The digitalization of port infrastructure[1]

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Ports, a critical link in sea logistics, are currently undergoing a digital transformation. In this paper, we review recent digital innovations that affect the way port infrastructure and operations are managed and discuss their effect on the business models of future smart ports.

Introduction

Highly fragmented industries characterized by extreme information asymmetries are the first to be affected by the 'platform revolution' (Sarkar 2016). In that respect, sea logistics is a sector in need of improved efficiency (Gustafsson et al. 2015). The digital transformation, coupled with a transition to a platform economy, have the potential to facilitate just such a change. One of the main effects of digital platforms in this transformation is the shift towards multi-sided markets and the facilitation of network effects.

Ports, the interface between sea and land logistics, have historically provided services to multiple players, including vessel operators, cargo owners, land logistics operators or port operators like stevedoring companies. With the advent of 'smart ports', there is the potential to provide more value through data-based services and data-driven business models. The general trend of 'infrastructure as a service' will greatly affect the business models of ports, as the information about infrastructure use becomes more valuable than the possession of that infrastructure. In a platform economy, the competitive advantage changes from the control of valuable resources to the ability to orchestrate information flows and to organize activities among ecosystem actors (van Alstyne et al. 2016).

The increasing volumes of data generated regarding maritime transport creates opportunities for the appearance and growth of new business models and the 'port as a service' types of platforms. Incumbent actors such as the port authorities have a choice to either proactively use the enabling technologies to reinvent their own business models or they risk having their value proposition commoditized in the fourth industrial revolution. In this paper, we review the recent digital developments related to ports and discuss their effects on the transformation of sea logistics and, in particular, on port operations.

Management of port infrastructure

Port infrastructure includes port terminal infrastructure, that is, static structures such as buildings, docking areas, roads, warehouses and power supply; there is also port operational equipment such as the vehicles or machinery needed to provide port services, for example, towing and cargo stowage.

Monitoring static terminal infrastructure to ensure safe and continuous operation is one of the main tasks of port authorities. Smart sensors, advanced computing and video analytics help the port authorities to more efficiently monitor large and diverse infrastructures in port, including networks, roads, railways, restricted areas and warehouses, quays, banks, water depth and locks (Frost & Sullivan 2020). Port infrastructure can be monitored through connected camera and computer image analytics that detect damaged land-based infrastructure. Since water depth and berth status are crucial in moving and mooring vessels within the port, sounding drones with ultrasonic sensors or cameras can constantly monitor the depth and berth and provide data for dredging and maintenance operations (Frost & Sullivan 2020). With the resulting data and algorithms, it is possible to automate the planning of control operations and maintenance actions, and switch to prescriptive maintenance.

Following the same trend, predictive and prescriptive maintenance is also discussed and partly carried out with the management of cargo handling equipment in ports. Sensor and other information reported from cargo-han-

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dling cranes is analyzed in order to improve crane maintenance, repair and operations. The data analytics algorithms developed by cargo handling equipment suppliers can be further improved by collecting global crane data rather than by focusing in on individual pieces of equipment.

Following the development of the building construction sector, BIM can be applied in the design and management of port infrastructure, as well as in 3D models of assets and when enabling the assessment of collected data. In the process, an asset's current and historical data are gathered in order to enhance infrastructure management, which is based on predictive maintenance. The development of digital twins for ports can also aid in the strategic planning of infrastructure investments, port design, and terminal capacity based on the analysis of cargo flow through ports (Lind et al. 2020).

Efficient port operations

Ports vary depending on their capacity, the type of cargo they can receive and their role in the logistic chain. For instance, there are larger 'hub' container ports and smaller final-destination or 'hinterland' ports. Nonetheless, a key criterion for port efficiency is vessel turnaround time. Ports generally aim to reduce vessel turnaround time to increase earnings for port actors by serving as many vessels as possible and by being an efficient link in the longer supply chain and thus ensuring that chain's competitiveness. Smaller ports require a competitive edge as they do not have many ship-calls to efficiently connect land and sea transport and to guarantee the reliability and swiftness of the supply chains related to the hinterland industries they serve.

While some of the vessels' time in port is used for loading or unloading cargo, a great deal of time can be spent waiting, for example for berth or cargo-handling equipment and for customs clearance. Thus, the main applications for port-related digitalization will be on improving port calls through better coordination and communication among the multiple actors involved in sea transportation, port operations and land logistics. Second, there are digital innovations aimed at optimizing vessel and cargo flows through ports. While coordination requires data sharing, optimization requires data analysis such as predictive and prescriptive analytics to predict events and to plan optimal resource allocations (Lind et al. 2018).

There are a number of inefficiencies in how port calls are currently organized. Most ports apply the principle of 'first come, first served' for arriving vessels. This often leads to a 'rush to wait' situation, as vessels arriving in the port area at the same time, increase their speed in order to be first in line at the berth. Queuing in ports can also take several hours or even days if a vessel arrives outside of a port's working hours (Gustafsson et al. 2016). This unproductive time could be avoided or otherwise used, for example for slow steaming, through a timely exchange of information between different parties regarding the vessel's estimated time of arrival (ETA) and the availability of port quays and cargo-handling equipment. For instance, studies show that reducing the nominal speed from 27 to 22 knots (by 19%) can result in bunker savings of approximately 58% (Gustafsson et al. 2015, 2016). Algorithms predicting vessel arrival times and port infrastructure availability are the basis for real-time queuing and slot-booking systems in ports that can help solve the 'rush to wait' challenge. However, in this case, technical solutions are not enough. Companies need to change how they handle issues like work routines and contracts. There are already standard slow steaming and virtual arrival clauses, developed, for instance, by BIMCO, a renowned maritime association, but these are hardly used due to potential arbitration complications and missing reference cases.

Then, to facilitate the coordination necessary for efficient port calls, communication between actors must be drastically improved. These actors include port authorities, ship operators, shippers, port operators, port agents and many others. A vast number of different hardware and software systems from different time periods are currently employed to transmit data from ships to ports during a port call. The result is often a lack of data sharing and interoperability (Inkinen et al. 2019). There are initiatives for solving this problem by digitizing information exchange, such as through the European Maritime Single Window and the use of blockchain technology. Blockchain has been explored in Rotterdam and a few other leading ports globally due to its potential to flatten out multiple registration and control processes. This can involve up to 25 separate entities in relation to a single transport transaction (Lambert et al. 2019).

To further decrease vessel turnaround time, it is crucial to synchronize sea and land logistics by managing cargo flows in and to ports. Otherwise, the benefits of efficient 'digital calls' will be diminished due to delays in cargo stowage. Predictive algorithms based on things like data from container tracking sensors allow for improved planning of cargo arrival, storage and loading on vessels. One particular solution for ensuring smooth traffic flow and for alleviating the congestion caused by land transportation are sensors on roads leading to ports. Combined with data from drivers' devices, it tracks travel times and adjusts traffic lights or signage to facilitate smooth traffic flows to ports.

Achieving synchromodality in ports is a challenge due to significant differences in the logics of ship-to-port synchronization, port-to-port synchronization, and port-to-hinterland synchronization (Lind et al. 2018). Therefore, there is an increasing interest in platform-based digital solutions, which collect data from various sources and from actors involved in logistics, and then there is the possibility of providing custom analytics for specific actors to make informed decisions.

In this spirit, the Port of Rotterdam recently launched the company PortXchange to promote the Pronto digital platform service offered to ports, shipping companies and terminals. The aim of the company is to improve the efficiency of port calls and to help their clients reduce emissions with a joint platform enabling optimal planning, execution and monitoring for port call activities. Moreover, the port has been developing the Internet of Things. This employs a broad network of sensors to provide accurate and up-to-date water and weather data to help the port authority plan and manage shipping operations more effectively. The use of the system is expected to decrease waiting times, to optimize berthing and to accelerate loading times.

Another example of a digital platform for port operations is one developed by a start-up called Awake.AI. The platform combines data on sea and weather conditions, vessel port situational information, port infrastructure availability and cargo flow. It also provides relevant data and analytics for various actors (port authorities, ship operators, terminal operators and cargo owners) so they can improve their operations. In that respect, the company positions their platform as a 'smart port as a service' and sees this platform as a pre-requisite for the wide implementation of autonomous shipping.

To achieve real improvements in efficiency, it is crucial that digital platforms for sharing information and predicting vessel and port operations be implemented in ports, and, also, that the interoperability of data be ensured. Network effects can, then, be achieved, and the efficient use of maritime transport infrastructure drastically increases. Data on port operations, combined with vessel and cargo-related data, is an important input for system-level digital innovations such as platforms for finding optimal routes and vessels for transporting cargo. While these solutions aim to optimize the end-to-end logistic chain, they ultimately affect how much and how well port infrastructure is used.

Conclusions

The implementation of digital solutions in ports discussed in this paper empowers import and export companies; it also encourages infrastructure operators to provide the best availability and the promptest service in ports. Ultimately, ports will become links in an agile hyperconnected global logistics system. Here there is the possibility of getting around current problems including products idling in storages, too many unsold products, and products, unnecessarily, crisscrossing the world (Montreuil 2011).

Digitalization can potentially enable smart ports and facilitate new business models for port actors. However, it is important to note that technical solutions are not a panacea for all the bottlenecks and outdated practices in sea logistics. In fact, the implementation of digital solutions often proves challenging due to the established structure of the relevant business ecosystem and institutionalized lock-ins (Tsvetkova et al. 2019). Thus, maritime transportation will undergo a system-level transformation, where digitalization has an important role or even acts as a catalyzer. However, there is still a need to redefine the value creation and capturing of logics, business models and their interconnections in the ecosystem, as well as the roles, the contractual and the legal frameworks that shape industry architecture (Tsvetkova et al. 2017). The question remains: which actors will lead this transformation, which incumbents will reinvent their role and business models, and which will cease to exist? The business models of future smart ports will have a strong influence on how logistics chains will be transformed.

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