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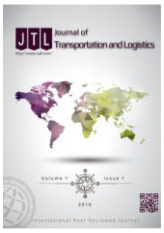

What Are The Barriers to the Adoption of Industry 4.0 in Container Terminals? A Qualitative Study on Turkish Ports*

Elif Koç[1]

ABSTRACT

Seaports are nodal points in global supply chains. Industry 4.0 applications, which have entered our lives with the rapid technological developments, are also seen in the port sector. The use of Industry 4.0 technologies started in container ports first, and applications were predominantly encountered in this type of ports. The aim of the study was to investigate the nature of digital technologies in container ports and to reveal the major barriers to the adoption of Industry 4.0 in Turkish container ports. First, extant literature was reviewed, and the main obstacles to the adoption of Industry 4.0 were determined. Later, considering the literature findings, in-depth interviews were conducted with port managers. Then, content analysis was performed by examining transcripts and notes taken during the interviews using a professional computer-assisted qualitative data analysis software, MAXQDA-12. According to the findings, four main difficulties were identified as technological, operational, legal, and organizational difficulties. Operational barriers were revealed to be industry-related obstacles. Technological and operational challenges were the most frequently mentioned ones by the participants. Finally, the findings of the study were discussed, and suggestions were proposed to overcome those obstacles.

Keywords: Industry 4.0, Seaports, Digitization, Automation, Smart Ports

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1. Introduction

Maritime industry has been under the influence of social, economic, and especially technological developments in recent years. Ports, which are the most essential coastal facilities in shipping, are also affected by these developments (Shahbakhsh, Emad and Cahoon, 2021). Seaports are the interface between land and sea for marine vehicles that carry cargo and people from the point of departure to their destination (Kasypi and Shah, 2012). These ports located in coastal areas ensure that the flow of cargo is coordinated in an efficient, safe, and environmentally friendly way (Salido, Rodriguez-Molins and Barber, 2011; Martín-Soberón et al., 2014). Digital transformations in ports are one of the main drivers of changes in ports (Zarzuelo, 2021). With the introduction of Industry 4.0, ports can gain competitiveness in local and global markets by utilizing smart technologies such as the internet of things, big data management, augmented virtual reality, cloud computing, blockchains, automated vehicles, drones, and cyber-physical systems (Bastug et al., 2020). They can make their processes faster, more flexible, and productive (Rüssmann et al., 2015; Castelo-Branco, Cruz-Jesus and Oliveira, 2019). In addition, it is possible to increase efficiency in the value chain by reducing operating costs and to make the world more collaborative and connected. The effects of this concept were first seen in the production processes, and in the following years, it has been used in logistics and the entire supply chain (Rüssmann et al., 2015; Morrar, Arman and Mousa, 2017). Ports, which are the most essential nodal points and infrastructural facilities of supply chain systems, also get their share from these developments. Especially with information technologies and digitalization, which form the basis of Industry 4.0, significant changes are being experienced in port management and operations (Agatić and Kolanović, 2020).

The world is becoming more connected in line with the demands and expectations of customers. In parallel, ports are also under the influence of digital technology trends, as in many branches of logistics and maritime industry, such as vessel design, construction, maintenance, and operational concepts, etc. (Arabelen and Bastug, 2019; Sanchez-Gonzalez et a., 2019; Sullivan, 2020; Shahbakhsh, Emad and Cahoon, 2021). The use of Industry 4.0 technologies first started in container ports, and the applications are predominantly seen in this type of ports. The existence of a standard transport unit and the possibility of performing better operations in terms of time, efficiency, safety, and environmental awareness make the container terminals more available to apply digital technologies (Martín-Soberón et al., 2017). In this study, it was aimed to investigate the nature of digital technologies in container ports and to reveal the major barriers to the adoption of industry 4.0 in Turkish container ports. First, relevant literature was extensively reviewed, and the major impediments to the adoption of Industry 4.0 were determined. Then, considering the literature findings, in-depth and online face-to-face interviews were conducted with port managers. Content analysis method was applied to the obtained data and the difficulties in the implementation of Industry 4.0 applications in Turkish container ports were divided into four main groups: technological, operational, legal, and organizational. While technological, legal, and operational barriers were similar to other barriers identified in the literature, operational barriers were revealed as sector-specific obstacles. Technological and operational challenges were the heavily expressed ones by the participants. In the end, the findings of the study were discussed, and suggestions were proposed to overcome those obstacles.

2. Industry 4.0 in Seaports

Sub-components of Industry 4.0; internet of things, big data and business analytics, block chain, cloud computing, cyber security, cloud computing, 3D printing, augmented reality, and simulation and modeling, etc. exist in modern logistics networks which also cover sea ports (Sullivan, 2020; Zarzuelo, Soeane and Bermúdez, 2020; Bastug et al., 2020). Industry 4.0 applications are materialized and implemented by system stakeholders. The parties keep furthering their level of digitization; the ability of port authorities to stay online, the number of autonomous systems used, and big data analysis are constantly increasing. Internet of Things (IoT) technology puts traditional business models in port business into a modern form. This technology adds value to the entire supply chain by connecting all ecosystem stakeholders. This connection is provided by "block chain systems". These technologies help supply chains to work in a more integrated way by connecting all stakeholders in order to manage business processes effectively. Thus, workflows can be managed digitally and seamlessly (Esmer, 2017; Gromovs ve Lammi, 2017). In addition, IoT systems, in which all stakeholders are connected electronically, are supported by the use of "big data". In big data technology, all connected devices produce data that any system stakeholder can easily use and benefit from. This sharing cannot be done without "cloud computing" or online security of software (Szozda, 2017). Big data can be managed by different stakeholders at the same time, and stakeholders can use a standardized set of programs and applications available in the cloud. On the other hand, the use of big data and cloud computing technology can only be achieved by having a strong "cybersecurity" system that can prevent cyber attacks and protect privacy (Solé, 2018).

The need and degree of digital transformation largely depends on the enthusiasm of the ports for transformation. Hamburg, Rotterdam, Shanghai, and Singapore ports are the leading ports operating with the highest level of smart systems. The first automated port activities in the world started to be carried out at the ECT Delta Terminal of the Port of Rotterdam in 1993. They introduced the concept of "automated terminals" to the industry to represent ports with these digital features. The port was equipped with Automated Stacking Cranes (ASC) and Automated Guided Vehicles (AGV), allowing unmanned operation of these vehicles (Martín-Soberón et al., 2017). Another port, Port of Hamburg, implemented new business models to connect terminals, authorities, shipping companies, and other stakeholders providing transportation, logistics, and administrative services, and to ensure better communication and cooperation between parties. In the port, different smart applications were connected to a single integrated platform. Also on that platform, data from sensors, mobile devices, and databases of various stakeholders were combined and utilized. With these systems, which improve internal operations and collect real-time information about in-port traffic, port authorities and stakeholders can minimize bottlenecks at port area and terminal entrances. Applications with position determination feature can precisely locate vehicles entering the port and optimize the volume of vehicle traffic in the area (Riedl et al., 2018). In addition, considering the academic studies about this port, Ferreti and Schiavone (2016) revealed the implementation of IoT systems by redesigning the business processes in the Port of Hamburg, while Thaver (2019) examined the use of IoT and sensors that can adjust themselves according to the current weather conditions.

Furthermore, the Port of Hamburg started a new business model development project called "smartPORT logistics2 (SPL)" in 2010 in order to improve the traffic and freight flows in the port area by investing in port infrastructure and modern information systems. The main purpose of the project was to integrate different traffic control centers (road, sea, railway) with a main port traffic station. Its system also allowed decision making and continuous interaction with other actors based on real-time data. Thus, traffic and infrastructure integration were ensured. In order to benefit from the infrastructure in a more flexible and sustainable way, sensors were added to various points in the port (bridges, road lighting, etc.) (Heilig et al., 2017).

Another example of such a new business model was the agreement DP World made with Kazakhstan in 2017. In the consensus, it was decided to establish an electronic platform under the name of "Port Community System". Related parties would carry out all their sea, land, and air transportation related processes in the logistics network from this platform. On this community, sea and dry ports, logistics centers, customs units, customers, and other related parties would perform an average of 50 thousand digital transactions per day. Thanks to these digital and automated systems, Kazakhstan would have an essential position in "One Belt One Road" project of China. As it is obvious here, port facilities are considered to be the nodal point of these digital systems (Esmer, 2017).

Today, the most contemporary and comprehensive example of the business model, including ports, is the global supply chain management platform called "TradeLens". TradeLens is a blockchain technology for container shipping and logistics developed by the partnership of Maersk and IBM to modernize the supply chain ecosystems of the world, and it was launched in April 2018. This technology enables many stakeholders (e.g., shippers, shipowners, port and terminal operators, logistics companies, inland transport and customs administrations, and government officials) to connect with each other, share information and cooperate with mutual trust (Maersk, 2019). On this platform, the data in the supply chain can be tracked without any changes and can be shared if it is permitted (Cointelegraph, 2020). In this way, manual and paper-based documents are modernized, and industry standards for digital exchange of documents are generated (Turkish Time Magazine, 2018; Blockchain Turkey, 2020).

There are more than twenty ports and terminal operators worldwide (e.g., APM Terminals, Modern Terminals, Adani Ports) in the TradeLens Blockchain system (TradeLens, 2020). DP World, one of the world's leading global terminal operators, also joined this community as of May 2020. DP World aims to connect the operations and logistic units of 82 ports around the World through this platform (DP World, 2020). Turkish-owned Yılport Holding, which operates in Gebze and Gemlik in Turkey and also manages their 22 international and

6 domestic terminals in 11 different countries, joined TradeLens in August 2020 (Deniz Haber, 2020). LimakPort operating in Iskenderun has also been included in this chain in August 2020. Apart from ports and terminals, global container shipping companies such as CMA CGM, MSC, AP Moller-Maersk, Hapag Lloyd, Hamburg-Sud; customs offices of various countries such as Russia, Saudi Arabia, Qatar, Canada, Indonesia; logistics and intermodal service providers such as Agility, CEVA Logistics, DAMCO, Unifeeder, CP Rail, Imoto Lines are actively involved in this chain (TradeLens, 2020). In March 2020, London-based Standard Chartered Company also joined the platform and became the first financial institution in the system (Cointelegraph, 2020). In conclusion, considering all these developments, it is possible to say that different ports around the world (especially container terminals) are expanding and developing their port management activities by implementing new business models and using smart systems (e.g., connected platforms, cloud computing-based services, mobile devices and applications, sensors, and other Internet of Things technologies).

3. Barriers to The Adoption of Industry 4.0

Within the scope of the study, relevant literature was extensively reviewed to summarize the existing knowledge on barriers to the adoption of industry 4.0. All these difficulties are presented in Table 1. In Industry 4.0, it is necessary to ensure both horizontal and vertical integration with digital technologies. Vertical integration refers to ensuring the coordination of different stakeholders on a single network and the contribution of each stakeholder to the value chain, and also establishing coordination and cooperation across organizational units within a particular enterprise (Schroder, 2017: 11; Raj et al., 2020). Horizontal integration is the integration of material, energy and information flows within business processes. The interoperability of different technologies and systems should be ensured, and a cyber-physical infrastructure should be established (Kumar et al., 2021).

With the implementation of new technological applications, various legal uncertainties and problems can also create impediments to digitalization. Although legal uncertainties are significantly reduced by the detailed preparation of contracts, the issues to be regulated are still complex (Schroder, 2017: 18). As the competitive environment develops, uncertainties and difficulties increase in digitalization, such as standardization, identification of responsible parties, and data protection (Kamble, Gunasekaran and Sharma, 2018: 101; Majumdar, Garg and Jain, 2021: 3). In addition, it is of great importance for state bodies to determine strategies and roadmaps for compliance with Industry 4.0 on a country basis (Majumdar, Garg and Jain, 2021: 3). Today, government policies on the issue are not sufficient in many countries. Governments should set roadmaps for the transformation of traditional business functions into smarter and more sustainable processes (Luthra and Mangla, 2018: 172).

Table 1. Major barriers to the adoption of Industry 4.0

Contractual and legal uncertainty	*Oesterreich and Teuteberg (2016); Schroder (2017); Kamble, Gunasekaran and Sharma (2018); Aggarwal, Gupta, Ojha (2019); Chauhan, Singh and Luthra (2021); Majumdar, Garg and Jain (2021); Chauhan, Singh and Luthra (2021); Kumar et al. (2021)*
Lack of government support and policies	*Zhou, Liu and Zhou (2015); Oesterreich and Teuteberg (2016); Schroder (2017); Thoben, Wiesner and Wuest (2017); Luthra and Mangla (2018); Kamble et al. (2019); Aggarwal, Gupta, Ojha (2019); Bakhtari et al. (2020); Chauhan, Singh and Luthra (2021); Majumdar, Garg and Jain (2021); Kumar et al. (2021)*
Poor integration (Value-chain, process, data, technological)	*Zhou, Liu and Zhou (2015); McKinsey Digital (2016); Haddud et al.(2017); Schroder (2017); Thoben, Wiesner and Wuest (2017); Moktadir et al. (2018); Kamble, Gunasekaran and Sharma (2018); Aggarwal, Gupta, Ojha (2019); Kamble et al. (2019); Horváth and Szabó (2019); Raj et al. (2020); Bakhtari et al. (2020); Majumdar, Garg and Jain (2021); Chauhan, Singh and Luthra (2021)*
Cyber-security challenges	*Oesterreich and Teuteberg (2016); McKinsey Digital (2016); Petrillo et al. (2018); Moktadir et al. (2018); Kamble, Gunasekaran and Sharma (2018); Horváth and Szabó (2019); Aggarwal, Gupta, Ojha (2019); Kamble et al. (2019); Raj et al. (2020); Moeuf et al. (2020); Bakhtari et al. (2020); Turkyilmaz et al. (2021); Majumdar, Garg and Jain (2021); Chauhan, Singh and Luthra (2021) Zarzuelo (2021)*
Uncertainty about benefits	*Zhou, Liu and Zhou (2015); McKinsey Digital (2016); Haddud et al.(2017); Kamble, Gunasekaran and Sharma (2018); Raj et al. (2020); Bakhtari et al. (2020); Majumdar, Garg and Jain (2021); Chauhan, Singh and Luthra (2021); Kumar et al. (2021)*
Lack of adequate skills in the workforce	*Oesterreich and Teuteberg (2016); McKinsey Digital (2016); Haddud et al.(2017); Kamble, Gunasekaran and Sharma (2018); Petrillo et al. (2018); Machado et al. (2019); Kamble et al. (2019); Marcon et al. (2019); Peillon and Dubruc (2019); Horváth and Szabó (2019); Bakhtari et al. (2020); Raj et al. (2020); Moeuf et al. (2020); Turkyilmaz et al. (2021); Majumdar, Garg and Jain (2021); Chauhan, Singh and Luthra (2021); Kumar et al. (2021)*
High implementation cost	*Oesterreich and Teuteberg (2016); Majeed and Rupasinghe (2017); Haddud et al.(2017); Schroder (2017); Kamble, Gunasekaran and Sharma (2018); Moktadir et al. (2018); Kamble et al. (2019); Marcon (2019); Horváth and Szabó (2019); Raj et al. (2020); Bakhtari et al. (2020); Turkyilmaz et al. (2021); Majumdar, Garg and Jain (2021); Chauhan, Singh and Luthra (2021)*
Lack of infrastructure	*Oesterreich and Teuteberg (2016); Schroder (2017); Thoben, Wiesner and Wuest (2017); Kamble, Gunasekaran and Sharma (2018); Moktadir et al. (2018); Xu, Xu and Li (2018); Aggarwal, Gupta, Ojha (2019); Kamble et al. (2019); Marcon (2019); Peillon and Dubruc (2019); Bakhtari et al. (2020); Raj et al. (2020); Turkyilmaz et al. (2021); Majumdar, Garg and Jain (2021); Chauhan, Singh and Luthra (2021); Kumar et al. (2021)*
Job/Employment disruptions	*Kergroach (2017); Thoben, Wiesner and Wuest (2017); Kamble, Gunasekaran and Sharma (2018); Moktadir et al. (2018); Bakhtari et al. (2020); Raj et al. (2020); Chauhan, Singh and Luthra (2021); Majumdar, Garg and Jain (2021)*
Standardization problems	*Oesterreich and Teuteberg (2016); Haddud et al.(2017); Schroder (2017); Thoben, Wiesner and Wuest (2017); Kamble et al. (2019); Horváth and Szabó (2019); Raj et al. (2020); Bakhtari et al. (2020); Chauhan, Singh and Luthra (2021); Kumar et al. (2021)*
Challenges in data management and data quality	*Zhou, Liu and Zhou (2015); Ryan and Watson (2017); Haddud et al.(2017); Schroder (2017); Thoben, Wiesner and Wuest (2017); Petrillo et al. (2018); Horváth and Szabó (2019); Raj et al. (2020); Chauhan, Singh and Luthra (2021); Kumar et al. (2021)*

Table 1. Major barriers to the adoption of Industry 4.0 (continued)

Resistance to change	*Khan and Haleem (2015); Oesterreich and Teuteberg (2016); Haddud et al.(2017); Machado et al. (2019); Aggarwal, Gupta, Ojha (2019); Marcon (2019); Peillon and Dubruc (2019); Horváth and Szabó (2019); Raj et al. (2020); Chauhan, Singh and Luthra (2021); Kumar et al. (2021)*
Ineffective change management	*Oesterreich and Teuteberg (2016); McKinsey Digital (2016); Thoben, Wiesner and Wuest (2017); Horváth and Szabó (2019); Raj et al. (2020); Majumdar, Garg and Jain (2021); Chauhan, Singh and Luthra (2021); Kumar et al. (2021)*
Lack of internal digital culture and training	*Khan and Haleem (2015); Schroder (2017); Thoben, Wiesner and Wuest (2017); Petrillo et al. (2018); Marcon (2019); Raj et al. (2020); Moeuf et al. (2020); Bakhtari et al. (2020); Majumdar, Garg and Jain (2021)*
Concerns about privacy and data ownership	*McKinsey Digital (2016); Ryan and Watson (2017); Haddud et al.(2017); Schroder (2017); Thoben, Wiesner and Wuest (2017); Kamble et al. (2019); Marcon (2019); Horváth and Szabó (2019)*
Lack of a skilled management team	*Khan and Haleem (2015); Moktadir et al. (2018); Aggarwal, Gupta, Ojha (2019); Peillon and Dubruc (2019); Horváth and Szabó (2019); Bakhtari et al. (2020); Moeuf et al. (2020); Turkyilmaz et al. (2021); Majumdar, Garg and Jain (2021); Chauhan, Singh and Luthra (2021); Kumar et al. (2021)*
Lack of a digital strategy	*Schroder (2017); Petrillo et al. (2018); Raj et al. (2020)*
Unstable connectivity among companies	*Deloitte (2015); Zhou et al. (2016); Khan et al. (2017); Moktadir et al. (2018); Chauhan, Singh and Luthra (2021)*
Difficulty of coordination and collaboration across organizational units	*McKinsey Digital (2016); Kamble et al. (2018); Luthra et al. (2020); Majumdar, Garg and Jain (2021); Chauhan, Singh and Luthra (2021)*
Complexity in integrating IT and OT	*Lee et al. (2014, 2015); Lu (2017); Moktadir et al. (2018)*

The lack of basic and supporting infrastructure required for every stakeholder in the chain is one of the major challenges for the implementation of Industry 4.0 applications. In particular, IT infrastructure and internet network coverage must be provided uninterruptedly (Kamble, Gunasekaran and Sharma, 2018: 101). Digital applications are in the development stages in many industries, and there are uncertainties in potential cost-benefit expectations. The lack of clear understanding and approach about the ultimate value is among the obstacles (Kamble, Gunasekaran and Sharma, 2018: 101). Also, although various industry executives are aware of the importance of Industry 4.0, there are uncertainties about their ultimate contribution to achieving sustainability goals in the supply chain (Luthra and Mangla, 2018: 172).

There is a huge amount of information flow on Industry 4.0 platforms. There are concerns about the privacy and security of this information. In particular, issues such as cyber security risks, system access, verification, and authorization are essential challenges for organizations (Kamble, Gunasekaran and Sharma, 2018: 101). In Industry 4.0, all elements in the entire value chain are interconnected, and these highly integrated systems may encounter cybersecurity threats. This also raises concerns for stakeholders (Raj et al., 2020; Kumar et al., 2021). In addition, one of the requirements of Industry 4.0 is highly qualified employees with the skills to use technology. Employees' lack of digital skills is a major challenge in implementing digital solutions (Kumar et al., 2021). Employees need continuous training to improve their technical skills (Raj et al., 2020). Resistance to change by the employees is also an important obstacle, and it can be overcome by effectively managing the changes (Haddud et al., 2017; Chauhan, Singh and Luthra, 2021).

Industry 4.0 initiatives require huge capital investments (Moktadir et al., 2018). Machinery, equipment, personnel training, consultancy, etc. are substantial cost items (Aggarwal, Gupta and Ojha, 2019). In addition, robots have started to replace humans, and the intensive use of automation eliminates many job positions (Moktadir et al., 2018). It is very important for organizations to have a talented management team that will implement new and digital business models. Industry 4.0 applications require revolutionary transformations and willingness of the management, and support for organizational change are indispensable (Luthra and Mangla, 2018). In order for Industry 4.0 to come to life, all stakeholders in a supply chain must be digitally integrated with each other. The inability to achieve this integration efficiently in many sectors is also an main difficulty (McKinsey Digital, 2016; Chauhan, Singh and Luthra, 2021).

4. Methodology

In this study, it was aimed to explore the barriers to the adoption of Industry 4.0 in Turkish seaports and whether the barriers obtained from the literature review were meaningful for this sector. To achieve this goal, in-depth online and face-to-face interviews with 5 port managers were done as part of data collection. The reason for choosing such data collection tool was to encourage participants to talk about related topics and explore contextual boundaries about unknown phenomena (Malhotra and Birks, 2007: 207). The interviews were conducted in August 2021. Each interview lasted approximately 40 to 60 minutes. A semi-structured interview protocol with open-ended questions was employed to facilitate the interview. The protocol was based on the literature, and the questions were based on the difficulties to the adoption of Industry 4.0 mentioned in the literature. As the sampling method, purposive methods were used for the interviews.

Table 2. Profiles of the Interviews

	Job Title	Gender	Education Level	Total Experience	Region	Duration	Date
P1	Operations Manager	Male	Undergraduate	20 years	Bursa	40 min.	05.09.2021
P2	Operations Director	Male	Undergraduate	23 years	Kocaeli	40 min.	08.09.2021
P3	Commercial & Operations Manager	Female	Undergraduate	12 years	Izmir	60 min.	10.09.2021
P4	Operations Manager	Male	Undergraduate	18 years	Bursa	40 min.	06.09.2021
P5	Operations Manager	Male	Undergraduate	11 years	Antalya	65 min.	15.09.2021

As seen in Table 2, there were four interviewees. All of them had an undergraduate degree. Each participant had more than 10 years of experience in the port sector. As they have extensive knowledge about port operations thanks to their long years of experience, port managers were preferred as participants. This made the study more meaningful. The participants were from seaports located in Bursa, Kocaeli, Antalya, and Izmir. The participants were selected from the managers of the ports located in different cities and port areas as much as possible. Names and any other identifying information of the participants are confidential.

During the interviews, the concept of "Industry 4.0" was defined and explained to the managers with examples, and then they were asked one main question and several sub-questions. The main question was *"What are the barriers to the adoption of industry 4.0 for Turkish seaports?"* This question was detailed with iterative questioning techniques and probing (Kvale, 1996) during the interview, taking into account the barriers of Industry 4.0 in the literature. All the interviews were recorded using a voice recording device and transcribed verbatim. Grammatical errors made in the statements of participants during the interviews were not corrected as per the requirements of qualitative analysis. Otherwise, there would be a possibility that the thoughts and tendencies of the researcher on the subject might affect the raw data; in other words, that might cause researcher bias (Brennen, 2013: 21). Then, content analysis was performed by examining transcripts and notes using MAXQDA-12, a professional computer-assisted qualitative data analysis software. All transcriptions were thoroughly read by two researchers (the author and an independent expert coder) to avoid any possible bias, and they were systematically coded to discover the major obstacles to the transition to Industry 4.0. To obtain compatible coding results and ensure the reliability of the data, the same coding rules and instructions were applied for both coders to assess similar phenomena. When disputes occurred, they discussed them until building consensus, so inter-coder reliability could be achieved (Krippendorf, 2013: 271). The inter-coder similarity between the codings created by the two researchers was 85%, and this ratio is at an acceptable level (Creswell, 2009: 191; Miles and Huberman, 2014: 85).

5. Findings and Discussion

Main findings of the qualitative study were compiled under four main themes: technological, operational, legal, and organizational barriers. While technological, operational, and organizational challenges each had six items, legal obstacles had five. Figure 1 presents a hierarchical code-subcodes model and the frequency of the codes associated with the interview results. There were 23 codes in total that were used to evaluate each interview.

Based on the interviews, four types of challenges have been identified. The most prevalent challenge was technological one, and it was coded 54 times. While operational obstacles were coded 52 times as the second highest frequency, legal and organizational barriers were coded 46 and 26 times respectively.

Sub-themes, their repetitions, and major quotes by the participants about technological barriers are represented below. There are six major obstacles, and the most prevalent one is "high costs for digital installations". All of the participants stated that digitalization requires significant investments, and this issue creates a significant challenge for sea ports. In similar studies, while Bucak, Dincer and Demirel (2019) argued that one of the most important challenges for Industry 4.0 applications in maritime is the high investment cost; Zarzuelo, Soeane, and Bermúdez (2020) emphasized that such digital investments in ports require high investment costs as a challenge for Industry 4.0. Second highly mentioned difficulty is lack of internet coverage and IT facilities. Tas (2021) also determined this matter as an obstacle in logistics processes. The necessity of improving the internet infrastructure throughout the country was especially emphasized by most of the participants.

Cyber security threats were another important issue highlighted by the participants. Duck (2017) also stated that everything connected to the internet can be cyber-attacked today, and this is also valid for seaports and terminals. Also, Zarzuelo, Soeane and Bermúdez (2020) emphasized that cyber security is one of the primary issues of maritime companies and ports, and reminded that after the cyber attacks on the Port of Rotterdam in 2011 and 2016, a "Port Cyber Resilience Officer" was appointed to the port. Zarzuelo (2021) underscored the importance of seaports and terminals in the global supply chain as a nodal point and argued that a cyber-attack on a port would adversely affect the entire supply chain. Furthermore, in this study, it was emphasized that aiming to switch to Industry 4.0 is not sufficient alone, and the technological infrastructure throughout the country should be developed. Other obstacles stated by the participants were the necessity of keeping the software and hardware systems used constantly new and up-to-date, the difficulties of integrating multiple systems, the challenges in data management, and identifying qualified data. Sullivan (2020) also revealed the significance of data generation, data collection and data analysis with digital and information-based interfaces in the Industry 4.0 adoption, thanks to data management.

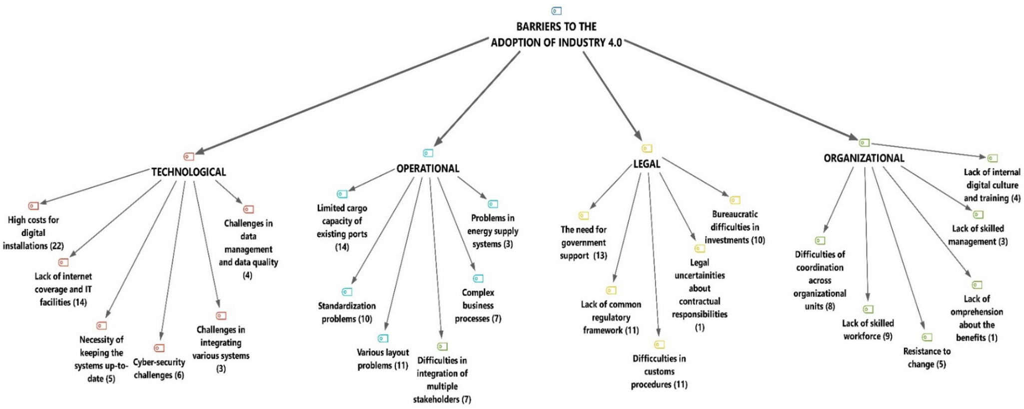

Figure 1 : Hierarchical Code-Subcodes Model

The second highly mentioned obstacle was operational-related matters. While the challenges related to technological, legal, and organizational issues were similar to the literature review findings, operational matters were revealed as industry-specific barriers within the scope of this study. Large port areas are needed for the digital operations in Turkish ports, and wider maneuvering areas are required for automatic handling equipments. Besides, field operations involve many complex business processes. In many ports, ship operations and yard operations are intertwined. CFS operations are performed in port areas. Furthermore, additional customs controls are also carried out in the port areas. These complex business processes were among the essential obstacles highlighted by the participants. Port managers also emphasized the frequent power cuts in the country. The cranes in the ports consume large amounts of energy, and it is not possible to manage the power cuts by using generators. For the development in line with digitalization, it is necessary to provide uninterrupted energy supply. Additionally, digitalization in ports requires all system stakeholders to have the necessary technological infrastructure to use these systems simultaneously. The absence of these capabilities was one of the obstacles stated by the participants.

During the interviews, almost all participants mentioned legal challenges. They expressed that bureaucracy was an essential challenge in investment and growth initiatives for ports, and it was necessary to obtain numerous permits from various institutions. Custom procedures were another vital issue strongly emphasized regarding daily port operation processes. Since digitalization is a new concept in our lives, there are uncertainties about the authorities and responsibilities of the parties. All participants underscored the importance of the governments' regulatory role in this regard. These findings were also consistent with extant literature regarding maritime industry of Turkey. The study of Arabelen and Bastug (2019) and Bucak, Dincer and Demirel (2019) argued that the legal infrastructure, especially customs procedures and a single window system, should be improved. Mollaoglu (2021) also emphasized the leading role of government institutions in the direction of Industry 4.0.

The least mentioned barriers were organizational matters, and all of the items in this section were similar to the literature findings. Parallel to the technological developments experienced, the need for qualified personnel with the skills to use technology has arisen in ports, as in other sectors. The critical skills shortages make it difficult to employ people and to manage human resources. This matter was especially emphasized by P3, P5, and P2 participants. Similarly, Erdogdu (2021) argued that the lack of technical and digital skills of managers and employees, and then the need for training, is one of the essential obstacles to the implementation of new digital technologies in logistics. Bucak, Dincer and Demirel (2019) also determined "lack of qualified staff" as a weakness of maritime industry regarding digitalization in Turkey. Also, consistent with the study of Tas (2021), lack of internal digital culture and training was another mentioned obstacle. The culture created by the managers is essential at this point. In addition, the participants indicated that certain habits of employees lead them to resist to change from time to time. All identified barriers-related items, their repetitions and major supporting quotes are detailed in Tables 3-6 below.

Table 3. Selective Supporting Interview Quotes for Technological Barriers

Themes/Sub-themes	Supporting Interview Quotes	Frequency
	Technological	
High costs for digital installations	*"Of course, it is a bit difficult to apply 4.0 in small ports. Because they require large investments. These are the costs."* ***P2*** *"......Therefore, the cost issue is important for us. I think there should be government incentives here. On the other hand, I think a second stage of government incentives is that the government should manage regulatory activities at this point."* ***P3*** *".... Also, these are the things that force small ports in terms of cost."* ***P5***	22
Lack of internet coverage and IT facilities	*"It needs to work completely conjugate, it needs to work conjugate with stackers. This means that each machine must be given this infrastructure."* ***P3*** *"Communication problems, better operation of backup servers, reduction of interruptions, increased mobility, improvement of software and hardware infrastructure will bring our system closer to its counterparts in Europe."* ***P5***	14
Necessity of keeping the systems up-to-date	*"Simultaneous updating of vehicles, no malfunction. The costs of maintaining them..... so when we look at them in general, internet systems, cloud systems must be updated."* ***P3*** *"You have to buy a lot of technological stuff. You need to invest in them and update them."* ***P1***	5
Cyber-security challenges	*Even the lines operating with large volumes and large capacity ships in the world are currently experiencing cyber security problems."* ***P3***	6
Challenges in integrating various systems	*"In order to automate, your STS needs to work fully synchronized with the terminal truck and the entrance and exit system at the door."* ***P3***	3
Challenges in data management and data quality	*"Therefore, in order to manage this data, you have to be aware of the data, you have to have a command of that data and you have to have a command of the system."* ***P5***	4

Table 4. Selective Supporting Interview Quotes for Organizational Barriers

Themes/Sub-themes	Supporting Interview Quotes	Frequency
	Organizational	
Lack of skilled workforce	*"People should have experience, but also information technology capabilities are necessary."* ***P2*** *"At this point, it is necessary to employ people with IT competence."* ***P5***	9
Difficulties of coordination across organizational units	*"In order to automate, your STS needs to work fully synchronized with the terminal truck and the entrance and exit system at the door."* ***P3***	8
Resistance to change	*"Apart from that, there are personnel who do not accept even though they know it. There are companies that face issues related to resistance to change."* ***P1***	5
Lack of internal digital culture and training	*"Staff must adapt to it. He needs to be trained accordingly."* ***P5***	4
Lack of skilled management	*"While managers should have understood accounting, finance and law 10 years ago, now they need to understand the system, software, hardware and system installation. This will take time."* ***P4***	3
Lack of comprehension about the benefits	*"Most importantly, cost-benefit analysis is required. What good does it do us? How much will it increase our productivity and what will it cost?"* ***P5***	1

Table 5. Selective Supporting Interview Quotes for Operational Barriers

Themes/Sub-themes	Supporting Interview Quotes	Frequency
	Operational	
Limited cargo capacity of existing ports	*"The fact that the ports are not large enough to undertake such huge investments. It is a little difficult to apply 4.0 in small ports. Because they require large investments." **P2***	14
Various layout problems	*"Technically existing sites should be wide enough for all processes and automated equipment, but this is not the case at the moment." **P4*** *"Here are certain lines, stacking structures, etc. they all need to be adjusted accordingly. Of course, there is no such infrastructure in the previously established ports." **P1***	11
Standardization problems	*"Because a standard has to be determined and followed." **P5***	10
Difficulties in integration of multiple stakeholders	*"I think that such a transformation should be entered into as a sectoral as a whole." **P3***	7
Complex business processes	*"Ship operations and yard operations are complex and intertwined. Inside the yard operations there is aslo CFS activity." **P3***	7
Problems in energy supply systems	*"We have power cuts from time to time." **P2*** *"Electric power infrastructure in port areas needs to be strengthened." **P3***	3

Table 6. Selective Supporting Interview Quotes for Legal Barriers

Themes/Sub-themes	Supporting Interview Quotes	Frequency
	Legal	
The need for government support	*"In addition, incentives are required for investment. Tax advantages can be provided in such large investments. Domestic software can be promoted, such as national software. Those kinds of things are substantial." **P5***	13
Difficulties in customs procedures	*"The main obstacle is the bureaucratic process in customs procedures." **P4*** *"The prolongation of the control in customs processes takes us away from full automation in ports." **P3***	11
Bureaucratic difficulties in investments	*"Port expansion efforts face serious obstacles. You spend 5-6 years on the project you need to implement." **P2***	10
Lack of common regulatory framework	*"I think that such problems can be overcome if we focus on this system with legal regulations and infrastructures that we can create with the help of the government." **P3***	11
Legal uncertainities about contractual responsibilities	*"…. Therefore, there are many problems in legal regulations in this sense. Confusion in authority and responsibilities." **P3***	1

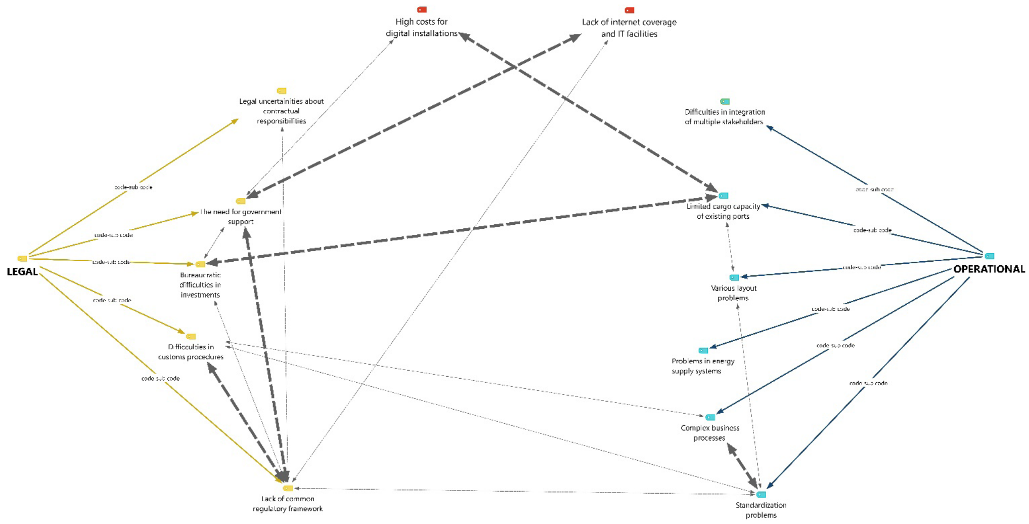

Figure 2: Code Co-Occurance Model

Within the scope of this study, relationships between codes were also investigated. First, code matrix browser was checked, and it was determined that the most intersecting relationships were between legal and operation-related codes. Then, the code co-occurance model (as seen in Figure 2) was created. In addition to legal and operation-related barriers, "high costs for digital installations" and "lack of internet coverage and IT facilities", the most prevalent sub-code of technological obstacles, were also included in the model because they were highly mentioned together with legal matters.

As seen in Figure 2, the participants who mentioned any legal obstacles also expressed other legal issues. Especially "difficulties in customs procedures" and "lack of common regulatory framework" were among the highly co-occurring items. All of the participants emphasized the requirement of the government's prescriptive and regulatory role while talking about legal matters, which was consistent with the studies of Bucak, Dincer and Demirel (2019) and Mollaoglu (2021).

Many of the participants stated that custom procedures complicate business processes at ports and hinder standardization. They advocated more applicable rules that support the standardization of processes to overcome the difficulties in line with digitalization. It was also stated that technological investments require large costs and therefore government incentives are so crucial for the port investors. The participants also expressed the regulatory role of the government in other matters regarding operational challenges. Participant P5 said "Government should lead authoritatively, by setting the standards. Because when they set the rules, we abide by them. When the government sets its own standards and wants companies to comply with them, companies will adapt anyway".

As the implementation of technological equipment and infrastructures requires bearing serious costs, P3 and P5 participants emphasized the necessity of government incentives on this subject. P3 stated that "…….. therefore, the cost-related matters are important for us. I think there should be government incentives here". Then, P5 said, "We also need an incentive for investment. Tax advantages can be provided in such large investments. Domestic software products can be promoted. Those things are life-sustaining". These statements also support the findings of Bucak, Dincer and Demirel (2019) and Zarzuelo, Soeane and Bermúdez (2020).

Similarly, the participants who pointed to the code "lack of internet coverage and IT facilities" also emphasized the importance of government incentives at this point. Regarding this, participant P5 said, "This is a point that the government needs to develop. For example, the internet bandwidth is determined by the government. Because this is something about the infrastructure of Telekom. Although some channels have been privatized, the main contractor is still Telekom, which is currently a state firm". "Limited cargo capacity of existing ports" and "bureaucratic difficulties in investments" were two other related difficulties. Ports established in the past encountered many bureaucratic obstacles when they wanted to expand. In addition, it is not financially advantageous for small-scale ports to undertake these large investments. Participant P2 stated that "it's a fact that the ports are not large enough to undertake such huge investments. It is difficult to apply 4.0 in small ports. Because they require large investments." and that "Port expansion efforts face serious obstacles. You spend 5-6 years on the project you need to implement." In his first sentence, the "high costs for digital installation" barrier was also mentioned.

6. Conclusion

Ports, which initially provided only basic services such as sheltering, loading and unloading, have experienced major developments within years, influenced by the developments in industry and technology (Agatić and Kolanović, 2020). With the introduction of Industry 4.0, the changes around ports have accelerated. Within the scope of this study, the obstacles encountered in the implementation of Industry 4.0 applications in Turkish ports, especially in container ports, were determined.

This study makes a number of contributions to the literature. First, while previous research highlights the concept of digitalization in general, namely Maritime 4.0, in this study, only port-related issues are revealed. Second, this study contributes to the research on barriers to digitization in sea ports especially in a developing country. This study is one of the few studies that comprehensively summarizes the obstacles to digitalization in Turkish ports. These barriers were grouped under four headings: technological, operational, legal, and organizational. In addition, technological, legal, and operational barriers are similar to other barriers identified in the literature, operational barriers such as layout, standardization and energy supply problems were revealed as sector-specific obstacles. Technological and operational challenges were the most mentioned ones by the participants. Serious costs for digital installations and deficiencies in the internet and IT infrastructure were the most common technological barriers. Disruptions in energy supply were among the major problems in terms of infrastructural matters. It is necessary to take precautions to solve this problem both port-wide (port site lighting with solar energy) and country-wide (the establishment of renewable power plants). The findings of this study also support other studies that highlight the concerns of cybersecurity in the maritime field and the fact that it is an important issue in the transition to digitization (Duck, 2017; Bucak, Dincer and Demirel, 2019; Zarzuelo, Soeane and Bermúdez, 2020; Zarzuelo, 2021). Cyber security concerns also support the hesitations of the ports about digitalization.

These findings have important implications for port managers, operators, and policy makers. First, physical inspection activities in customs processes when necessary (falling into the red line) and CFS operations organized in port areas are essential difficulties to the standardization and automation of processes. At this point, such activities can be carried out outside port areas, as in fully automated ports abroad. Second, the importance of the government's roles in terms of providing the infrastructure, setting rules and regulating the sytems have been pointed out in this study. Many participants have argued that the existing customs legislation should be arranged to make it more compatible with Industry 4.0 practices. The government has vital duties to develop the technological infrastructure throughout the country. Participants also advocated that the investors need government incentives because digital investments are expensive ventures, and the production of domestic and national technologies are necessary to facilitate the digitization.

Third, port expansion projects take a long time in Turkey. Since the investment initiatives are not carried out in accordance with a certain master plan, new ports are opened when the ports reach their natural limits in terms of capacity. For example, there are Gemport, Borusan, and Roda Ports in the Gemlik Region. In the past, Roda Port was established because Gemport was insufficient to meet the demand in the region and could not expand its capacity. Thus, small-scale ports were established side by side in the region. In Kocaeli, Evyap Port was 100% full until DP World Yarimca Port was opened, and 50% of Evyap's cargo volume was shifted to this port. Additionally, small and medium-sized ports cannot fully benefit from the technological advantages of digitization since the ports do not have enough space to grow. In these cases, only efficiency and cost can be considered. On the other hand, such technological investments are reasonable at high TEU capacities. At this point, reducing the bureaucratic processes in enlargement and improvement projects will probably make a great contribution towards digitalization. These findings also support the the studies of Bucak, Dincer and Demirel (2019) and Mollaoglu (2021) regarding the governments' regulatory role and the requirement of developed legal infrastructure.

The last implication was about human resource-related matters. The rapid technological developments have created a mismatch between the current abilities of the employees and the changing requirements of the job positions in the port industry, as in many other maritime-related sectors (Bucak, Dincer and Demirel, 2019). The critical skills shortages make it difficult to employ people who can use these technologies and to manage human resource-related matters. Finding and employing the required talent create an essential competitive advantage for the companies. Besides, after the recruitment process, various opportunities should be provided to the employees to improve their skills. Also, in the process of adaptation to digital technologies, the culture created under the leadership of the managers within the enterprise is of great importance at this point (Tas, 2021). In this way, both the effective management of human resources and the retention of these skilled people can be achieved. However, it should be taken into account that the cheap labor force is also an obstacle to digitalization for Turkey.

There are several limitations of this research that may show the ways for future research. First of all, due to some constraints, only five major ports were included. Future studies should undertake the more number of ports operating in all regions of Turkey. This study was conducted among port managers who are only one of the stakeholders in port community. Therefore, further research should include other stakeholders, especially port users, to extend the findings of this study. Last but not the least, future research could also include government authorities in order to provide solutions regarding the legal issues in practice.

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