DOKUZ EYLÜL UNIVERSITY

GRADUATE SCHOOL OF SOCIAL SCIENCES

DEPARTMENT OF MARITIME BUSINESS ADMINISTRATION

MARITIME BUSINESS ADMINISTRATION PROGRAM

MASTER’S THESIS

DIGITALIZATION READINESS IN TURKISH SEAPORTS BY USING CONTENT ANALYSIS METHODOLOGY

Berk SARI

Supervisor

Prof. Dr. Durmuş Ali Deveci

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APPROVAL PAGE

DECLARATION

I hereby declare that this master's thesis titled as "Digitalization Level Evaluation in Turkish Seaports by Using Website Content Analysis Methodology" has been written by me in accordance with the academic rules and ethical conduct. I also declare that all materials benefited in this thesis consist of the mentioned resources in the reference list. I verify all these with my honor.

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Berk SARI

ABSTRACT

Master's Thesis

Digitalization Readiness in Turkish Seaports by Using Content Analysis Methodology

Berk SARI

Dokuz Eylül University

Graduate School of Social Sciences

Department of Maritime Business Administration

Maritime Business Administration Program

In recent years, the maritime industry has witnessed a paradigm shift driven by rapid advancements in technology and the growing influence of digitalization. Seaports, being the vital interface between land and sea transportation, play a pivotal role in facilitating the transportation of goods and commodities across the world. With the increasing complexity of global supply chains, the efficient functioning of seaports has become a critical factor in ensuring seamless cargo flow, reducing transit times, and minimizing logistical bottlenecks. The successful integration of digital technologies in seaport operations can significantly enhance their overall competitiveness and resilience. Automated and data-driven processes enable real-time monitoring, predictive analytics, and intelligent decision-making, empowering port authorities to proactively address challenges such as congestion, berth scheduling, and resource allocation. Furthermore, enhanced digital communication and collaboration among stakeholders, including shipping lines, freight forwarders, customs authorities, and inland transportation providers, foster a more interconnected and efficient logistics ecosystem. To achieve these transformative benefits, it is imperative to gauge the digitalization readiness of seaports accurately. This research study presents a comprehensive analysis of the digitalization readiness in seaports, focusing on the evaluation of web content of 5 seaports located in Northwest Marmara Sea. The study utilizes a systematic literature review by employing the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines to gather relevant research articles and publications on the topic. The primary objective is to assess the current digitalization readiness in seaports and provide insights into the level of integration within the port industry. The research methodology involves a conceptual content analysis and creating coding system to extract and analyze data from the websites of selected seaports. The system utilizes MAXQDA Webcollector tool and coding structure to automate data collection process and provide reproducible research process. The collected data and conceptual terms related to digitalization, enabling a qualitative assessment of the digitalization levels in different seaports. The evaluation of digitalization readiness levels is conducted using the DRIP (Digital Readiness in the Port) framework, which categorizes ports into different stages of digitalization. The DRIP scores are calculated based on the presence of specific technologies and index components on the seaport websites.

The findings of the study provide valuable insights into the digitalization readiness levels of seaports, highlighting the degree of integration, collaboration, and adoption of advanced technologies within the port industry. The evaluation reveals the varying levels of digitalization among different seaports, ranging from analog ports with minimal digital presence to smart ports that exhibit a high level of connectivity and integration with stakeholders and global logistics networks. The research adds to the existing knowledge base by providing a comprehensive assessment of digitalization in seaports using a novel approach of conceptual content analysis. The findings offer guidance to port authorities, operators, and industry stakeholders in understanding their current digitalization levels, identifying areas for improvement, and formulating strategies for further enhancement.

Keywords: Digitalization, Smart Port, Conceptual Content Analysis, digital readiness index, Systematic literature review, PRISMA guidelines.

ÖZET
Yüksek Lisans Tezi

Digitalization Readiness in Turkish Seaports by Using Content Analysis Methodology

Türk Limanlarında Dijital Hazırlılık Düzeyinin İçerik Analizi Metodolojisi Kullanılarak Ölçülmesi

Dokuz Eylül Üniversitesi

Sosyal Bilimler Enstitüsü

Denizcilik İşletmeleri Yönetimi Anabilim Dalı

Denizcilik İşletmeleri Yönetimi Programı

Son yıllarda, denizcilik endüstrisi hızlı teknolojik ilerlemeler ve dijitalleşmenin artan etkisiyle köklü bir değişim yaşamaktadır. Kara ve deniz taşımacılığı arasındaki önemli arayüz olan limanlar, dünya genelinde mal ve ticari ürünlerin hareketini kolaylaştırmada hayati bir rol oynamaktadır. Küresel tedarik zincirlerinin giderek karmaşıklaşmasıyla birlikte, limanların verimli işleyişi, sorunsuz kargo akışının sağlanması, transit sürelerin azaltılması ve lojistik engellerin en aza indirilmesi açısından kritik bir faktör haline gelmiştir. Dijital teknolojilerin başarılı bir şekilde liman operasyonlarına entegre edilmesi, genel rekabet gücünü ve dayanıklılığı önemli ölçüde artırabilir. Otomatik ve veri odaklı süreçler, gerçek zamanlı izleme, öngörüsel analitikler ve akıllı karar verme imkanı sağlayarak, liman yetkililerinin yoğunluk, yanaşma planlaması ve kaynak tahsisi gibi zorlukları proaktif bir şekilde ele almalarını sağlar. Ayrıca, deniz taşımacılığı şirketleri, nakliyeciler, gümrük otoriteleri ve taşıma işleri komsiyoncuları gibi ilgili taraflar arasında gelişmiş dijital iletişim ve işbirliği, daha bağlantılı ve verimli bir lojistik ekosistem oluşturur. Bu dönüşümcü faydaları elde etmek için, limanların dijitalleşme düzeylerini doğru bir şekilde değerlendirmek elzemdir.

Bu araştırma çalışması, Marmara Denizi'nin Kuzeybatısı'nda bulunan 5 limanın web içeriğinin değerlendirilmesine odaklanarak limanlardaki dijitalleşme hazırlıklarının kapsamlı bir analizini sunar. Temel amaç, mevcut dijitalleşme hazırlığını değerlendirmek ve liman endüstrisi içindeki entegrasyon seviyelerine dair içgörüler sunmaktır. Araştırma metodolojisi, kavramsal içerik analizi ve seçilen limanların web sitelerinden veri çıkarmak ve analiz etmek için kodlama sistemi oluşturmayı içerir. Sistem, MAXQDA Webcollector aracını ve kodlama yapısını kullanarak veri toplama sürecini otomatikleştirmek ve tekrarlanabilir bir araştırma süreci sağlamak için kullanılır. Toplanan veri ve dijitalleşme ile ilgili kavramsal terimler, farklı limanlardaki dijitalleşme seviyelerinin nitel bir değerlendirmesine olanak tanır. Dijitalleşme hazırlık seviyelerinin değerlendirmesi, limanların DRIP (Portföydeki Dijital Hazırlık) çerçevesini kullanarak farklı dijitalleşme aşamalarına kategorize eder. DRIP puanları, liman web sitelerinde belirli teknolojilerin ve endeks bileşenlerinin varlığına dayanarak hesaplanır. Çalışmanın bulguları, limanların dijitalleşme hazırlık seviyelerine dair değerli içgörüler sunar, entegrasyonun, işbirliğinin ve gelişmiş teknolojilerin liman endüstrisi içindeki benimsenme derecesini vurgular. Değerlendirme, farklı limanlar arasında değişen dijitalleşme seviyelerini ortaya koyar; minimal dijital varlığa sahip analog limanlardan, paydaşlar ve küresel lojistik ağlarla yüksek düzeyde bağlantı ve entegrasyon sergileyen akıllı limanlara kadar. Araştırma, kavramsal içerik analizi kullanarak limanlardaki dijitalleşmeyi kapsamlı bir şekilde değerlendiren yeni bir yaklaşım sunarak mevcut bilgi tabanına katkıda bulunur. Bulgular, liman otoritelerine, işletmelere ve endüstri paydaşlarına mevcut dijitalleşme seviyelerini anlama, iyileştirme alanlarını belirleme ve daha fazla geliştirme için stratejiler oluşturma konusunda rehberlik sağlar.

Anahtar kelimeler: Dijitalleşme, Akıllı Liman, Kavramsal İçerik Analizi, dijital hazırlılık endeksi, Sistematik literatür taraması, PRISMA kılavuzları.

DIGITALIZATION READINESS IN TURKISH SEAPORTS BY USING CONTENT ANALYSIS METHODOLOGY

CONTENT

ABBREVIATIONS

IOT	Internet of Things
KPI’s	Key Performance Indicators
DRIP	Digital Readiness Index for Ports
SPI	Smart Port Indicator
TAM	Technology Acceptance Model
ICTs	Integrating Information and Communication Technologies
IT	Information Technology
RFID	Radio Frequency Identification
PRISMA	Preferred Reporting Items &Systematic Reviews and Meta-Analysis
DEA	Data Envelopment Analysis
DCTs	Digital Communication Technologies
IR 4.0	Industrial Revoultion 4.0
FGD	Focus Group Discussion
CSFs	Critical Sustainable Factors
SPN2030	National Port Strategy
TRI	Technology Readiness Index
PEOU	Perceived Ease Of Use
PU	Perceived Usefulness
NRI	Networked Readiness Index
GDP	Gross Domestic Product
SWOT	Strengths, Weaknesses, Opportunities, Threats
TÜRKLİM	Türkiye Liman İşletmecileri Derneği

AI	Artificial Intelligence
DiGiX	Digitization Index
CPS	Cyber Physical Systems
HTML	Hypertext Markup Language
HTTP	Hypertext Transfer Protocol
BFS	Breadth-First Search
DFS	Depth-First Search
URL	Uniform Resource Locator
HITS	Hyperlink-Induced Topic Search
SALSA	Stochastic Approach for Link Structure Analysis

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INTRODUCTION

The concept of smart ports, also referred to as intelligent ports, robotic ports, and autonomous ports, has garnered significant attention in recent years. While researchers may have varying definitions of smart ports, they generally revolve around leveraging advanced technologies such as the Internet of Things (IoT), Information and Communication Technology (ICT), Big Data, and environmentally friendly practices to enhance port productivity and efficiency (Botti et al., 2017; Buiza-Camacho-Camacho et al., 2016; Ferretti and Schiavone, 2016; Yang et al., 2018). Cho and Won (2014) define smart ports as ports that incorporate automation, high productivity, and greening facilities in their operations, logistics equipment, and infrastructure. Sakty (2016) and Buiza-Camacho-Camacho et al. (2016) emphasize specialization in the areas of operation, energy, and environment.

The optimization of port productivity and energy consumption, along with the incorporation of ICT technology, are crucial elements in the development of smart ports. ICT solutions play a central role in enhancing supply chain efficiency, improving interoperability among port and onshore logistics systems, and facilitating collaboration among stakeholders (Botti et al., 2017). By leveraging real-time data and information systems, smart ports can enhance logistics flow, manage port areas more efficiently, and foster stakeholder participation and collaboration (Jun et al., 2018c). However, despite the growing interest in smart ports, limited empirical evidence and a lack of benchmarks at the international level pose challenges to understanding the current trends and potential areas for improvement (Molavi et al., 2019).

There is an increasing focus on digital technologies in the maritime transport sector, with ports like Rotterdam and Hamburg actively investing in digital database technologies to achieve sustainable expansion, improved security, process optimization, and enhanced sustainability. In contrast, many important hub and transshipment ports in Turkey lack knowledge about Industry 4.0, IoT, and Blockchain, impeding their understanding of the potential benefits these technologies offer. Despite the growing significance of trade routes in Turkey, the inclusion of regional Turkish ports is essential for realizing the innovative concept of smart port development. Unfortunately, there is a lack of concepts and models for assessing the digital performance of ports. Without such tools, auditing the digital status of ports and developing a concrete strategic roadmap for digital transformation becomes unattainable.

Given the importance of evaluating the digitalization level of seaports and the need for comprehensive definitions and empirical assessments, this study aims to fill the existing research gap. By employing a conceptual content analysis research defines the current digitalization readiness of seaports and examines the technology implementation status to embrace smart port concepts. Additionally, we employ a systematic literature review approach using the PRISMA guidelines to provide an extensive overview of the current literature on smart ports. Consequently, this study aims to address the research question: What is the level of digitalization readiness in seaports, with a specific focus on the evaluation of web content?

The study also seeks to derive strategic recommendations for ports to promote sustainable development towards becoming smart ports.

Website content analysis is chosen as a method for its effectiveness in extracting valuable insights from the textual and visual content present on websites. This method allows researchers to systematically examine and interpret the information available on websites, providing a comprehensive understanding of the communication strategies, messaging, and information presented. It is particularly useful for studying digital presence, communication patterns, and the representation of information on online platforms. By analyzing website content, researchers can uncover trends, identify key themes, and gain insights into the strategies employed by organizations or entities. This method is well-suited for exploring the digital landscape, assessing the information available to the public, and informing broader research inquiries related to online communication and digital strategies.

The findings of this research will contribute to a better understanding of the digitalization landscape in seaports and provide valuable insights for port authorities, stakeholders, and policymakers to enhance port operations, increase efficiency, and foster sustainable growth in the global logistics landscape.

1. LITERATURE REVIEW ON PORT DIGITALIZATION

The literature review section of the Master's Thesis aims to provide a comprehensive summary of existing research on the topic of digitalization in seaports. This will be achieved by identifying common themes and addressing key issues discussed in the relevant studies. To conduct the literature review, a systematic search was performed using various electronic databases, including Proquest, Proquest Global Thesis, Scopus, Web of Science, and Yök Tez Merkezi. The search terms used in both English and Turkish languages encompassed eight key phrases: "smart port," "digitalization readiness index," "digital transformation in seaports," "port digitalization level," "smart port evaluation," "digital competitiveness in maritime business," "port 4.0," and "smart port index." The search covered the period from 2000 to November 2023, aiming to capture the most recent and relevant scholarly literature on the subject.

Table 1: Keyword Searches in Databases

	Keywords
1	*Smart Port*
2	*Digitalization Readiness Index*
3	*Digital Transformation In Seaports*
4	*Port Digitalization Level*
5	*Smart Port Evaluation*
6	*Digital Competitiveness In Maritime Business*
7	*Port 4.0*
8	*Smart Port Index*

Source: Created by the Author

During the scanning process, specific criteria were employed to restrict the scope of the search. The selected sources encompassed academic articles, conference proceedings, global theses, and dissertations. Additionally, a temporal constraint was applied to the search parameters. The investigation utilized five databases, which were freely accessible through Dokuz Eylül University libraries. The systematic literature review was conducted following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. The review process consisted of title screening, abstract screening, and full-text screening, employing the RAYYAN software for title and abstract screening and MAXQDA for full-text screening.

The PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) method is a widely recognized guideline for conducting systematic literature reviews. It provides a structured and transparent approach to systematically identify, select, evaluate, and synthesize relevant studies in a comprehensive and unbiased manner. The PRISMA method ensures the reproducibility and accuracy of the review process (Moher et al., 2009).

The PRISMA statement was first published in 2009 and has been updated over time to enhance the quality and transparency of systematic reviews and meta-analyses. It consists of a 27-item checklist that serves as a practical tool for researchers to conduct and report their systematic reviews effectively. The checklist covers key components such as title, abstract, introduction, methods, results, discussion, and funding. The PRISMA method emphasizes the need for a thorough search strategy, inclusion and exclusion criteria, data extraction, and critical appraisal of the selected studies. It promotes transparency by encouraging researchers to provide detailed information about their search methods, study selection process, data extraction procedures, and quality assessment of included studies. By following the PRISMA method, researchers can minimize biases, enhance the validity of their findings, and facilitate the reproducibility of their systematic reviews. The PRISMA guidelines have been widely adopted in various disciplines and have become a standard reference for conducting high-quality systematic reviews.

Table 2: PRISMA Guideline

Identification of studies via databases and registers		
Identification	Records identified from*: Databases (n =5) Registers (n = 8 keywords)	Records removed before screening: 3864 Duplicate records removed (n = 709) Records marked as ineligible by automation tools (n = 2158) Records removed for other reasons (n = 1161)
	Title screened Records (n = 3155)	Records excluded** (n = 2158)
Screening	Abstract screened for retrieval (n = 997)	Reports not retrieved (n = 718)
	Reports assessed for eligibility (n = 279)	Reports excluded: Reason 1 (n = no digitalization sign) Reason 2 (n = no connection with maritime business) Reason 3 (n = environmental study) etc.
Included	Studies included in review (n = 60)	

Source: Created by the Author

The quantity of research addressing the concept of smart port evaluation criteria, digitalization level indices, and geo-specific digitalization evaluations is relatively scarce compared to studies focused on topics such as "smart port indexing" and "index component contributions,". Recognizing this gap in the existing literature, the present study conducted an extensive analysis using the eight aforementioned keywords within the databases specified in **Table 3**. Furthermore, a systematic literature review was undertaken to identify the research methodologies employed, as well as the objectives and findings of the papers.

Table 3: Quantity Of Research Papers On Port Digitalization In Various Electronic Databases

Keywords	*Proquest*	*Proquest Global Thesis*	*Scopus*	*Web Of Science*
Smart Port	40	3	44	97
Digitalization Readiness Index	6	13	85	5
Digital Transformation In Seaports	19	4	27	5
Port Digitalization Level	35	4	10	12
Smart Port Evaluation	26	35	16	12
Digital Competitiveness In Maritime Business	65	17	7	2
Port 4.0	2	0	26	46
Smart Port Index	98	45	7	10

Source: Created by the Author

1.1. Identification of Relevant Studies

The initial screening process involved assessing the relevance of studies based on their titles. The RAYYAN software was used to manage and streamline the title screening process. Irrelevant studies were excluded, focusing on titles that aligned with the research topic. RAYYAN is a web-based systematic review tool designed to facilitate the process of conducting literature reviews and systematic reviews. It provides a platform for researchers to efficiently screen, organize, and analyze research articles. RAYYAN supports collaboration among multiple researchers and assists in the systematic review process by automating tasks such as study selection, data extraction, and quality assessment. The tool aims to streamline and enhance the efficiency of the systematic review workflow.

The remaining studies after title screening underwent abstract screening. The abstracts of the selected studies were assessed for their relevance to the research objectives by facilitating the systematic management and assessment of abstracts. Studies that did not meet the predefined inclusion criteria were excluded. The studies that passed the abstract screening stage proceeded to full-text screening. MAXQDA software was employed to manage and analyze the full texts of the selected studies. The full texts were examined thoroughly to determine their suitability for the research objectives. Studies that met the inclusion criteria were retained for further analysis. The quality and reliability of the selected studies were assessed to ensure the validity of the research. The internal validity of the research was enhanced by excluding studies that did not align with the scope of the study. The inclusion of high-quality studies contributed to the overall robustness of the systematic literature review. The findings from the selected studies were synthesized and presented coherently. The results were analyzed, patterns were identified, and key themes were extracted from the literature. The synthesized literature was used to draw conclusions, highlight gaps in the existing literature, and provide recommendations for future research. By following the PRISMA guidelines and employing the RAYYAN tool for title and abstract screening, as well as MAXQDA for full-text screening, a comprehensive and systematic literature review was conducted. This approach ensured the inclusion of relevant studies and the systematic analysis of their key characteristics, contributing to the overall reliability and validity of the research.

Following the established criteria, each paper group was categorized under the relevant headings, and individually reviewed, and papers that appeared in multiple databases were identified and separated. To guarantee the dependability and internal consistency of the research, studies that did not align completely with the scope of this study based on their subjects were excluded. Consequently, a total of 60 papers, meeting the predetermined criteria, were selected after the scanning process and were examined in terms of their research subject, research type, data analysis methods, research objectives, and findings. The comprehensive database scan encompassed articles and conference proceedings that specifically incorporated the designated keywords within the title and were published between 2000 and 2023, the period corresponding to the emergence of the smart port concept. A significant number of studies focused on the concept of smart ports. Specifically, 60 studies closely connected to the topic at hand were identified and thoroughly investigated as part of this research study. Based on a systematic review of 60 studies about the concepts of port digitalization, the analysis reveals that the predominant subjects discussed are the quality of digital services in seaports, the facilitators and obstacles encountered in implementing digital services in seaports, the design of smart ports, the management of intelligent ports, and the development of smart port indices. Furthermore, three studies emphasize the significant factors associated with the evaluation criteria and components for smart port assessment. It is important to acknowledge that when a study encompasses multiple subjects listed in Figure 1, the classification of keywords provided by the authors was considered. Therefore, the studies were categorized according to the subjects indicated by their respective keywords.

Referring to the compilation and distribution of studies across different journals within the scope of the literature review, approximately 22.64% of the papers consist of diverse academic research, while the remaining 77.36% comprise articles published in various journals. Among the total papers, 4 articles, accounting for 7.55%, were published in the Sustainability Journal. Following this, the journals with the highest number of published articles include Maritime Economics and Logistics, Maritime Policy and Management, Sensors, Maritime Business Review, Management, Research in Transportation Business and Management, International Conference on Logistics Operations Management Proceedings, and Journal of Industrial Engineering and Management.

The analysis of data analysis methods utilized in the examined studies within the domain of port digitalization was conducted. It was found that the most commonly employed data analysis method in the reviewed studies on port digitalization was Literature Review, accounting for 29.85% of the total. The case study method was also frequently utilized. Methods such as interviews, multi-criteria decision-making (MCDM), surveys, and statistical analysis using tools like SPSS, DEA, PDE, and PSIR were employed. in descending order of frequency. Additionally, only one paper was identified in the literature that employed Focus Group and Workshop methods for data analysis.

1.2. Literature Review

1.2.1. Impact of Implementing the Related Technology

This section of the study provides a comprehensive overview of the papers examined, focusing on their subjects. It entails a detailed analysis of the objectives, findings, and data analysis methods employed in studies about port digitalization between the years 2000 and 2023. In the existing literature, there is a total of 22 papers focused on examining the Impact of Implementation Technology in ports. These papers constitute 36.67% of the overall research papers available, making them the most widely studied subject in the related field up to the present time.

According to Agatić and Kolanović (2020), the choice of digital technologies to be implemented in seaport services is influenced by factors such as competition, business performance, seaport size and location, role in trade, and strategic goals. It is observed that not all seaports use digital technologies to the same extent, with smaller and mid-sized seaports lagging in terms of digitalization, resulting in lower competitiveness compared to those seaports that have successfully implemented digital technologies. The leading seaports prioritize service quality and have embraced digital technologies, with the Internet of Things (IoT) being one of the most frequently implemented technologies for enhancing seaport services. The IoT refers to a networked system of devices, machines, objects, and people that can exchange data without direct human or computer interaction.

The feasibility of utilizing RFID technology for vehicle tracking in container terminals has been explored in several studies. Ting et al. (2012) identified a relative lack of research in this area and conducted a series of experiments to assess the applicability and accuracy of RFID in a container terminal environment. The study focused on factors influencing RFID usage and investigated the performance of RFID communication in different areas of the terminal. The experimental results revealed that RFID communication was reliable in container areas near the terminal but faced challenges in other areas such as the seaside and free area. The study emphasized the impact of the container terminal environment, including various transport vehicles, on RFID readability. The authors highlighted the importance of proper RFID reader and tag setup to ensure feasibility and minimize costs. The research provided valuable insights into the implementation of RFID-enabled vehicle tracking systems in container terminals, which could enhance operational management, reduce response time to emergencies, optimize job assignment to nearby tractors, offer statistical data for future operations, track driver behavior, and provide routing solutions. This contribution represents an original endeavor in the field of RFID adoption in container terminals.

Furthermore, the study highlighted the strategic task of transforming the development patterns of ports into modern service industries. The construction goals of intelligent ports were identified as achieving adaptive dynamic optimization and fostering close cooperation among participants in the marine logistics and land logistics supply chain. The integration of IoT technology in intelligent ports was emphasized to enhance information sharing, dynamic collaboration, efficiency, accuracy, visualization, safety, smoothness, and environmental protection in port operations. The authors noted that IoT technology has already made progress in container terminals and is expected to play a crucial role in the economic development and construction of Intelligent Ports. The impact of digital transformation in modern seaports and the need for strategic decision-making regarding cooperation among port actors have been explored in various research studies. Heilig et al. (2017) emphasized the importance of adapting organizational structures to ensure the success of digital initiatives in seaports. The paper proposed a conceptual game theoretic framework that integrates intra-, inter-, and meta-organizational perspectives to analyze the costs and benefits of digital transformations. The authors discussed the application of this framework in evaluating different strategic coalitions of port actors and provided examples using the mobile cloud platform port-IO for real-time information exchange and inter-terminal transport management. The study highlighted the significance of considering collaborative strategies and game theory to design effective cooperation in the digital transformation of seaports. The authors also expressed their intent to explore the economic impact of digitalization in future research efforts and extend a similar analysis to other industries such as public transport and healthcare.

Kao et al. (2020) developed a fuzzy logic-based decision-making support system (DMSS) that integrates marine GIS and AIS to automatically determine the route priority for vessels entering and exiting port waters monitored by VTS. The DMSS provides real-time route priority values to captains and VTS operators, enhancing navigation safety. The simulation results demonstrate the effectiveness of the DMSS, offering valuable suggestions for port entry/exit and training opportunities for inexperienced operators and deck officers. The fuzzy logic DMSS contributes to port risk management literature by reducing human error and improving navigational safety.

Chan et al. (2017) emphasize the importance of business models in operations management for extracting value from data. While big data research has gained attention, the extraction of value from unstructured data remains a challenge. The paper presents a case study on container throughput forecasting in port operations, aiming to establish an intelligent logistics center. Descriptive statistics and variable selection techniques are employed to identify influencing factors and construct a forecasting model using the support vector machine algorithm. The proposed method outperforms other models, demonstrating its effectiveness in decision-making support. The study highlights the use of intelligent data mining algorithms to estimate the causality between input data and port operational issues. Regional economic indicators and the growing impact of the tertiary industry on throughput capacity are identified. The research contributes a user-friendly decision support system and data dashboard for stakeholders, providing reasonable suggestions for the establishment of an intelligent logistics center. The proposed system aids managers in making informed decisions, and the results can be effectively presented through a concise and clear dashboard.

Fernández et al. (2016) discuss the use of new technologies in seaports, emphasizing the importance of effectively managing and visualizing the large volume of data generated. They introduce SmartPort, a GIS application that facilitates the organization, analysis, and visualization of seaport data. The system utilizes the FIWARE platform, IoT solutions, and the G3M framework for 3D visualization. SmartPort offers a comprehensive solution for analyzing and controlling data sources in the Las Palmas Port Authority, providing geospatial and temporal views of the data. The project aims to be scalable, flexible, and highly customizable. SmartPort is set to be deployed in the Las Palmas Port Authority, enhancing their decision-making process.

Ramadhani et al. (2020) present a Smart Port Service that utilizes a configured system to estimate ship docking time and support efficient ship queuing at the port. The ship docking time is predicted using the K-Nearest Neighbor (KNN) classification based on ship specifications such as length, tonnage, and commodities. The ship specifications are obtained from Long Range (LoRa) devices that detect approaching ships. The KNN system, trained with data from Tanjung Perak Harbor, achieves an accuracy of 94.3% in estimating docking time. The research identifies ship commodity as the most influential parameter, and optimizing the stevedoring process can lead to cost savings for ship operations. The study also reveals that liquid bulk commodities have longer docking times compared to other commodities, and cargo in Jamrud Selatan has a shorter docking time than cargo in Kalimas. Further improvements are needed in terms of precision and recall values for the system.

Castellano et al. (2019) examine the impact of Digital Communication Technologies (DCTs) on port efficiency and competitiveness. They propose a framework to evaluate the influence of DCTs on port efficiency using Data Envelopment Analysis (DEA) models applied to a dataset of 24 Italian ports. The degree of DCT adoption is measured through indicators related to websites and social media marketing. The study finds that the introduction of DCTs has led to increased efficiency in most of the Italian ports analyzed. Four ports experienced a significant improvement in efficiency, while

DCTs acted as drivers toward efficiency in three ports. The research suggests that further studies should consider inputs related to smart services and devices, particularly those associated with the Internet of Things (IoT), to explore the broader context of port competitiveness. Additionally, incorporating longitudinal data can provide insights into the evolving relationship between port efficiency and smart technologies over time.

1.2.2. Industry 4.0

This study examined 7 publications that discussed the concepts of Industry 4.0 and Port 4.0. Bastug et al. (2020) conducted a study to explore the role of Industry 4.0 in the value chain of seaports. The literature review identifies value chain activities in the port industry, and content analysis of ten major innovative seaports' websites is conducted to examine the Industry 4.0 applications utilized by ports. The study categorizes Industry 4.0 into seven technological characteristics: digitalization, autonomization, transparency, mobility, modularization, network collaboration, and socializing. The findings reveal that ports engage with Industry 4.0 through port community systems, cyber-physical systems, the Internet of Things, and big data. These modules enable ports to achieve cost leadership advantages for competitiveness. However, to achieve differentiation, increased connectivity with customers and stakeholders through communication channels like social media is necessary. The study acknowledges limitations in the sampling strategy, as the materials were primarily gathered from English-language websites. Future research should consider targeting non-English language websites for a more comprehensive review of Industry 4.0 technologies in seaports. Additionally, the study notes that value chain analysis and the usage of Industry 4.0 technologies may differ between the manufacturing industry and the seaport industry.

Mohd Salleh et al. (2021) examine the implementation of Industrial Revolution 4.0 (IR 4.0) in the context of Malaysian seaports. They emphasize the need for seaports to align their development with global technological trends and requirements to ensure sustainability and competitive advantage. Through a Focus Group Discussion (FGD) involving 13 domain experts from maritime stakeholders, the authors identify critical sustainable factors (CSFs) for IR 4.0 implementation in Malaysian seaports. The findings reveal that while many seaports globally have made progress in adopting IR 4.0, Malaysian seaports are still in the early stages of exploring their concepts and lagging behind the global benchmark. The study highlights dimensions such as environmental protection, social equity and culture, economic value, operational value and technical quality, communication and cooperation, and political and legal parameters as crucial considerations for sustainable implementation. The research contributes to a comprehensive understanding of the implementation of IR 4.0 in the seaport industry and suggests the need for further exploration and validation of the factors influencing IR 4.0 implementation in Malaysian seaports. It underscores the importance of proactive investment and clear policy-making strategies to propel Malaysian seaports toward the desired destination of IR 4.0 implementation.

1.2.3. Port Management

Golzarjannat et al. (2021) examine business model configurations in digitalized ecosystem contexts using the port ecosystem as a case study. Their study emphasizes the strategic bundling of business models based on ecosystem characteristics. Technologically, they highlight the importance of high-quality wireless communication, edge cloud computing, and digital twin information service platforms. These advancements enhance operational optimization, enable new businesses, and ensure compliance with standards and regulations. The research provides valuable insights for ports in terms of aligning business models with ecosystems and leveraging digital technologies for improved performance and value creation.

Loukili et al. (2018) emphasize the importance of port logistics in the national economy and the need for smart strategies to support port reform in Morocco. The "SPN2030" national port strategy aims to enhance port competitiveness and requires significant investments and resources. The authors propose integrating a smart approach within the strategy to ensure its effectiveness and address internal and external challenges. They present a model using the UML language that combines the "SPN2030" with a smart approach, aligning sectorial strategies and contributing to port performance. The study highlights the importance of research centers and universities in fostering innovation and professional efficiency. Additionally, future research aims to develop a forecasting tool to aid decision-making and align investments with the evolving economic sectors related to the national port strategy.

1.2.4. E-readiness

Rahman et al. (2017) address the important issue of technology adoption among marginalized communities to reduce global poverty. The study focuses on the technology acceptance model and conducts an empirical test to examine the influence of the Technology Readiness Index (TRI) 2.0 on the perceived ease of use (PEOU) and perceived usefulness (PU) of bKash technology among bKash entrepreneurs in Bangladesh. The results indicate that optimism and innovativeness strongly affect PEOU and PU. Furthermore, subjective well-being is strongly predicted by PEOU and PU. The findings suggest that individuals from disadvantaged backgrounds are willing to embrace technology and experience improved well-being as a result. This study contributes to the understanding of how technology influences market structures and societal development. By demonstrating that marginalized individuals are ready to use technology and can positively shape their future, the study highlights the potential of technology in enhancing well-being and bridging the digital divide.

Luyt (2006) critically examines the Networked Readiness Index (NRI) and its role in defining policy problems related to the digital divide. The article argues that e-readiness indicators not only assess readiness for technology but actively shape policy agendas. It suggests the need for more inclusive indicators to address the digital divide. Menou (2001) emphasizes the importance of considering both the positive and negative effects of ICT development, highlighting the need for a comprehensive approach. These contributions offer critical perspectives on e-readiness indicators and advocate for more inclusive policies regarding the digital divide.

1.2.5. Status of the Digitalization

Digital technologies are gaining importance in the maritime transport sector, but smaller ports lack knowledge and understanding of Industry 4.0, IoT, and Blockchain. To achieve smart port development, it is crucial to include small and medium-sized ports. However, there is a lack of concepts and models to assess the digital performance of ports and guide their digital transformation. In this study, Philipp (2020) investigates how the digital performance of ports can be evaluated and provides strategic recommendations for sustainable development towards a smart port. Using a digital readiness index, the study applies a digital performance assessment to five selected seaports. The results demonstrate the strategic positioning of the ports and inform recommendations for their digital transformation. The study proposes the use of a digital readiness index and a port maturity model to assess digital performance, guide decision-making, and support the development of a roadmap for the digital transformation of ports. Nonetheless, the lack of comparable research studies poses a methodological limitation.

Ports are increasingly focusing on digitalization to enhance their operational efficiency. However, the level of digitalization varies among ports due to factors like size, turnover, and cargo type. Paulauskas et al. (2021) propose a methodology for assessing ports' digitalization levels using a mathematical model and conducted a case study of 30 ports. They found that small and medium-sized ports lag behind large ports in terms of digitalization by approximately 30%. These findings are valuable for ports seeking to evaluate their digitalization progress and identify suitable digital improvement strategies. Further research is needed to track changes in digitalization rankings and address the challenges faced by smaller ports with limited resources. Enhanced digitalization in smaller ports can stimulate their activities, improve port services, and strengthen their competitiveness in the maritime transport market.

Honti et al. (2020) present a comprehensive dataset for measuring regional Industry 4.0 (I4.0+) readiness. The dataset includes 101 indicators collected from various open data sources related to education, science, government, and media coverage. These indicators cover domains specific to Industry 4.0, such as higher education, innovation, technological investment, labor market, and technological readiness. The authors construct an I4.0+ index using the Promethee method to rank regions based on their performance in Industry 4.0. The validity of the index is confirmed by comparing it with economic (GDP) and innovation indexes. The dataset's indicators are categorized into dimensions related to higher education, lifelong learning, labor market, innovation, investment, and technology readiness.

González-Cancelas et al. (2020) discuss the digitalization of ports, focusing on the case of Spanish ports and the Ports 4.0 initiative launched by Puertos del Estado. The authors highlight the positive impact of smart ports on the supply chain and emphasize the need to assess the level of digitalization in Spanish ports. They propose a SWOT analysis as a suitable tool to evaluate the port system's strengths, weaknesses, opportunities, and threats to digitalization. This analysis serves as a foundation for developing a concrete action plan to support the Ports 4.0 project. The study concludes that Spanish ports are currently at a medium-high level of digitalization and are continuously updating and innovating to enhance their competitiveness. However, there is still a considerable distance to cover in terms of digitalization. One of the main challenges identified is the need for integrated and collaborative use of technology by all stakeholders in the port community. The authors also emphasize the importance of transparency, data management, and cybersecurity in the future of port digitalization.

Rodrigo González et al. (2020) discuss the concept of "Smart Port" and its relevance in the current port environment. They highlight the need for ports to embrace digitalization, information and communication technology (ICT), and process automation to become more intelligent and efficient. The paper focuses on analyzing the Spanish Port System and evaluating its ports based on the Smart Port concept. The authors define indicators and variables to quantitatively measure the adaptation and achievement of Smart Port characteristics and objectives. By studying these indicators, a Smart Port index is developed, enabling the ranking of Spanish Smart Ports. The study emphasizes the importance of digitalization and automation for the future growth and competitiveness of the Spanish Port System. The authors stress the need for substantial investments in these processes to ensure efficiency, comply with international regulations, and avoid potential sanctions. They recommend the rapid development and effective implementation of port projects in the coming years to facilitate the adoption of these systems.

1.2.6. Related Literature on Enablers and Barriers

This literature review focuses on the role of open data in ports and highlights the challenges they face in terms of expertise and implementation. The study suggests that information related to port transport infrastructure, particularly static road and rail data, holds potential for open data applications. However, ports lack active promotion of their existing data reserves and face issues with machine readability. Specific information needs in ports include depth data and RFID technologies for enhanced security operations (Inkinen et al., 2019). The study explores 32 ICT innovation cases in the port sector, assessing their importance, success, driving forces, costs, and benefits. It identifies alignment between company strategies and success levels in ICT initiatives, highlighting their profit-driven nature. The findings emphasize the need for greater transparency in cost-benefit information and analyses. Terminal alignment with appropriate ICT infrastructure is crucial for success, while divergent stakeholder interests challenge cooperation. Regulation is not seen as a significant barrier or facilitator. The sample provides valuable insights, although potential biases exist, such as a higher proportion of successful cases and self-financing (Carlan et al., 2017).

2. METHODOLOGY

To address the research inquiries of the study, a literature review was conducted, and coding categories were identified. Subsequently, the websites of five seaports TÜRKLİM association in the Northwest Region of Marmara were subjected to content analysis using the MAXQDA software. Content analysis is classified in various ways in the literature, differentiating between conceptual and relational approaches. Kulatunga et al. (2007). For this study, conceptual content analysis is employed to identify dominant concepts and themes on the official websites by following the DRIP index components. The analysis of web content in this study diverges from the types typically examined in traditional content analysis, aligning with the trend in web studies that explore different content types. Following the framework proposed by Weare and Lin (2000), the content analysis of web pages involves four steps: sampling and data collection, unitization, categorization, and coding.

Table 4: Implementation Stages of The Study

Process of the Study	
To identify Research Gap	Define Research Problem Conducting Literature Review
Data Collection	Sampling Frame (N=5) Conducting Data Collection (5 websites and subdomains)
Data Analysis	Unitization Categorization: Management Human Capital Functionality Technology Information
Interpretation of Results	Data Analysis Interpret Findings and Reporting

Source: Adapted from Baştuğ et al. (2020)

In general, most of the readiness indices and maturity models related to digitalization and Industry 4.0 at the micro level, both in theory and practice, are designed to assess the performance of manufacturing firms. This emphasis is rooted in the understanding that manufacturing firms constitute the primary target group in the context of Industry 4.0. Notably, the broader logistics sector has not been extensively addressed by these readiness indices and maturity models focused on digitalization and Industry 4.0. Decker and Blaschczok (2018) asserted in their study that they were the pioneers in conducting a digital readiness analysis within the logistics sector, specifically introducing a digital readiness index for Logistics Service Providers (LSPs). This claim was substantiated by research from Philipp et al. (2020b). Additionally, the authors proposed, on a theoretical basis, a digital readiness index for ports in a literature review article, effectively addressing the identified research gap related to the absence of digital performance instruments for ports. This digital readiness index for ports, named DRIP, was developed based on a thorough examination and triangulation of literature findings from the research landscape, practices related to Performance Prediction Indicators (PPIs), and existing digital and Industry 4.0 readiness indices and maturity models.

As illustrated in the Table, the DRIP comprises five dimensions and 38 associated indicators, with some of them serving as Performance Prediction Indicators (PPIs). As emphasized in the study by Philipp et al. (2020b), the specified weighting factors in the DRIP model reflect the significance of each dimension. In their study, these factors were established through expert interviews with project specialists. It is noteworthy that within each dimension, all 38 indicators are accorded equal weight.

Table 5: Digital Readiness Index Assessment

Dimension	*Weight(%)*	*No*	*İndicator*	*Scale Applied*
Management	20	1	Digitalisation Strategy:	Implementation status: 1) Not existing, 2) Pilot initiatives are planned, 3) In development phase, 4) Formulated and defined, 5) Is in implementation phase, 6) Is implemented
		2	Digital Business Model	
		3	Innovation Cooperation	
		4	Investments in Digitalization	
Human Capital	20	5	IT Knowledge and Skills (Education)*	
		6	IT Capabilities	
		7	IT Training and Education Opportunities	
Functionality	25	8	Integrated Communication Infrastructure	
		9	Information Regarding Status of Shipment	
		10	On-time of information	
		11	Operating System	
		12	Processes	
		13	Security	
Technology	30	14	Smart ERP System	Degree of usage: 1) Technology/System not known, 2) No use case available, 3) Usage not planned, 4) Usage is planned, 5) Inspecific projects already mplemented, 6) Comprehensive usage
		15	Smart WMS System	
		16	Smart PCS System	
		17	Web-based Communication Platform	
		18	Mobile Data Access for Employees	
		19	Mobile Data Access for Customers	
		20	IoT	
		21	Cloud Computing	
		22	Localisation Technologies	
		23	Sensors	
		24	Big Data & Predictive Analysis	
		25	Blockchain	
		26	AI	
		27	Robotics	
		28	Drones	
		29	Autonomous Solutions	
		30	D. Twinning, Aug. & Virtual Reality	
Information	5	31	Personal Network	Degree of information procurement: 1) Very low, 2) Low, 3) Rather low, 4) Rather high, 5) High, 6) Very high
		32	Printed Media	
		33	Internet	
		34	Social Media Resources	
		35	Fairs	
		36	Conferences	
		37	Associations	
		38	Scientific Institutions	

Source: Adapted from Philipp (2020)

2.1. Sampling and Data Collection

This study focuses on assessing the digitalization levels of five distinct container ports, namely Asyaport, Ceyport, Kumport, Mardaş, and Marport. The evaluation of digitalization status encompasses various dimensions, including Management, Human

Capital, Functionality, Technology, and Information. To measure these dimensions, a total of thirty-eight indicators were employed as quantitative measures.
As for the selection of Türklim member container terminals located in the Northwest Region of the Marmara Sea, there are several reasons behind this choice. Firstly, these terminals represent a significant subset of container ports in the region, providing a representative sample for the study. Additionally, being Türklim members suggests that these ports are part of a recognized association in the Turkish maritime industry, implying their importance and relevance in the context of port operations and digitalization efforts. Finally, the Northwest Region of the Marmara Sea is strategically located and serves as a crucial hub for maritime activities, making it an appropriate area for examining digitalization levels in port operations.

The selection of the Northwest Region of the Marmara Sea as the focus area for evaluating the digitalization levels of container ports offers several justifications. Significance in the maritime industry: The Northwest Region of the Marmara Sea is known for its strategic importance in the maritime sector. It serves as a major transportation hub, connecting various trade routes and facilitating international shipping. Therefore, studying the digitalization levels of container ports in this region provides valuable insights into the overall digital transformation trends and practices within the maritime industry.

The selected Türklim member container terminals in the Northwest Region of the Marmara Sea encompass a range of port sizes, operational capacities, and infrastructure capabilities. By examining the digitalization levels of these diverse ports, the study can capture a comprehensive picture of digital readiness and adoption across different scales and types of container terminals. Regional comparability and benchmarking: Focusing on a specific geographic region allows for effective comparison and benchmarking of digitalization levels among the chosen container ports. By assessing the digitalization status of ports within the same region, it becomes possible to identify best practices, variations, and potential areas for improvement specific to that particular geographic context.

Conducting research within the Northwest Region of the Marmara Sea provides practical advantages in terms of accessibility to port facilities and availability of data. Researchers can directly engage with port authorities, stakeholders, and personnel to gather relevant information and ensure accurate assessments of digitalization levels. Data collection took place on the websites of the chosen five Türklim member seaports. These websites offer various language options, including English, Turkish, and Bulgarian. The content across different language versions is identical, with an English option available. Consequently, data were collected from the English-language version. To ensure an evidence-based approach and considering the dynamic nature of web page updates, snapshots of the web pages were archived at a specific time. Therefore, for this study, the content of the five main domain web pages for the five seaports (amounting to approximately 570 megabytes of data) was gathered between November 18 and 19, 2023, and preserved for subsequent content analysis.

2.2. Unitisation

Unitisation involves the process of defining the unit of analysis, which includes selecting sampling, recording, and context units. The initial step in unitisation is the choice of sampling, where researchers may adopt a strategy to determine which websites will be examined to facilitate data collection. (Baştug et al., 2020). In this study, the strategy involved identifying sampling units based on domain names. The first-level domain names of seaports (e.g., https://marport.com.tr/) were chosen as the sampling frame, and lower-level domain names were also included. Small recording units were utilized as statistical data and coding structures, focusing on the services, organization, and news pages of selected seaports' websites written in English and limited to content related to Digitalization Readiness. The study specifically concentrated on customized websites that highlight digitalization and technology implementation activities in conjunction with digitalization readiness components.

2.3. Categorisation

The creation of categories to describe individual recording and context units stands out as the most crucial aspect of content analysis. This phase is intricately linked to the research questions, and therefore, the set of categories should align with them to facilitate coding. The list of categories should be directly derived from the research questions, as they offer valuable insights. In this context, the research questions aimed to assess which seaports possess the highest DRIP score. The DRIP index, being a measure of digital readiness in ports, serves as a key criterion for categorization. During this stage in the content analysis process using MAXQDA, the focus is on establishing categories that directly correspond to the aspects measured by the DRIP index, ensuring a comprehensive and relevant evaluation of the seaports' digitalization readiness.

IT Capability Assesment Sub-Indicators Categorization
IT Infrastructure
Automation Technology
Data Analytics
Data Security /Communications Security
Development of / application of assistance systems
Collaboration Software
Non-technical skills such as systems thinking and process understanding

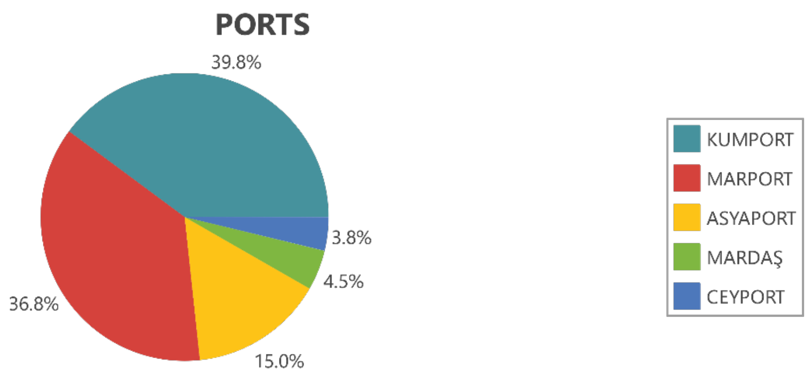
Source: Created by the Author

2.4. Coding

There are two primary coding approaches: inductive and deductive coding, also referred to as emergent and priori coding. This study employed deductive coding, which involves establishing categories and codes based on the Digitalization Readiness Index(DRIP) before applying them to the text. Deductive coding is well-suited for the confirmatory stage of research, as it provides a structured approach with pre-established categories. While this method ensures organized data analysis, it may overlook concepts and categories that do not fit into the predetermined framework. In traditional content analysis, a research team develops a coding scheme and trains coders before analyzing message characteristics. There are various options for computer-assisted qualitative data analysis software (CAQDAS). These tools are designed to assist researchers in analyzing qualitative data systematically and efficiently. MAXQDA is one of the notable options and a comprehensive CAQDAS tool that allows researchers to analyze text, audio, video, and image data. It offers tools for coding, categorizing, and exploring qualitative data.

In this study, digitalization readiness index components were coded in terms of the Related technology implementations of the seaports. Dimensions were then identified and coded into 5 main topics: management, human capital, functionality, technology, and information. Most of the categories were then divided into sub-categories using keywords and added to MAXQDA as a coding structure to evaluate the sample websites. To address the research inquiries, it is essential to analyze the digitalization readiness scores among seaports through matrix coding. Matrix coding queries are specifically employed to identify potential categories and dimensions associated with higher-scoring concepts, facilitating multiple comparisons between cases and concepts. In essence, matrix coding allows for the comparison of diverse contexts defined by keywords within categories. The findings are then organized in MAXQDA tables, where each row corresponds to related seaports concerning a specific pair of components (e.g., percentage coverage values for the corresponding coded data). Matrix coding can query data based on coding presence, providing a comprehensive examination of digitalization readiness across seaports.

Figure 1: Presence of the Digitalization Readiness Components in Seaports.



Source: Created by the Author

2.5. Statistical Analysis

The chosen statistical tests were carefully selected to ensure the validity and reliability of the study's findings. Descriptive analysis allowed for a detailed exploration of the central tendencies and variabilities within each port, providing a foundational understanding of the data. The tests for homogeneity of variances, including Levene's tests based on mean, median, adjusted df, and trimmed mean, were crucial to confirm the appropriateness of employing ANOVA. These tests ensured that the assumption of homogeneity was met, a prerequisite for the validity of ANOVA results. ANOVA, with its ability to analyze differences in means among multiple groups simultaneously, was the primary test for assessing whether there were significant variations in scores among the ports. The inclusion of effect size metrics, such as eta-squared and omega-squared, added depth to the interpretation by quantifying the practical significance of observed differences. Post hoc tests, specifically Tukey's HSD, were employed to identify specific pairs of ports with significantly different means, offering a nuanced understanding of the unique characteristics of each port. The consideration of homogeneous subsets further refined the interpretation by grouping ports with similar mean scores. The statistical analysis was conducted using SPSS software and involved multiple steps to comprehensively explore the differences in scores among different ports. Descriptive analysis provided means, standard deviations, and confidence intervals for MARPORT, CEYPORT, KUMPORT, MARDAS, and ASYAPORT. The homogeneity of variances across ports was assessed through Levene's tests, considering various metrics such as mean, median, adjusted df, and trimmed mean. All tests indicated no significant departure from homogeneity, reinforcing the reliability of subsequent analyses.

Table 6: Homogeneity of Variances

Tests of Homogeneity of Variances

		Levene Statistic	df1	df2	Sig.
Score	Based on Mean	.869	4	20	.500
	Based on Median	.437	4	20	.780
	Based on Median and with adjusted df	.437	4	14.342	.780
	Based on trimmed mean	.828	4	20	.523

Source: Created by the Author

The one-way ANOVA revealed a significant overall effect ($p < 0.001$), suggesting differences in mean scores among at least two ports. Effect size measures, including eta-squared, epsilon-squared, and omega-squared (fixed and random effects), provided insights into the practical significance of these differences. Post hoc tests, specifically Tukey's Honestly Significant Difference (HSD), identified significant mean differences between several port pairs, such as MARPORT and CEYPORT, KUMPORT and CEYPORT, and others.

Table 7: One Way ANOVA

ANOVA

Score

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	43.786	4	10.947	18.968	<.001
Within Groups	11.542	20	.577		
Total	55.328	24			

Source: Created by the Author

Homogeneous subsets were examined to identify groups with similar means. For an alpha level of 0.05, subsets were formed, indicating that CEYPORT and MARDAS constituted one subset, while ASYAPORT, MARPORT, and KUMPORT each formed separate subsets. These subsets provided a nuanced understanding of which ports exhibited comparable mean scores.

Table 8: Tukey's HSD

Score

	Port	N	Subset for alpha = 0.05	
			1	2
Tukey HSD[a]	CEYPORT	5	1.6857843137	
	MARDAS	5	1.8142857143	
	ASYAPORT	5		4.0929271709
	MARPORT	5		4.5007703081
	KUMPORT	5		4.6740196078
	Sig.		.999	.746
Tukey B[a]	CEYPORT	5	1.6857843137	
	MARDAS	5	1.8142857143	
	ASYAPORT	5		4.0929271709
	MARPORT	5		4.5007703081
	KUMPORT	5		4.6740196078

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 5.000.

Source: Created by the Author

Table 9: Anova Effect Sizes

ANOVA Effect Sizes[a]

		Point Estimate	95% Confidence Interval	
			Lower	Upper
Score	Eta-squared	.791	.509	.849
	Epsilon-squared	.750	.411	.819
	Omega-squared Fixed-effect	.742	.401	.813
	Omega-squared Random-effect	.418	.143	.520

a. Eta-squared and Epsilon-squared are estimated based on the fixed-effect model.

Source: Created by the Author

The ANOVA effect size table provides valuable insights into the magnitude and practical significance of the observed differences among the ports. The primary effect size metric, eta-squared, indicates that approximately 79.1% of the total variance in scores can be attributed to differences among the ports. This substantial effect size underscores the practical significance of the variations identified by ANOVA. Epsilon-squared, a related measure, reinforces this interpretation by suggesting that about 75% of the variance can be explained by the differences among ports, highlighting the robustness of the observed effects. The inclusion of omega-squared, both fixed-effect and random-effect, adds further nuance to the effect size estimation. The fixed-effect omega-squared (0.742) signifies the proportion of variance attributed to fixed effects, offering a perspective on the systematic differences among ports. Meanwhile, the random-effect omega-squared (0.418) acknowledges the presence of variability due to random effects, reflecting the broader context of the study. Collectively, these effect size metrics contribute to a comprehensive understanding of the practical significance and explanatory power of the observed differences among the ports, enhancing the overall interpretation of the study.

3. FINDINGS

In accordance with the DRIP matrix provided in the table, an assessment was undertaken for the seaports including Marport, Ceyport, Kumport, Mardaş, and Asyaport.

Table 10: Digital Readiness Index Scores

Dimensions	*MARPORT*	*CEYPORT*	*KUMPORT*	*MARDAŞ*	*ASYAPORT*
Management	4.75	1.00	5.25	1.50	3.00
Human Capital	4.29	1.33	5.00	1.24	3.95
Functionality	5.17	2.50	5.83	2.83	5.17
Technology	4.18	1.47	4.41	2.00	4.47
Information	4.13	2.13	2.88	1.50	3.88
DRIP SCORES (without weighting factors)	4.50	1.69	4.67	1.81	4.09
DRIP SCORES (Weighted)	4.64	1.64	4.98	1.93	4.22

Source: Created by the Author

As the examination of "IT Capabilities" under the "Human Capital" dimension progressed, it involved a more detailed breakdown into distinct sub-indicators. These sub-indicators encompassed aspects such as "IT infrastructure," "Automation technology," "Data analytics," "Data security/communications security," "Development of/application of assistance systems," "Collaboration software," and "Non-technical skills such as systems thinking and process understanding." The specific findings about the subdimension of "IT Capabilities" are outlined in the accompanying table.

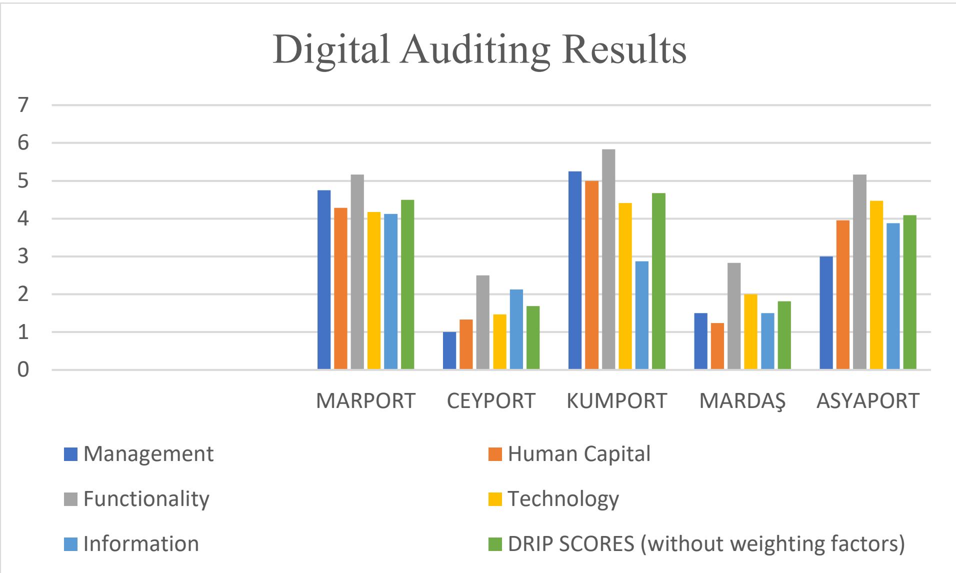
Table 11: IT Capabilities Assessment

IT Capability Assesment	*MARPORT*	*CEYPORT*	*KUMPORT*	*MARDAŞ*	*ASYAPORT*
IT Infrastructure	5	2	5	1	6
Automation Technology	5	1	5	1	6
Data Analytics	5	1	6	1	1
Data Security /Communications Security	5	1	6	2	6
Development of / application of assistance systems	5	4	6	3	1
Collaboration Software	5	4	6	3	6
Non-technical skills such as systems thinking and pr	4	1	1	1	1
Arithmetic Mean	**4.86**	**2.00**	**5.00**	**1.71**	**3.86**

Source: Created by the Author

According to the data outlined in the table, Kumport container port stands out as the leading performer in the study. This conclusion is drawn from the evaluation of the Digital Readiness Index (DRIP), wherein Kumport secured the highest score or index of 4.98. Consequently, among all the cases examined, Kumport Seaport demonstrates the highest level of digital readiness. Thus, within the benchmarking context of this study, the seaport is highlighted as the epitome of best practices in its specific region. Kumport is classified as a Developer Port in the DRIP matrix. This classification signifies that Kumport, along with its hinterland players, is interconnected within a unified digital environment, extending the advantages of preceding stages to a wider set of stakeholders. The commitment to a continual improvement approach and leveraging digitalization to gain a competitive edge aligns with the characteristics of a Developer Port. Kumport aims to sustain this advantage by focusing on sustainable integration, and continuous improvements, and actively seeking opportunities for generating new businesses and expanding partnerships within the broader ecosystem. Concerning the outcomes per dimension as outlined in Table, it is evident that there is significant improvement in the areas of "Human Capital" (5) and "Technology" (4.41). Consequently, to transition into a small port, it is advisable to strategically prioritize actions in these two domains. Conversely, the digital performances in the dimensions of "Management" (5.25) and "Functionality (IT)" (5.83) are already at a very high level.

Figure 2: Digital Auditing Results



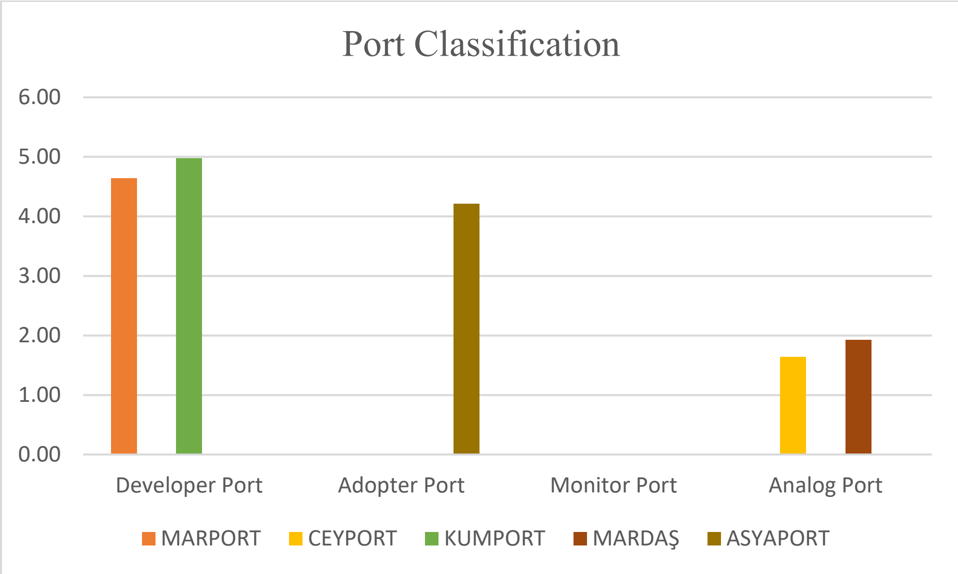
Source: Created by the Author

Table 12: Port Classification and Characteristics

Port Classification	*Characteristics*	*Strategy Description*	*DRIP Score(x)*
Smart Port	The port is intricately linked through a communication network and seamlessly integrated with its surroundings, encompassing all stakeholders in the industry, as well as other global ports and logistics entities. The scheduling of diverse transportation modes is streamlined, and real-time cargo tracking involving all pertinent parties is facilitated.	Combine the physical and digital realms. Ensure consistent enhancement through ongoing development of sustainable and innovative business scenarios.	5.5≤x≤6.0
Developer Port	The port and the players in the hinterland are linked within a unified digital environment, extending the benefits of preceding stages to a broader array of stakeholders. Anticipated additional advantages include enhanced overall planning and scheduling within both the port and its hinterland. The port is committed to a continual improvement approach.	Leveraging digitalization to establish a competitive edge and sustain that advantage by focusing on sustainable integration and continuous improvements. There is a need to generate new businesses and broaden partnerships within the ecosystem.	4.5≤x<5.5
Adopter Port	The port and closely associated organizations (typically including authorities, operators, customs, etc.) initiated the integration of their information systems to enhance communication. Consequently, a unified digital environment is being established, offering several benefits such as improved coordination and reduced waiting times for all modes of transportation. The overall aim is to create a more efficient and streamlined operational environment.	The prioritization of customer relationships is contingent on one's internal processes and service framework. Strategic decisions should be guided by analytical insights, responding proactively to environmental changes and factoring them into the decision-making process. The overarching goal is to identify and capitalize on new business opportunities.	3.5≤x<4.5
Monitor Port	Separate automations within the port may develop. The port authority, operator, and affiliated organizations in close proximity to the port independently uphold their processes and databases, commencing their individual digitalization efforts. Consequently, information and pertinent data are collected through specific nodes. Continuous monitoring of the port environment is conducted. In terms of customers, a policy guided by statistics is implemented.	Emphasize and enhance adaptive capabilities, with a particular focus on improving the skills and knowledge of employees at all hierarchical levels. Consider outsourcing as a viable alternative for digital expertise. Aim to transition from an observer role, even if only slightly, to a more proactive role.	2.5≤x<3.5
Analog Port	Automation is absent in this context. The port lacks or has minimal understanding of digitalization and, consequently, is either unaware of how to make changes or is unwilling to do so. Additionally, the port typically carries out landlord functions. In terms of customer service, a standard first-come-first-serve policy is generally implemented.	Shift your mindset by gaining an understanding of the advantages and additional value derived from sustainable digital development, commonly referred to as digital transformation. Begin to perceive and actively influence the ongoing process.	1.0≤x<2.5

Source: Adapted from Philipp (2020)

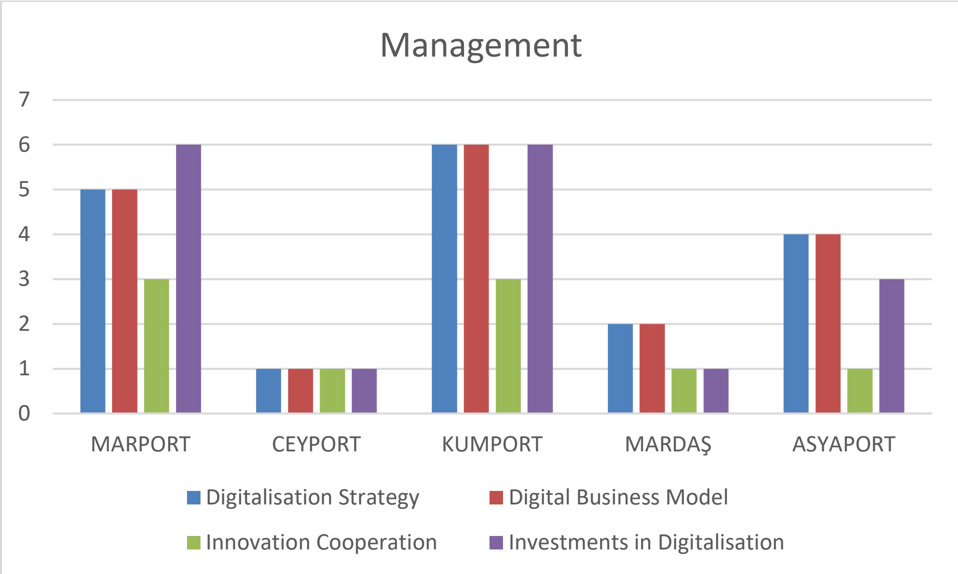
Figure 3: Port Classification



Source: Created by the Author

In this research, Marport attains the second position, securing a DRIP score of 4.638. Analyzing the dimension-specific results, it can be observed that in terms of the "Management" dimension and to some extent in the "Technology" dimension, the seaport of Marport is comparable to the high level exhibited by the seaport of Kumport. Related port also shows significant improvement across all other dimensions ("Human Capital" = 4.29, "Functionality(IT)" = 5.17, "Information" = 4.13). Based on the assessed digital readiness index of 4.638 and considering Table, the Marport port may also be categorized as a "Developer port."

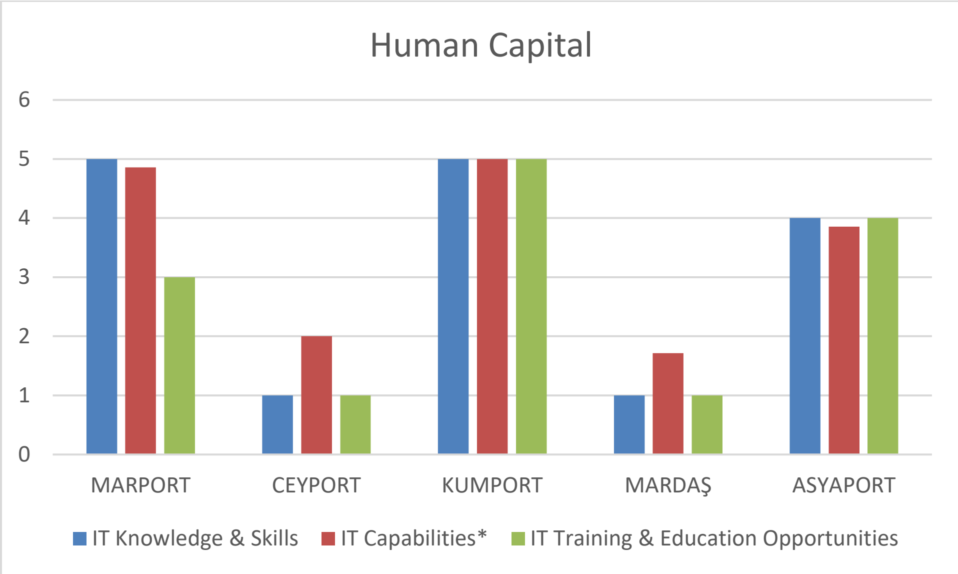
Figure 4:Dimensions(Management)



Source: Created by the Author

Asyaport secures the third position with a digital readiness score of 4.217, as per research results. The table highlights noteworthy achievements in the "Technology" dimension, matching the best practice example, Kumport, with a score of 4.47. Similarly, the "Functionality (IT)" dimension also attains a commendable score of 5.17. However, areas demanding more attention include "Management" (3.00), "Human Capital" (3.95), and "Information" (3.88). Despite these concerns, the overall index of 4.217 positions Asyaport as an "Adopter port". In this classification, Asyaport has initiated the integration of its information systems to enhance communication, establishing a unified digital environment. This integration offers benefits such as improved coordination and reduced waiting times for all modes of transportation, aligning with the overarching goal of creating a more efficient and streamlined operational environment. The focus on prioritizing customer relationships and leveraging analytical insights for strategic decisions demonstrates the adoption of a proactive approach to respond to environmental changes and identify new business opportunities.

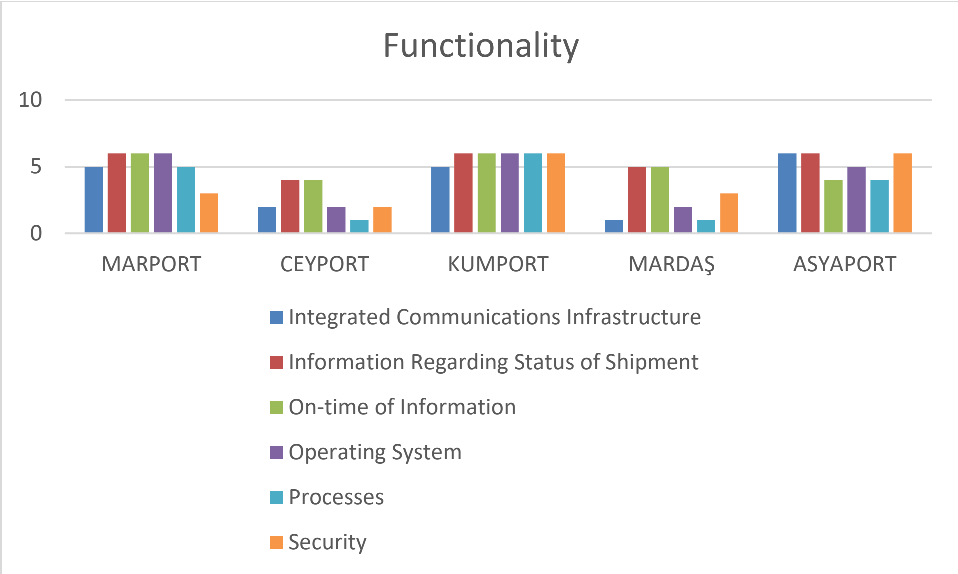
Figure 5: Dimensions(Human Capital)



Source: Created by the Author

Mardaş is ranked fourth in the current study, attaining a digital readiness index of 1.93 (refer to Table). Areas requiring improvement are evident across all dimensions outlined in Table, with scores of 1.50 for "Management," 1.24 for "Human Capital," 2.83 for "Functionality (IT)," 2.00 for "Technology," and 1.50 for "Information." Overall, Mardaş's digital readiness index of 3.088, as indicated in Table, categorizes it as a traditional "Analog Port." Mardaş indicates a lack or minimal presence of automation and a limited understanding of digitalization. The port is characterized by a tendency to perform landlord functions and typically adheres to a standard first-come-first-serve policy in customer service. To enhance its position, Mardaş should embrace a mindset shift, recognizing the benefits and added value associated with sustainable digital development, commonly known as digital transformation, and actively engaging in the ongoing process.

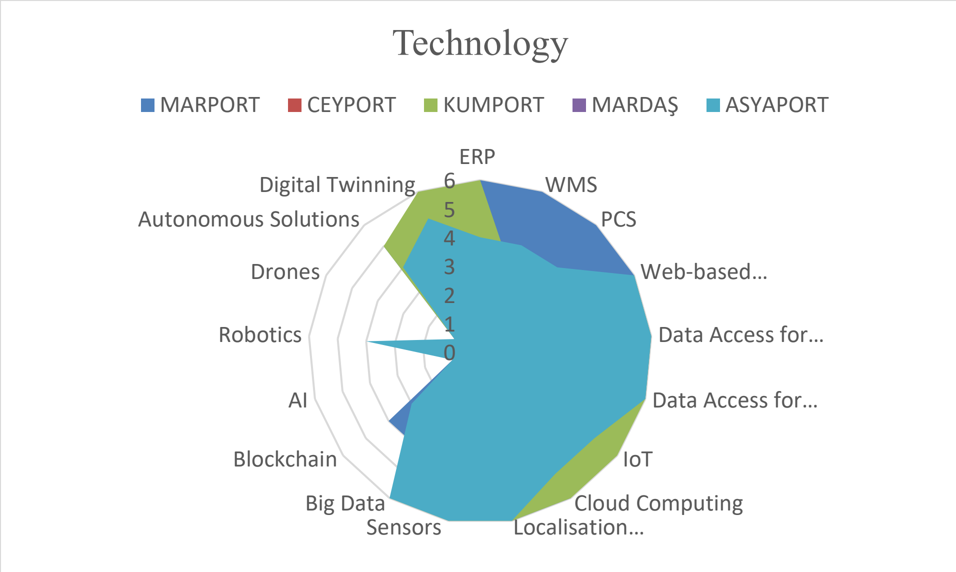
Figure 6: Dimensions(Functionality)



Source: Created by the Author

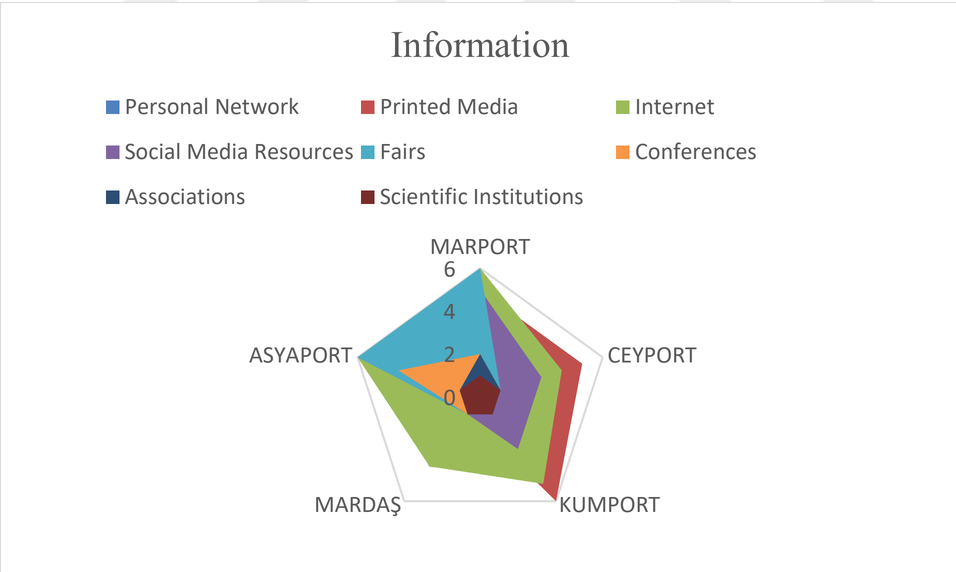
Ceyport Tekirdağ, positioned at the lowest rank, obtained a comprehensive digital readiness score of 1.64, as detailed in the table. Areas in need of enhancement are apparent across all dimensions specified in the table, with scores of 1.00 for "Management," 1.33 for "Human Capital," 2.50 for "Functionality (IT)," 1.47 for "Technology," and 2.13 for "Information." The overall digital readiness index of 1.64 for Ceyport classifies it as a conventional "Analog Port," underscoring its limited readiness for digitalization. The collective assessment places Ceyport in the traditional category of "Analog Ports," suggesting a limited level of readiness for digitalization. In this context, the port exhibits characteristics associated with analog operations, such as a lack of advanced automation, minimal understanding of digital technologies, and a conventional approach to management and information practices.

Figure 7: Technology Dimension



Source: Created by the Author

Figure 8: Information Dimension



Source: Created by the Author

CONCLUSION & DISCUSSION

The digital readiness index for ports (DRIP) encompasses five dimensions and 38 associated indicators. These dimensions—namely "Management," "Human Capital," "Functionality (IT)," "Technology," and "Information"—have been integrated into the digital auditing tool, recognizing that the transformation of ports hinges not only on innovative technologies but also on effective management, employee skills, and IT processes. The DRIP model underscores the significance of acquiring information about current digitalization trends, enabling port representatives to identify opportunities and make strategic, informed decisions. Weighting factors in the DRIP model were established through expert interviews and may be subject to further discussions. While the current model assigns equal weights to all indicators within each dimension, this approach is open to debate, and adjustments may take into account regional peculiarities and stakeholders' interests.

Another area of discussion pertains to the evaluation of the PPI "IT Capability" and its seven sub-indicators. Some argue that "IT Capabilities" are pivotal for sustainable development towards a smart port and should carry more weight in the DRIP model. However, in this study, these sub-indicators are treated equally to other indicators within the dimension of "Human Capital." To enhance smart port development, strategic recommendations extend the DRIP by incorporating a maturity model. The strategic positioning of ports, based on their digital performance and classification, provides specific recommendations for each port type. For instance, "Developer ports" like Kumport and Marport are advised to leverage their high degrees of digitalization for a competitive advantage and ecosystem expansion. "Adopter ports" like Asyaport should prioritize customer relationships and consider environmental changes in decision-making. "Analog Ports" like Mardaş and Ceyport should focus on enhancing their adaptive capacities, increasing employee knowledge, and transitioning to a more proactive role in the digital landscape.

The findings of the current study align with and contribute to existing literature on the digitalization of ports. The strategic recommendations based on the digital

performance and classification of ports resonate with the emphasis in the literature on the impact of implementing related technology, Industry 4.0, port management, e-readiness, and the overall status of digitalization in the maritime transport sector.
In the existing literature, studies like Agatić and Kolanović (2020) and Paulauskas et al. (2021) highlight the impact of technology implementation in seaports and the varying degrees of digitalization among ports based on factors like competition, business performance, and size. The current study builds upon these insights by providing specific recommendations tailored to different types of ports, emphasizing the need for "Developer ports" to leverage their high digitalization degrees, "Adopter ports" to prioritize customer relationships, and "Analog Ports" to enhance adaptive capacities. The concept of Industry 4.0 is explored in literature, as seen in Bastug et al. (2020) and Mohd Salleh et al. (2021), discussing the role and applications of Industry 4.0 in seaports. The current study complements this literature by offering strategic recommendations that align with the technological characteristics of Industry 4.0, such as digitalization, autonomization, transparency, and network collaboration. Regarding port management, Golzarjannat et al. (2021) emphasize business model configurations in a digitalized ecosystem, while Loukili et al. (2018) discuss the importance of smart strategies in port reform. The current study extends this literature by providing recommendations that directly align with the strategic bundling of business models and leveraging digital technologies for improved performance and value creation. E-readiness is addressed in the literature, with Rahman et al. (2017) examining the influence of the Technology Readiness Index on technology acceptance. The present study contributes to this literature by proposing a digital readiness index and a port maturity model, offering a more comprehensive framework to assess digital performance and guide decision-making in ports.

Finally, the literature acknowledges the status of digitalization in the maritime transport sector, with smaller ports lacking knowledge and understanding, as highlighted in Philipp (2020) and Paulauskas et al. (2021). The current study contributes by proposing specific recommendations for smaller ports, addressing their adaptive capacities, employee knowledge, and proactive role in the digital landscape.

In summary, the findings of the current study align with existing literature and provide specific, actionable recommendations based on the digital performance and classification of ports, contributing to the ongoing discourse on the digitalization of the maritime transport sector.

LIMITATION AND FURTHER STUDIES

The strategic graduation model presented in this study signifies a transformation of the previously employed DRIP concept into a maturity model for smart port development. The application of the digital readiness index for ports generated DRIP scores, enabling the identification of the current digital positioning of seaports. This, in turn, facilitated the derivation of strategic directions and recommendations for sustainable development towards smart ports based on individual digital port classifications. The developed port maturity model, integrating the DRIP concept and a strategic graduation matrix, empowers practitioners and researchers, particularly port authorities, operators, and policymakers. It enables the assessment of digital performance, identification of strategic positions, categorization based on digital maturity, and formulation of concrete digital strategic actions. Essentially, this model provides a roadmap for the digital transformation of ports. However, it's important to note a methodological limitation due to the lack of comparable research studies.

Future research endeavors are envisioned to expand the number of ports and incorporate Performance Prediction Indicators (PPIs) focusing on operational performance. This expansion will allow the exploration of potential relationships between digital and operational performance in ports. Additionally, the study reveals a notable deficiency in digital readiness for certain technologies like "Blockchain (incl. Smart Contracts)" and "Artificial Intelligence (AI)" across all investigated ports. Despite existing studies on these topics, future research should concentrate on proposing practical use cases since the present findings indicate limited implementation or utilization of these technologies in ports. The developed methodology allowed for the assessment of port digitalization levels using the DRIP score. However, it is essential to note that the obtained results are specific to ports within the analyzed geographical areas, primarily the Northwest of the Marmara Sea. Future studies should consider expanding the research to evaluate the digitalization readiness of ports in other regions in Turkey, such as the Mediterranean Sea, Black Sea, and Aegean Sea. In addition to the methodologies used, several limitations are associated with the content analysis employed to assess the digitalization readiness of seaports. One limitation pertains to the potential subjectivity in interpreting and coding qualitative data. Content analysis relies on the interpretation of textual information, which may introduce a degree of subjectivity in the analysis process. Another limitation is related to the dynamic nature of digital technologies. Content analysis captures information available at a specific point in time, and the rapidly evolving landscape of digital technologies may result in an incomplete or outdated representation. Emerging technologies or recent advancements might not be fully reflected in the content analysis, limiting the comprehensiveness of the assessment. Furthermore, the scope of content analysis is contingent on the availability and accessibility of relevant data. The quality and quantity of information accessible for analysis could vary among different ports, potentially leading to disparities in the depth and accuracy of the assessments. Incomplete or limited data may hinder a comprehensive understanding of the digitalization readiness of seaports. Additionally, content analysis may overlook contextual nuances and specific details that could be crucial for a thorough evaluation. The qualitative nature of content analysis might not capture the intricate relationships, local dynamics, or unique circumstances that influence the digitalization readiness of seaports. A more nuanced and context-specific approach may be required to address these intricacies.

Lastly, content analysis might not provide insights into the practical implementation and effectiveness of digitalization initiatives. While it can identify stated intentions and strategies, it may not assess the actual impact or success of the implemented measures. A holistic evaluation of digitalization readiness would necessitate complementary methods to gauge the real-world outcomes of digital initiatives in seaports.

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