustainable Development (RESD)*, vol. 2, no. 2, pp. 91-95, 2016.

[39] H. Lee, N. Aydin, Y. Choi, S. Lekhavat and Z. Irani, "A decision support system for vessel speed decision in maritime logistics using weather archive big data," *Computers and Operations Research*, vol. 98, pp. 330-342, 2018.

[40] J. F. Srour, M. v. Oosterhou and P. v. Baalen, "Port Community System Implementation:," 1 August 2007.

[41] A. Gottheil, "The IoT Magazine," 5 November 2017. [Online]. Available: https://theiotmagazine.com/iot-for-the-shipping-industry-41c8f85a654e. [Accessed 15 3 2019].

[42] B. Jiang, J. Li and X. MAO, "Container Ports Multimodal Transport in China from the View of low Carbon," *The Asian Journal of Shipping and Logistics*, vol. 28, no. 3, pp. 321-344, 2012.

[43] "IMO and the Sustainable Development Goals," International Maritime Organization, 2019. [Online]. Available: http://www.imo.org/en/MediaCentre/HotTopics/Pages/SustainableDevelopmentGoals.aspx. [Accessed 25 May 2019].

[44] A. Rajabi, A. K. Saryazdi, A. Belfkih and C. Duvallet, "Towards Smart Port: An Application of AIS Data," Le Havre, 2018.

[45] J. J. Corbett, J. J. Winebrake, E. H. Green, P. Kasibhatla, V. Eyring and A. Lauer, "Mortality from Ship Emissions: A Global Assessment," *Environ. Sci. Technology,* 2007.

[46] H. Boyes, R. Isbell and Luck Alexandra, "Code of Practice: Cyber Security for Ports and Port Systems," Institution of Engineering and Technology, London, 2016.

[47] T. E. I. Unit, "A turning point: The potential role of ICT innovations in ports and logistics," DP World, 2015.

[48] P. M. Dingeldey, "Port Automation and Cyber Risk," 27 December 2017. [Online]. Available: https://www.maritime-executive.com/editorials/port-automation-and-cyber-risk. [Accessed 5 February 2019].

[49] D. Global, "Global drivers to 2030: Impacts on Ports Industry," Deloitte Global, Rotterdam, 2017.

[50] S. Bauk, "EMPLOYING WIRELESS NETWORKS IN ENHANCING OCCUPATIONAL SAFETY AT THE DEVELOPING SEAPORT – TWO PROPOSALS," *POLISH MARITIME RESEARCH 1,* vol. 24, no. 93, pp. 115-124, 2017.

[51] P. Chwelos, I. Benbasat and A. S. Dexter, "Empirical Test of an EDI Adoption Model," *Information Systems Research,* vol. 12, no. 3, pp. 304-321, 2001.

[52] Y. Keceli, H. R. Choi, Y. S. Cha and V. Y. Aydogdu, "A Study on Adoption of Port Community Systems," in *Third 2008 International Conference on Convergence and Hybrid Information Technology,* 2008.

[53] C. Schröder, "The Challenges of Industry 4.0 for Small and Medium-sized Enterprises," Friedrich-Ebert-Stiftung, 2017.

[54] K. Lichtblau, V. Stich, R. Bertenrath, M. Blum, M. Bleider, A. Millack, K. Schmitt, E. Schmitz and M. Schröter, "INDUSTRIE 4.0 READINESS," IMPULS, 2015.

[55] "Digital Acceleration Index," Boston Consulting Group, 2018. [Online]. Available: https://www.bcg.com/capabilities/technology-digital/digital-acceleration-index.aspx. [Accessed 10 April 2019].

[56] Oriol, Josep;, "ELECTRONIC DATA INTERCHANGE IN PORT MANAGEMENT THE EXPERIENCE OF THE PORT OF BARCELONA," *FAL BULLETIN- FACILITATION OF TRADE AND TRANSPORT IN LATIN AMERICA AND THE CARIBBEAN,* no. 131, 1997.

[57] Egloff, Camille; Sanders, Ulrik; Riedl, Jens; Mohottala, Sanjaya ; Georgaki, Konstantina;, "The Digital Imperative in Container Shipping," The Boston Consulting Group, 2018.

[58] M. Ghobakhloo, M. S. Sabouri, T. S. Hong and N. Zulkifli, "Information Technology Adoption in Small and Medium-sized Enterprises; An Appraisal of Two Decades Literature," *Interdisciplinary Journal of Research in Business,* vol. 1, no. 7, pp. 53-80, 2011.

[59] G. Miragliotta, A. Perego and A. Tumino, "RFID TECHNOLOGY IN A CONTAINER PORT: AN ACTIVITY-BASED MODEL TO ASSESS COSTS AND BENEFITS".

[60] F.-M. (. Tsai and C.-M. Huang, "Cost-Benefit Analysis of Implementing RFID System in Port of Kaohsiung," in *International Conference on Asia Pacific Business Innovation and Technology Management,* 2012.

[61] D. P. Services, "Smart Ports Point of View," DEloitte Global, 2017.

[62] T. Morrall, D. Griffiths, T. Varelas, T. Katsoulakos,, I. K. S. Furió, G. Ferrús and Ø. J. Rødseth, "TTG4 e-Maritime: Publication on e-Maritime for shipping and port operations," Maritime Europe Strategy Action, 2016.

[63] Skema, "Inventory of Port Single Windows and Port," SKEMA Coordination Action, 2009.

[64] S. Mittal, M. A. Khan, D. Romero and T. Wuest, "A Critical Review of Smart Manufacturing & Industry 4.0 Maturity Models: Implications for Small and Medium-sized Enterprises (SMEs)," *Journal of Manufacturing Systems,* 2018.

[65] K. Czachorowski, M. Solesvik and Y. Kondratenko, "The Application of Blockchain Technology in the Maritime Industry," *Green IT Engineering: Social, Business,* pp. 561-577, 2019.

[66] M. Staff, "Building a Connected, Smart Port of the Future," MH&L, 1 February 2018. [Online]. Available: https://www.mhlnews.com/technology-automation/building-connected-smart-port-future. [Accessed 01 05 2019].

[67] Y. Shin, V. Thai and K. F. Yuen, "The impact of supply chain relationship quality on performance in the maritime logistics industry in light of firm characteristics," *The International Journal of Logistics Management,* vol. 29, no. 3, pp. 1077-1097, 2018.