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DIGITALISATION IN ROPAX PORTS: THE TYPOLOGY OF AVAILABLE SOLUTIONS

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Sea logistics is slow to adopt digitalisation technologies and still relies heavily on old communication and data exchange methods. However, digitalising activities in RoPax ports can improve logistic chains. Managing and combining flows and services of cargo and passengers leads to several specific challenges, creating digitalisation opportunities. Data was gathered through desktop studies, interviews, site visits, and workshops to identify available and potential digital solutions. The research resulted in a typology of digital solutions classified based on their functional value and how much they impact logistics chains.

Keywords:
port,
digitalisation,
logistics,
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1 Introduction

Digitalisation can allow companies to gain a competitive advantage, enabling new value creation (Kamalaldin et al., 2020) and opportunities for business model innovation. Business model innovation can stem from exploiting digital technologies and digital technology development at the firm (Cozzolino et al., 2018). Digitalisation's impact on business models has been covered in extensive literature reviews (Caputo et al., 2021). While many studies review the impact of the firms' capability to innovate business models with digitalisation's help or benefit from digital technologies, in this research, the perspective of digital solutions providers and developing their value propositions towards users of digital solutions interests us.

While industries face ubiquitous digitalisation in the sense it has concerned innovative and traditional sectors (Teece, 2010; Warner & Wäger, 2019), the specifics of digitalisation and emerging business models are context-specific. Studies have shown the effect of increasing digitalisation in the manufacturing industry regarding the solutions that manufacturing firms offer (Kohtamäki et al., 2019) and the specific value process the industry can gain from digitalisation (Kamalaldin et al., 2021). However, as Caputo et al. (2021) propose, continuing research is needed on different forms and archetypes of business models developed in recent years (Caputo et al., 2021).

Maritime logistics, which can be considered a network industry, faces a different set of challenges and thus can gain unique benefits from digitalisation, which brings forward the specific value digitalisation can create for business actors in the logistics chain. In particular, port authorities (PAs) are increasingly implementing digital solutions to improve coordination among many port stakeholders to make operations safer and more sustainable and efficient along logistics chains (Tijan et al., 2021; Tsvetkova, Gustafsson et al., 2021). This article explores the case of RoPax ports, referring to ports handling vessels capable of carrying wheeled cargo and passengers. Significant research has been devoted to digital solutions that large container ports have introduced (Haezendonck & Langenus, 2019; Henríquez et al., 2022). However, small to medium-sized RoPax ports face unique digitalisation challenges and opportunities that make it challenging to compare their efforts. In particular, small and medium-sized ports are limited regarding resources and

investments (Del Giudice et al., 2021; Inkinen et al., 2019; von Malmborg, 2004) and have challenges in understanding digitalisation's influence on strategic business development (Inkinen et al., 2019). We are interested in the new value propositions emerging in the context of the RoPax port ecosystem and set out to explore how value is created through digitalisation in the logistics sector.

In the study of digital solutions that have been implemented or are under development in RoPax ports, we explore the various types of digital solutions regarding their functionalities and capabilities, thus value creation potential for the PAs who manage and develop the port area. Given the multitude of such solutions, understanding the differences and interrelations between these solutions is relevant, thus focusing on the digital business ecosystem that is forming and evolving (Hanelt & Schneider, 2020). This article presents the typology for relevant digital solutions for RoPax ports, forming the basis for understanding new value propositions in this underexplored empirical context. In addition to the solutions already implemented by ports and confirmed as relevant, this paper considers solutions under development through collaboration with port actors as part of the relevant digital solutions for RoPax ports.

2 Literature Review

2.1 Digitalisation and its Effect on Business Models and Ecosystems

Digitalisation facilitated transitioning the business model innovation within the same industry towards cross-industrial and ecosystem business model innovation (Kamalaldin et al., 2021; Leminen et al., 2020; Sjödin, Parida, Jovanovic et al., 2020). However, materialising digitalisation demands developed digital infrastructure, suitable technologies, and interoperability of data format.

Business model innovation and ecosystem transition go hand-by-hand. Business model innovation enabled by introducing new digital solutions often requires redefining industry structures and business ecosystems due to the change in information or operation flows (Huikkola et al., 2020; Linde et al., 2021). Hence, incumbent companies must consider ecosystem transition dynamics to stay alert for new value creation and capturing opportunities.

Regarding maritime logistics, the advent of ‘smart ports’ are opportunities to create more value through data-based services and data-driven business models. The general trend of ‘infrastructure as a service’ will likely affect ports’ business models as the information about infrastructure use becomes more valuable than possessing that infrastructure (Tsvetkova et al., 2020). While coordinating activities among port stakeholders requires data sharing, more complex solutions like providing optimisation require data analysis, such as predictive and prescriptive analytics, to predict events and plan the optimal resource allocations (Haraldson et al., 2021). This brings the need for aligning value creation in multiple firms and affects incumbent actors in the port ecosystems and digital solutions providers.

2.2 Typologies for Digital Solutions in Industrial Sectors

Digitalisation-related literature focused on numerous perspectives on the types of business models and offerings stemming from digitalisation (Caputo et al., 2021; Kohtamäki et al., 2019). In particular, this literature has explicated the capabilities of digital solutions and smart products and how these capabilities enable new value creation: digital servitisation-based business models and value propositions that digitalisation can enable (Caputo et al., 2021; Coreynen et al., 2017; Porter & Heppelmann, 2014; Sjödin, Parida, Kohtamäki et al., 2020).

Digitalisation’s impact on business models has been described in diverse industrial contexts. Kamaladin et al. (2021) studied digitalisation in the process industry and how it enables process innovation; Tsvetkova et al. (2021) studied maritime infrastructure digitalisation, mentioning that a digital solution’s outcome differs based on the layers each solution addresses: infrastructure, service, and system layers.

Digitalisation in the maritime sector is changing the overall business and operational processes (Tsvetkova, Hellström et al., 2021). Like other areas in maritime logistics, port digitalisation’s implications on the business models of relevant actors remain understudied. The current research on digitalisation in ports has been focused on phases of port digitalisation (Inkinen et al., 2021), influences of digitalisation on ports’ business performance (Holmström et al., 2019), barriers for implementing digitalisation (Brunila et al., 2021), and the comparison of technological configurations (Hirata et al., 2022). Few studies approached the topic with empirical

examples, mostly among large container ports, such as Amsterdam and Barcelona (Anwar et al., 2019; Heikkilä et al., 2022; Henríquez et al., 2022).

Compared to large container ports, smaller-sized ports face different difficulties concerning digitalisation (Inkinen et al., 2019). PAs have fewer resources for implementing digitalisation. Conversely, the traffic flow has a different pattern in RoPax ports due to the simultaneous involvement of passenger and cargo traffic.

Thus, the value digital solutions create is critical but unapparent regarding RoPax ports. We aim to contribute to understanding how value can be created through digitalisation in RoPax ports with our study.

3 Methodology

3.1 Research Design

The current research results from a three-year project devoted to developing digital solutions for smart RoPax ports. The project aimed to improve operation efficiency through collectively developed digital solutions for RoPax ports. Different types of actors were present: some are incumbent in the port operation ecosystem, such as PAs, shipping companies, and a set of digital solution providers, while others are new and aim to join the ecosystem based on their successful experience in another ecosystem.

We did an explorative case study (Mills et al., 2012) to develop a typology of digital solutions relevant to RoPax ports based on a systematic combining approach grounded in abductive logic. The research process was continuous and manifested in the evolution of a theoretical framework, empirical fieldwork, and case analysis (Dubois & Gadde, 2002). As we collected data on the available and planned digital solutions for RoPax ports and studied the empirical context, we iteratively improved the theoretical framework, constituting the basis for the typology of digital solutions in RoPax ports. As new data appeared, we reconsidered the typology and searched for categories allowing us to accommodate the empirical evidence. This iterative process involved six researchers and the collection of feedback from the project participants.

3.2 Data Collection and Analysis

We collected the data through desktop study, interviews (including site visits to ports), and group workshops. Data collection occurred inside and outside the focal project. We explored the available and potential digital solutions developed in the focal project. Conversely, we benchmarked six Northern European RoPax ports to identify digital solutions that PAs implemented or planned. We interviewed many relevant organisations regarding port digitalisation to support our understanding of the function and value of digital solutions. In particular, we interviewed municipality departments and digital solution providers in the urban and transportation sectors. The interviews lasted about an hour each; one or more managerial-level representatives participated in a semi-structured interview. The interviews were recorded and transcribed, and we made observation notes.

Altogether, 40 interviews were conducted during the project and were used in this paper's research. Table 1 presents a list of the primary research data. Based on the interview outcomes, we gathered additional secondary data that interviewees mentioned as relevant documents.

Apart from interviews with individual actors, six field visits to ports and two workshops on identifying the types of digital solutions relevant to RoPax ports were organised. Field visits were made to the two focal project ports. One workshop focused on passenger traffic and another on cargo flow, where the participants identified the bottlenecks, goals, potential digital solutions, and collaboration steps for improving passenger and cargo traffic flows. The workshops were approximately two hours each, recorded and transcribed. Through these interactions, we better understood the current operations' challenges and development bottlenecks.

Table 1: Overview of Primary Data Sources

Companies	Informants' roles	Number of participants (number of interactions)	Form of interaction
Port authorities	PA: technical director, COO, sales and deputy managing director, and IT manager	5 (2)	Interviews
	Benchmarking RoPax ports	5 (5)	Interviews
Shipping company	Head of digitalisation	1 (2)	Interview; interview and site visit
	Head of IT group, captain, and cargo planner	4 (1)	Interview and site visit
	Terminal manager	1 (1)	Interview
	Sales manager	1 (1)	Interview
	Operative manager	1 (1)	Interview and site visit
Incumbent digital solution providers	Research leaders	2 (1)	Interview
	CEO and project manager	2 (1)	Interview
	CEO	1 (1)	Interview
	CEO and research leader	2 (1)	Interview
New digital solution providers	CPO and CFO	2 (1)	Interview
	Director and research leader	2 (1)	Interview
	CEO	1 (1)	Interview
	CEO	1 (1)	Interview
	Research leader	1 (1)	Interview
Project participants	Project update workshops	36 (9)	Workshop
Various stakeholders	Workshops devoted to identifying digital solutions	36 (2)	Workshop
Municipality, authorities, and external stakeholders	Land planning department and traffic planner	4 (1)	Interview
	Regional logistic coordinator	1 (1)	Interview
	Carbon neutral development	1 (1)	Interview
	Urban mobility developer	1 (1)	Interview
	City infostructure builder	1 (1)	Interview

Traffic management department	1 (1)	Interview
Road digital solution provider, CEO	1 (1)	Interview
Total	78 (40)	

Note: The numbers of unique participants were reported. The numbers of interviews and workshops we conducted or participated in are in parentheses.

It is important to note that a relatively bigger volume of data was collected in relation to the two ports that participated in the research project described above. The primary data regarding the other four ports included one-hour interviews with the representative of each PA. However, the secondary data such as annual reports and strategy documents have been studied to enrich the study. We acknowledge the possibility of other biases influencing the data collection process. We made efforts to minimize biases in the data collection process by including diverse perspectives and roles, using a variety of data collection methods, and continuously revising our theoretical framework. The typology was also validated with the project participants in one of the workshops and through other regular interactions, and its relevance and applicability was confirmed.

4 Findings

4.1 Challenges Faced by RoPax Ports

The coexistence of cargo, vehicle, and passenger flows in RoPax ports leads to several specific challenges, creating digitalisation opportunities. During the research project described in section 3, we have identified several recurring challenges that RoPax ports face.

Passenger flow improvement faces challenges regarding information sharing and safe travel. For instance, the unavailability of real-time intermodal traffic information causes delays along the transit journeys to and from the terminal; relevant information comprises transport connections, schedules, services, and notifications on traffic disturbances. During check-in, security, and embarkation procedures cause unnecessary crowding and queuing in the passenger terminal, which the uptake and implementation of digital solutions could alleviate. The technology could take safety

and security matters to another level as tools for managing crowds and identifying passengers' unusual behaviour or unattended luggage.

The multimodal transport chain is hampered by uncoordinated road traffic pulses and congestion at ship arrivals and departures inside the port, its associated urban area, and its main approach roads – a problem less likely to diminish with residential and recreational urban areas expanding and the associated shrinkage of the port facilities and stowing areas. Furthermore, the vessels' cargo capacity will likely grow, further worsening the overcrowding of the road network. Traffic jams, in their turn, will increase idling and unnecessary emissions.

Due to relatively short distances over the sea and ship turnaround times in ports, the RoPax short sea segment is more time-sensitive concerning timely and efficient loading and unloading procedures, as delays may be difficult to compensate with speed out at sea. Accumulating trucks in the port area and using this area as a waiting or parking area long before the actual departure is another unwanted phenomenon. This is principally due to a limited number of dedicated resting and parking areas for trucks in the port's vicinity. Introducing an integral just-in-time (JIT) solution with an associated pre-parking concept offered to road haulage customers would benefit all stakeholders' operations and performance. Truck drivers would be informed and called in when their vehicle could drive to the port area through a dedicated application or another interface. To a predetermined degree, the given slot times would enhance specific trucks' orderly and timely arrival in certain batches, benefiting the actual optimal onboard stowing plan and order.

4.2 Typology Development

During the research, it became apparent that digital solutions designed for or implemented in RoPax ports provide different functions – adding value to port actors – and involve smaller or bigger constellations of actors and respective data. Considering their effect, the solutions ranged from those addressing limited activities within one port actor's boundaries to those affecting the efficiency of whole logistics chains. Certain solutions, such as those for situational awareness (SA) in ports, could provide data for other solutions that offer, for example, cargo or passenger flow optimisation.

The solutions were categorised into two dimensions. The first dimension includes six capabilities and functions of digital solutions: Communication, Visualisation, Monitoring, Control & Automation, Prediction, and Optimisation. The capabilities were inspired by the four capabilities proposed by Porter and Heppelmann (2014) and further developed with three additional capabilities. Communication refers to the ability of digital solutions to exchange information between different actors, whereas Visualisation concerns the presentation of data in an easily understandable way. Monitoring and Control & Automation capabilities allow for real-time monitoring and control of port operations, respectively. Prediction involves the use of data to anticipate events and potential problems, and Optimisation refers to the ability to improve efficiency and performance. Examples of solutions that exhibit these capabilities are digital twins of port infrastructure for Visualisation or Monitoring, traffic and cargo management systems for Control & Automation, and predictive algorithms for Prediction. The typology development includes these capabilities and functions as part of the framework for analysing and classifying digital solutions in RoPax ports.

The second dimension included three layers of digitalising port operations, following the layers of digitalisation in maritime logistics (Tsvetkova, Gustafsson et al., 2021): infrastructure, service, and system layers. The infrastructure layer includes solutions directly related to efficiently operating and maintaining maritime infrastructure, such as digital twins of port infrastructure and smart buoys, that help identify maintenance needs through predictive algorithms. The service layer includes solutions to improve how the users utilise this infrastructure. These solutions include managing the throughput of traffic and cargo and vessel flows through ports, so the maritime infrastructure is utilised efficiently, and the service quality is maximised for cargo shippers, ship operators, and other parties relying on port infrastructure. Combining the data related to maritime infrastructure and cargo flows makes it possible to achieve efficiencies on a larger scale at a system level, ensuring a smart cargo and passenger flow through digital corridors, end-to-end journeys, and optimising whole supply chains.

4.3 Analysis of Digital Solutions for RoPax Ports

We identified various solutions implemented or planned for implementation in the RoPax ports we studied (marked in blue in Figure 1) and the solutions developed or discussed within the case project (marked in yellow in Figure 1).

One finding is that RoPax ports strongly focus on digitising and improving communication among the many actors. Without digitising documentation flow and notification processes, more profound digitalisation and integration efforts across organisations is infeasible. The solutions the studied ports mention mostly focus on documentation exchange and notifications regarding cargo and vessel arrival. Several solutions relate to communication for passenger flow, creating an intriguing opportunity for improving customer satisfaction concerning passengers as customers of RoPax terminals. Moreover, using digital solutions, such as mobile applications or other interfaces, could help streamline security and embarkation procedures, reducing crowding and queuing in passenger terminals.

Regarding monitoring, ports have implemented solutions for monitoring processes directly related to the infrastructure layer, such as energy use or air quality in the port area. Naturally, security monitoring exists in any RoPax port. However, new solutions were proposed for more automated security monitoring, including, for example, automated identification of abandoned luggage or identification of crowding in the terminal. These solutions can help to address safety and security matters as discussed in section 3.1. The project also developed solutions for identifying and counting passengers and vehicles, which can provide input for several automation or optimisation solutions.

Control and automation are seemingly high on the agenda for many ports, as passenger and vehicle flow automation can save costs, improve customer satisfaction, and reduce the workload of port workers. Many overlaps between the solutions developed within the case project and solutions were implemented (often partly) or planned by RoPax ports, confirming that the value of these solutions is indisputable.

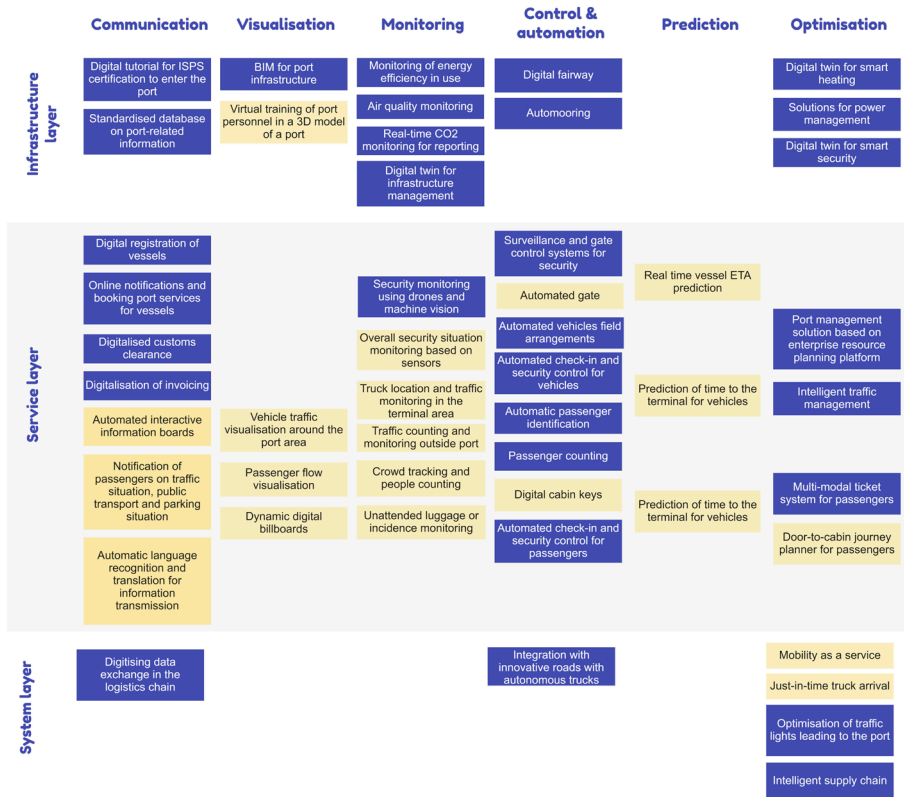


Figure 1: The typology of digital solutions in RoPax ports

Similar to visualisation, solutions falling under prediction capability are crucial for human decision-making in RoPax terminals or optimisation solutions. There are opportunities for predicting critical data points concerning passenger, vehicle, and vessel flow, which can ultimately help improve the timely and efficient loading and unloading procedures, reducing delays that may be difficult to compensate with speed out at sea.

Regarding optimisation, ports have implemented several solutions addressing the infrastructure layer and are thus limited to the scope of a RoPax port (heat and power optimisation in the terminal area, smart security). Other solutions aim at integrating several processes going beyond actual port operations. However, the system layer is addressed much less. While RoPax ports have mentioned intelligent supply chains, it has yet to be developed into a working concept. The case project has produced

concepts for several optimisation solutions. For instance, passengers' end-to-end journey planner can reduce the passengers' need for private vehicles when arriving at the port, thereby alleviating traffic congestion in the port area. Another solution for integrating truck traffic flow with port and vessel operations can enhance specific trucks' orderly and timely arrival in certain batches, benefiting the actual optimal onboard stowing plan and order.

5 Discussion and Conclusions

The digitalisation of end-to-end supply chains can fundamentally change logistics and thus has implications for the future management of maritime infrastructure. Specifically, increased transparency and a better understanding of cargo and vessel flow through ports are inputs for smarter decisions regarding port infrastructure investments going forward. Combining the data related to maritime infrastructure and cargo flows makes it possible to achieve efficiencies on a larger scale at a system level, ensuring a smart cargo flow through digital corridors and optimising whole supply chains. Such synchronous modality can allow significant transport cost reductions and optimum utilisation of transport infrastructure while adhering to the respective delivery conditions (Tsvetkova, Gustafsson et al., 2021).

We observed potential differences between the technology push and market pull regarding digital solutions for the RoPax port. In particular, solutions for visualisation or prediction developed in the case project can provide valuable input for other functions, such as optimisation or control. It is necessary to understand, for example, how predictions or visualisations of terminal flows can be used in, e.g. security management or passenger and cargo flow optimisation to develop a viable business offering. Besides the unclear value proposition of such solutions, we identified another challenge related to the digitalisation in RoPax ports, namely, the difficulty of justifying investment in digital infrastructure that may not directly benefit the port authorities but require resources from them.

While earlier studies (Kohtamäki et al., 2019) focused on making typologies of different digital BMs, this study specifically addresses the value propositions of digital solutions and their place in a functioning digital business ecosystem. The typology of digital solutions for RoPax ports can be a benchmark for different solution providers to identify their solution's role and the value it can create for port

actors. Simultaneously, it identifies common trends in digitalising RoPax ports, which can be a reference for PAs and port actors to discover new technological opportunities. For example, a port operator could use this typology to identify areas where they could improve their operations using digital solutions, such as optimizing cargo flows or improving situational awareness in the port. A digital solution provider, on the other hand, could use this typology to identify gaps in the market and develop new solutions that address specific capabilities or functions that are currently lacking in the market. By using this typology, both port actors and solution providers can make more informed decisions and identify new opportunities for innovation.

Further research would be needed to better understand how the structure of port business ecosystems shapes value creation. In particular, the interplay between the value captured by PAs and shipping companies from their customers is interesting regarding digitalising port operations. Further, this article's typology is based on earlier studies' proposed capabilities but adjusted with empirical evidence. While we believe it captures the current digitalisation state in RoPax ports, the evolving nature of digital solutions may necessitate future revisions. An example is the 'autonomy' capability, initially part of Porter and Heppelman's (2014) four capabilities, but omitted in this typology as no solutions provided it. Autonomous shipping may require RoPax ports to incorporate autonomous capabilities in the future. We recognize geographical limitations as our study focused solely on ports in Northern Europe. Furthermore, this typology is tailored to the RoPax shipping context, which enhances its empirical significance, but also restricts its applicability to other ports and shipping modes. A comparative study of the types of digital solutions in different shipping segments is a promising avenue for further research.

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