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Prevailing Technologies and Adoption Obstacles in Maritime Logistics

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Purpose: *Digital technologies (DTs) are transforming logistics operations in the shipping industry. Yet, the industry is only in the early stages of digitalization. Consequently, there is a lack of empirical evidence on applied DTs and related obstacles for DT adoption.*

Methodology: *A multiple case study was conducted comprising ports, freight forwarders, and carriers. Based on 18 expert interviews and additional data sources, differences and similarities concerning currently applied DTs and associated obstacles to DT adoption were examined.*

Findings: *Presented findings indicate comprehensive efforts toward a paperless and digitalized way of operating within maritime container logistics (MCL) by using DTs such as blockchain, cloud solutions, and artificial intelligence. Especially ports strive to achieve collaborative data usage but are frequently hindered by a lack of inter-organizational data sharing. Furthermore, the inherent complexity of the MCL chain and employees' and managers' defensiveness toward technological change needs to be overcome by applying suitable measures for DT adoption.*

Originality: *The research contributes to the scarce literature of DT adoption within MCL by providing empirical insights into the state-of-the-art of DTs for ports, freight forwarders, and carriers. Additionally, this research is the first to address implications for tackling existing obstacles for successful DT adoption in MCL.*

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1 Introduction

Maritime logistics is of outstanding importance for global supply chains, being responsible for the majority of overall freight logistics (OECD, 2022). In 2020, maritime container logistics (MCL) was in charge of the shipment of approximately 20% of tons loaded in overall international maritime logistics (UNCTAD, 2021). From 2022 to 2026, MCL is expected to grow 4.6% annually – thus exceeding the growth expectation of overall maritime logistics of 2.4% annually (UNCTAD, 2021), emphasizing its current and future significance for global supply chains. However, the container shortage, starting in 2020, negatively influenced the reliability and increased costs in MCL (UNCTAD, 2021), displaying the need to incorporate digital technologies (DTs) in MCL to compensate for the negative effects on global supply chains (Panwar, Pinkse and Marchi, 2022). Emerging DTs, such as artificial intelligence (AI), machine learning (ML), blockchain, or the Internet of things (IoT), are characterized by not merely digitizing products and processes of organizations, but beyond being responsible for the digitalization of organizations, radically modifying logistics chains, renewing business models, and affecting the logistics industry's structures (Ceipek, et al., 2021). Also before the COVID-19-crisis, the significance of emerging DTs in MCL was highlighted (Fruth and Teuteberg, 2017), as the following examples illustrate: (1) DTs, such as the Internet of Things (IoT), are applied to allow seamless tracking and tracing of containers (Sanchez-Gonzalez, et al., 2019); (2) blockchain technology is used for the standardization and digitization of paper-based processes (Yang, 2019); (3) sensors, among other things, support monitoring activities within ports (Fruth and Teuteberg, 2017); and (4) artificial intelligence (AI) was found to optimize routing problems (Jurdana, Krylov and Yamnenko, 2020) or to monitor and predict weather and ice conditions (Benz, Münch and Hartmann, 2021). These examples display that DTs have a huge potential for transforming MCL towards increased transparency and real-time information availability (Bathke, et al., 2022). However, Munim, et al. (2020) indicated that the mere existence of DTs is not efficient until it is widely adopted in overall MCL.

Regarding appropriate DT adoption, the research in MCL is still in its infancy (Fruth and Teuteberg, 2017; Tijan, et al., 2021a). Although the adoption of specific DTs such as blockchain (Yang, 2019) or AI (Jurdana, Krylov and Yamnenko, 2020) have already been examined, no differences between incumbent actors in MCL were elaborated. However, as MCL is moving towards digitalization at different speeds in different domains (Sanchez-Gonzalez, et al., 2019), the behavior of organizations regarding DT adoption may differ (Fruth and Teuteberg, 2017). Additionally, emerging DT adoption was found to be one of the biggest challenges that organizations in logistics currently face (Mathauer and Hofmann, 2019; Karakas, Acar and Kucukaltan, 2021), and thus, several obstacles need to be overcome for successful DT adoption (Cichosz, Wallenburg and Knemeyer, 2020; Tijan, et al., 2021a; Yang, Fu and Zhang, 2021). These potential obstacles to DT adoption are currently lacking research in MCL. Referring to potential inherent differences between the main incumbent actors of MCL—ports, freight forwarders, and carriers (Talley and Ng, 2013), this research aims to answer the following research questions (RQs):

RQ1: What is the state-of-the-art of DT adoption comparing ports, freight forwarders, and carriers?

RQ2: What are the obstacles that need to be overcome for successful DT adoption for ports, freight forwarders, and carriers?

To answer the RQs, an empirical case study is conducted. Thereby, the study is structured as follows: After providing theoretical background information about the topic, the underlying methodology is explained. Next, a cross-case analysis is conducted, discussing the findings gathered from the case study. Lastly, managerial and theoretical implications, limitations, and paths for future research are displayed.

2 Theoretical background

The objective of this paper is to demonstrate the current DT adoption status and obstacles to DT adoption in MCL. Therefore, first, theoretical information regarding DT adoption is provided, followed by an analysis of obstacles to DT adoption in general.

2.1 Adopting digital technologies

DTs have significant impacts on different levels of logistics organizations: (1) within logistics organizations regarding a change in business models and processes; (2) between logistics organizations considering governance and relational configurations; and (3) at the level of the logistics industry regarding disruptions to the status quo and the emergence of new product or service providers (Wang and Sarkis, 2021). In particular, in MCL, DTs enable standardization, digitization, and easing of paperwork (Yang, 2019). Additionally, DTs may minimize the employee role in MCL organizations to that of a system observer, as DTs have the potential to self-optimize processes (Jurdana, Krylov and Yamnenko, 2020) and to take over error-prone tasks (Bălan, 2020). This results in a simplification of freight calculations, and a decrease in the costs of fuels and human resources (Bălan, 2020; Jurdana, Krylov and Yamnenko, 2020).

When adopting DTs, the study by Yang, Fu and Zhang (2021) stated that organizations go through several stages depending on their level of technological intelligence and supply chain collaboration. The authors' developed matrix can be adapted to MCL, as presented in Figure 1. The first axis, *technological intelligence*, is defined as the degree of intelligence to which DTs are adopted in MCL (Schoenherr and Swink, 2015). Little technological intelligence means that traditional DTs, such as enterprise resource planning (ERP), transportation management systems (TMS), application programming interfaces (API), robotics process automation (RPA), data collection and visualization, or data processing technologies, are used in MCL (Munim, et al., 2020; Núñez-Merino, et al., 2020; Yang, Fu and Zhang, 2021), thus representing digitized solutions that merely convert analog into digital information. On contrary, high technological intelligence implies that real-time data can be processed by applying smart sensors, and predictive analyses are applied for forecasting and real-time planning (Yang, Fu and Zhang, 2021), consequently being related to digitalization. High technological intelligence is represented by IoT, augmented and virtual reality (AR/VR), additive manufacturing, blockchain, cloud and edge computing (Sanchez-Gonzalez, et al., 2019), as well as AI and machine learning (ML) (Sanchez-Gonzalez, et al., 2019; Jurdana, Krylov and Yamnenko, 2020; Munim, et al., 2020). The second axis represents the *level of collaboration* between MCL organizations (Cloutier, Oktaei and Lehoux, 2020). By inter-organizational application, DTs are considered to lead to intelligent supply chains and involve connections between different actors within supply chains (Núñez-Merino, et al., 2020). Low collaboration means that DTs are solely applied intra-organizational, whereby high collaboration refers to the application of DTs and data sharing across several organizations (Cloutier, Oktaei and Lehoux, 2020; Yang, Fu and Zhang, 2021).

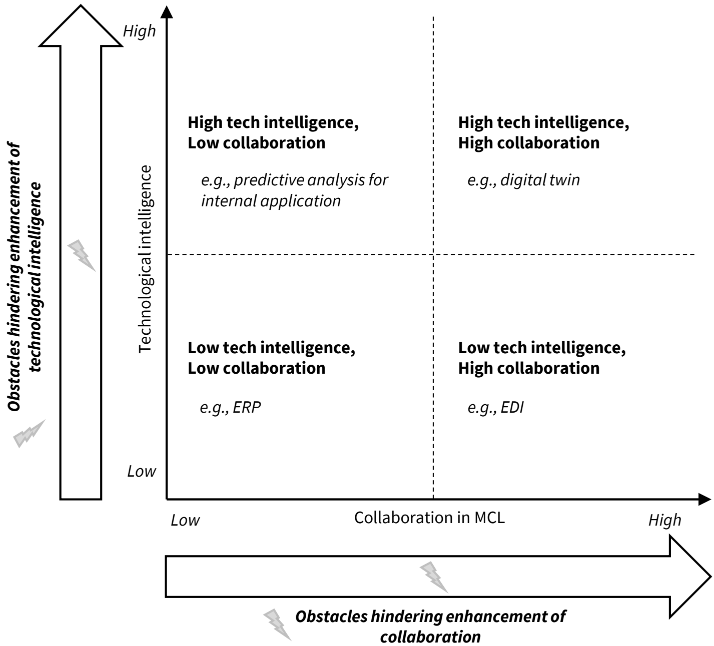

Figure 1: Research framework, adapted from Yang, Fu and Zhang (2021)

2.2 Obstacles to successful DT adoption in logistics

The mere existence of DTs has no impact until they are adopted in the whole MCL industry (Munim, et al., 2020). However, the inappropriate DT adoption potentially results in a disruptive change that leads to high risk and uncertainty (Yang, Fu and Zhang, 2021). Thus, DT adoption is referred to several potential disadvantages, such as cyber risks (Hofmann, et al., 2019), or the high potential volatility (Büyüközkan and Göçer, 2018). In addition, the uncertainty dilemma, stating that timely and accurate data is an arduous task and often not completely achievable in a volatile, uncertain, complex, and ambiguous environment, is a challenge regarding the usage of DTs (Lechler, Canzaniello and Hartmann, 2019). Consequently, obstacles inherent to DT adoption must be overcome to succeed in DT adoption (Yang, Fu and Zhang, 2021), as represented in the research framework in Figure 1. Potential general obstacles to DT adoption in logistics, found by screening respective literature, are summarized in Table 1. The results of Table 1 result from a desk research, using the databases Scopus and Google Scholar and applying the keyword sequence “digital technology” OR "digital technologies" AND "adoption" OR "implementation" AND "logistics" OR “supply chain” and additional relevant sources. The table serves as a basis for the analysis of the case study results regarding DT adoption obstacles in MCL.

Table 1: Obstacles to DT adoption according to literature

Obstacles to DT adoption	**Reference(s)**
Heterogeneous information systems and lack of standards	*Cichosz, Wallenburg and Knemeyer (2020), Inkinen, Helminen and Saarikoski (2019), Tijan, et al. (2021a), Yang (2019)*
Heterogeneous organizational structures or cultures	*Harris, Wang and Wang (2015), Tijan, et al. (2021a)*
High implementation costs and risks	*Harris, Wang and Wang (2015), Tijan, et al. (2021a)*
Lack of capabilities to change	*Balci and Surucu-Balci (2021), Tijan, et al. (2021a)*

Obstacles to DT adoption	Reference(s)
Lack of coordination and collaboration	*Tijan, et al. (2021a), Yang (2019)*
Lack of early adopters	*Balci and Surucu-Balci (2021)*
Lack of investments in DTs	*Harris, Wang and Wang (2015), Tijan, et al. (2021a)*
Lack of knowledge about DTs	*Balci and Surucu-Balci (2021), Tijan, et al. (2021a)*
Lack of regulation	*Balci and Surucu-Balci (2021), Harris, Wang and Wang (2015), Tijan, et al. (2021a), Yang (2019)*
Lack of skills	*Cichosz, Wallenburg and Knemeyer (2020),Tijan, et al. (2021a)*
Lack of support from stakeholders	*Balci and Surucu-Balci (2021), Harris, Wang and Wang (2015)*
Lack of trust in DTs	*Balci and Surucu-Balci (2021)*
Lack of urgency to adopt DTs	*Tijan, et al. (2021a)*
Privacy concerns/no cyber security	*Balci and Surucu-Balci (2021), Cichosz, Wallenburg and Knemeyer (2020), Harris, Wang and Wang (2015), Kala and Balakrishnan (2019), Tijan, et al. (2021a)*

Obstacles to DT adoption	**Reference(s)**
Resistance of stakeholders (e.g., employees) to adopt	*Balci and Surucu-Balci (2021), Cichosz, Wallenburg and Knemeyer (2020), Tijan, et al. (2021a)*

3 Methodology

The methodology applied to answer the RQs is a multiple-case design, collecting empirical data (Yin, 2018). Thereby, the following chapter is structured as follows: first, a short background about the case study design is provided. Afterward, the sample and data collection are presented in detail, followed by a description of the data handling.

3.1 Case study design

The case study approach is considered appropriate for our research for several reasons: (1) research regarding DT adoption in MCL is still at the beginning and existing knowledge regarding DT adoption is not sufficient (Fruth and Teuteberg, 2017); (2) the case study helps to widely evaluate the research problem and observe it within its actual practice (Yin, 2018); (3) the case study allows the close investigation of Yang, Fu and Zhang's (2021) DT adoption framework and expanding it based on the insights gathered from the interviews (Siggelkow, 2007); and (4) by using at least three sources of evidence per case, required triangulation is ensured (Eisenhardt and Graebner, 2007).

While executing the case study, construct validity, internal and external validity, and reliability need to be ensured to allow high-quality results (Yin, 2018). Construct validity is enabled by developing and adapting the questionnaire based on an extensive literature review and collecting multiple sources of data (Yin, 2018). Internal validity is allowed by analyzing existing literature regarding DT adoption and conducting interviews with a heterogeneous group of experts (Yin, 2018). External validity is ensured by conducting a multiple instead of a single case study; and reliability relies on the selection based on predefined criteria, the sharing of the questionnaire in advance, and support by another researcher while analyzing the results (Yin, 2018).

3.2 Sample and data

We aimed to evaluate the differences between the three incumbent MCL actors “ports,” “freight forwarders,” and “carriers” (Talley and Ng, 2013). Thereby, the experts were selected according to the following, predefined criteria (Eisenhardt, 1989):

- Ports were required to be among the top 15 largest container ports around the world according to the handled volume. Experts from port authorities were chosen as interview partners in this category, as recent literature emphasized the significant role of port authorities regarding DT adoption in MCL, potentially becoming digital hubs in the future (Tijan, et al., 2021b);
- Freight forwarders needed to ship a volume of 500,000 twenty-foot-equivalent units per year by vessel; and
- Carriers were supposed to possess over 5% market share.

The literature provides several recommendations regarding the number of cases that seem appropriate for a multiple-case study. While some authors suggest that no more than 15 cases shall not be included (Perry, 1998), others propose that four to ten cases are sufficient (Eisenhardt, 1989). According to Corbin and Strauss (1990), additional cases shall be incorporated until saturation is achieved. They consider that any further cases would merely provide little variation compared to the already gathered data, marginally new insights, and no further relevant managerial and theoretical implications (Corbin and Strauss, 1990). Information regarding the final set of interview participants can be found in Table 2. The final set consists of nine cases and 18 interview participants. According to anonymization reasons, the size of the organizations is shown as an incremental range.

Table 2: Overview of cases

Case	**Current position of the contact person**	**Organizational type**	**Number of employees**
Alpha₁	Port Representative (Digital products)	Port authority	50,000–100,000
Alpha₂	Chief Digital & Innovation officer		
Beta₁	Project Manager for Digital Projects	Port authority	10,000–50,000
Beta₂	Consultant for Digital and Business Transformation		
Gamma₁	Proposition Manager Digital Business Solutions	Port authority	>100,000
Gamma₂	Product Lead Digital Products		
Delta₁	Vice President and Global Head Ocean freight processes	Freight forwarder	>100,000
Delta₂	Head of International Supply Chain		
Epsilon₁	Vice President Global IT	Freight forwarder	50,000–100,000
Epsilon₂	Senior Product Manager for Digital Innovation		
Zeta₁	Vice President Global Sea freight Processes and Systems	Freight forwarder	50,000–100,000
Zeta₂	Vice President Global Sea Logistics Operations		

Case	Current position of the contact person	Organizational type	Number of employees
Eta₁	Member of the strategy office	Carrier	10,000–50,000
Eta₂	Digitalization Manager		
Theta₁	Deployment Lead (Transformation and Change Management)	Carrier	50,000–100,000
Theta₂	Investment Advisor Digital Products		
Iota₁	Global Chief Digital & Information Officer	Carrier	50,000–100,000
Iota₂	Projects Manager for Digital & Innovation		

3.3 Data handling

High construct validity was ensured by an extensive review of respective literature and discussions within the research team (Eisenhardt, 1989). This allowed the development of an interview guideline with a semi-structured design, using open questions, to react flexibly during the interviews (Yin, 2018). In addition, the interview questions were adapted during the conduction of the interviews. Before conducting the interviews, the potential experts were made familiar with the DT adoption framework by Yang, Fu and Zhang (2021) to understand the process of DT adoption. Furthermore, they were asked to classify their organization in this matrix.

All 18 interviews were conducted by two researchers of the research team. The interviewees had on average 14 years of experience in MCL. Data gathered from the semi-structured interviews served as the primary and most valuable data source (Yin, 2018). By additionally using secondary data besides the interview material, a potential social desirability bias can be reduced (Crane, 1999). The interviews were then transcribed. Subsequently, the transcript and a summary of the interview were sent to each interviewee with the confirmation request to avoid misunderstandings and to guarantee the accuracy of the information supplied (Yin, 2018).

The data was analyzed by revealing common patterns and differences regarding DT adoption across the nine cases by a cross-case analysis. The identification of structures and patterns in the unstructured qualitative interview data and secondary data was allowed by a systematic coding process (Corbin and Strauss, 1990). Subsequently, categories were built on the identified codes. To allow inter-rater reliability and a high-qualitative analysis, an iterative coding approach was applied (Pagell and Krause, 2005). Consequently, another researcher of the research team revised and verified the identified codes and patterns during each coding step. Thereby, deviating results were iteratively approximated in three research meetings, leading to an agreement regarding the codes and patterns. Using the same categories for all interview transcripts allowed to efficiently compare the different case organizations (Eisenhardt, 1989). To facilitate the handling of the large amount of data, the categorization of the data was supported by computer-aided qualitative data analysis software (Yin, 2018).

4 Cross-case analysis

4.1 Digital technologies currently applied in maritime container logistics

According to the classification of the case organizations in Yang, Fu and Zhang's (2021) DT adoption matrix, Table 3 displays the level of technological intelligence and level of collaboration of the different case organizations.

Table 3: Current level of DT adoption of the nine cases

Case	Classification in DT adoption matrix	DTs applied in case organizations
Alpha	*High tech intelligence/high collaboration*	APIs, Autonomous shipping, Blockchain, Digital twin, Drones, ERP, IoT, Sensors
Beta	*High tech intelligence/low collaboration*	3D printing, Digital twin, Drones, ERP, ML, RPA, VR/AR
Gamma	*High tech intelligence/low collaboration*	AI, Autonomous shipping, Blockchain, Cloud computing, Drones, ERP, IoT, ML, RPA
Delta	*Low tech intelligence/low collaboration*	APIs, Chatbot, EDI, ERP, ML, Process mining
Epsilon	*Low tech intelligence/high collaboration*	APIs, AI, Chatbot, Cloud computing, Drones, ERP, IoT, ML, Quantum computing, RPA
Zeta	*Low tech intelligence/high collaboration*	APIs, AI, Blockchain, EDI, ERP, Predictive analytics, RPA
Eta	*Medium tech intelligence/low collaboration*	APIs, Blockchain, Cloud computing, ERP, RPA
Theta	*Medium tech intelligence/medium collaboration*	AI, Blockchain, Control tower solutions, ERP, IoT, ML, Process mining, RPA

Case	Classification in DT adoption matrix	DTs applied in case organizations
Iota	*Low tech intelligence/medium collaboration*	APIs, AI, Blockchain, Cloud computing, ERP, IoT, Predictive analytics

All ports state that they hold a high technological intelligence. However, the level of collaboration differs among the interviewed experts. Whereas Alpha displays a high level of collaboration, Beta and Gamma do not show high collaboration efforts. Alpha strives toward establishing a *"digital nervous system on top of the physical ports […] to focus on safety and security in the port area "(*Alpha$_1$), therefore testing the application of digital twins. This DT is also applied by Beta. However, Beta still displays silo-thinking and thus hinders collaboration efforts to some extent. All ports apply drones to *"detect oil spills"* (Alpha$_1$) or to *"inspect buildings"* (Beta$_2$). Blockchain is furthermore adopted by the ports for the transfer of documents. Additionally, Beta enhances its monitoring efforts by using sensors and AR.

Freight forwarders, on contrary, all display a low level of technological intelligence. While Delta further emphasizes its low level of collaboration, Zeta and Epsilon strive toward high collaboration with their MCL partners. Consequently, DTs to enhance data sharing are highly relevant for these two organizations. They adopted several cloud solutions to interact with their customers and manage their end-to-end logistics chain. Furthermore, AI simplifies their interaction with customers: *"With AI, we have the repository, where we have a lot of replies to a lot of questions collected over time"* (Epsilon$_2$) which can then be used for automated chatbots. Moreover, optical character recognition helps to scan physical documents that are arriving at the organizations: *"We had a lot of business inquiries from potential customers: Can you fulfill this requirement? Or do you have this standard? […] Now, we can do it in an hour instead, because we OCR scan these documents from the customers"* (Epsilon$_1$).

The carriers are all located in the lower left-hand corner of the DT adoption matrix, having low to medium technological intelligence and low to medium collaboration. Two out of three carriers apply IoT in their organization. For example, Iota uses IoT for *"the* *monitoring of containers"* and the establishment of smart containers. In addition, the application of AI, ML, or predictive analytics was emphasized by the experts. ML can help *"analyzing all data that could eventually become […] a new product that we could bring as part of our digital offering to our customers"* ($Iota_1$). Some carriers strive towards establishing new services for their customers and therefore need to analyze data. Moreover, the experts mentioned that currently paper-heavy solutions are being replaced by digitized ones, such as electronic solutions for the bill of lading, and *"many of the traditional paper-based architectures are or will be paperless"* (Eta_2). Tracking and tracing efforts by the application of blockchain and IoT are essential for the interviewed experts of the carriers. For Theta, it is not only relevant where the container is on the vessel, but beyond that *"getting real-time visibility when your container is moving on a truck, where that truck is right now"* ($Theta_1$) to enable *"new potential different products and services along that end-to-end journey"* ($Theta_1$).

The DTs adopted by the different case organizations are summarized in the following graph, presented in Figure 2.

	Ports			Freight forwarders			Carriers		
	Alpha	Beta	Gamma	Delta	Epsilon	Zeta	Eta	Theta	Iota
3D printing		x							
AI			x		x	x		x	x
APIs	x			x	x	x	x		x
Autonomous shipping	x		x						
Blockchain	x		x			x	x	x	x
Chatbot				x	x				
Cloud computing			x		x		x		x
Control tower solutions								x	
Digital twin	x	x							
Drones	x	x	x	x	x				
EDI						x			
ERP	x	x	x	x	x	x	x	x	x
IoT	x		x		x			x	x
ML		x	x	x	x			x	
Predictive analytics						x			x
Process mining				x				x	
Quantum computing					x				
RPA		x	x		x	x	x	x	
Sensors	x								
VR/AR		x							

Figure 2: DTs adopted by different stakeholders in MCL

4.2 Obstacles to digital technology adoption in maritime container logistics

The obstacles to DT adoption in MCL can be classified into obstacles that hinder the enhancement of technological intelligence, obstacles that impede the enhancement of collaboration, as well as obstacles that hinder both. In this context, the obstacles mentioned during the interviews are displayed in Table 4. Table 1 in chapter 2.2 served as a basis for the analysis of the following results.

Table 4: Obstacles hindering DT adoption in MCL

No.	Obstacles to DT adoption	Examples	Barrier to technological intelligence	Barrier to collaboration
O1	Competitors and external stakeholders *Alpha, Delta, Eta*	*Market power of carriers; freight forwarders hindering DT adoption*	No	Yes
O2	Complexity of MCL network *Alpha, Gamma, Delta, Epsilon, Zeta, Eta*	*Volatility of the market; involvement of many parties*	Yes	Yes
O3	Customers *Alpha, Delta, Eta*	*Smaller customers; customers in specific countries*	Yes	No
O4	Heterogenous organizational structures *Beta, Delta, Epsilon, Zeta, Theta, Iota*	*Size of the organizations; working in silos*	Yes	No
O5	Heterogenous systems/lack of standards *Alpha, Delta, Epsilon, Eta, Theta, Iota*	*Plenty of different systems and interfaces; lack of standardization*	No	Yes

No.	Obstacles to DT adoption	Examples	Barrier to technological intelligence	Barrier to collaboration
O6	Internal bureaucracy *Beta, Gamma, Delta, Epsilon, Zeta, Theta, Iota*	*Strong hierarchical structures; long decision processes*	Yes	No
O7	Lack of collaboration *Alpha, Beta, Gamma, Delta, Zeta, Eta, Theta, Iota*	*No willingness to share data; lack of finding adequate partnerships*	No	Yes
O8	Lack of adequate government regulations *Gamma, Delta, Epsilon, Zeta, Iota*	*No clear "digital" laws; plenty of different laws and regulations in different countries*	Yes	Yes
O9	Lack of necessary resources *Alpha, Gamma, Delta, Epsilon, Eta, Theta, Iota*	*No employee capacity; lack of IT skills; lack of financial resources*	Yes	No
O10	Lack of strategy/urgency Alpha, Gamma, Eta, Theta, Iota	*No clear vision; no shared business and technology strategy*	Yes	Yes

No.	Obstacles to DT adoption	Examples	Barrier to technological intelligence	Barrier to collaboration
O11	Lack of support from managers/C-level *Beta, Gamma, Epsilon, Eta, Theta*	*Lack of management attention; lack of C-level attention*	Yes	Yes
O12	Lack of trust *Alpha, Epsilon, Eta, Iota*	*No trust in systems or numbers; fear of losing competitive advantage*	Yes	Yes
O13	Legacy of old systems *Alpha, Beta, Gamma, Delta, Epsilon, Zeta, Eta, Theta, Iota*	*Running costs for old systems; no innovation focus on internal processes*	Yes	No
O14	Old-fashioned industry *Beta, Gamma, Delta, Epsilon, Zeta, Eta, Theta, Iota*	*No job rotation; predominant incumbent organizations*	Yes	Yes
O15	Privacy concerns/no data security *Alpha, Beta, Epsilon, Iota*	*Fear of too much transparency of the organization; lack of data security*	Yes	Yes

No.	Obstacles to DT adoption	Examples	Barrier to technological intelligence	Barrier to collaboration
O16	Resistance of employees *Beta, Gamma, Delta, Epsilon, Zeta, Eta, Iota*	*Older employees; employees hindering DT adoption*	Yes	No

All experts mentioned that the legacy of old systems, such as *"the amount of investments and support that we need to still do and have in regards of the legacy systems"* (Zeta$_1$), hinders the investments and the available capacity for the adoption of emerging DTs. In this regard, the experts further emphasized that the maritime industry itself is old-fashioned with an antiquated culture and that *"people in our industry generally are not quickly changing jobs. So, […] our staff works at least 10 years in the company"* (Eta$_1$). The missing collaboration is mentioned by 8 out of 9 organizations. However, especially within ports, many actors need to collaborate to guarantee efficient and disruption-free processes in the ports: *"There is still a certain degree of competition among the port players and actually we should position ourselves more strongly as a closed port"* (Beta$_1$).

Regarding the obstacle of the lacking resources, the organizations emphasize the challenge of *"investments and a proper budget to be spent on something that we know that we may fail"* (Iota$_1$). Besides *"the competence of the workforce"* (Gamma$_2$), the challenge to attract the right "digital" skills to be able to cope with the respective DTs often hinders the adoption of emerging DTs. This is fueled by internal bureaucracy, as emphasized by all experts working in freight forwarding: *"If something has to be researched, then you need a certain budget for it, then it has to be approved, and then […] ten committees have to be passed"* (Delta$_1$). This is closely related to the resistance of employees. As several experts mentioned, especially older employees delay the DT adoption as they refuse to learn and adapt to new circumstances. Some employees fear being replaced by DTs. The employees further often lack trust in the systems and numbers: "*They do not always trust the numbers, and they do not trust the AI results"*

(Iota$_1$), sticking to Excel sheets and thus hindering appropriate communication and analysis enabled DTs. This is related to privacy concerns between the different organizations, as mentioned by some experts: *“Digitalization is one thing, but it has a flip side”* (Alpha$_2$). Some organizations are worried about cyber risks resulting from emerging DTs.

In particular for carriers, both internal and external, heterogeneous systems and lacking standardization impede DT adoption. There is not *“ a unique platform, a unique standard that allows everyone to talk the same language when it comes to data”* (Iota$_1$). The experts of freight forwarders emphasized the heterogeneous structures in MCL. Often, these organizations have *“many siloed approaches between several teams”* (Delta$_1$), leading to a strategy for DT adoption that is rather organized in silos. This is related to the complexity of the MCL network, as for *“a container of food shipped from Africa to Europe, 30 parties [are] involved and 200 data transactions [are necessary]”* (Alpha$_1$). Furthermore, several different laws and regulations exist on different continents and countries, being an obstacle to enhancing both collaboration and technological intelligence.

Additionally, the missing support by managers slows down DT adoption by being closely related to manager’s priorities and alignment (Theta$_2$). In this context, several experts emphasized that a shared business and technology strategy is relevant to appropriate DT adoption: There is *“a barrier between the business strategy and the technology strategy. So there are two different processes, […] and there is always a bit of discrepancy that is a problem for implementing a common strategy and reinterpreting it with technology”* (Theta$_2$). As further opined by several experts, some customers hinder the advancement of technological intelligence. *“Many boxes continue to be booked by small customers. Small producers in China, small forwarders, and in many cases, they are still manual themselves”* (Eta$_1$). Besides smaller customers in general that are less digitized, customers in specific regions impede DT adoption: *“There are still a few small two-man companies in China that want to [communicate] by fax”* (Delta$_1$). Competitors, in particular carriers, were identified as barriers by the other stakeholders as “*there is a relatively small market of large carriers that cover the market and at the moment everyone is happy to get any capacity at all”* (Delta$_2$).

The findings of the analyses in chapter 4.1 and chapter 4.2 are summarized in Figure 3, complementing the presented research framework.

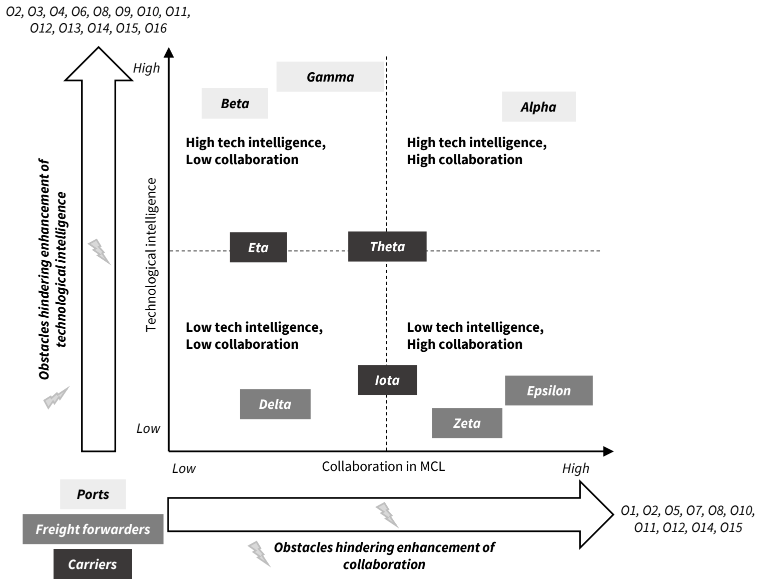

Figure 3: Expanded research framework, adapted according to Yang, Fu and Zhang (2021)

5 Discussion

Merely Alpha assessed themselves as being at a high level of both technological intelligence and collaboration. Beta, Gamma, Eta, Theta, Iota, and Delta need to overcome several obstacles hindering collaboration. As collaboration was found to have a positive impact on the competitive advantage of ports (Seo, Dinwoodie and Roe, 2016), also Beta and Gamma need to strive toward the upper-left-hand corner of the matrix. Zeta displays a high level of collaboration, but mentioned that it is difficult to find adequate partners for collaboration and ecosystems: *“In South America, […] Africa and* *some areas in Asia, it is very difficult to find partners that would say let's see what we can do in terms of blockchain"* (Zeta$_2$). The collaboration is hindered by trust, as one expert opined: *"We make a decision only after we do all the steps that we used to do 15 years ago and a good feeling, […], not looking in the numbers."* (Eta$_1$) Furthermore, lacking data security is impeding the enhancement of trust: *"We have massive problems driving digital projects forward because our lawyers and IT architects say, […] before we do anything with the data, we have to make sure that it is protected, that it is secure."* (Epsilon$_1$) In general, DTs, such as blockchain, were found to enhance trust by enabling cyber security, thus leading to increasing collaboration (Dubey, et al., 2020). Moreover, according to some experts, support from business associations, such as the digital container shipping association (DCSA), is necessary to develop and successfully implement standards regarding DT adoption. This is especially relevant due to the complexity of the MCL network (Jensen, Vatrapu and Bjørn-Andersen, 2018). Standardization is further emphasized regarding the *"very different customs rules and customs processes in different countries"* (Delta$_2$). Consequently, government support is essential. Nevertheless, in case blockchain is already adopted (Yang, 2019), standardization efforts can be advanced and thus other obstacles removed.

The obstacles hindering the enhancement of technological intelligence are mostly related to intra-organizational challenges. Maritime organizations mainly consist of old-fashioned people: *"So, […] our staff works at least 10 years in the company"* (Eta$_1$), which impedes bringing new insights regarding the usefulness of several DTs in the organization (Yang, 2019) because *"traditional values are still predominant"* (Beta$_2$). As *"there is a lot of demand for digital experts in various areas"* (Epsilon$_2$), MCL is having a problem attracting the right skills (Canepa, et al., 2021), for example in *"software development and hardware engineering talent, to get enough people"* (Theta$_2$). The commitment of the management- and C-level is relevant for DT adoption (Ko, et al., 2022). As one expert aptly opined, *"Our CEO once said, we are not Google. We are not an internet company. He is right, we are not, but the future is"* (Eta$_2$). This requires an adequate strategy for DT adoption. As mentioned by several experts, they often have a strategy regarding DT adoption, but they are *"struggling with making the strategy a bit more tangible for the various subdivisions in the company and cascading it down to* *management in a coherent way"* (Theta$_1$). Thus, the strategy of DT adoption should be shared across organizational units, as there is an *"enormous divergence in maturity, in understanding what digital is all about"* (Alpha$_1$), dissolving silo approaches in the maritime organizations.

6 Conclusion, implications, and further research

As far as known by the authors, this research is the first to address the state-of-the-art of DT adoption and obstacles to further DT adoption in MCL by elaborating on similarities and differences between ports, freight forwarders, and carriers.

By applying a multiple-case approach, we identified that ports already display high levels of technological intelligence, but that collaboration efforts can be enhanced between the ports and external stakeholders with the support of governments and business associations such as the DCSA. DT adoption in ports is currently hindered by a legacy of old systems and ways of working within their organizations. The freight forwarders all display low levels of technological intelligence, but their collaboration level differs. They strive toward the application of DTs but are hindered by their silo approach. Their DT adoption is further impeded by the market power of the carriers. The carriers, however, are located in the midfield of the DT adoption matrix. Therefore, for carriers, obstacles for both leveraging the level of collaboration, such as heterogeneous systems, and the level of technological intelligence, such as their old-fashioned ways of working, need to be overcome. To summarize, our developed framework helps MCL organizations to derive implications for tackling the existing obstacles for successful DT adoption and to adapt their DT adoption strategy accordingly.

Theoretically, our research contributes by providing a detailed DT adoption framework for MCL, displaying the levels of DT adoption of the different incumbent maritime organizations based on the research of Yang, Fu and Zhang (2021). Our adapted framework highlights the obstacles that need to be overcome to further enhance the level of DT adoption in maritime organizations. Thereby, our research is the first to empirically provide such a framework in the context of MCL and supports incumbent maritime organizations in benchmarking themselves with other organizations.

The research exposes certain limitations that, in turn, reveal potential avenues for further research. One limitation regards the selection of the cases. Even though the number of cases seems sufficient according to Eisenhardt (1989), more research including smaller stakeholders in MCL may help to enhance the generalizability of the results, referring to required standardization efforts of the whole MCL industry. Additionally, merely organizations in MCL are considered for the research. In this context, further research needs to elaborate on whether the findings of this research are also applicable to other types of maritime logistics. Lastly, as MCL is inherently multimodal, especially the collaboration obstacles need to be regarded from an angle of collaboration with actors outside of MCL, incorporating other modes of freight transportation.

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