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## The Role of Port Authority in New Blockchain Scenarios for Maritime Port Management: The Case of Denmark

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### Abstract

The purpose of the paper is to determine and examine, to what extent blockchain scenarios for the shipping industry have practical explication from maritime ports' perspective and how these are sync with ports' long-term development strategies, particularly in Denmark. The present study involved qualitative interviews with representatives of the biggest maritime ports of Denmark, varied by location, volumes, operations and cargo type. Data saturation is achieved through several rounds of in-depth semi-structured interviews. Results showed uncertainties in the long-term investment strategy of the considered ports. While focused on land expansion and operation development, the port authorities lack inner-port coordination with related enterprises, which consequently affects overall efficiency. While the development strategy appears to be identical among the port authorities, it varies significantly within specific blockchain scenarios and port's strategy regarding short-term port optimization. Besides, the role of port authority was debated. Authorities are willing to be more involved in supply chain operations as a consultancy rather than just a controlling party, yet are burden by the state restrictions. Unlike generally-discussed blockchain compatibility studies, the current research contributes by revealing core business uncertainties within port area development and communication. Moreover, the case could serve as a representation of small- to middle-size ports in the EU.

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**Keywords:** blockchain; port area development; port management; port clusters

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### 1. Introduction

Blockchain, a decentralized database that has entered the rising market of innovative technologies, since then has been one of the main drivers to continuous connectivity and decentralized online monitoring tool for business development and optimization of cost-efficiency. The technology has been extensively used in finance (Casino et al,

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2019), traditional banking services by reforming the method of payment (Fanning and Centers, 2016), governance (Hou et al, 2018; Moura and Gomes, 2017), data management (Francisconi, 2017) and supply chain and logistics (Casino et al, 2019).

More frequently blockchain projects are reviewed as solutions in the field of shipping and supply chain (Tsiulin et al, 2020; Kshetri, 2018; Casino et al, 2019), primarily for better control over cargo handling and over time spent on transportation. The issue is caused by inaccurate and incomplete information handling along the way, i.e. lack of notification on cargo's arrival, type, origins, and other relative information for customs and other parties e.g. receiving port or terminal (Kshetri 2018). Unplanned delays significantly influence further transportation as well as the cargo security that is exposed to damage or theft. This creates uncertainties for the recipient and the sender (T-Mining 2018).

While the range of existing literature fully covers the potential of blockchain for the shipping process on a generalized level (Kshetri 2018; Casino et al, 2019), it considerably lacks the explanation of relationships at the certain spots of the supply chain, whether or not blockchain scenarios would be practically applicable for an intermediate part of the supply chain, e.g. within port transportation: the port authority, customs, terminal operator and enterprises based at the area. In addition, how such innovation influences the relationships between the port and within a port community system. Moreover, the study by Tsiulin et al (2020) examined the tendencies among blockchain projects in port management. A great number of the considered projects have the status "in development" and thus cannot provide the detailed architecture of the proposed solutions as well as the numerical results.

The purpose of the paper is to determine and examine, to what extent blockchain scenarios for shipping have practical explication from the perspective of port authority and port terminal operator and how these scenarios are sync with ports' long-term development strategies, particularly in Denmark. In present study, the main identified scenarios of blockchain have been used as a basis to define how these might influence the port for better document coordination, digitalization, goods tracking and port area control. The focus is given to the qualitative research method i.e. semi-structured interviews to define a closer perspective at the current state of the port operations in Denmark, meaning also development strategies both in short- and long-term perspectives.

The article is structured as follows. The next section presents port area development as an intermediate supply chain spot. Thereafter, Section 3 presents the methodology. Section 4 summarizes the results assigned to themes. Section 5 provides a discussion of the results as well as future opportunities of considered scenarios.

## 2. Literature review

Maritime ports are defined as convergence points along with the domains of freight circulation that involve the coverage of global trade by marine and land areas. Historically handling the largest amount of goods, ports jointly accommodate transshipments from on-land and hence have always been competing with cities they service (Rodrigue, 2020). The complexity of the port environment and its development grew significantly within the intensification of ports' cargo base and hinterland areas with the involvement of other activities e.g. production and fishing, recreational activities and a closer connection to in-land logistic services (Rodrigue, 2020; Baalen et al, 2008).

Peter de Langen (2020) regards port area development to a system of clusters. Four major categories are defined by the author: 1) Transport hub; 2) Industrial complex; 3) Value-added logistics hub; 4) Site for tourism and co-working. Each cluster represents the average value of importance, in accordance with various parameters, e.g. land use size, turnover, revenue and etc (de Langen, 2020). The significance of each cluster, according to de Langen (2020), will drastically change over time. The role of currently-dominant, conventional cluster of cargo operations at the port will be reduced while the role of other three increases considerably (Figure 1). It is associated with the commercial sector, which is likely to undertake the publicly owned land as it proved to be highly more efficient (de Langen, 2020).

Within the constant development of port areas and contiguous clusters, the first attempts to establish an efficient communication between port actors are known as the concept of Port Community System (PCS). PCS implies a central information hub, connecting shipment stakeholders (e.g. port authority, importers and exports, freight forwarder, customs, consolidation center) and the focus is on enabling an intelligent exchange of information and documents (Baalen et al, 2017; Francisconi 2017). PCS's objective is to collect and automatically redirect information flows to required port parties, reducing the number of errors, processing costs and time delays.

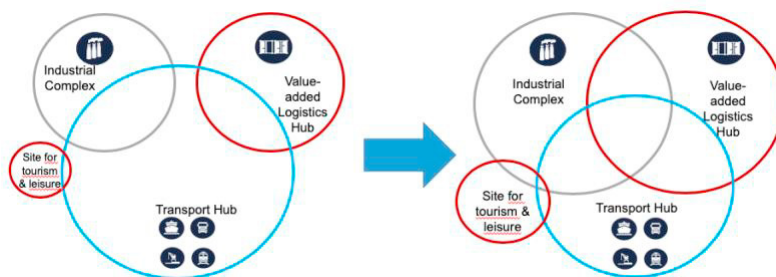


Fig. 1 Future evolution of port ecosystem in accordance with Peter de Langen (2020)

However, PCS faced essential challenges in terms of ownership and data security (Rodrigue, 2020). Being a centralized party, information flows within PCS should be regulated to protect port users from potential data leaks or monopoly. Implementation of the concept, despite the overall attractiveness of potential benefits, has been hindered by the unwillingness of network partners to store information and share it, including the need of adjusting paper flow to new standards (Baalén et al. 2008; Francisconi 2017). The main inconsistency in agreements appears was due to data security concerns, i.e. being dependent on a third-party actor. Nevertheless, PCS is one of the conceptual attempts to shift document management, cooperation and decision-making processes to electronic format (Skwarek, 2017; Francisconi 2017).

Considering attempts in simplifying shipping and in-port communication via PCS, blockchain has been promoted as an exact solution to the abovementioned issues related to communication, data security, elimination of the role of central gatekeeper, establishing point-to-point communication with transactions visibility and permissioned transparency (Tsiulin et al, 2020).

Table 1. Summary of three blockchain conceptual areas (modified from Tsiulin et al, 2020)

Concept name	Proposal
<b>Document Workflow Management</b>	Shift document exchange between shipping parties to digital format, unify documentation, eliminate unnecessary interactions between parties, simplify approvals to a digital signature, automate paper flow and notifications, track approvals and unauthorized logins
<b>Financial Processes</b>	Integrate shipment-related financial enterprises and banks into port community to speed-up information updates on cargo, automate payments and hence reduce time-delays
<b>Device Connectivity</b>	Organize a system of nodes throughout a particular supply chain, trace the place of product's origin, track the product in real-time, integrate side-sources of information (physical and damage sensors), automate self-made condition reports and pre-arrival notifications, track approvals and unauthorized logins Also (exclusively for ports): digitalize monitoring over container yard, automate port gate queuing, provide online approval for cargo pick-up, provide cross-check of cargo at the port exit to eliminate pick-up errors

Comparing to existing data-management methods that commonly imply one single privileged authority, blockchain differs by overall distribution of data among authorized and confirmed parties. It is a decentralized and distributed database, where all history records are interconnected along. The fundamentals of blockchain and its areas of use have been extensively covered in literature (Casino, 2019; Francisconi, 2017; Kshetri, 2018), nevertheless lacking attention to the area of sea shipping in particular. Seebacher and Schüritz (2017) defined blockchain as a distributed database based on the peer-to-peer networks, which “*consists of a linked sequence of blocks, holding timestamped transactions that secured by cryptography and verified by the network community. Once an element is appended to the blockchain, it cannot be altered, turning a blockchain into an immutable record of past activity*”.

Being decentralized in nature, blockchain does not allow any changes once information has been approved and stored in the database. That secures data from unauthorized access, manipulation and falsification, making the process transparent and trackable through historical records.

In regard to sea shipping and port management, a recent study by Tsiulin et al (2020) built a conceptual framework of existing blockchain projects within maritime shipping; authors identified three main concepts (Table 1) that all reviewed literature can be compiled to Document Workflow Management, Financial Processes, and Device Connectivity.

### 3. Method

The current study uses a semi-structured qualitative research method to create a dialog with greater response flexibility. Flexibility in qualitative research implies the complexity of the interview where emergent discussion (Kvale and Brinkmann, 2015) could lead to a new understanding of the content and therefore present an extra value for the study (Mason and May, 2019).

For the present study, a pool of the biggest maritime ports of Denmark has been selected, varied by location, size, operational volumes, cargo type and organizational structures. The sample consists of six ports: Aarhus, Copenhagen-Malmö, Esbjerg, Aalborg, Fredericia and Hirtshals; and is sufficient to represent the situation of freight port operations that happen within the country (Figure 2). The study combines a round of six semi-structured interviews conducted during autumn 2018 with a newer round of empirical study from autumn 2019 with the same respondents.

Interviews were conducted separately, with long-term employees of each organization. The roles of respondents included the following positions: chief executive officer, chief of the terminal, general manager, chief operating officer. Each is in the possession of insights and great know-how of their individual organization and the industry overall. All discussions lasted approximately an hour, had been recorded, transcribed and translated into English.

As for content, the themes for discussion were designed to identify a closer perspective at the current state of the maritime ports in Denmark, industry's complexity and development strategies. For themes regarding port clusters, authors followed de Langen's concept of clusters (2020), where a maritime port is considered as a cluster of the system. Also, the topic of interrelations between different port stakeholders has been taken into consideration i.e. port authority and terminal operators, the communicational issues of which may impede the further development of the port as a logistics cluster.

Data saturation is achieved through two rounds of in-depth semi-structured interviews. For results' validation, the Hermeneutics concept is used (Gadamer, 2007), meaning an approach that is devoted to interpretation and understanding of the discussion by relating to a wider discursive context, explicating its reach and extending the contribution (Mason and May, 2019). Thus, a newer survey has been conducted in autumn 2019 with a few particular respondents to fill-up the context understanding gaps and observe intermediate changes of discussed topics since the first interview round, hence creating a new understanding.

According to Johnson and Onwuegbuzie (2004), strengths and weaknesses of qualitative research are shaped around participant's own categories of meanings. In this case, produced knowledge may not be generalized to other settings unless supported by a group of respondents sharing a similar perspective that is enough to represent a certain understanding. In this regard, validation is implied "to check on credibility, plausibility and trustworthiness of findings" (Brinkmann & Kvale 2015).

Validation through two rounds solves the issue of interviewing only people who represent one 'position' or 'role' in relation to the phenomena. The conducted approach provides an appropriate level of objectivity yet does not completely exclude biases concerning respondents in the position of decision-makers who are potentially not willing to criticize their own company.

Method of Meaning Condensation has been used for interview analysis (Kvale and Brinkmann, 2015). Each interview contains a set of statements regarding a particular topic. By analyzing the interview, the statements then were extracted individually and assigned to a topic. Topics served as categories for the prominent meanings of each discussion, and comparison of the statements within a particular topic revealed similarities and common challenges, strategic viewpoints among participants organizations and companies. For the purpose of complying with GDPR rules, we keep respondents and quotes anonymized.

### 4. Results

#### 4.1. Long-term development strategy

Interviews showed that maritime ports in Denmark vary in the level of ownership that affects its further development. Similar to other EU countries, the vast majority of ports have a status of governmentally-owned or semi-governmental, where port territories belong to local municipalities. Port authority takes a controlling role yet is restricted to do physical operations with cargo. In other words, port authority leases the land to companies that do

cargo handling and all accompanying operations. Therefore, the company that operates with cargo (terminal operator) is represented only as a tenant that does not have a possibility to manipulate with port infrastructure i.e. removing/adding new facilities or significantly changing the operational flow. Such internal changes occur either mutually following an agreement with the port authorities, or only at the initiative of port authority.

Discussing the development strategy over a five to ten years period, respondents among port authorities commonly emphasized territorial expansion in the first place. Initially planned for containership and trailer expansion, these areas are seen as the best short-term solution for the yard, with a reason that container handling leaves flexibility for prompt re-design of the space for bulk cargo if needed. A respondent from the port of Fredericia argued that land expansion allows the port to enlarge the number of services provided by the port, for instance, last-mile deliveries. As such, possessing a land within the hinterland area, construction of a distribution terminal is considered as an additional supply chain spot. Even though port authority is still restricted from providing any cargo operations themselves, it can lead to increased investments into asset-heavy infrastructure i.e. port area, unloading equipment and etc.

#### *4.2. Shift towards digitalization of internal data*

Improving the efficiency of loading/unloading equipment at the port is always associated with the analysis of massive data flows and their online optimization. Digitalization of such flows is of importance via cloud storage of documents and its subsequent coordination, automatic handling of physical documents, cargo certificates and etc. Greater digitalization is considered as a boost for higher control over inner-communication and manpower. Regarding that, a few respondents highlighted the dependency of such new systems on the port's size and turnover: "When the number of containers goes relatively small turnover, the importance of such IT systems accordingly decreases".

Moreover, a clear motivation in the interviews has been shown to develop flexibility in the management of the container yard. That involves booking, online-monitoring and expansion of port's extra-services. Not just it brings flexibility to the customer, but also a maneuver for port authority to get information on upcoming cargo. One respondent from port authorities stated: "With digitalized flow, we would have slightly more info regarding what is in the ship, when and where it comes from, including certain details from the Bill of Lading. We would also be able to scan contracts automatically and update pricing depending on the time that container stayed in the yard". Nevertheless, authorities are still struggling to see any particular information on the type of cargo that is inside of containers.

According to the interviews with port authorities, the success of the port entirely depends on the success of the terminal operator within the port. Development of port areas commonly aims to fulfill all requests from terminal operators in terms of infrastructure, construction, operational management and land use. Therefore, the more PA is involved in daily cargo operations, the more efficient the terminal operator is. Currently, "Terminal operators work independently and do not provide cargo operational details and accompanying data".

The exchange of information, unlike cargo operations, is consistent with government regulation: "Advising, shared costs and information comply with the state law as well as joint investments — as long as we don't interrupt in cargo operations". The biggest challenge is to implement such data integration: "In the scenario of greater information exchange with terminal operator, we do not want to speculate on the data, but to ensure that we are investing in proper strategic decisions".

One of the respondents highlighted the significance of such data exchange for further Operator-Authority communication: "Port Authority business model is quite simple. We are asset-heavy, while most of the market wants to be asset-lite. Most of the time we have a neutral role that we turn to our benefit. We can advise and be close to Operator on a strategic level, to better know what they want so we can better calculate and fill up their demand." Also, the importance of being integrated into information flows is explained through motivation for better rebuilding loading and unloading capabilities and control over manpower.

#### *4.3. Blockchain scenario Document workflow management*

The majority of the respondents stated that the current approach of document processing is outdated, regularly completed using e-mail, telephone call, fax or ERP module. Across each of the paperwork stages in transportation, the risks of the human factor, falsification, miscommunication and delays increase. None of the respondents is

questioned by the fact that no matter the form, the digitalization of workflow will be implemented, whether it will be a blockchain or other technological advances. Considering the specific scenario “Document Workflow Management” (Tsiulin et al, 2020), though responding positively to the scenario’s features, the biggest concern among the interviewed ports is how to incorporate customs into such an information-sharing system. According to the assumptions of interviewees “Customs will be willing to use the system, but there is a low chance about them contributing to it for further parties”.

The position of extensive data collection by PA resonates with other actors, who in general do not require extensive information about the cargo, arguing that what happens with the cargo after port-loading/unloading is out of operator’s responsibility: “We just need to know how big the container is to put it into the right place. Also, we need to know the time.” Moreover, the trust level between operator and authority is sufficient enough. Thus, the blockchain with its fundamentals of bringing transparency into information flow will not significantly impact the existing relationships between parties.

The blockchain, however, might be used as a database for port’s extra services: port gate monitoring and notifying the receiver on container’s status along with its condition proves, e.g. photos of the container going through gates after being picked up by the forwarder. For PA, such transparency between port actors will also help to optimize the containership to specific products: “But if we are able to get the information from, say, blockchain system, then it is much easier to be proactive”.

Besides limitations within the organizational aspects of the scenario, another problem is that the market and specifically industry majors offer “turnkey” solutions, implying the creation of the system and consequent support. “In the long-run, the creator could exclude certain participants of the system in order to replace them with own services, and therefore promote more an end-to-end solution”. Having such, even bringing decentralized values and digitalized democracy, could limit the partners in the future and lead to the emergence of monopolies. Being aware of such possibilities, blockchain startups proposed the concept of transferring the rules for maintaining or amending unified documents to state organizations, such as a port or municipality.

#### 4.4. Blockchain scenarios of Device Connectivity and port area security

Blockchain might be also used exclusively within the port area for security reasons. For instance, to prevent cargo theft. Port authorities in Denmark see such a scenario more as a way to create an extra value around the existing service: “We would like to invest in an automatic gate function: scanning documents in and out, checking if the cargo is damaged or not, scanning license plates of drivers. We need to know, at any time, what is happening in our port area: traffic, number of movements, pick-up errors”.

Table 2. A summary of findings on themes across the ports

Theme	Argument	Relevance
Long-term development strategy	Territorial expansion, berth depth enlargement for higher turnover possibilities;	PA: 6/6
	Expansion of available services provided by the port, better involvement in existing in-land supply chains e.g. on distribution level or last-mile delivery;	PA: 3/6
	Focus on cost reduction and maintaining the infrastructure in the current state, not innovation development;	PA: 5/6
Digitalization of internal data	Digitalization priorities through development of online-monitoring over containership, improvement of container yard booking system;	PA: 4/6
	Counter-argument: “The significance of containerships digitalization is only visible within high operational volumes”	TO: 3/6
	Second priority: control over manpower at the yard, port gate automation, port area monitoring;	PA: 2/6
Inner-port communication	Port authority expects a better involvement in daily cargo operations in close cooperation with terminal operator; motivation lays in port capacity optimization through better document and information exchange	PA: 2/6
	Counter-argument: terminal operator does not require extensive information on the cargo	TO: 1/6
Blockchain scenario Document Workflow Management	Challenge of reconstructing the already existing port community systems	PA: 2/6
	Counter argument: industry’s major companies tend to create an end-to-end solution, eliminating mediators and thus creating a bigger monopoly on the market	PA: 2/6
	Uncertainty of the willingness and responsiveness of customs to be the part of scenario’s network	PA: 4/6
	Transparency of database’s transactions allows more flexible response in short-term decisions and “Makes it easier to be proactive”	PA: 3/6
Blockchain scenario Device Connectivity	Scenario is mainly considered as a side-database for port’s extra services: extensive tracking, port gate control, container security	PA: 3/6
	Feasibility is seen for container-check at the port gates to improve monitoring and reduce number of pick-up errors	PA: 4/6

Container pick-up errors are a frequent happening in ports among the respondents. Thus, the frequency of such cases reaches up to 5 in those that operate with containerized cargo (Port of Hirtshals). Since the container yard is not automated, it misleads the pick-up parties who are navigated mostly by the container number or a parking slot number at the yard. Likewise, the situation is poorly controlled at the gate when driving out with no cross-checks. Consequently, that leaves room for the human factor.

From the perspective of terminal operator, the pick-up errors are not of a great issue unlike the utilization rate of the containers that are driven mostly empty. Thus, 80% of the containers operated in Aarhus are empty with a low value. “Empty container is a waste for the customer. We don’t have much to send back from Aarhus — everything that comes to us is export.” Solving an issue with utilization rate of containers through export or somehow else will be “crucial for the financial development of the port within the next decade”.

In the table, there are three columns: theme, argument and relevance. Relevance indicates how common the similar argument has been mentioned by the respondents among port authorities (PA) or terminal operators (TO).

## 5. Discussion

Regarding the development of intra-port infrastructure clusters, an interesting trend has been observed that shows similarity to the cluster theory proposed by Peter de Langen (2020). Maritime port authorities in Denmark are well-aware of state restrictions, therefore all infrastructure development besides the port operational area is considered to be taken over by commercial enterprises as it brings higher efficiency and utilization rate. The Danish governance-type of ownership slowly, but gradually shifts the industry towards cluster changes i.e. the creation of co-working clusters of similar, yet not identical types of business. Similar to the literature (Rodrigue, 2020; Peter De Langen, 2020), the key transition towards greater port optimization as an ecosystem is an improvement of entrepreneurial port development capabilities.

In the future perspective, maritime ports in Denmark are seen as expanded infrastructural assets and direct participants in the logistic chain, possibly within the distribution and the last mile delivery levels. The role of the port authority is likely to expand as well, the closer partnership is a key method towards reaching more cost-efficient optimization of the port facilities.

As for the scenario with blockchain and digitalization of paper workflow, the increased interest of technology regarding the maritime industry, in particular, is explained by industry’s overdue for IT infrastructural upgrades and unwillingness to optimize daily business processes mainly due to risks of breakdowns, manpower re-coordination, costs for staff education, IT support and etc. Within the averagely outdated technological advances at the port, IT progress pushes poorly updated ports towards digital innovations. Besides blockchain, various concepts were proposed by both research and entrepreneurial community in order to optimize inner-port processes e.g. improved Port Community System (Baalén et al, 2008; Rodrigue 2020), as well as software for optimization of workflow and port traffic monitoring (Tsiulin et al, 2020; Kshetri, 2018).

Regarding research limitations, it should be noted that the technology is still considered as new and thus does not have an extensive numerical and practical implementation practice. That was the main reason for current research using qualitative research method. Being experienced with technology’s specifics, the focus in research was not on requiring the respondent to know the fundamentals of blockchain. The survey is designed to answer the feasibility of such a tool within traditional Transport Hub cluster within the port, without mentioning blockchain directly to the respondent. Another aspect considered as limitation is “lack of self-criticism” i.e. design implications of interviewing people who represent one “role” in relation to the phenomena.

## 6. Conclusion

The main aim of this paper was to determine, how feasible are the common blockchain scenarios from the perspective of port authority and terminal operator in Denmark. Having the selection of six major maritime ports, the



study involved qualitative interviews with representatives of maritime ports of Denmark, varied by location, volumes, operations and cargo type.

The results showed, that the long-term development strategy among the ports appears to be identical, yet varies significantly regarding specific blockchain scenarios and port's strategy regarding short-term port optimization. The perspectives and practical use are scattered, especially in terms of embedment into existing port management software, uncertainty within the port community system and the role of customs; including concerns on state legislation that restricts port authorities from any operational involvement. Unlike the blockchain scenarios, accelerating communication among the port-based actors, better utilization of port resources and land use, higher involvement and cooperation with all parties along the supply chain appeared to be among the top priorities.

As for future research opportunities, Document Workflow Management scenario in the context of growing clusters and complex nature of relationships between the port actors represents the largest potential solutions for the market. What is still questionable, that is the role of trust within port communication, and whether blockchain can be integrated into existing accounting, operating and controlling systems, and be spread across a wide range of key stakeholders i.e. customs, cargo senders, freight forwarders and etc.

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