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CONNECT2SMALLPORTS PROJECT
Within the frame of the South Baltic Programme

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DEVELOPMENT OF STATE-OF-THE-ART ON BLOCKCHAIN IN PORTS AND TERMINALS: ACTIVITY 4.1

1 INTRODUCTION

This report is part of a deliverable assigned by the Connect2Small Ports Project. The emphasis of the report is to study and understand the components that hinder or promote the success in the application of Blockchain technology solutions for ports and terminals. The scope of this study is specifically on Blockchain and on small and medium size ports in the South Baltic Sea Region.

1.1 Global Supply Chains and the importance of ports

Globalization and the increasing demand for shipping has had a dramatic influence on port and terminal business models and operations, e.g. importance of efficient ports. Large ports, such as Port of Rotterdam, Port of Singapore and Port of Hamburg have redefined the sea freight logistics through the adoption of various emerging technologies such as Artificial Intelligence, Blockchain (Vincent Campfens and Charles Dekker, 2018), Cloud Computing and Internet of Things (Heilig et al., 2017d) (Carlan et al., 2017). However, there exist many small and medium size ports which play an important role in regional and national economies (Helminen, 2014). Due to the various reasons, such as lack of resources, small and medium size ports have a challenge in adopting technologies, such as those used by the larger ports. This report provides a description on Blockchain technologies and how "small" ports specifically those located in the South Baltic Region and are considered small. An analysis is further conducted in which advantages for adoption of Blockchain are presented, value creation is identified, and best practices are identified so as to understand what are the "do's and don'ts" are.

Blockchain and its opportunities in being used in sea freight logistics and specifically from a port-centric perspective is arguably still not clearly understood or a strong hesitation from the industry exists due to its unclear values. This report will provide the most current findings and results from available sources. Therefore, the "*state – of – the – art*" on the application of Blockchain is not comprehensive as new methods and technologies are being developed and/or applied. The authors have strived to present the most accurate data and information in this report by taking ethical research considerations during the research and in the publishing of the results.

1.2 What is Blockchain?

Since its inception by a person or perhaps a group of people by the name of Satoshi Nakamoto in 2008, the use of Block and Chain have been popularized as Blockchain. Satoshi Nakamoto improved the design of Blockchain by introducing technological solutions, such as a *hashcash*-like method in which Blocks could be added to a Chain without requiring them to be signed by a trusted party. A very well – known example of Blockchain is the cryptocurrency known as Bitcoin, which possess a public ledger for all transactions in the network

The current literature does not provide any clear definition of Blockchain, since the technology is presented in several variances and applications. A Blockchain solution can be public and private, anonymous or based on user's reputation with a validation mechanism that can be centralized or decentralized. These are just few examples that show the broad spectrum of different technologies identified with the word "Blockchain". This confusion on the technology definition generates lack of understanding on the potential uses of Blockchain in port logistics as well as its real benefits. The first scientific problem in the field of the research is the evaluation of the fundamental Blockchain's properties that can be turned into applications in the field of logistics. The idea at the base of the technology is the concept of "distributed transactional database" spread into different nodes of the network (Morabito, 2017). These nodes, which identifies different users, work together in the creation and storage of an encrypted sequence of transactional records, which is defined as "block" (Lemieux, 2016). The technology is expected to bring a substantial transformation in the logistic sector, based on the following characteristics:

- **Transparency:** Blockchain may prevent the creation of organizational silos within existing parties of the supply chain, enabling the different actors involved in the process to access the information. This feature leads to univocal, shared and real-time accessible pieces of information. Instead of having data buried in legacy silos, ERP or TMS, data are accessible in a distributed and decentralized way to supply chain members;

- **Traceability:** Blockchain is able to keep track of the different processes so that every supply chain member is able to produce or collect information about the product's lifecycle (supplier information, the manufacturing process information, logistics information and others). This not only provides a guarantee over the product's origins, but it also offers information about the requirement for the product's handling, transportation and storage. Finally, this feature enables an easier traceability of the causes and responsibilities for problems occurred in the process;

- **Security:** The information is stored in a ledger, which is a distributed data structure where transactions are organized in blocks (Kiayias et al., 2016). Each block is secure by encryption based on a hash mechanism so that the ledger becomes a proof-of-work puzzle. The access to information is based on a key system. Therefore, every member of the Blockchain, the so-called "node", is provided with a private key and a public key, which enable him to access the private information and the Blockchain respectively;

- **Built-in-trust:** The feature of encryption on which Blockchain is based represents the guarantee of trust towards the system. This enables the members of the Blockchain to bypass the third parties that serves as a guarantee of financial, physical and information transaction in today's supply chain. In logistics, this leads to the elimination of documents such as Bill-of-Landings, Letter-of credits and middlemen such as Freight forwarder and banks.

- **Real-time accessibility:** Blockchain provides to every user with authorization a real-time access to the information. This faster and broader access to information leads to speed-up the logistic processes and avoid bottle-necks. Benefits are not only related to the information flow, but also to the financial flow.

The implementation of Blockchain on port logistics opens the discussions on the efficiency and efficacy of the current port inter-organizational information systems. The implementation of Blockchain implies a change in the architecture from centralized to a distributed type. By using a decentralized approach, which modifies the current processes, proposes a new set of possibilities and business opportunities.

In work by Mattia Francisconi (2018), he states that "Blockchain is a relatively new technology and there is still misunderstanding on the potential applications and impact in the field. In this study, the Connect 2 Small Ports project, we adopt the concept of Business Model (BM) to evaluate small ports in the South Baltic region on the impact of technology, such as Blockchain. These concepts assist in evaluating ports by analysis of a Business Model Stress Testing, which is a tool to evaluate the robustness of a company's BM to external factors. This tool was introduced for the first time by De Vos (2012) as a tool to evaluate the robustness of a company's BM by evaluating the impact of a collection of alternative environments

To conclude, this research aims to fulfil the theoretical and practical research gap on Blockchain potential on port logistics. It plans to do that by providing an in-depth evaluation of the technology and the current market applications to clarify the use-cases in port logistics. Moreover, this research aims to identify the technology's role at port inter-organizational information system by assessing its potential in terms of information and physical flows optimization.

2 GLOSSARY OF TERMS

Term	Abbreviation	Description
Terminal operating System	TOS	Software system for managing the operations and processes in a terminal (container, bulk, RoRo, ferry, etc.)
Port handling equipment	PHE	The machines and physical equipment that are located in a port or terminal for handling cargo, such as bulk, container, RoRo, etc.)
Position detection system	PDS	Navigation system for measuring PHE position in real-time
Middle-ware		Software layer between TOS and PHE control system (see ECS)
Equipment Control System	ECS	Software that monitors and controls all events and processes at equipment level
Shuffle move		When a container is requested under another container, the topmost container must be moved (usually a short distance)
Straddle Carrier	SC	PHE
Rubber Tired Gantry crane	RTG	PHE
Rail Mounted Gantry crane	RMG	PHE
Automatic Stacking Crane	ASC	PHE
Ship-to-shore crane	STS	PHE
Terminal Tractor	TT	PHE

Automated Guided Vehicle	AGV	Unmanned vehicle for transporting containers, traditionally a flat-bed vehicle
Tier		The height (1…N) of the container in a stack of containers
Differential GPS	DGPS	Satellite positioning device
Programmable Logic Controller	PLC	Computer in PHE
Horizontal transport		System for transporting containers from STS to stacking area. May be e.g. TT, SC, AGV

3 SCOPE OF RESEARCH WORK - WHAT IS A PORT?

Since port, seaport, terminal and container terminal are terms often used interchangeably in research papers and discussions, an attempt is made to clarify the terminology. A *port* can be seen at first hand as a place to or from where goods may be shipped. The use of ports has long been associated with maritime trade and the use of ships to carry cargo. The advent of rail roads, automobiles, and airplanes associates the mode of transport using the port, i.e. airport, seaport. A *terminal* is a specialized part of the port that handles a particular type of goods, e.g. cars, containers, wood, people, etc. The situation today must reflect the change in institutional structures where port authorities are granting concessions to stevedoring companies to operate terminals (e.g. bulk terminals, container terminals, RoRo terminals, etc.) independently and competitively within the port area.

The primary aim of port and terminal managers is to develop strategies that improve customer satisfaction and the terminal's competitive position. The main functions of the terminal management are the *planning* and *controlling* of operations. Terminal management is often driven by tradition rather than theory, thus being conservative with respect to adopting new ideas or technologies. The management of a terminal can affect the choice of ship lines to use a particular terminal. Thus, it is imperative that the terminal management is able to satisfy its customers, such as minimizing the time that a ship spends berthed at a terminal. To shorten this time, terminal managers spend special effort in increasing the productivity in terms of cargo crane moves per hour, which is regarded to be one measure of port terminal performance.

The increasing complexity of terminal operations requires management to decide allocation of resources but also the sequence and timing of operations. Due to tradition and outdated practices, the management of a port terminal or port is often fragmented, with differing organizations handling specific tasks within the terminal. Through interviews and port visits we observed that many terminal managers are often faced with these types of problems, which are further supported in research articles, e.g., (Choe, et al. 2016, de Gijt 2010, Gambardella et al. 1998, and Frankel 1987, Legatto, et al. 2017).

- lack of planning
- not enough delegation
- ad hoc planning

- little insight in terminal operations
- lack of unity of control

The choice of organizational structure has been observed by Cullinane et al. 2002 to affect the efficiency and ultimately performance of a terminal. The most common structure in port and terminal management is a 'unity of command', where key decisions are made by a single manager or group of terminal managers (Cullinane et al. 2002). The development of specific departments leads to specialists in planning, e.g., ship planners, yard planners, and resource planners. The decisions made by port and terminal management demands an understanding of customer service requirements, such as:

- *Performance* – fast ship service ('turn-around') time,
- *Reliability* – predictable performance,
- *Cost* – desired to be competitive and predictable,
- *Quality* – no waste or damage during operations, and
- *Adaptability* – capacity of port terminal operators to implement solutions, i.e., changes to shipping line schedules and fulfil other customer requirements.

Additionally, terminal managers must understand their resource availabilities, operating costs, and other constraints, such as schedules, budgets, regulations, and the objectives of the terminal (Frankel 1987). The main objective for many terminals is cost leadership and terminal competitiveness. Through improving productivity, many terminals seek to gain cost leadership, since terminal costs according to Persyn (1998), are significant to the total costs of shipping goods. According to Frankel. (1987), port costs can be in excess of 50 percent of the total costs and where 55 percent of these port related costs are the result of poor ship turn-around times and low cargo handling speeds, which are strong determinants for consideration on using Blockchain solutions. In this study, the following types of ports are studied: Container, Bulk/ Liquid Bulk, Multipurpose, RoRo and Ferry.

3.1 Container Terminals

With the increasing cargo shipments every year, the container terminals have had to keep up with the demands. The container terminal is viewed not as a passive point of interface between sea and land transport but as the natural point of intermodal interchange. They have become logistic centres acting as 'nodal points' in a global transport system. This means efficient container terminal logistic operations and processes are a need for every container terminal to maintain the business (Voss et al., 2004). Ports such as Antwerp, Rotterdam, and Hamburg are expanding their terminals or creating new terminals to accommodate the projected rise in number of containers. Due to increases in speed and volume, the operations of a container terminal require a better regulating systems approach. Research results in AI, Blockchain and IoT, could answer some of the container terminal challenges, enabling a sustainable improvement of the terminal's capacity and performance, e.g. increasing the performance without large investments for terminal expansion and new equipment. Congestion and increasing cargo dwell times is a common scene in many of the world's ports. Government authorities such as customs and health may delay containers from reaching their destinations due to inspections. Shipping lines are unconcerned if there is a poor terminal productivity, as long as their vessel sails on time. Terminal operators are trying to reduce or stabilize the cost per TEU (twenty-foot equivalent unit: container) handled and thus maximize profit. Complications in container terminal systems arise in having the various computer systems work together, ad hoc planning, ill-defined data and poor information. Currently, ports are seeking better ways in improving their productivity and offering logistical solutions to shippers of cargo. No longer are ports handling just cargo, but more and more they are becoming "*information handlers*", (Henesey, 2002).

3.2 Container Terminal Operations

In viewing a container terminal as a system, the following operations exist and are illustrated according to their location in Figure 1; Vessel; Berth, Intralogistics, Yard, and Gate. For a more detailed account of container terminal operations research, c.f. (Stahlbock and Voß, 2007).

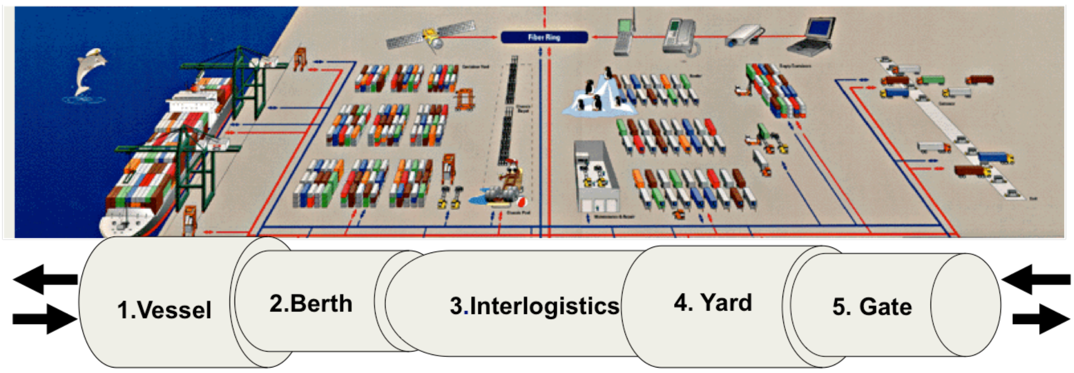


Figure 1. Operation Types in Container Terminal (Henesey, 2006)

Container Terminal Operations. A description of the following operations that exist in the movement of containers in and out of the container port is given as follows:

- **Vessel:** Synonymously used as the maritime interface where cranes handle vessels. Terminal operators experience problems in reducing the unproductive and expensive container moves. The number of cranes used to perform the operation varies depending on the size of the containership and the volume of containers to be handled. The vessel planning is typically executed 24 hours before a vessel call by the ship line. The plan includes a manifest, list of containers to be loaded or discharged.
- **Berth:** Each containership that arrives at a terminal will be assigned a berth and a location where a vessel can dock. The characteristics of a container berth are the length, depth, equipment (i.e. cranes), handling capacity, and service facilities.
- **Intralogistics:** Containers are moved from berth to the yard to be stacked or placed in an area for dispatch, or containers from the stack are delivered to the gantry crane at the berth to be loaded on a vessel. The import container information such as its number, weight, seal number, and other information are recorded along with the location identification to a central database, such as a yard system in the terminal. Depending on the operations, either yard tractors, front loaders, or straddle carriers are employed as transport in this operation. The export containers are transferred from a location in a stack, thus notifying a yard system that the location is free and will be given to a gantry crane to be loaded on a vessel.
- **Yard:** There exist three main types of storage systems: short term, long term, and specialized. Specialized storage is reserved for refrigerated, empty, liquid bulk, hazardous materials. The container storage system uses stacking algorithms in assigning a space for the container till it is loaded or dispatched.

- **Gate:** The interface to other modes of transport lies in this system. The managing of the gate is to obtain information of containers coming into the terminal so as to be properly physically handled before ship arrival and to release import containers before the arrival of trucks or rail. Controlling this access to the terminal is important in that it affects other parts of the container terminal system. The data collected for example are; container number, weight, port of destination, IMO number if hazardous, reefer, shipper, ship line, and seal number are used in deciding where to place containers for storage and later for loading.

3.3 Bulk Ports and Terminals - Dry Bulk/ Liquid Bulk Port

A bulk port or terminal comprises a berthing facility for loading or discharging of ships, marine works for the safe access and operation of ships, and land-based facilities for transit storage and the execution of related activities such as cleaning and blending.[1] Generally, the ship size determines the major features of a bulk terminal, since the basic ship dimensions have a direct influence on marine works.

There exist different classifications of bulk terminals according to their physical characteristics – berthing facility. Firstly, the offshore bulk terminals, which are mainly used in case of crude oil handling. Since the related berthing[2] facility is usually exposed to waves, currents and winds, its utilization depends on the allowable ship movements during the loading or unloading operations. Hereby, the major physical characteristics are determined by the degree of cargo fluidity. Liquid cargoes can be handled through flexible pipes allowing the ships to transfer their cargoes in relatively unsheltered waters. Secondly, the onshore terminals, which are mainly used for dry bulk handling, are associated with large breakwaters, huge locks and extensive land requirements.[3] [4]

Today, modern bulk terminals are often constructed away from major urban centres, because the required land and open spaces are quite often not available or not cost effective. Furthermore, they have evolved from being general purpose facilities to highly specialized and highly mechanized facilities, that are equipped to very efficiently handle only one type of cargo – liquid or dry bulk. (Caribbean Maritime Institute, 2002). The most common bulk commodities are crude oil, iron ore, coal, bauxite, alumina, phosphate rock, wheat, maize, soybeans, and barley.[5]

Dry Bulk Ports suggests that these are ports that handle bulk cargo, such as coal, ore, timber, etc. Bulk cargo is described as a commodity cargo that is transported unpackaged in large quantities. Dry bulk cargoes, which need to be kept dry, since any moisture that finds its way into the cargo could ruin the entire load, at considerable cost to the ship owner. Many dry bulk cargoes are classified as 'Dangerous Goods' that require special attention during loading, transportation and discharging, as they could shift during shipment and cause ship instability. Dry bulk terminals are used all around the world to handle large quantities of bulk commodities. In order to carry out these operations, certain technologies and machineries are necessary. Dry bulk commodities are cargos which may be loose, granular, free-flowing or solid – such as: grain, coal and ore; and are shipped in bulk rather than package form. (TransportationDictionary.org, 2008). Worldwide the main dry bulk goods in 2016-2017 were iron ore, coal and grain. Furthermore, a dry bulk terminal is a port facility specialized in

[1] Bulk Terminal (Samantha Masters, Mark Butler, 2015)
[2] Any dock, pier, jetty, quay, wharf, marine terminal or similar structure (whether floating or not) at which a ship may tie up.
[3] Development and Improvement of Ports / Development of Bulk Terminals (UNCTAD Secretariat)
[4] Review of Maritime Transport, United Nations (2018)
[5] Development and Improvement of Ports / Development of Bulk Terminals (UNCTAD Secretariat)

the handling, storage and control of dry bulk cargo to and from various transportation modes. (The Great Soviet Encyclopaedia, 1979). On the other hand, the handling (loading and discharging) of dry bulks often requires calm waters, usually provided by breakwaters, which represent quite expensive infrastructure investments, so that berthing facilities are often located onshore.[6] The majority of small and medium sized seaports in the SBSR focus on the handling of dry bulk.

Bulk ports can be referred to as facilities that handle material in either liquid or granular, particulate form, as a mass of relatively small solids, such as petroleum/crude oil, grain, coal, or gravel. Often, at Bulk ports, the cargo is usually dropped or poured, with a spout or shovel bucket, into a special built ship called a bulk carrier ship, which is then transported inside a bulk ship's hold, railroad car/railway wagon, or tanker truck/trailer/semi-trailer body. Smaller quantities (still considered "bulk") can be boxed (or drummed) and palletized, such as sawed timber or paper rolls (c.f. Figure 2). Bulk cargo is classified as either liquid or dry. Often characterized is that dry cargo and bulk ports or terminals are considered as an integrated part of a full logistical chain, e.g., the source area to the port, on to marine transport and ultimately to the recipient.

Figure 2. Bulk ship being loaded with paper at Dry bulk port. Photo courtesy by L. Henesey (2006)

Similar to bulk ports and terminals are ports that cater to the loading and discharge of liquid cargo, called liquid bulk and chemical ports or terminals. Liquid bulk cargoes include – for instance – crude oil, liquefied natural gas (LNG) and chemicals. They are poured into and sucked out of large tank spaces, known as the holds of a tanker. Liquid bulk cargoes also call for pipes, pumps and sometimes ponds, which give the terminal a distinct shape.[7]

Liquid bulk ports provide an essential link in the supply chain for the Oil & Gas and food industries. Liquid bulk terminal design and maritime facilities are often related to the experience of oil/gas and chemical terminals, such as the example in Figure 3, which shows a liquid LNG carrier at the port of Klaipeda, Lithuania. The experience of many bulk ports and terminals along the BSR is that they are often designed as maritime structures for both storage and distribution facilities for crude oil and oil products, liquid chemicals and edible products.

[6] Dry Bulk Terminal Technologies, Safety and Security (2015)
[7] Development and Improvement of Ports / Development of Bulk Terminals (UNCTAD Secretariat)

Figure 3. Photo of Liquid port handling LNG. Photo courtesy of Port of Klaipeda, Lithuania

The operation of bulk terminals is dominated by the need to minimize the berthing time of vessels in the port. Accordingly, a continuous flow of cargo is aimed. Since the overall performance of a handling system is governed by the element having the lowest performance, all parts of the system should be designed to allow the ship loader or unloader to work at its full potential.

The movement of cargoes on a continuous basis allows a handling system to work at its full potential all the time. This is achievable in case of liquids, where pipes and pumps are used. However, in case of dry bulks, the execution of activities exhibits a discontinuous nature – evoked by necessary grab, sample and weighing activities – which leads to spare capacity in some elements of the handling system for most of the time.[8]

3.4 Multipurpose Port

The Baltic Sea Region has over 200 ports of which many are considered to be multipurpose. Multipurpose often serve two or more traffic types and/or cargo types, such as bulk, container and or RoRo on the same port or terminal. An example is that of a liner ship that obeys a schedule and calls on a port on a set time whereas tramp ship arrives at random and can be served elsewhere on the port. In addition, with increasing vessel sizes, high volatility of cargo volumes, stronger competition and an increased demand for supply chain integration, ports are required to adapt. Thus, the flexibility of handling various types of ships and cargoes provides multipurpose ports and terminals a particular challenge to ports and terminals that have decided to specialize on a certain cargo type. For small traffic volumes of cargo, multipurpose terminals can help in reducing the underutilization of a port due to traffic randomness and variability of ship service time. Multipurpose ports seek to optimize their activities and efficiently serve different categories of vessels carrying various types of cargo, being often confronted with limited space. Dealing with a dynamic port landscape and ensuring that all related activities are performed efficiently often requires strategic adaptation.

[8] Bulk Liquid Cargo Management Guideline (2016)

Figure 4. Photo of Multipurpose port highlighting the handling of 3 types of cargo: Liquid, Bulk and RoRo. Photo courtesy of Port of Karlshamn

A. RoRo, RoPax and Ferry

Roll-on/roll-off (**RORO** or **ro-ro**) is when cargo is "rolled on or rolled off" from and to a ship. The vessels are designed to carry cargo that is wheeled, such as cars, trucks, railroad and project cargo on trailers that are driven on and off the ship on their own wheels or using a truck. As the RoRo vessels have either built-in or shore-based ramps that allow the cargo to be efficiently rolled on and off the vessel when in port this often viewed as a lease expensive port investment when compared to container operations. While smaller ferries that operate across rivers and other short distances often have built-in ramps, the term RORO is generally reserved for large oceangoing vessels.

RoPax, which means RoRo with passengers, features include RoRo capabilities (carriage of private vehicles, commercial vehicles, trucks, trains, and other types of cargo) with the addition of space for a large number of passengers that enter on foot. This variety of cargos impose additional technical and passenger safety requirements for terminals due to the different construction of RoPax ships as compared to RoRo. Competition between ports and with other modes of transport drives system performance.

When analysing the operations in a seaport there are a large number of interrelated variables to be considered, which makes it advisable to consider terminals as continuous production systems, made up of a succession of separate stages or subsystems where each must be optimized in order to increase the global performance and to avoid any possible bottleneck. This kind of approach to the terminal's operation allows focusing on each single process separately and helps understanding, improving, and ultimately, determining the capacity of each subsystem and the terminal as a whole as most authors, such as Henesey et al. (2003), consider that the operation of a terminal can be divided into four main subsystems, which roughly correspond to the distinct physical areas in the terminal: loading/unloading from/to ship to/from shore; transfer (from berth to storage area); storage; and delivery and receipt - all depending on the kind of traffic/terminal being dealt with.

RoRo terminals can be considered that a division into three subsystems instead of the more common four would suffice, since transfer time when loading/unloading is greatly affected by the storage configuration, making it difficult to approach separately the three subsystems on their own. In fact, RoRo terminals are characterized by, among other aspects, the shorter stay of the platforms in the terminal's premises as well as the unique feature that the cargo can move by its own means. In short, the three subsystems considered will be: berthing and stevedoring; storage; and delivery and receipt (as shown in Figure 5).

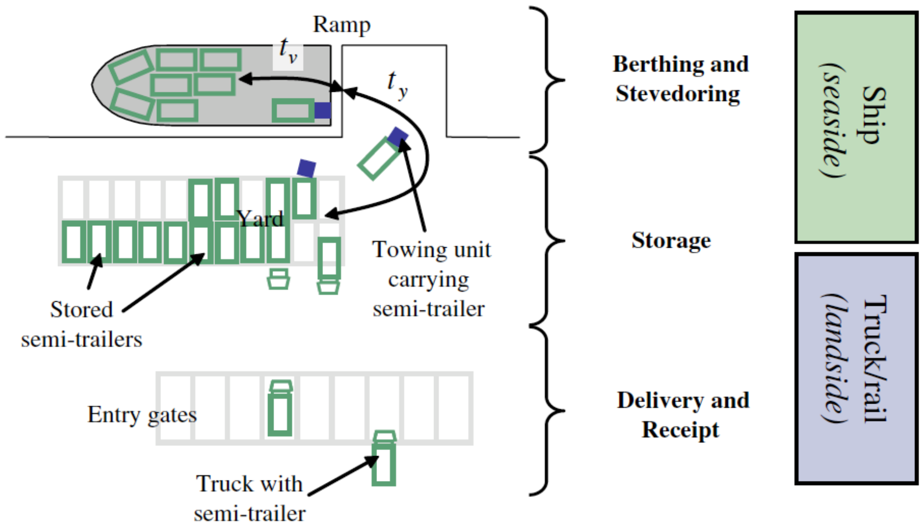


Figure 5. Operation Types in RoRo Terminal (Morales-Fusco, et al. 2010)

Increased complexity of this system is observed due to entwined cargo and different stakeholders e.g. port owner, ferry companies, shipping companies, and private customers. Those stakeholders often have different objectives, interests, and priorities. Special attention to operations of port terminals is required as they were identified by **(Morales-Fusco, et al. 2010)** as the weakest point of supply chains. Reliable RoPax/RoRo terminals are vital components, influencing their competitiveness within multimodal supply chains, while their resilience should allow for a quick response to any disruptions of services. As an example, the workflow for RoRo operations is presented in Figure 6, which indicates that many (often simultaneous) operations and processes are executed.

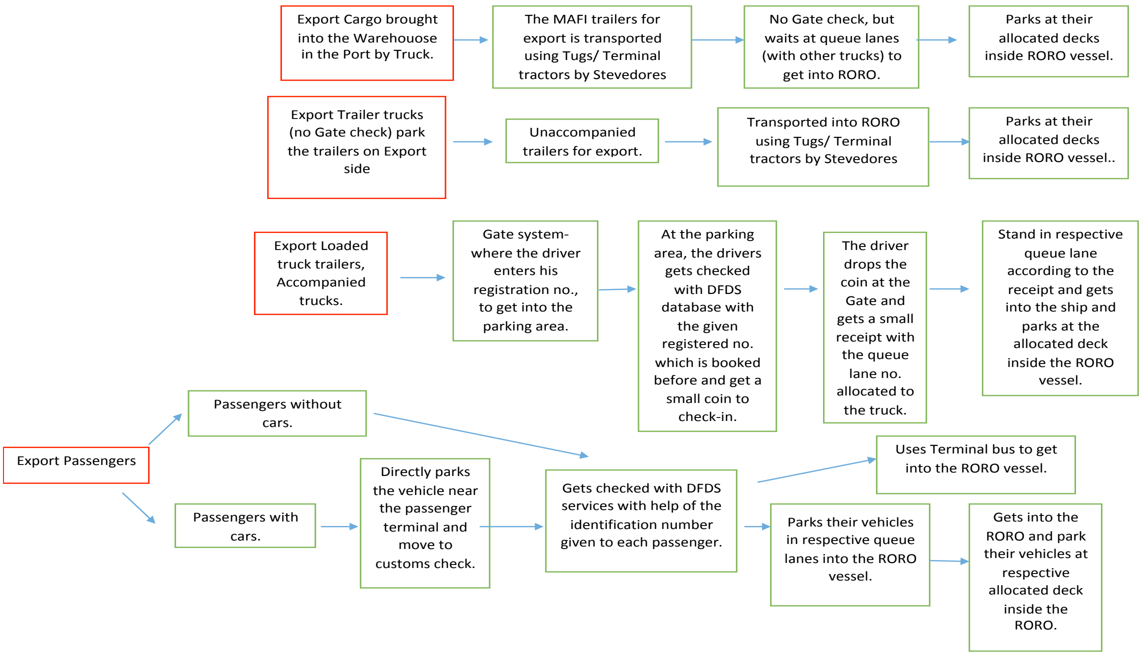


Figure 6. Example of the workflow operations for a RoRo / RoPax (Henesey 2019)

The management of RoPax system may have limited information about actions, ongoing development plans, and constraints on the complementary side of the system i.e. ports and ships. This may lead to friction and lack of trust between stakeholders. Despite that, all service providers of short sea shipping should have a great interest in collaborating to create a good image and reputation for the service. Failure to providing competitive services because of focus on quick profit and lack of necessary investments can hurt long-term demand. RoRo, RoPax and Ferry businesses should realize that providing superb services in comparison to competing modes of transportation is their path to success. Due to the growth of RoRo, RoPax and Ferry services in large depends on quality and satisfaction for their customers, system managers need to learn how to provide reliable, high quality services. This in turn can facilitate the long-term sustainability of their business. The RoRo, RoPax and Ferry ports seeks to have flawless interaction between port/terminal and ship operations as seen in the various loading configurations in Figure 7 and Figure 8.

Figure 7. Photo of RoRo Ramp
Photo courtesy of Port of Karlshamn

Figure 8. Photo of RoRo vessel
Photo courtesy of Port of Karlshamn

3.5 Port and Terminal Processes

In the operations of ports there exist many processes that are required in the execution of operations. The major processes that are identified to be important for the efficient handling of cargo is the following:

- **Documentation.** During freight transport verification and validation of the status of the shipments, handover of responsibility, custom documents etc. are exchanged.
- **Tracking and Tracing.** The location and identification of assets is equally important to the location of cargo itself. Improved visibility of assets, such as the equipment to handle the cargo/containers and people leads to higher productivity when such information is considered in moving cargoes
- **Sorting and Processing.** As a system, the ports and terminals are constantly sorting incoming and outgoing containers and cargo based on defined criteria and rules. To enable the port and terminal management to efficient control the various operations, a number of processing tasks are required that demand expert knowledge and/or the use of computer systems in executing desired decisions.
- **Resource Management.** Various specialized equipment types are used to handle various cargo, such as bulk, cars, containers, wood and other cargo. For many operators the objective is the efficient of use of equipment, number of workers and other resources in order to minimize costs whilst obtaining high performance.
- **Scheduling.** It is an ongoing process in ports affected by many variables that are often not controllable, such as: weather, strikes, congestion or traffic. For instance, the scheduling of arriving cargos with vessel calling requires coordination with the schedule of related yard operations and availability of the labour for moving cargo and containers.
- **Integration of Process Optimization.** Often viewed by port and terminal as a “holy-grail” is the decision making that takes into account the multitude of actions and processes to decide on the physical movement of a cargo by a PHE from one location to another with minimal costs. Various IT systems are deployed in assisting port and terminal management in trying to integrate the processes with the operations.

The described operations and processes often characterize the activities existing in major terminals and ports worldwide. As a result, many major ports and terminals often have dedicated IT staff or departments, this provides advantages in terms of being more competitive than smaller ports. In the distribution of digital technologies for transport, such as Blockchain and IoT, small and medium ports and their service portfolios are argued to be very limited, not shared and not integrated on the cross-border level. A recent European Union financed study that was conducted, the Connect2SmallPorts project, generated results that concluded very differing levels and meanings of digitalization in ports, e.g. ports of Wismar - Germany, Karlskrona - Sweden and Klaipeda- Lithuania. Most of the small and medium ports still pursue the classical infrastructural path without any clear vision and digitalization strategy. The development for future port and container transportation is a big challenge for such small and medium size ports.

4 METHODOLOGY

A structured approach is adopted in conducting this study in order to clarify how the results were obtained and their implications for ports considering Blockchain technology. In Table 3.1 provides a description of the methodology applied in this study. First, a literature review was conducted and is presented in section 5 of this report. A narrow review on ports and blockchain was performed through a structured questionnaire administered on port officials representing ports in the South Baltic. The results from the two methods are used into a framework, called SWOT – Strength Weakness Opportunity Threat.

The impact of Blockchain on port logistics is evaluated by defining a number of KPIs- Key Performance Indicators into defined case studies for analysis, while the impact on the port's business model identified performing a business model stress test analysis.

Table 1 – Research Methodology

Method	Objective	Related Questions	Input	Result
Blockchain Literature Review	Qualitative analysis on current understanding on the topic of Blockchains and application to ports	What research has been published and what gaps exist in our understanding.	Survey of published peer reviewed scientific literature.	Theoretical Foundation.
Port Interview & Blockchain Questionnaire	Qualitative and Quantitative methods for obtaining direct and up-to-date information	Clarification and Confirmation with experts from the domain.	Semi-structured interviews and questionnaire for eliciting empirical data.	What are the impacts of Blockchain?
Port Business Case Evaluation	Design and testing the impact of Blockchain on port flows	What are the potential use cases for using Blockchain in ports and what are the KPIs to use for evaluation?	Review of (a) literature survey and (b) interview and questionnaire in developing the cases.	A number of use cases are identified in using Blockchain.
SWOT Analysis	Evaluation of the port business model components and Blockchain's impact on them.	What is the current port business model and how can it be adapted for Blockchain implementation?	Validation of Business Case Evaluation by domain experts on use cases.	Port business cases are identified and tested for accuracy and practicality.

5 BLOCKCHAIN LITERATURE REVIEW

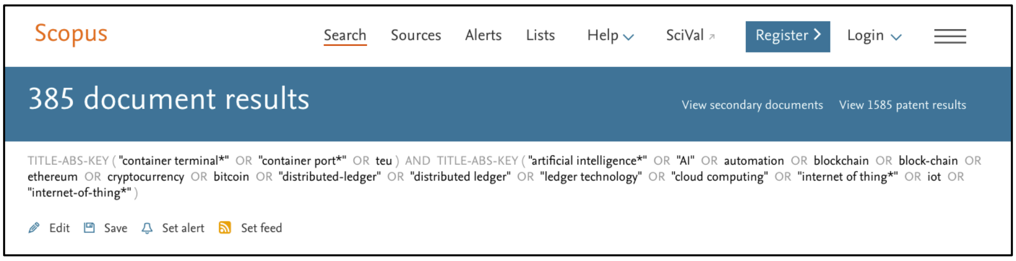
In conducting the literature review in this study, the papers were filtered at different stages of the literature survey that is described in Table 1 on the next page. As part of Stage 1, the metadata from the two databases was stored in Microsoft Excel sheet and exclusion criteria 1-3 (listed in Table 1) were applied. After manual exclusion at the end of Stage 1 there were a total of 123 articles (out of 398). In Stage 2, exclusion was based on criteria 4 and this was manually removed studies by screening the abstracts. At the start of Stage 3, 96 articles were studied during this selection process to distinguish literature in which the focus was on ports and digitalization. Exclusion criteria from 5 to 7 were applied and studies that had main topic, such as tugboat planning etc. were removed as well as papers that did not have a main focus on technology such as discussed in Section 3.1. The result of the selection process yielded 64 articles.

Table 1 - Exclusion Criteria for Systematic Literature Review

Exclusion Number	Criteria
Exclusion 1	Exclude studies not available in English
Exclusion 2	Exclude studies except journal articles, conference papers and book chapters.
Exclusion 3	Remove duplicates
Exclusion 4	Exclude papers in which seaport or terminal is not the core topic
Exclusion 5	Exclude papers that cover container terminal design aspects or shipside topics or post port gate operations
Exclusion 6	Exclude retracted papers
Exclusion 7	Exclude studies where technology perspective with respect to port or terminal is not touched such as calculation of mis-overlay of cargo remarshalling.

5.1 Search Synthesis and Classification Matrix

Since the focus is on operations management and processes in port terminals and ports, the literature survey synthesis was conducted based on a classification matrix proposed in Table 2, which includes different aspects of the port terminal or port. The horizontal axis is grouped into 4 categories: port terminal operation types, port terminal processes, technology type and research type. The vertical axis lists the authors of the publication. For example, in Figure 9, screen shots from World of Science database and SCOPUS database are presented in which shows the key words used and actions taken in identifying papers to be reviewed.



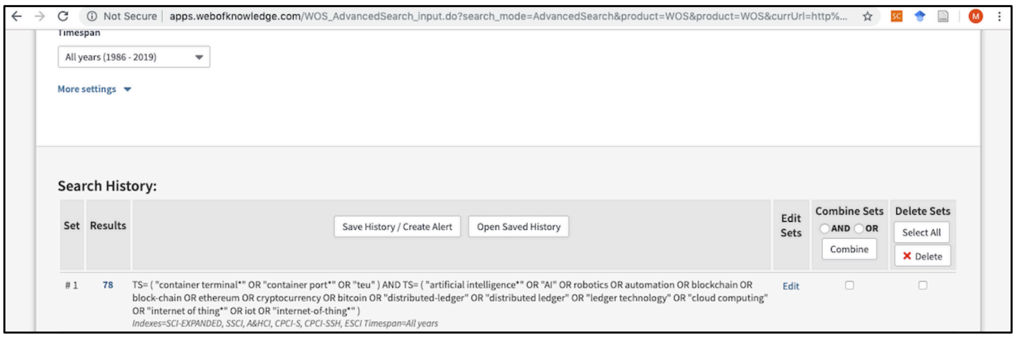


Figure 9. Screen shot of SCOPUS and World of Science (WoS)

The attributes in the operation group include vessel (or shipside) operations, intralogistics operations, berth/quay operations, yard operations and the operations at gate. The attributes in port terminal processes include documentation (such as custom documents or bill of lading), tracking and tracing of cargo and other equipment, sorting and processing of cargo in the yard, resource management for equipment and space, scheduling of operations and resources and if the study advocates integrated process optimization. Technology type records data on the four technologies that are focus of this study: AI, Blockchain, Cloud Computing (CC) and IoTs. The research type has attributes for research methodology and for the validation type of the study (Deployed or not). All the attributes of the classification matrix can have either, Yes (Y) or No (N), except description of the research methodology with can have either of these options: Design, Model, Simulation, Experiment or Implementation. The classification chart presents the quantitative visualization of the data extracted from the selected studies under survey. It helps in categorization and comparison with other primary studies. The matrix is scalable in terms of adding new attributes such as another technology type.

5.2 Literature Review Results and Analysis

In the graph presented in Figure 10, it shows an overview of the 64 selected studies with respect to the distribution over the years and the contribution in terms of the technology discussion. A noticeable trend observed was that an increasing interest in technology publications over last 3 decades around the shipping port sector of which 78% of the articles were written in the last 10 years (2009 - 2018).

Table 2 - Research Classification Matrix

	Operation Types					Process Type						Technology Type				Research Type	
Author	Vessel	Intra-logistics	Berth	Yard	Gate	Document-ation	Tracking / Tracing	Sorting / Processin g	Resource Management	Scheduling	Integrated Process Optimization	AI	Block-chain	CC	IoT	Method	Deployed
Hoseini S.F., et al.	Y	Y	Y	N	N	N	N	N	Y	Y	Y	Y	N	N	N	Model	N
Kearney A., et al.	N	N	N	N	N	N	N	N	N	N	N	N	Y	N	N	Review	N
Ndraha N., et. al	N	N	N	N	N	N	Y	Y	Y	N	N	Y	Y	Y	Y	Review	N
Sturmanis A., et al.	N	N	N	N	N	N	N	N	N	N	N	N	Y	N	N	Review	N
Li S., et al.	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Review	N
Tierney et. Al	Y	Y	N	N	N	N	N	Y	Y	N	N	Y	N	N	N	Simulation	N
Legato P., Mazza R.M.	N	N	N	Y	N	N	N	N	Y	N	Y	Y	N	N	N	Simulation	N
Hill A., Böse J.W.	N	Y	N	Y	N	N	N	N	Y	Y	N	Y	N	N	N	Experiment	N
Liu Y., Shahbazzade S.	N	Y	Y	Y	N	N	N	N	Y	Y	Y	Y	N	N	N	Experiment	N
Myriam Gaete G., et al.	N	N	N	Y	N	N	N	Y	Y	Y	N	Y	N	N	N	Simulation	N
Castilla-Rodríguez I., et al.	Y	Y	Y	N	N	N	N	Y	Y	Y	N	Y	N	N	N	Simulation	N
Li M.-W., et al.	N	Y	Y	N	N	N	N	N	Y	Y	Y	Y	N	N	N	Simulation	N
Heilig L., et al.	N	Y	N	N	Y	N	Y	N	Y	Y	Y	Y	N	Y	N	Experiment	N
Supeno H., et al.	N	Y	N	Y	N	N	N	N	Y	Y	N	Y	N	N	N	Simulation	N
Huang Q., Zheng G.	N	Y	N	Y	N	N	Y	N	Y	N	N	Y	N	N	Y	Simulation	N
Niu B., et al.	N	Y	N	Y	N	N	N	N	Y	Y	N	Y	N	N	N	Experiment	N
Choe R., et al.	N	Y	N	Y	N	N	Y	Y	Y	Y	N	Y	N	N	Y	Simulation	N
Tsertou A., et al.	N	Y	N	N	Y	N	Y	N	Y	Y	Y	N	N	Y	N	Design	N
Chafik R., et al.	N	N	N	Y	N	N	N	Y	Y	N	N	Y	N	N	N	Model	N
Singgih I.K., et al.	Y	Y	Y	N	N	N	N	N	Y	Y	Y	Y	N	N	N	Model	N
Li Q., et al.	N	Y	Y	Y	N	N	Y	N	Y	N	N	Y	N	N	N	Simulation	N
Heilig, et al.	N	Y	N	N	Y	N	Y	N	Y	Y	Y	N	N	Y	N	Prototype	N
Duinkerken M.B., Lodewijk	N	Y	Y	Y	N	N	Y	N	Y	Y	N	Y	N	N	N	Simulation	N
Kocifaj M., Adamko N.	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	N	N	N	Simulation	N
Heilig, Leonard; Voss, Stef	N	Y	N	N	Y	N	Y	N	Y	Y	Y	N	N	Y	N	Design	N
Chen L., et al.	N	Y	N	Y	N	N	Y	Y	Y	Y	N	N	N	N	Y	Simulation	N
Lalla-Ruiz E., et al.	N	N	Y	N	N	N	N	N	Y	N	N	Y	N	N	N	Simulation	N
Shetty R., et al.	N	Y	N	N	Y	Y	Y	N	N	N	N	Y	N	N	Y	Model	N
Rodriguez-Molins M., et al.	N	Y	Y	N	N	N	N	N	Y	Y	Y	Y	N	N	N	Experiments	N
Rodrigues L.M., et al.	Y	Y	Y	N	N	N	N	Y	Y	Y	N	Y	N	N	N	Simulation	N
Zhang C., et al.	N	Y	N	Y	N	N	N	Y	Y	Y	Y	Y	N	N	N	Experiment	N
Shi X., et al.	N	Y	N	N	Y	N	Y	N	N	N	N	Y	N	N	Y	Survey	N
Salido M.A., et al.	N	Y	Y	Y	N	N	N	Y	Y	Y	Y	Y	N	N	N	Simulation	N
Ngai E.W.T., et al.	N	N	Y	Y	Y	N	Y	Y	Y	N	Y	Y	N	N	Y	Prototype	Y
Schütt H.	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	N	N	N	Design	N
Huynh N., Walton C.M.	N	Y	N	Y	Y	N	Y	N	Y	Y	N	Y	N	N	N	Design	N
Lee M.-T., et al.	N	Y	N	N	Y	Y	Y	N	Y	N	N	Y	N	N	Y	Design	N
Park T., et al.	N	N	N	Y	N	N	N	Y	Y	N	N	Y	N	N	N	Model	N
Choe R., et al.	N	Y	Y		N	N	Y	N	Y	N	N	Y	N	N	N	Simulation	N
Miguel A.S., et al.	N	N	Y	Y	N	N	N	Y	Y	Y	Y	Y	N	N	N	Experiments	N
Zhang X., et al.	N	N	N	Y	N	N	N	Y	Y	Y	N	Y	N	N	N	Simulation	N
Park T., et al.	N	N	N	Y	N	N	N	Y	Y	Y	N	Y	N	N	N	Simulation	N
Kim K.H., Lee J.H.	N	Y	Y	Y	N	N	N	Y	Y	Y	Y	Y	N	N	N	Simulation	N
Zhu M., et al.	N	Y	Y	N	N	N	N	N	Y	Y	Y	Y	N	N	N	Simulation	N
Guo X., et al.	N	Y	N	Y	N	N	N	Y	Y	N	N	Y	N	N	N	Simulation	N
Salido M.A., et al.	N	Y	Y	Y	N	N	N	Y	Y	N	N	Y	N	N	N	Simulation	N
He J., et al.	N	Y	Y	N	N	N	N	N	Y	Y	N	Y	N	N	N	Simulation	N
Guiliang Z., Lina M.	N	N	N	Y	N	N	N	Y	Y	N	N	Y	N	N	N	Design	N
Salido M.A., et al.	N	N	N	Y	N	N	N	Y	Y	N	N	Y	N	N	N	Simulation	N
Yoo Y., et al.	N	Y	N	N	Y	Y	Y	N	Y	N	N	Y	N	N	Y	Model	N
Yan N., et al.	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	N	N	Design	N
Eun Y.A., et al.	N	Y	Y	Y	N	N	N	N	Y	Y	Y	Y	N	N	N	Simulation	N
Guo X., et al.	N	Y	Y	Y	N	N	Y	N	Y	Y	Y	Y	N	N	N	Simulation	N
Costa G., et al.	Y	Y	Y	Y	Y	N	Y	Y	N	N	N	Y	N	Y	Y	Model	N
Lokuge P., Alahakoon D.	N	Y	Y	Y	N	N	Y	Y	Y	Y	N	Y	N	N	Y	Design	N
Chowdhury M.A., et al.	N	Y	N	N	N	Y	N	N	Y	N	Y	Y	N	N	N	Design	N
Su W., Bo M.	Y	N	N	N	N	N	N	N	Y	Y	N	Y	N	N	N	Model	N
Choi L., et al.	N	Y	N	N	N	N	N	N	Y	Y	N	Y	N	N	N	Experiment	N
Su W., Bo M.	Y	N	N	N	N	N	N	N	Y	Y	N	Y	N	N	N	Experiment	N
Thurston T., Hu H.	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	N	N	N	Design	N
Vis I.F.A., et al.	N	Y	N	N	N	N	N	N	Y	Y	N	N	N	N	N	Design	N
Lee John C.M., et al.	N	Y	N	N	Y	Y	Y	N	Y	N	N	Y	N	N	Y	Prototype	Y
Gambardella L.M., at al.	Y	Y	N	Y	N	N	N	N	Y	Y	Y	Y	N	N	N	Simulation	N
Itmi Mhamed, et al.	N	N	N	Y	N	N	N	Y	Y	N	N	Y	N	N	N	Implementati	N

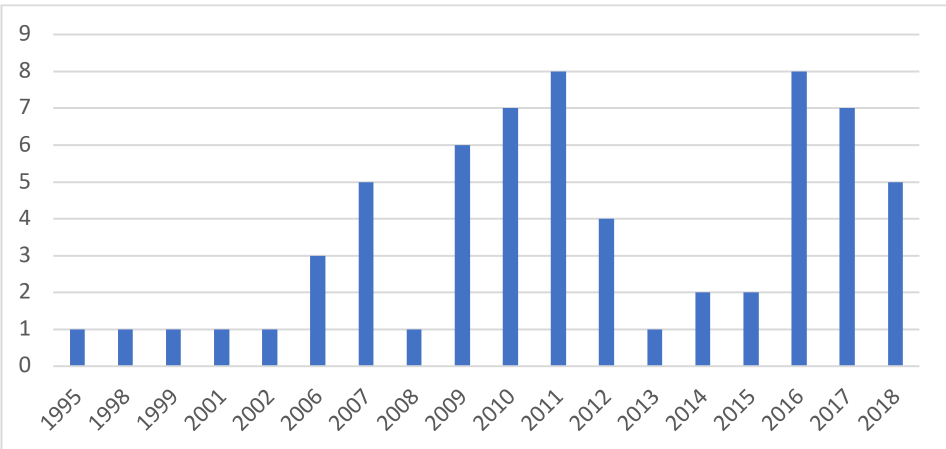


Figure 10. No. of papers published per year

5.3 Classification Matrix of Seaport Terminal Operations, Processes and Technologies

The classification matrix of 64 publications according to the suggested classification criteria described in Section 4.2 is presented in Figure 11 and Table 2. The use of exclusive values, such as Yes or No is explicit in showing what was or was not covered in the literature. No studies exist on the use of Blockchain in ports and port terminals using our systematic literature strategy. The analysis of studies related to AI and IoT are shared below.

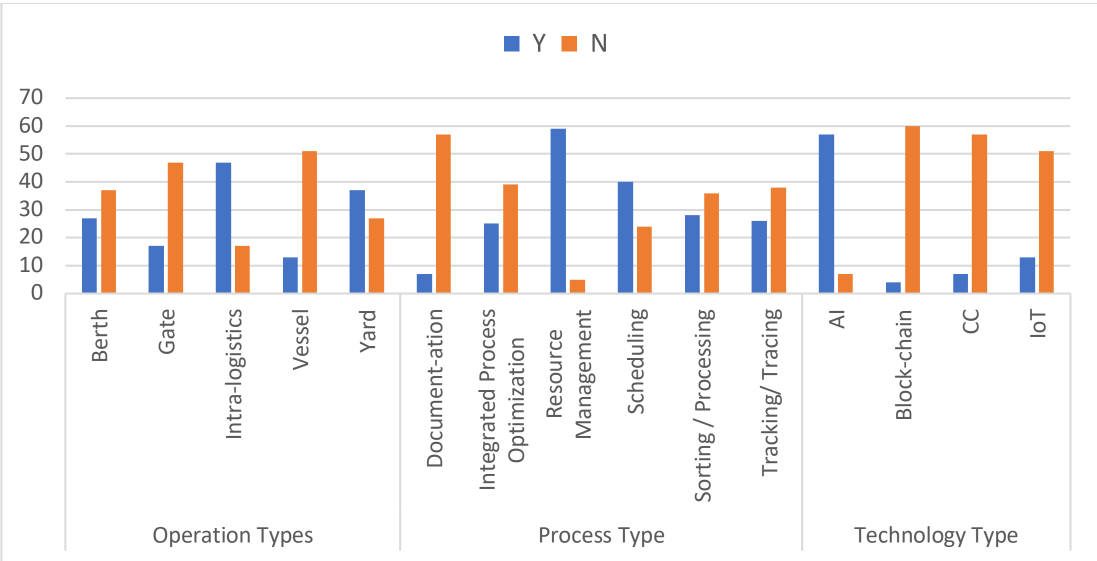


Figure 11. Classification matrix breakdown

5.3.1 Artificial Intelligence

Though, the reception of digital technologies, such as those highlighted in this study, in the sea port or terminal domain, has been slow, but it has been steady and evolving. In the end of 1990s, the researchers cantered their work on different issues faced by the planners and managers of the ports and terminals using different approaches. For example, for the issue of cargo stacking (Itmi et al., 1995) advocated the concept of a society of agents that are essentially entities or processes with goals. The authors suggest a cooperative mechanism whereby; the agents achieve cargo stacking via N-puzzle game. (Gambardella et al., 1998) dealt with the allocation of yard and cranes to the container by proposing a decision support tool for planning purposes. The authors used simulation to test the decision policies and compared with actual experiences. (Lee, 1999) contributed with a successfully implemented automatic character recognition system for identification of vehicle and container numbers.

5.3.2 Internet of Thing and Cloud Computing

With the progress from barcode and magnetic strip, now the radio-frequency identification (RFID) tag is used at container terminal gate to Check-in the truck and container (Yoo et al., 2009) (Lee et al., 2011). The RFID tag refers to the digital encoded label, which is linked with a software system that records the data. In the survey, papers are classified in the context of AI and IoT, as it lays foundation for Internet of things and enables automation. (Lee et al., 2011) refer to the use of smart RFID labels to track container journey in the terminal and suggest it being linked to the overall information workflow to assist in the documentation.

When it comes to use pervasive technologies like IoT and Cloud computing in ports and terminals, very few research work has been proposed in literature, e.g. (Lee et al., 2011), (Ngai et al., 2011), (Shi et al., 2011), (Chen et al., 2013), (Choe et al., 2016), (Huang and Zheng, 2016), (Tsertou et al., 2016), (Li et al., 2018), (Heilig et al., 2017b) and (Ndraha et al., 2018). All of the studies are theoretical, such as reviews on potential application of IoT in Port (Shi et al., 2011), (Lee et al., 2011) or in cold food chain shipment (Ndraha et al., 2018).

During the investigation, Cloud technology was found to be discussed more of an enabler for IoT and Blockchain. (Tsertou et al., 2016) emphasized for a cloud-based information portal for the stakeholders linked with IoT sensors for real-time information analytics. (Heilig et al., 2017c) shares an idea of having an integrative mobile cloud platform for real-time inter-terminal truck routing. (Costa et al., 2007; Heilig et al., 2017b; Heilig and Voß, 2014; Ndraha et al., 2018) relay the same concept of real-time information access from people to people and machine to people.

5.3.3 Blockchain

Three articles were located, all from 2018 that touched upon the concept of distributed ledger, Blockchain technology. One of them (Kearney et al., 2018) attempts to set up the framework for seaport stakeholders and policymakers for to enable innovation, such as by Blockchain, in the seaport sector. Also observed, is research in the cold food chain direction where use of Blockchain could help with temperature monitoring (Ndraha et al., 2018) of containers carrying fruits or vegetables. The authors bring into the limelight the demand of having centralized information platform for communication between people and containers and refer to the Blockchain technology to fulfil the requisite whereby making the information exchange between all objects (human and machines) more secure, fast and transparent. It is worth mentioning to point out the recent academic work (Sturmanis et al., 2018) around the challenges faced by the logistic community by the implementation of Blockchain technology.

6 PORT INTERVIEWS AND BLOCKCHAIN QUESTIONNAIRE

Based on interviews with small ports, we recognized that needs of small ports (majority SMEs) address rather infrastructure, missing technical and ICT interoperability and management issues. Having improved the technical base, small ports are able to develop softer skills and innovate. This is unfortunately not possible without clear joint infrastructure upgrade, which is missing at the moment. In contrast, core TEN-T Network ports have huge infrastructure and technical investments. In order to benefit from technical and infrastructural upgrade and to achieve interoperability among transport systems and small ports, to access other ports and hinterlands, there is a need for a common approach to be developed and shared. Here, different and common challenges and needs of small ports around the South Baltics should be focused on. Only if infrastructure needs can be shared among small ports, there can be achieved costly acceptable solutions for all of them. Additionally, by acting together small ports have better opportunities in attracting investments and surviving on global arena. Competition pressure is also rather to be lower when having common strategy.

INTERVIEW TEMPLATE:

Interviewer:

Name of the interviewer:

Name of the institution of the interviewer:

Interviewee:

Name of the Interviewee:
Position of the Interviewee:
Name of the Port:
Name and legal form of the organisation:
Name:
Legal form:
Address of the organisation:
City/town:
Postal code:
Country:
Street and No.:
E-Mail Address:
Date, duration and location of interview:
Date:
Duration:
Location:

Questions:

1. In your opinion, is this proposed research project of interest to your organisation?	
Yes,	78%
Somewhat	11%
No,	11%

2. Is your organisation solely responsible for port operations Y/N?	
Yes,	67%
No,	33%

3. Which of the following best represents your overall annual revenue in 2018?	
Less than € 5 million	49%
€ 5 million to less than €10 million	17%
€ 10 million to less than €20 million	17%
€ 20 million to less than €30 million	0%
€ 30 million to less than €50 million	0%
€ 50 million to less than €100 million	17%
€ 100 million to or more	0%

4. Who has direct responsibilities for managing the port?	
Port Authority	67%
Terminal Operator	11%
Ship Line / Shipping Company	0%
Port Agency	0%
Local Municipality	22%
Regional Authority	0%
National Government	0%

5. In which functional area do you work?	
Information Technology (IT)	34%
Sales	0%
Finance	0%
Administration	0%
Strategy	22%
Innovation	11%
Other.	22%
Marketing	11%

6. Is Blockchain a priority for your organization?	
YES	22%
Somewhat yes	34%
Indifferent	22%
Somewhat no	11%
No	11%

What is your level of agreement or disagreement with each of the following statements regarding blockchain technology?

7. Blockchain technology is broadly scalable and will eventually achieve mainstream adoption	
Yes	11%
Somewhat yes	0%
Indifferent	22%
Somewhat no	67%
No	0%

8. Suppliers, customers, and/or competitors are discussing or working on blockchain solutions to address challenges in the value chain	
Yes	12%
Somewhat yes	11%
Indifferent	33%
Somewhat no	33%
No	11%

9. Executive team believes there is a compelling business case for use of blockchain technology	
Yes	22%
Somewhat yes	22%
Indifferent	22%
Somewhat no	0%
No	34%

10. Planning to replace current systems of record (e.g., financial ledgers, CRM and ERP modules, inventory tracking systems, etc.) with blockchain	
Yes	11%
Somewhat yes	11%
Indifferent	22%
Somewhat no	22%
No	34%

11. Will lose a competitive advantage if we don't adopt blockchain technology	
Yes	22%
Somewhat yes	45%
Indifferent	11%
Somewhat no	0%
No	22%

12. Blockchain technology will disrupt our industry	
Yes	0%
Somewhat yes	34%
Indifferent	22%
Somewhat no	34%
No	12%

13. Blockchain is overhyped	
Yes	22%
Somewhat yes	11%
Indifferent	55%
Somewhat no	11%
No	0%

Which one of the following, if any, do you believe is the most significant advantage of blockchain over existing systems when thinking of your specific industry?

14. Greater speed compared to existing systems	
Yes	0%
Somewhat yes	45%
Indifferent	33%
Somewhat no	22%
No	0%

15. Maintaining current customer and supplier relationships.	
Yes	0%
Somewhat yes	67%
Indifferent	11%
Somewhat no	22%
No	0%

16. New business models and revenue sources	
Yes	45%
Somewhat yes	33%
Indifferent	11%
Somewhat no	11%
No	0%

17. Greater security/lower risk	
Yes	22%
Somewhat yes	34%
Indifferent	22%
Somewhat no	11%
No	11%

18. Lower costs	
Yes	11%
Somewhat yes	67%
Indifferent	11%
Somewhat no	11%
No	0%

19. None - no perceived advantages over existing system	
Yes	0%
Somewhat yes	22%
Indifferent	33%
Somewhat no	11%
No	34%

20. New Other/not sure	
Yes	22%
Somewhat yes	45%
Indifferent	22%
Somewhat no	0%
No	11%

21. Do you believe that a blockchain-based solution is currently more secure or less secure than systems built from more conventional information technologies?	
More secure	34%
Unsure	55%
Less secure	11%

22. Which of the following best describes your position in your organization?	
All Divisions and Employees Equally.	0%
Division E-Commerce, Marketing, or Sales.	11%
Chief Digital Officer (CDO) (or similar).	22%
Chief Information Officer (CIO).	11%
Cross-divisional team.	0%
There is no point of contact for digitalization.	22%
Other.	34%

23.Which of the following best describes how your organization currently views the relevance of blockchain to your organization?	
Critical – in our top 5 strategic priorities	0%
Important, but not in the top 5 strategic priorities	33%
Relevant, but not a strategic priority	33%
Unsure/no conclusion	22%
Will not be relevant	12%

24. Which of the following best describes your organization's position on participating in a blockchain consortium with competitors?	
Currently participate in one	33%
Likely to join one	33%
Considering forming our own	11%
Planning to go it alone	0%
Other/unsure	23%

25.Which area of your Port /company is making the key business decisions about its blockchain activities?	
IT	22%
The business as a whole (not one particular area)	22%
Innovation/R&D	11%
Finance	0%
Other/unsure	45%

26.Which blockchain model are you focusing your activities on?	
Permissioned blockchain	11%
Private blockchain (internal to your company)	0%
Public blockchain like Bitcoin or Ethereum	0%
Other/unsure	44.5%
None	44.5%

27. Which stakeholders outside your company are asking or engaging with you about your blockchain strategy?	
Suppliers	11%
Customers	11%
Partners	33%
Other/unsure	0%
None	45%

28.Which Port Customers are asking or engaging with you about your blockchain strategy?	
Cargo owners	0%
Agents	11%
Terminal Operators	11%
Shiplines	11%
None	67%

29.Which of the following blockchain use cases are you considering or working with?	
Supply Chain	0%
Internet of Things	22%
Digital Identity	22%
Digital Records	11%
Digital Currency	0%
Unsure	5%
None	10%

30.What is your current status on project related to or will be affected by Blockchain?	
Full Implementation	0%
Pilot Project	11%
Proof Concept	11%
Initial Planning	33%
None or not sure	45%

31.What Expected Benefits of Blockchain do you see over the Next Three Years?	
Increased efficiency	56%
Increased revenues	11%
Lower costs	11%
Ability to offer new products or services	12%
None or not sure	0%

32. Based on Information Technology tools, which are used in your organisation, what innovative tools are used and how do evaluate them according importance on a scale from 1(low) to 5 (high)?
Average = 2. TOS (5), SharePoint (2), E-Mail (5), HR-System (5), FiCo-System (5), QM-System (5). Port community system, Port SW, Radar system, CCTV, GIS, etc. Port infrastructure and navigational safety in ports and ports areas

33. Do you have investments in regard to Information Technology planned in the next FIVE year, if so, what are they?
Average: 55% yes will have investment plans that include Terminal system integrated with customers, Port Management System (TOS etc.), Single Window, Digital entry of cargo at the port or could not disclose. Nearly 33% had no plans with remaining 11% respondents starting they were not sure.

34. What Information Technology tools are you using, or you wish to integrate in the next FIVE years (e.g. Port Single Window, Port Community System, etc.)?
Average = 3. A new information/Communication technology and integration with customers. no plan yet. Port Single Window, Port Community System, etc

7 PORT BUSINESS CASE EVALUATION

In developing the use case for evaluation of Blockchain technologies in the port industry. A view is taken from other research and studies in which there exist three flows in port logistics: Information, Physical and Financial (Francesconi, M. 2018). In Table 3, a list of the three flows is presented and then evaluated to the task(s) at the port they are related to with a comparison to four types of activities identified for Blockchain applications: Cargo Documentation Transactions, Process Traceability, Trade Finance and IoT and Smart Contract Automatization.

Table 3 – Comparison and Evaluation of Port Case for Blockchain (c.f. Francescon, M. 2018)

Flow	Port Task	Cargo Documentation Transaction	Process Traceability	Trade Finance	IoT and Smart Contract Automatization
Financial	Freight bill Accuracy				
	Overall Cost for the Information flow of a unit of cargo from theirs to the last nodal point				
	Average cost for detention/demurrage				
Operational	Ship Turnaround time				
	Road vehicle turnaround time				
	Time spent by cargo awaiting commercial viability				
	Time for goods to be cleared				
	Time spent by cargo awaiting departure of next mode of transport (road or rail)				
	Overall time of cargo in port				
	Ship's capacity utilization				
	Hinterland transportation modes' capacity utilization				

Information	Security in information sharing				
	Degree of Flexibility in using information technology				
	Access speed to information				
	Accuracy of information regarding status of shipment				
	Provision of on-time updates of cargo information				
	Time required to receive necessary process information				

The Bill of Lading (BoL) is a legal document issued by an exporter to the shipowner that points the details about goods, vessel, freight, terms, and signature of the involved parties. There are 17 types and forms of BoL (Branch, 2014). In Shipped BoL document there are multiple parties involved. *Exporter* (E) or Shipper, is an individual or an entity, that owns the goods and wishes to transport them via ship. Shipowner or an authorized person called *Ship Agent* (SA) is an individual or an entity that transports goods and is accountable for any damage or loss of the goods during the transport. For both, import and export of the cargo, a *Custom Agent* (CA) checks the BOL and cargo. For financial settlement, the Bank (BA) reviews the document as well. Many a times, a *Freight Agent* (FA) is also part of the loop.

Some of the common issues with paper-based BoL are pointed out by (Branch, 2014):

- Delays in the arrival and overall process of BoL completion.
- Data is inconsistent or is unavailable (such as, freight details) when needed.
- Modifications in the BOL are not attested by the ship agent or the company.
- The endorsements regarding loss/damaged cargo are not sorted, hence, unacceptable to the banks.
- Discrepancies in between action and what is stipulated.

To digitalize BoL with Blockchain let us first consider the following environment. The database is the foundation technology for Blockchain implementation. It stores and manages the entries of BoL such as name of the Exporter, name of the vessel, details of the cargo (type, package number, measurements, etc), freight details, date of goods received and etc. The database is distributed over peer-to-peer network. It is decentralized i.e. synchronized, stored, maintained and updated by different network nodes i.e. parties. Each party is a node in the network with access to view, update and sign the transactions in the ledger or database. The involved parties in a typical BoL process are E, SA, CA, FA and BA as described in Figure 12. Each party may or may not trust each other. In the background the consensus algorithm is running that governs who initiates the entry and who has the privileges to make and entry or to sign it. This means all parties in the network agree to work together on the distributed and transparent database.

All parties agree to the transaction before it is added to the ledger. In this case all parties endorse the transaction, but it may not always be the case. The protocol of who endorses what, and in what sequence is decided and agreed before allowing party’s access to the system. This is coded in the endorsement algorithm.

A common scenario where the BoL involves following parties: E, SA, CA, FA and BA, which are geographically divided via peer-to-peer network of computers. Each node has same rights and privileges to perform the transaction and no central administrator is deciding for each of them. Every resource in this network is shared with all the nodes equally. The concept of centralized party is void. Party SA wishes to initiate the BoL. Once written, it triggers other parties who can either accept or reject the new transaction. As no single administrator is involved, the collective action of all other parties will decide the acceptance or rejection of the newly created entry in the database.
The data shared by Party SA is the input to the cryptographic hash algorithm which creates a unique string of characters known as a hash which summarizes everything present in the plain text. This is known as digital fingerprint or hash. It can be 32 or 64 bits long and may appear meaningless in the sense that it cannot be reversed to create the original plain.

The CA and FA are notified about the creation of BoL and about the arrival of goods. If anything, pertaining to custom clearance or freight is missing, such as Freight information the FA may reject this transaction, hence indicating the SA to share complete information. This saves last minutes hassles and allows all parties to act proactively. Upon arrival of goods at the destination port, the CA is prepared to receive and perform clearance tasks. If an ambiguity is found, for example, merchandise is found to be different than what is stipulated in the BoL, CA may issue trigger. The transparency allows all parties to be notified about the discrepancy and to adjust accordingly.
It is not possible for CA to make changes in the BoL, such as type of goods. Firstly, because the protocol does not authorize CA to make change that SA is allocated to do. Secondly, due to immutability nature of the technology, doing so would trigger the amendment via a flag in the original data. This notifies the SA to make necessary amends. The BoL paper-documents would have to be taken to the SA as opposed to Blockchain based BoL, where SA instantly makes the needed correction and the CA is able to perform clearance. As the information is updated, another block of information is created. The hash value of the previous block of information is shared with the new block of information, and likewise a new hash for second block is also generated.

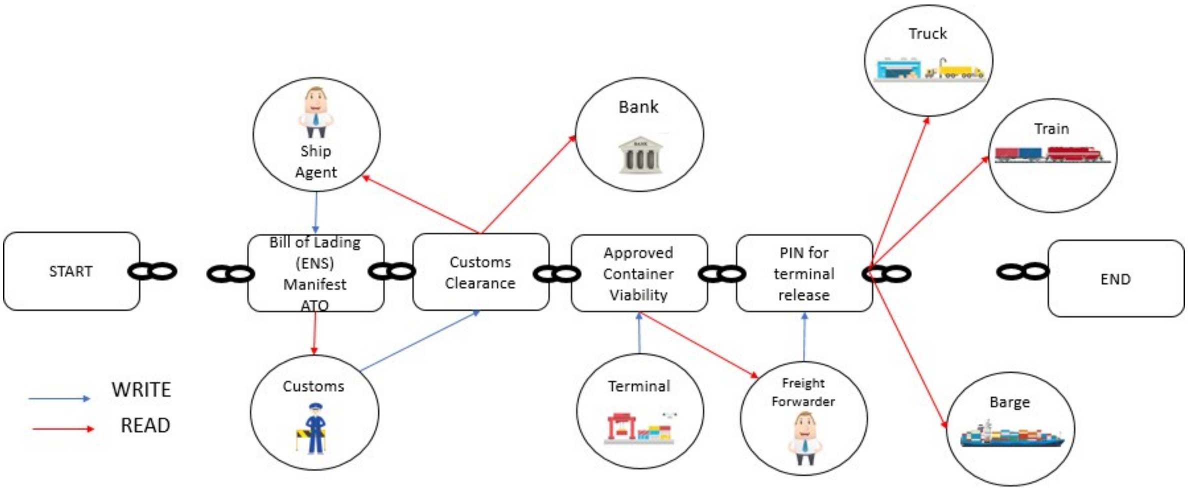


Figure 12. Example of blockchain application for process information storing

Similarly, when party FA signs the transaction, the hash for latest block is created and likewise the hash of previous block is shared with it. These forms blocks of information which are chained together with hash values, hence the term Blockchain. The Blockchain can have a new entry but it is not possible to go to an old entry and change it. The Blockchain network is, hence, irrefutable and permanent. It is scalable (can add more parties) and hard to take down. Of potential interest is seen in Figure 13 where smart machines can automatically execute tasks or processes based on information and data from Blockchain.

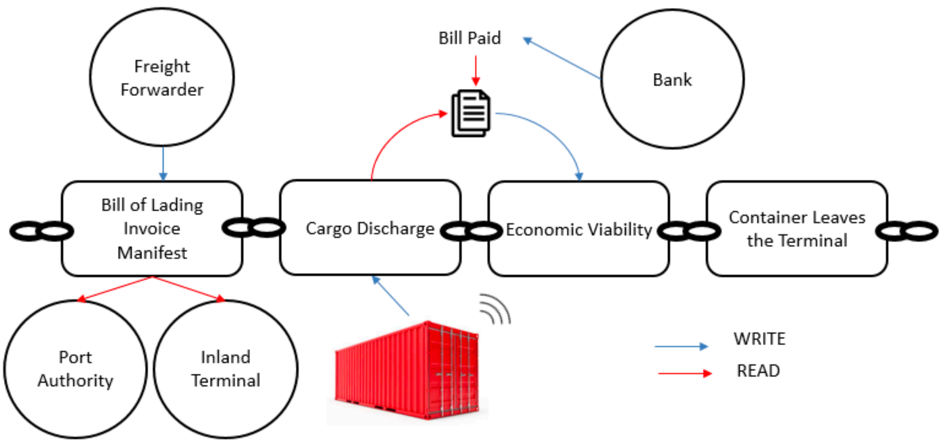


Figure 13. Example of blockchain application using IoT and Smart Contracts

8 SWOT ANALYSIS -EVALUATION OF BLOCKCHAIN IN PORTS &TERMINALS

Based upon the collected literature that was reviewed coupled with results from a questionnaire a number of use cases were identified for ports and blockchain. The business case modelling helped to pinpoint areas for using blockchain. A SWOT analysis was performed and described in Table 4.

Table 4. SWOT analysis of port blockchain solutions.

STRENGTHS	WEAKNESSES
√ Transparency	√ Low Performance
√ No loss of data or modification on existing data	√ Energy Consumption
√ Globally accessible	√ Reduced privacy
√ No intermediaries or "middlemen"	√ Hacking on autonomous code is possible
√ Fast and low cost - such as transfer of money	√ need to verify or reply on external oracles (issues of governance)
√ Higher efficiency.	√ still in early stages of development
√ More Secure	√ similar results can be achieved by other technologies that are proven
√ Auditable trail / 100% traceability	√ Storage
√ Low risk and cost	
OPPORTUNITIES	**THREATS**
√ Availability of huge amounts of data supplied by multiple actors in the ports	Perceived as non-secure
√ Possibility to attract new markets	low adoption rate
√ Increase competitive advantages	Governments and world authorities do not view blockchain positively Medium to long term investment
√ Speed up process of Bill of Lading and transfer payments	
√ Smart Contracts, e.g. insurance	Medium to long term investment
√ Improved port client experience	May not be suitable for existing (expensive) processes or solutions Clients may not like not having personal interactions
√ Automation of operational processes	More research needs to be done

9 CONCLUSION ON BLOCKCHAIN TECHNOLOGIES IN PORTS AND TERMINALS.

9.1 Discussion

Modern technologies require heavy costs to setup the needed infrastructure and equipment, to develop new business model that assists in forming digital culture and to revisit the processes and operation workflows to make needed transformational adjustments. These capabilities are easier to find in a large port setup as compared to small or medium ports entity. The question is how emerging and evolving technologies could be beneficial for smaller seaports. It is suggested that small and medium ports should consider some of the areas that have been adapted from the studies under this review. It is recommended that small container ports consider one problem at a time and devise a solution that suits their budget and value proposition. For instance, it is no use of investing in automated guided vehicles in a small yard or to enable an IoT suited infrastructure without considering the heavy power and maintenance costs or human resource education costs that it will incur. Also, the stakeholders could consider RFID tags with other sensors available in market, such as WIFI tags to bring down the overall costs.

Understandably, due to the technicalities involved in the container transportation; efficient documentation and information management is in high demand. The results from the survey indicate the use of technology to facilitate the documentation has not been a common research topic. In addition, numerous paperwork flows are involved for the container, from the issuance of purchase order to the final delivery can sometimes take up to 2 months. Having the process digitized via a Blockchain such as the main nodes and Check points could reduce the time and effort spent on paper work and have the documentation prepared and shared with customs on the other hand before the arrival of the container. A pilot was executed with the collaboration of Dutch Customs, IBM, Maersk, U.S. Department of Homeland Security Science and Technology Directorate, and, U.S. Customs and Border Protection, where container from the Port of Rotterdam was shipped to the Port of Newark and a Blockchain was implemented to create a joint electronic shipment ledger which provided real-time shipment information to the involved entities[9]. Hence, the research community should take steps to exploit the use of technology for efficient operations management, especially with regards to small ports.

As discussed in Section 2 the container terminal has multiple inter-related operations and processes being executed on daily basis. This requires decision-making by the assigned expert, sometimes with the assistance of decision support tools. From the literature survey it was observed that the use of decision support system is for effectively supporting the operations manager in determining the proper operational policies and equipment management

9.2 Conclusion and Future Work

According to the European Sea Ports Organization (ESPO), 90 percent of Europe's cargo trade in goods passes through the more than 1,200 seaports in the 23 maritime member states of the European Union (EU). An extensive scientific literature review was conducted to understand the current "state-of the-art" technology that is researched regarding to container ports operations and processes. It was observed that many papers had detailed work on algorithms for resource allocation and management in the berth and yard section.

[9] https://www-03.ibm.com/press/us/en/pressrelease/51712.wss

Research on documentation and information exchange between the teams on ground and decision makers was lacking. This motivate the need to conduct more research on this area. Furthermore, there is little to no research on other types of terminals besides containers. It appears that most to all research is on container and not on bulk, RoRo, Liquid Bulk, Multipurpose, etc. As the majority of terminals and ports in the Baltic are focusing on cargo other than container – this leads to a need for more research and projects on this area.

Use of Cloud and IoT was discussed in terms of survey and design papers. Strong evidence on use of Blockchain within the operational setup of cargo transportation was also missing. Blockchain technology is gaining interest in the container port sector and it concurrently is the rising interest of the academic community towards this topic. The literature review provides insights on how technology could be applied in the cargo supply chain network. However, based on the survey conducted, there is a lack of scientific literature that specifically focuses on implementation or even design aspects of Blockchain application scenario in the container terminal sector. Hence, a strong need for port visits is necessary if not paramount to collecting real and up-to-date information that is factual. Ports to be visited are Port of Rotterdam (considered to be a fore runner in applying SMART PORT solutions), Port of Antwerp, and ports in Greece, Finland to obtain alternative views and solutions on handling cargo. In addition, it is also suggested to visit ports in ASIA as they have various methods for handling cargo and do have an effect on operations in many parts of the world, e.g., Baltic Region. Therefore, it is suggested that either Shanghai, Hong Kong or Singapore be visited to obtain data and information. As for future work, additional databases could be utilized in order to obtain further studies on Blockchain and digitalization. It is also recommended that more studies be conducted in this fast-evolving field of digitalization

More knowledge transfer is needed and a demonstrated lack of projects has caused many port and terminal operators to take a "wait and see" approach. One way to remove the barriers that hinder many small ports in the Baltic Sea Region is to invest on more research, more training and clear pilot projects that can show-case what is possible in terms of helping the ports to be more competitive. In summary the work and research planned by Connect2Small Ports project could yield results with a strong impact.

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