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DIGITALIZATION IN SHIPPING: TECHNOLOGIES, IMPACTS AND CASE STUDIES

Dimoulis Konstantinos

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The members of the committee were:

- Peter J. Stavroulakis (Supervisor)
- Andreas Andrikopoulos
- Vasilios Naoum

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ABSTRACT

This thesis explores the transformative role of digitalization in the global shipping industry, with particular emphasis on the Greek maritime sector. It examines how technologies such as Artificial Intelligence, Big Data, the Internet of Things and blockchain are reshaping operations, management and sustainability across shipping. Through a combination of theoretical analysis and real-world case studies of Maersk, NYK Line and leading Greek companies, the study identifies key benefits, challenges and emerging best practices. Findings highlight that digitalization enhances efficiency, safety and environmental performance but also demands significant cultural and organizational change. The research concludes that successful digital transformation depends not only on technology adoption but on human capital development, strategic vision and ethical leadership. Ultimately, the dissertation argues for a human-centric approach to digitalization that combines innovation with maritime tradition and long-term sustainability.

Keywords: digitalization, maritime management, Greece, sustainability, technology transformation

ΠΕΡΙΛΗΨΗ

Η παρούσα εργασία εξετάζει τον μετασχηματιστικό ρόλο της ψηφιοποίησης στη διεθνή ναυτιλιακή βιομηχανία, με ιδιαίτερη έμφαση στον ελληνικό ναυτιλιακό τομέα. Αναλύει πώς τεχνολογίες όπως η Τεχνητή Νοημοσύνη, τα Μεγάλα Δεδομένα, το Διαδίκτυο των Πραγμάτων και το blockchain αναδιαμορφώνουν τις λειτουργίες, τη διαχείριση και τη βιωσιμότητα στον χώρο της ναυτιλίας. Μέσα από έναν συνδυασμό θεωρητικής ανάλυσης και μελετών περιπτώσεων πραγματικών εταιρειών όπως οι Maersk, NYK Line και κορυφαίες ελληνικές εταιρείες, η μελέτη εντοπίζει τα κύρια οφέλη, τις προκλήσεις και τις αναδυόμενες βέλτιστες πρακτικές. Τα αποτελέσματα υπογραμμίζουν ότι η ψηφιοποίηση ενισχύει την αποδοτικότητα, την ασφάλεια και την περιβαλλοντική απόδοση, αλλά απαιτεί επίσης σημαντικές πολιτισμικές και οργανωτικές αλλαγές. Η έρευνα καταλήγει στο ότι η επιτυχημένη ψηφιακή μεταμόρφωση εξαρτάται όχι μόνο από την υιοθέτηση τεχνολογιών, αλλά και από την ανάπτυξη ανθρώπινου δυναμικού, τη στρατηγική όραση και την ηθική ηγεσία. Τελικά, η διατριβή υποστηρίζει μια ανθρωποκεντρική προσέγγιση στην ψηφιοποίηση, που συνδυάζει την καινοτομία με την ναυτική παράδοση και τη μακροπρόθεσμη βιωσιμότητα. Λέξεις-κλειδιά: ψηφιοποίηση, ναυτιλιακή διαχείριση, Ελλάδα, βιωσιμότητα, τεχνολογικός μετασχηματισμός

CHAPTER 1 - INTRODUCTION

1.1 PURPOSE AND OBJECTIVES

The main objectives of the dissertation are:

1. Offer a conceptual and theoretical framework for digitalization in shipping.
2. Discuss the core technologies driving digital transformation.
3. Examine the operational, strategic and human capital implications of becoming digital.
4. Provide case studies of leading shipping companies.
5. Seek out insights and challenges specific to the Greek shipping industry.
6. Develop recommendations for the sustainable digital transformation of the industry.

1.2 RESEARCH QUESTIONS

The research will be guided by the following fundamental question:

What are the key benefits, challenges and frontiers of digitalization in shipping, focusing in particular on the Greek shipping sector?

Sub-support questions are:

7. What technologies are most identified with shipping, and why?
8. How does digitalization affect efficiency, safety, cost and sustainability?
9. What barriers exist to its adoption, such as financial, organizational or regulatory challenges?
10. How are leading shipping operators driving digital transformation?
11. What are the implications for Greek shipping firms and policymakers?

1.3 METHODOLOGY

The dissertation shall be built primarily on secondary research. Academic literature, industry reports (e.g., by the International Maritime Organization, BIMCO, Clarkson Research, UGS) and shipping company announcements shall be utilized to build the theoretical and empirical base of the research.

In addition, case studies will be conducted on international shipping lines (Maersk, NYK Line) and a group of selected Greek shipping companies. Greek shipping insights would further be supplemented by investigating technologies such as MarineTraffic, DeepSea Technologies and METIS. Primary qualitative data would be collected through legitimate shipping companies' web sources and, if possible, with short interviews or correspondence with shipping industry executives trying to gain first-hand perspectives on trends and issues of digitalization.

The study will thus combine:

- Theory-based literature review.
- Document analysis of reports and case studies.
- Qualitative data from industry representatives, if available.

This mixed method is considered appropriate because of the limited availability of quantitative data, along with an attempt to portray the rapidly evolving nature of digitalization.

The dissertation will have the following structure:

- Chapter 1 – Introduction: Outlines purpose, aims, research question, methodology and structure.
- Chapter 2 – Theoretical Background: Provides an overview of the maritime industry, its historical technological evolution and the digitalization theory.
- Chapter 3 – Key Digital Technologies in Shipping: Introduces leading technologies such as IoT, Big Data, AI, blockchain and autonomous systems.

1.4 STRUCTURE OF THE DISSERTATION

CHAPTER 2 - THEORITICAL BACKGROUND

2.1 INTRODUCTION

Clearly, well-developed theory and concepts form the foundation of every scientific discipline, leading to the necessity of conceptualizing and analyzing the digitalization in shipping not as a buzz-word but rather as the intersection between maritime economics/shipping management and new technologies. In this chapter, we provide an overview of the digitalization discourse in shipping, the theoretical models applied to it, and its implications for maritime strategy and performance.

- Chapter 4 – Impacts of Digitalization: Analyses operational, economic, human, regulatory and cybersecurity impacts.
- Chapter 5 – Case Studies: Examines Maersk, NYK Line and the Greek shipping industry observations.
- Chapter 6 – Conclusions and Recommendations: Summarizes findings, identifies limitations and provides recommendations for the future of digital transformation in shipping.

Digitalization in shipping is a phenomenon that cannot solely be regarded as technological; it furthermore has an organizational, cultural and economic dimension. Hence, this chapter presents a multi-dimensional view of digitalization in shipping, namely how economic, managerial and global trade theories influence the digitalization adventure in the shipping industry.

2.2 HISTORICAL CONTEXT OF TECHNOLOGICAL CHANGE IN SHIPPING

However, it is technology that is the main driver for continual change in international shipping. Each era in the history of international shipping, from the age of sail to the steam age in the nineteenth century, to the containerization era of the 1950s, is driven by technological developments (Stopford, 2020). Each of these major advances in maritime technology not only changed the structure and function of ships, but it also changed global commerce and impacted the societies associated with the sailors and workers who made this commerce possible. For example, the transition from sail to steam required new engineering skills and changes in the economics of ship ownership and global trade routes.

Containerization was another innovation for this technology that not only accelerated the flow of goods but also transformed international trade. As the container became the organizing principle for cargo handling, the entire environment was transformed at the ports, across global flows of capital, and in seafaring employment. In this sense, the containerization of global trade was as much a social revolution, for the relationships between shipowners, port operators, and global supply chains, as an economic one.

Digitalization, as the next chapter of this historical development of the seas, prompts operators and shippers to rethink not only individual components but also the business philosophy itself: The interaction of data, communication networks, and smart systems moves the decision-making process in maritime logistics from the customary intuition-based management toward data-driven management.

According to UNCTAD (2023), new technologies such as the Internet of Things (IoT), Artificial Intelligence (AI) and Big Data analytics, which can be referred to as the Digital Maritime Revolution, also have the capability to reshape maritime transport again. They work in the new 'ecosystem' that characterizes modern shipping in terms of navigation, logistics, maintenance, safety, and environmental compliance (Green Shipping). What distinguishes this revolution from earlier ones is

the real-time nature of the information flow between ship and shore, which is transforming efficiency, competitiveness and sustainability across the maritime industry.

2.3 CONCEPTUALIZING DIGITALIZATION

2.3.1 DEFINITION AND SCOPE

Digitalization is about the use of digital technologies to create or modify business models, processes, and activities with the goal of improving performance, efficiency, and value creation of the company (BIMCO, 2022). Digitalization should not be mistaken for digitization, which is the conversion from analog to a digital format (Acciaro & Wilmsmeier, 2022).

In my view, digitalization in shipping means a systemic change of interaction between ships, ports and logistic systems. It includes data analysis, data-driven remote control, automated documentation, cybersecurity and smart decision support. Thus, digitalization is not only the use of technology but also the use of a data culture and data interpretation.

2.3.2 THEORETICAL FRAMEWORKS

The Resource-Based View and the Dynamic Capabilities Framework share a theoretical foundation. According to the RBV, resources (including digital ones) and capabilities are the main sources of competitive advantage (Barney, 1991). In contrast, the DCF stresses the need to reconfigure resources to meet the challenges of a digitally transforming world (Teece, 2018).

In a shipping context, this could be how a firm uses its digital capabilities to optimize its fleet, reduce its emissions, or sense and respond to its customers' needs. In my view, the Dynamic Capabilities perspective fits the sea better than the Resource Based view - shipping companies are used to sailing in turbulent waters of markets, regulation, and technology.

2.4 DRIVERS OF DIGITAL TRANSFORMATION

2.4.1 ECONOMIC DRIVERS

Shipping is cyclical and a highly capital-intensive industry. Volatility of energy prices and freight rates and new compliance and enforcement costs from new regulations have contributed to increased penetration of digital technologies (Clarkson Research, 2023).

For me, digitalization is a survival strategy. Only once you get used to efficiency, you have something left to defend. Companies use predictive analytics and IoT to run their fleets with more efficiency, increasing return and service levels.

2.4.2 ENVIRONMENTAL AND REGULATORY DRIVERS

Environmental regulation forces companies to report emissions in greater detail (IMO, 2021). This is especially true around the “2030 and 2050” decarbonization targets by the International Maritime Organization (IMO). Digital solutions enable compliance and sustainability. Emission tracking software, digital twins and AI-based optimization are examples of these solutions.

That is the place where technology and ethics meet for me. People have long criticized the shipping industry for opacity and pollution. Digitalization creates transparency. Therefore, it makes shipping more responsible and cleaner than ever before.

2.4.3 TECHNOLOGICAL DRIVERS

Sensors, satellite communications and artificial intelligence have become more accessible, and the price of computing power and storage in the cloud has fallen, making it affordable for medium-sized businesses to use technology that was once only available to larger organizations (DNV, 2022).

I think clearly the most exciting thing at the moment is the democratization of technology, the degree to which, for the first time, smaller players can compete on an almost level playing field with data and clever systems.

2.5 BARRIERS TO DIGITAL ADOPTION

As such, several barriers exist for digitalization in shipping.

2.5.1 FINANCIAL CONSTRAINTS

To digitalize, one must invest heavily in hardware, software and training as the impact shifts. Small shipowners, like those in the bulk and tanker sectors (OECD, 2022), cannot afford these investments. I truly believe that this creates a growing digital divide between large companies like Maersk and small Greek or Asian operators, who still work in a customary way.

2.5.2 ORGANIZATIONAL RESISTANCE AND CULTURE

Operational culture is strongly rooted in experience and intuition (as opposed to data-driven decisions) and slows the adaptation to tech (Acciaro & Sys, 2020). I personally believe leadership style is the key here. Many heads of customary organizations still see digitalization mainly as an IT project, rather than a planned transformation.

2.5.3 FRAGMENTATION AND LACK OF STANDARDIZATION

Interoperability between systems remains a challenge, as ships operate disparate monitoring and communication systems that do not "speak the same language" (World Economic Forum, 2020), preventing the full integration of data across fleets.

This is one of the most frustrating realities of maritime digitalization: the technology exists, but there just isn't an ecosystem ready to make it all work.

2.6 DIGITALIZATION AND MARITIME ECONOMICS

Digitalization is shifting the economic logic of the shipping industry. Historically, control over the means of production and the resources related to vessels, ports and cargo was important to success (Stopford, 2020). Today, data itself is a calculated asset, with algorithms that can forecast rates, maintenance cycles and voyage performance, which reduces uncertainty and increases market visibility.

Perhaps the most economically relevant change resulting from digitalization is that firms that collect and process operational data more quickly than their competitors have an immediate economic edge. For example, predictive models for freight allow firms to book ships when they expect the best margins and not necessarily when market prices are favorable (Clarkson Research, 2023).

Digitalization also eases new business models, including subscription-based fleet management systems, pay-per-use fuel analytics and digital freight platforms (Acciaro & Wilmsmeier, 2022). In this sense, digitalization is seen as a move from heavy asset ownership in maritime economics to service-based ecosystems.

I think that will transform competition, not only between shipowners but also against other forms of digital services. Future competition will be as much about digital skills as about the ships themselves. I think companies like METIS, DeepSea Technologies and Wärtsilä Voyage will have the same importance as shipyards and classification societies.

2.6.1 EFFICIENCY AND MARKET TRANSPARENCY

Digital freight platforms such as Shipfix and Freightos offer more market transparency, connecting the cargo and tonnage market in real-time while also increasing liquidity in the spot market and reducing the brokerage fee (OECD, 2022). Although this is welcome, it exerts downward pressure on the profit margin, diminishing the opportunity to time the market, thereby requiring reliance on operational efficiency.

2.6.2 CAPITAL ALLOCATION AND FINANCING

Increasingly, investors demand confirmation of performance data before committing capital. Remote monitoring allows financiers to better assess operational risk and environmental compliance (DNV, 2022). I think this is a very healthy development cause it is better to be efficient and accountable than famous.

However, the provision of funding may be biased, since small and less digitalized companies might receive less. If banks and financial institutions do not receive transitional support, digitalization may create inequity.

2.7 POLICY AND INSTITUTIONAL FRAMEWORKS SUPPORTING DIGITAL TRANSFORMATION

However, shipping technology is framed by several governance frameworks at the international, regional and national levels.

2.7.1 THE IMO AND GLOBAL GOVERNANCE

At the international level, standards on cybersecurity, digital safety and data interoperability are set by the International Maritime Organization (IMO). For example, following Guidelines on Maritime Cyber Risk Management (MSC-FAL.1/Circ 3), operators must account for cyber risks in their Safety Management Systems (IMO, 2021).

However, personally, I see this as one of the biggest steps IMOs took on a future-proof approach. For decades, they have focused on physical safety. Now, they're dealing with digital safety. The problem is enforcement in the sense that many flag states and small companies do not have the capacity to implement these standards.

2.7.2 EUROPEAN UNION AND REGIONAL POLICIES

The European Union, another policy driver, promotes a “smart, green and digital shipping” agenda through EU Digital Transport Corridors projects and Horizon Europe, which provides funding for innovation and interoperability in the European port system (EU Commission, 2023).

From their perspective, the relevance of regional support is important because Greek companies have global dominance, and many are not part of EU regulatory funding regimes. I would suggest specific incentives for Greek shipowners to participate in EU digital initiatives as a possible solution.

2.7.3 NATIONAL POLICIES AND INDUSTRY ASSOCIATIONS

Organizations such as the Union of Greek Shipowners (UGS) and the Hellenic Chamber of Shipping begin to prioritize digitalization on a national level as well (UGS, 2023). Initiatives from the University of Piraeus, the National Technical University of Athens and Greek maritime startups have created a burgeoning ecosystem, albeit a young one.

Greece must invest in its entrepreneurial spirit. Greeks are quick, adaptive and very international. With government incentives and reform to maritime education, our country has the potential to become the digital maritime innovation hub of the Mediterranean Sea.

2.8 CRITICAL REFLECTIONS

The best way to analyze the digitalization of shipping, in terms of theory and policy, is as a systemic evolution, which includes economic logic, organization and international regulation. To me, this leads to three conclusions:

12. Technology without culture fails.

13. People and processes driving digital tools determine their effectiveness.

14. Without context, data is noise.

The shipping industry needs to create knowledge. It can do this by contextualizing its data for the purpose of making better, faster and fairer decisions.

To collaborate is to compete now. No single company can digitalize the industry alone. Interoperability and common standards will determine the winner.

These reflections are the groundwork for the problem analysis of technologies (Chapter 3) and of their impacts (Chapter 4) in the next chapters.

2.9 CONCLUSION

In this chapter, theoretical and contextual foundations were discussed. A historical development of technological change in shipping was described. Theoretical approaches were seen, drivers and barriers were analyzed, and the economic and policy context for digitalization was developed.

To conclude, digitalization of the maritime sector must not be interpreted as a linear process of technology-strategy-governance. The coming decade will determine whether the maritime sector can transform digitalization into a sustainable competitive advantage or not. The shipping companies that invest in enabling technologies, build the skill sets of their employees and collaborate openly will create a sustainable data-driven future for the maritime sector.

CHAPTER 3 - KEY DIGITAL TECHNOLOGIES IN SHIPPING

3.1 INTRODUCTION

The digital revolution transformed and will continue to transform every part of the maritime world, from how people pilot, operate and manage ships, to how they connect ships to global supply chains. A sector which has relied on experience, intuition and handwritten logs is slowly learning to read streams of data, use predictive algorithms and rely on sensors instead of sailors to make decisions (Stopford, 2020).

Digitalization is no longer an issue of how and when. It is currently a substantial element in a company's competitiveness. What fascinates me is how these technologies can help make processes faster and more efficient. They also help redefine the nature of shipping itself. So in this chapter, I would like to focus on six of the most disruptive digital technologies regarding reshaping the world of shipping: IoT, Big Data and analytics, AI and machine learning, blockchain and DLT, autonomous ships and robotics, plus cybersecurity.

3.2 INTERNET OF THINGS

IoT, Internet of Things, means a network of connected devices and sensors. These devices and sensors collect and share data in real time. IoT connects the engine, hull, container and port within shipping (Balaji et al., 2020). IoT is the core of our digital ship for me. It is the unseen link that animates the ship using data.

3.2.1 APPLICATIONS IN SHIPPING

IoT technology has changed the way maritime businesses measure performance:

Predictive Maintenance Analysis: Detect anomalies in engine vibrations and temperatures before an engine failure.

Smart connected fuel meters enable operations managers to monitor and reduce fuel use and emissions in real time according to DNV (2022).

Cargo Monitors: Real-time temperature and humidity sensors maintain the integrity regarding high-value and perishable goods (Lee & Lam, 2019).

Port Connectivity: IoT connects the ship to port infrastructure, which helps people load and unload cargo.

3.2.2 BENEFITS

The single most valuable thing IoT can deliver is visibility. Shipping was a “black box” for the longest time, once you left port. Now managers track everything from machinery health to weather deviations, toward making shipping more predictable, transparent and responsive.

3.2.3 CHALLENGES

Connectivity, cybersecurity and operational plus data standards do not allow for the adoption of IoT in shipping (World Economic Forum, 2020). For smaller companies and older ships, cost-effectively retrofitting IoT devices is difficult. In my view, this creates a digital divide with major players becoming data-rich and the smaller players remaining data-poor.

3.3 BIG DATA AND ADVANCED ANALYTICS

If IoT is the nerves of digital shipping, Big Data is the brain. Every modern ship produces large quantities of data from navigational equipment, sensors, Automatic Identification System (AIS) signals and maintenance logs. The challenge, which also happens to be the opportunity, is finding a way to analyze that information cleverly (Poulsen & Sampson, 2019).

3.3.1 APPLICATIONS

- Voyage Optimization: Operators join weather, current and performance data, so they can optimize routes to achieve better times and save fuel (Hinnant et al., 2019).
- Performance Benchmarking: Data allows companies to compare vessels, identify inefficiencies and improve fleet management.
- Emission Tracking: Real-time data helps ensure compliance with IMO decarbonization targets, such as EEXI and CII (IMO, 2021).
- Market Forecasting: Advanced analytical packages use freight rate information and macroeconomic data to predict chartering activity (Clarkson Research, 2023).

3.3.2 BENEFITS

Within shipping, Big Data has allowed operators to move from a mode of operation that is reactive to one that is proactive and predictive. Shipping managers can use data analytics to predict maintenance problems, fuel consumption, and overall performance of the fleet. The digital transition here is not only a technology transition, but also a cultural one, where data and analytics complement experience and intuition to make operations, products, and services safer, more reliable, and more competitive.

3.3.3 CHALLENGES

However, it still has its own issues, such as ownership, standardization and the quality of the data (Acciaro & Sys, 2020). I think one of the biggest mistakes related to big data is that you might collect huge volumes of data, but then you do not analyze it or use it properly. As I prefer to say, data without perception is just noise.

3.4 ARTIFICIAL INTELLIGENCE AND MACHINE LEARNING

Artificial Intelligence (AI) and Machine Learning (ML) are the next wave, and they power smart technologies that learn from data and adapt to make decisions and recommendations without human intervention (Bal, 2021).

In my opinion, it's about augmenting the human. Seafarers, chartering managers and operations officers can use tools that let them “see" trends in the market, anticipate and plan for maintenance issues and better optimize their planning and operations. In addition, make better decisions in the deepest sense of the phrase.

3.4.1 KEY APPLICATIONS

- Autonomous Navigation: AI systems analyze radar and sensor data with collision avoidance and route optimization (Rødseth & Burmeister, 2019).
- Predictive Maintenance: Machine learning algorithms detect failure patterns before the patterns become costly problems (Jia et al., 2021).
- Fleet Optimization: AI models to help find the most efficient way to deploy vessels, taking into account the weather, markets and vessel data (Stopford, 2020).
- Commercial Decision Support: Chartering departments use Artificial Intelligence to forecast freight rates and recommend timing for fixing vessels.

3.4.2 BENEFITS

AI enables shipping to make faster, more accurate, and less biased decisions. AI provides shipping companies with the ability to find patterns in big data that would be imperceptible to and too complex for the human brain to process. Shipping, which has relied on experiential decisions for centuries, is now embracing a quantitative approach. Though it is near impossible to remove judgment entirely, the best decisions are made when the human touch is helped by data to reduce uncertainty and build confidence.

3.4.3 CHALLENGES

At the same time, AI systems may fail if they do not train enough or if humans do not involve themselves at key stages. Operators and decision-makers face a big challenge because they may decide too much with automated decision-making systems, which can erode situational awareness

and critical thinking. However, the regulatory framework lags behind technological advances, and no rules exist to fully guide the decision-making using autonomous or artificial intelligence assistance onboard ships per IMO (2021), leaving questions over the legal and safety aspects of their operation.

3.5 BLOCKCHAIN AND DISTRIBUTED LEDGER TECHNOLOGIES

Blockchain technology has drawn more attention in recent years and is seen as a form of technology that can increase transparency and reduce fraud, according to (Hackius & Petersen, 2017).

In layman's terms, blockchain is a secure, shared and immutable record of transactions. The idea that a technology developed to support cryptocurrency now helps modernize one of the oldest industries in the world truly fascinates me.

3.5.1 APPLICATIONS

- Digital Bills of Lading: Blockchain-based documentation ensures authenticity and reduces delays in cargo handling.
- Smart Contracts: Automatically execute charter agreements once predefined conditions are met (Batubara et al., 2018).
- Supply Chain Visibility: Blockchain enables seamless data exchange across stakeholders from shipowners and ports to insurers and customs authorities (World Economic Forum, 2020).

3.5.2 BENEFITS

The transparency, reduced bureaucracy, and security that blockchain and DLT offer mean less paperwork and reduced transaction costs with fewer intermediaries in maritime operations such as chartering, tracking cargo, and paperwork. Aside from the efficiency gains, blockchain is also expected to increase trust, due to everyone having equal access to one shared version of the truth, increased accountability, and fewer disputes.

3.5.3 CHALLENGES

Still, uptake remains low. The closure of Maersk's TradeLens platform in 2023 shows that even well-resourced applications with cutting-edge technology will not endure without mass adoption (IBM, 2023). I see the potential for blockchain in shipping to be dependent upon firms being able to compete on cooperation, not competition, to develop data ecosystems.

3.6 AUTONOMOUS SHIPS AND ROBOTICS

Autonomous or unmanned ships are not just science fiction anymore. For example, the Norwegian Yara Birkeland has already been tested at sea (for the first time), signaling the start of an era of maritime activity of fully autonomous ships (DNV, 2022).

3.6.1 APPLICATIONS

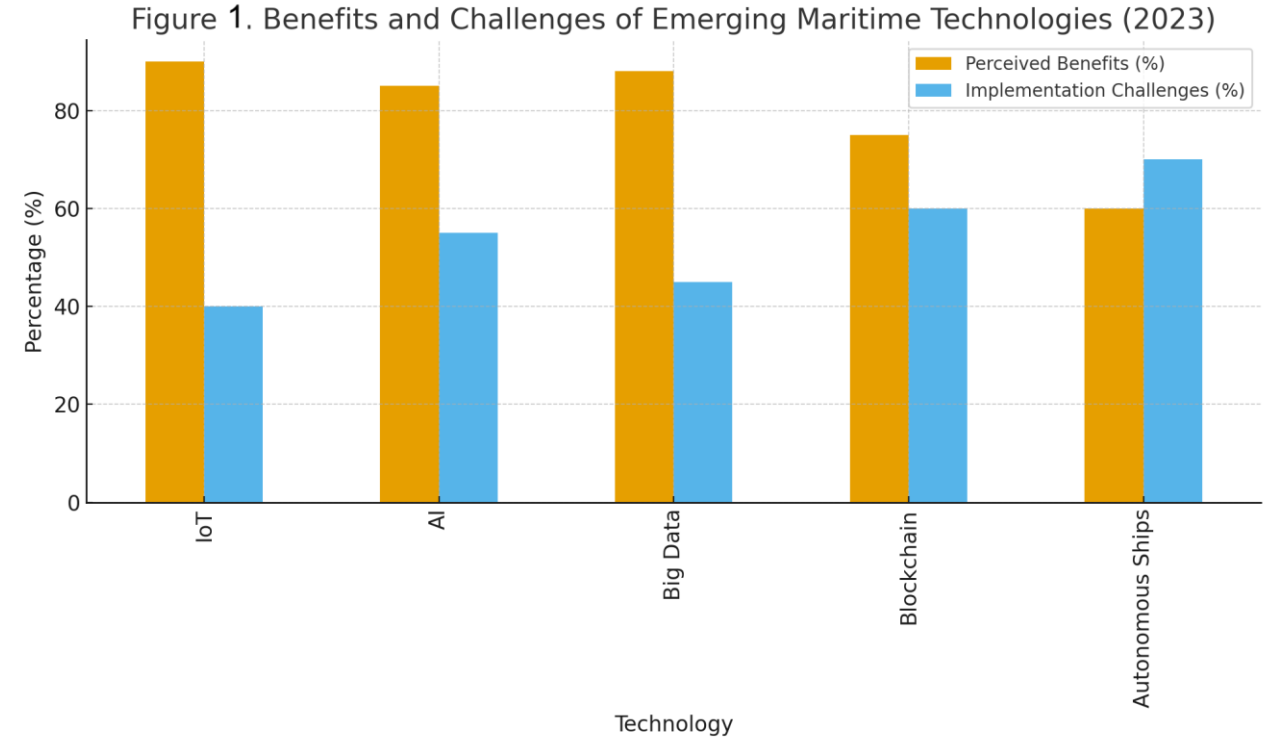
- Remote Operation: Control over ships is often transferred to operators in onshore command centers.
- Autonomous Navigation: Autonomous navigation by AI autopilot systems uses radar, GPS and LIDAR sensors.
- Robotic Inspection: A ship hull can be inspected and tanks cleaned using drones and robotic arms (Gilbert et al., 2021).

3.6.2 BENEFITS

Despite the attractions of automated systems as a way of making things safer and cheaper, I see automation as unavoidable and something that should be carefully managed. Automation can assist, not replace crews, by doing the ordinary and dangerous tasks while human crews make the complex or novel decisions.

3.6.3 CHALLENGES

However, the main issue is the legal and ethical implications of maritime law, assuming there is always a master on board, which could be challenged by the fully automated ship (IMO, 2021). Trust and insurance in these unmanned ships are also lacking.



3.7 CYBERSECURITY IN THE MARITIME INDUSTRY

As vessels depend more on digital technologies, the consideration of cybersecurity becomes an important maritime safety issue. Cybersecurity attacks may target vessels or ports and may impact safety, security, the integrity of cargo and pose a threat to human life, according to (IMO, 2021).

To me, cybersecurity is not a technical issue; it's a state of mind within the organization. Cyber intrusions are still undervalued by shipowners, who believe the maritime sector is too “niche” for cyber attacks to occur. The reality is different.

Figure 1. Benefits and Challenges of Emerging Maritime Technologies (2023)
This figure presents the perceived benefits and implementation challenges associated with major digital technologies currently shaping the maritime sector, including IoT, AI, Big Data analytics, Blockchain, and autonomous ships. The results illustrate that while most technologies show high potential for efficiency gains, their adoption is often hindered by integration and regulatory complexities.
Source: Author’s elaboration based on UNCTAD (2023) and relevant academic literature.

3.7.1 COMMON CYBER THREATS

- Malware and Ransomware Attacks: These can disable navigation or cargo systems.
- GPS Spoofing: False coordinates can mislead a vessel’s route.

- Phishing and Insider Threats: Crew members or shore staff can unintentionally expose sensitive systems.

The 2017 NotPetya cyberattack against Maersk that forced Maersk to shut down global operations for days (Maersk, 2018), costing the company nearly 300 million USD, was a reminder that even the most advanced operators are not immune to such attacks.

3.7.2 COUNTERMEASURES

For cybersecurity, people must remain aware and trained, people must monitor the network, and people must work with classification societies (DNV, 2022). In my opinion, cybersecurity should be in the culture of maritime, like safety drills. Each crew member should know the digital firewall like the lifeboat.

3.8 SYNTHESIS AND DISCUSSION

Once each technology is considered individually, the synergies between them become apparent. IoT supplies data, Big Data and AI process the data to turn it into perception, blockchain secures the transaction and automation acts on the perception in real time.

From my perspective, what makes digitalization revolutionary is not the individual tools but their integration. When a shipping company can track fuel consumption (IoT), predict maintenance (AI), verify documentation (blockchain) and manage cybersecurity (policy frameworks) simultaneously, the operational paradigm changes entirely.

The synthesis of these technologies is leading toward what some call “Smart Shipping Ecosystems”(networks of connected ships, ports and logistics operators that share data seamlessly) (World Economic Forum, 2020).

But I still think that we must be careful around human beings, because human beings are irreplaceable. So the best systems will not be systems for eliminating humans, but systems that empower humans with information, i.e., augment judgment, rather than eliminate judgment.

3.9 ETHICAL AND HUMAN DIMENSIONS OF TECHNOLOGY

The industry is focused on digitalization to provide efficient, profitable shipping, but we also need to consider the people. Shipping is not just about technology. We should ask how automation and AI could impact jobs, training and the well-being of seafarers (ICS, 2023).

Many seafarers are concerned that technology will take their jobs, and that's fair enough, but technology will also create new jobs. It will automate some seafarer activities, but also create jobs, for example, in data analysis, system management and monitoring and digital security.

We need to train seafarers for us to get the most out of these digital systems. Technology will not succeed if we do not train people in the way needed. I don't think the future of digital shipping is a “smart ship” so much as it is about “smart people”.

3.10 INTEGRATION OF DIGITAL SYSTEMS AND INTEROPERABILITY CHALLENGES

Interoperability challenges digitalization in maritime transport. Maritime logistics systems remain fragmented, although individual technologies have made great strides (OECD, 2022).

3.10.1 FRAGMENTED DIGITAL ECOSYSTEM

Technology providers have proprietary systems that don't integrate easily. For example, an engine IoT system from one provider might not integrate easily with a voyage optimization system from a different provider. This limits efficiency, raising operational costs.

By observing Greek shipping companies, it is easily understandable that interoperability is often the biggest frustration. Owners invest in digital solutions, only to find that these systems cannot “talk” to each other. This results in duplicate data entry and inconsistent information.

3.10.2 THE CASE FOR STANDARDIZATION

While organizations such as the IMO, ISO, BIMCO and others have developed data standards to ease integration (the IMO Data Model and API port call catalogue guidelines) (IMO, 2021), adoption is still inconsistent. One possible solution, I think, is for collaboration instead of competition - companies, software vendors and open digital frameworks to work together effectively.

3.10.3 THE HUMAN AND STRATEGIC SIDE OF INTEGRATION

Integration is mainly seen as a calculated challenge. For shipping companies to use data successfully, alignment of IT, operations and management is needed. I believe a company's technology strategy needs to be integrated as much as its business strategy, or technology investments simply will not pay off.

In Greece, some forward-thinking companies are already taking this holistic approach. Firms like DeepSea Technologies and METIS Cyberspace Technology are developing integrated performance systems that connect ship sensors with decision-making dashboards (DeepSea, 2023). This represents the next phase of maritime digitalization, from isolated solutions to connected intelligence.

3.11 CONCLUSION

In this chapter we have explored the main enabling digital technologies impacting the shipping sector, as well as the benefits they generate: efficiency (IoT and Big Data), transparency (Blockchain), and safety (Cybersecurity and AI). Their true transformational power lies in their integration and assimilation into humanity.

Digital shipping must be about impressive the right balance between automation and decision-making, innovation and safety, efficiency and ethics. The shipping industry is not in a race to digitalize at all cost. We must instead digitalize with wisdom.

In the future, I believe the companies best placed to succeed will approach digital transformation as an adventure. The adventure embraces technology, people, and collaboration within the entire maritime ecosystem.

CHAPTER 4 - IMPACTS OF DIGITALIZATION

4.1 INTRODUCTION

In many organizations, the digitization of the shipping industry has triggered a massive transformation of the way we do business in the maritime domain, whether it is in maritime operations, the economy, our people or our regulatory environment. About the most fascinating thing is that it is not just all about technology. It is about how we think, how we organize ourselves and how we compete.

However, digitalization also enables planning, brings efficiency gains, improves safety and progresses on sustainability, while dealing with problems around cyber risk and workforce change needs (IMO, 2021; DNV, 2022). The chapter depicts the operational, economic, environmental, human and regulatory dimensions of maritime digitalization and ends with an analysis of the likely impact of digitalization on the future of global and Greek shipping.

4.2 OPERATIONAL IMPACTS

4.2.1 ENHANCED EFFICIENCY AND PREDICTABILITY

One of the most concrete impacts of digitalization is operational performance. Shipping with IoT, Big Data, and AI has become more predictable and transparent than ever before, according to DNV (2022). Systems that track vessels in real time, maintain them predictively and report automatically help fleet managers utilize vessels optimally and make them inactive for minimal periods.

From my standpoint, this has been a model shift in that a good shipping company today does not wait until a problem happens, but rather anticipates it and prevents it. For example, predictive maintenance has been shown to reduce machinery downtime by as much as 30%, while it also extends asset lifecycles from Clarkson Research (2023).

Several shipping companies throughout Greece, including Angelicoussis Group and Tsakos Energy Navigation, are using AI systems to evaluate fuel efficiency and failure predictions (DeepSea Technologies, 2023). These solutions improve performance and are used by charterers and regulators who increasingly require ship operators to be more reliable.

4.2.2 IMPROVED SAFETY AND RISK MANAGEMENT

Early detection may also occur using digital technologies through sensors and alarms that automatically signal the danger, and real-time analysis of the situation being faced. The International Chamber of Shipping (ICS, 2023) estimates that digital reporting systems may reduce response times to an incident by 40%.

Personally, the greatest benefit of digitalization is that lives and accidents can be saved through information. Digital twins, simulations of how these ships would respond to different navigational environments, can be used to plan for safety (DNV, 2022).

However, an over-reliance on technology can sometimes lead to complacency. I believe the answer to true safety in the digital age does not lie in ceding control to technology but in a symbiotic relationship between humans and machines.

4.3 ECONOMIC IMPACTS

4.3.1 COST REDUCTION AND PRODUCTIVITY GAINS

Digitalization reduces costs at all levels. Route optimization, data-driven scheduling and automated documentation reduce administrative costs and fuel consumption during operations (BIMCO, 2022). According to the OECD (2022), digital optimization of routes can save up to 10% of fuel during a voyage.

In my view, these savings are not just operational. They are competitive. As international trade is so sensitive that the tiniest cost savings of a few per cent can make the difference, the shipowners and, in particular, the Greek shipowners, have begun to realize that decision-making based on data is no longer an option but a prerequisite.

4.3.2 NEW REVENUE STREAMS AND BUSINESS MODELS

Furthermore, digital transformation can create new revenue streams. Digital platforms such as RightShip, StormGeo or Fleet Data by Inmarsat are examples of how shipping is moving from a product-based ecosystem to a service-based ecosystem (Stopford, 2020).

I personally think the most interesting trend is that ship owners are becoming maritime service providers. For example, predictive analytics could involve charging charterers or insurers for reports on the performance of their vessels. Digitalization is, therefore, turning shipping enterprises into knowledge organizations, where the data is the asset.

4.3.3 RISKS AND INEQUALITIES

Digitalization creates disparities, with digital infrastructures being developed mainly by large firms that have the capital to invest, while small ones lag behind (OECD, 2022). Over time, as this encourages a concentration of market power, it could lead to a class of “digital rich” and “digital poor”.

In my opinion, this digital gap is one of the most serious long-term threats to global shipping. If we want to move to a more sustainable, diverse maritime sector, policymakers and the finance sector must give smaller, independent companies affordable access to digital technologies.

4.4 ENVIRONMENTAL IMPACTS

4.4.1 CONTRIBUTION TO DECARBONIZATION

Shipping accounts for about 3% of global GHG emissions This is according to UNCTAD in 2023. That is critical if the shipping sector improves its environmental efficiency. Digitalization can help achieve this. AI and IoT technologies in real time can help in measuring emissions and Big Data analytics can help determine the most fuel-efficient routes/parameters (DNV, 2022).

For me, the power of this is that digitalization creates an opportunity, and it creates a win-win situation, since companies reduce their emissions, and at the same time they reduce their costs if they optimize their processes.

The advanced analytics through Maersk's digital twins and operational simulations have helped the company to reduce whole fleet CO_2 emissions by better understanding the impact of operational decisions (Maersk, 2023).

4.4.2 COMPLIANCE AND TRANSPARENCY

Digitalization can also support international frameworks, such as the IMO Carbon Intensity Indicator (CII) and Energy Efficiency Existing Ship Index (EEXI) framework, and ease monitoring and reporting of related data with less risk of human error (IMO, 2021).

Digital data transparency is a radical change to shipping with previously fragmented emissions data being unverifiable. Digital systems will expose inefficiency. I think it will change the way the regulators, the customers judge the efficiency of the shipping industry, and compete.

4.4.3 GREEN PORTS AND SMART LOGISTICS

Digitalization is transforming ports into “smart hubs” that use real-time data for berth allocation, energy consumption and traffic, to reduce congestion and emissions and improve supply chain cooperation (EU Commission, 2023). These advancements reduce congestion, lower emissions, and enhance coordination across the supply chain.

I find this interlinkage between sea and shore particularly exciting. When ports and ships exchange data, the whole maritime system becomes more sustainable and more efficient. It does require investment in the ports, however, as port infrastructure is lacking in many developing countries.

4.5 HUMAN CAPITAL IMPACTS

4.5.1 THE CHANGING NATURE OF MARITIME WORK

Digitalization is transforming the skills required in the maritime workforce, with seafaring roles moving towards data analytics, systems management and cyber security roles (ICS, 2023), among others. Automation may reduce the need for certain manual tasks, but it increases the need for digital literacy and problem-solving skills.

In my opinion, it's very exciting but a little bit scary because if you're a seafarer working with mechanical systems all day, it is totally different from working with digital dashboards and remote control. I think there is a feeling in the industry that computers are going to take over writing jobs. Which is understandable, but as history has shown, technology rarely eliminates jobs; more often transforms them.

4.5.2 TRAINING AND EDUCATION NEEDS

Maritime academies and universities should update their curricula to train the next generation of maritime professionals. For example, the University of Piraeus already has modules in digital shipping management and maritime data analytics (Lyridis & Zacharioudakis, 2020).

In my view, this is the future of education. The new seafarers, maritime professionals and maritime leaders will need to interpret data, be aware of cyber risks and analyze sustainability. I think that Greece, with its education and the number one fleet, has a huge opportunity to become the leader in maritime digital education.

4.5.3 WORK-LIFE BALANCE AND REMOTE OPERATIONS

As remote monitoring and automation technology develop, the boundary between ship and shore is reduced as remote operation centers allow engineers and managers to control fleets from onshore offices (DNV, 2022). While these measures can improve safety, they can also create additional stress for employees, such as constant monitoring of them.

Personally, I think it’s crucial that people do not forget the human side of digitalization. Even a fully digital ship must be a humane workplace. Rather, it should be about seafarers benefiting from the opportunities presented by such new technologies.

4.6 REGULATORY AND LEGAL IMPLICATIONS

4.6.1 UPDATING THE LEGAL FRAMEWORK

Much maritime regulation was developed in a pre-digital era, and issues such as autonomous vessels, digital documents and blockchain-based contracts pose difficulties to the regulatory framework (IMO, 2021).

From my perspective, the IMO has made meaningful progress in updating regulations through documents like the Maritime Cyber Risk Management Guidelines and the IMO Data Model for electronic reporting, but there is still no clear approach in international law for addressing liability in accidents where the fault lies with the automation. For example, if a ship's AI guidance assistant causes a collision, is the liability the ship-owner, the software provider or the device manufacturer?

I personally believe the maritime legal community must rethink traditional definitions of “master”, “crew,” and “control” in the age of automation. This is not only a legal challenge but a philosophical one.

4.6.2 COMPLIANCE AND DATA GOVERNANCE

Digitalization may entail compliance with data protection and privacy law, such as the EU's General Data Protection Regulation (GDPR), which may pose difficulties when data moves across jurisdictions (EU Commission, 2023).

In my opinion, we have to take data governance as seriously as safety compliance, because a data breach can sometimes be more damaging, and we should set some sort of global industry standard on data ownership, storage and sharing.

4.7 SOCIAL AND ETHICAL DIMENSIONS OF DIGITALIZATION

Digitalization transforms the shipping industry in its interaction with society. AI and automation integration will spark people inquiring about transparency, accountability and humans deciding in the industry (Acciaro & Wilmsmeier, 2022).

4.7.1 THE HUMAN FACTOR IN DECISION-MAKING

In my view, humans will never be replaced by something. Computers can sort data, but don't have the qualities we provide: empathy, morality, and context. Thus, while an autonomous ship may navigate correctly, it may still not be able to respond ethically in a crisis, meaning that some humans must be kept “in the loop”.

4.7.2 EQUITY AND INCLUSION

Furthermore, if only larger companies are able to deploy new technologies, smaller shipowners and developing countries may be entirely excluded from the digital economy (OECD, 2022), which weakens the spirit of the international and inclusive character of maritime transport. I believe in the role of policies to ensure equal opportunities for digitalization, rather than a concentration of power.

4.7.3 ENVIRONMENTAL JUSTICE

Digitalization can also create new forms of inequality. For example, while digitalization of the shipping industry can promote sustainability, it can also require expensive equipment and software. That means only the better-off owner-operators are able to comply with carbon measures while maintaining costs and revenues, resulting in small, poorer companies being disadvantaged, and I think regulators should provide transition or subsidy policies to avoid a shipping “green divide”.

4.8 FUTURE OUTLOOK: A HUMAN-CENTRIC DIGITAL MARITIME INDUSTRY

Regardless of the direction shipping digitalizes, it should balance optimal efficiency and the human element. In the coming decades, we will likely see AI, automation and smart ports develop more (UNCTAD, 2023). The most successful companies will not be the most digitalized, but the ones that combine technology, ethics and leadership.

I believe that the next generation of maritime leaders will need to combine digital skills with a good feel for the human side, as much about narrative as about data. Whether in Greece or other countries, companies that prosper are those that cultivate trust and transparency.

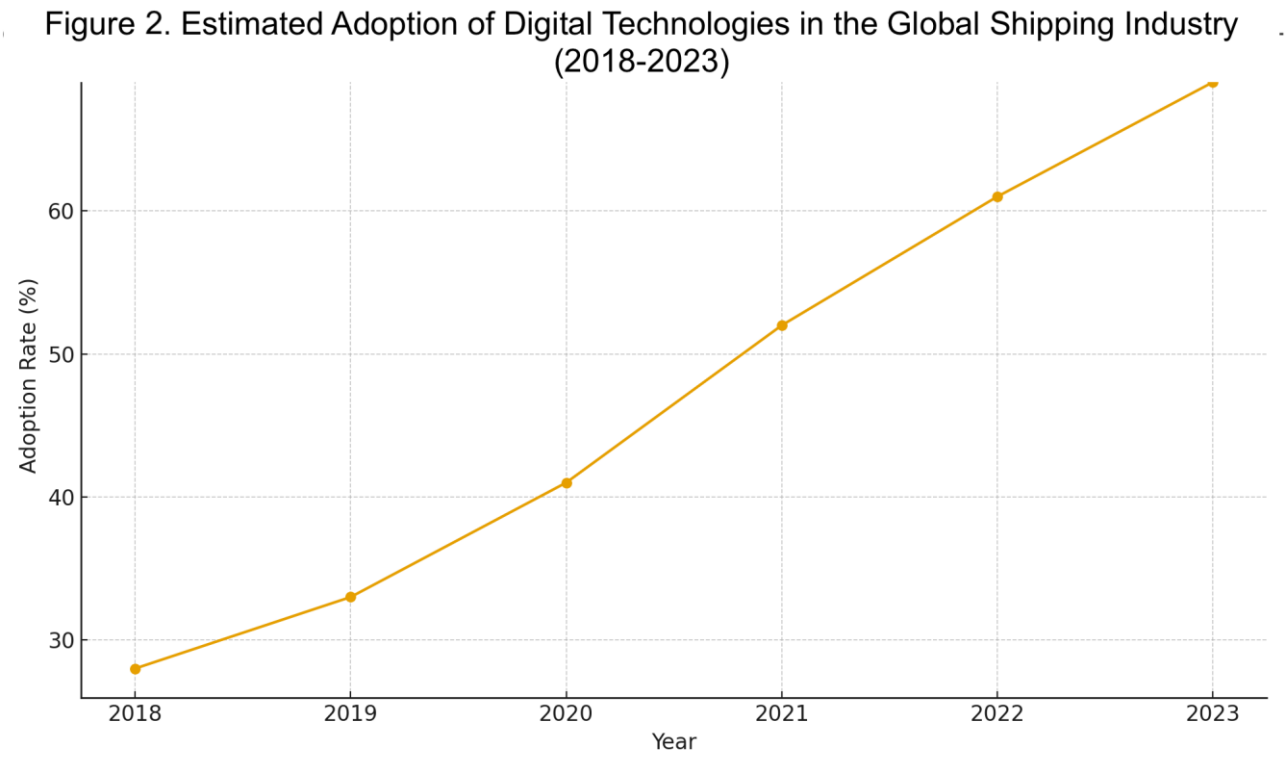
From a practical standpoint, I see three strategic imperatives for the next phase of maritime digitalization:

15. Invest in People as Much as in Technology. Human intelligence remains the most valuable maritime asset.

16. Adopt Open and Collaborative Digital Frameworks. Interoperability and cooperation will define long-term competitiveness.

17. Embrace Ethical and Sustainable Innovation. Technology should serve both profit and purpose.

Digitalization can make shipping smarter, fairer and more resilient, provided that we have a human-centered approach to this process. This, in my opinion, is the best way to make this possible.



CHAPTER 5 - CASE STUDIES

5.1 INTRODUCTION

Case studies provide an important foundation for understanding the operationalization of digitalization. In my opinion, examining the practical experiences of revolutionary companies helps close the divide between theoretical analysis and practical implementation in the industry.

Two global shipping companies are examined in this chapter: the Danish company Maersk Line and the Japanese company NYK Line. We will also look at the Greek ship-owning community as it has an interesting technology story to tell, given its historic ownership structure and global standing, as well as its growing interest in technology. For the shipping companies, I discuss technology,

Figure 2. Estimated Adoption of Digital Technologies in the Global Shipping Industry (2018–2023)
This figure illustrates the steady growth in the adoption rate of digital solutions—such as AI, IoT, and Big Data—across the global shipping industry between 2018 and 2023. The trend reflects the sector's ongoing transition toward digital transformation and data-driven decision-making.
Source: UNCTAD (2023), Review of Maritime Transport; author's calculations.

organizational and cultural change.

5.2 CASE STUDY 1: MAERSK LINE - A GLOBAL DIGITAL TRANSFORMATION LEADER

Maersk is a Danish-registered company that is among the most advanced digital players in the shipping industry, showing how a shipping line with several generations of history can be transformed into a data-driven logistics company, self-defining its identity and competitive advantage (Maersk, 2023).

5.2.1 DIGITAL TRANSFORMATION STRATEGY

Maersk's digital strategy focuses on becoming an integrated logistics provider rather than purely a carrier, and it is achieved through meaningful investment in automation, data analysis and digital

That was a huge move for me. Maersk faced the challenge to redefine its business model from "moving containers" to "managing global supply chains" and its organizational culture, workforce skills and technology architecture.

Key elements of Maersk's digital strategy include:

- Data-Driven Operations: Maersk uses Big Data and AI to optimize routes, predict equipment failures and monitor carbon emissions.
- Customer Experience Platforms: The Maersk.com digital portal allows clients to book, track and manage shipments in real time.
- Automation and Robotics: The company employs automated cranes and digital port systems to increase terminal efficiency.

customer-facing platforms (IBM, 2023).

5.2.2 COLLABORATION AND INNOVATION ECOSYSTEM

Key focus areas in Maersk's digitalization efforts are openness and collaboration across the entire maritime value chain. An example of an open collaborative effort is TradeLens, a blockchain-based digital platform for global trade co-developed with IBM (IBM, 2023). Although not fully commercialized by 2023, the project has served as an experiment in data sharing and transparency for a highly fragmented industry.

To me, TradeLens is a case of Maersk's willingness to experiment and to be a pioneer in the industry. The project failed to build the necessary critical mass, which would have made it sustainable for the long run, but the idea was the first serious attempt at digitalizing the supply chain in the shipping industry. In a field that often exhibits a conservative approach with proprietary data systems, this initiative showed that Maersk is prepared to lead and take bold steps into the future.

5.2.3 OPERATIONAL AND ENVIRONMENTAL OUTCOMES

According to Maersk's 2023 Sustainability and Digitalization Report, it has invested in advanced analytics and digitalization solutions that are already producing results. Data-driven optimization of routing, fuel management, and vessel performance has delivered a 9% decrease in output of average fuel consumption per container and a 7% reduction in CO_2 emissions, when compared to the company's emissions figures of 2019 (Maersk, 2023). This is an example of how digitalization can also be used to create economic value, as well as to tackle climate change.

Maersk can present these improvements through a transparent and data-driven approach to build trust with customers, regulators and industry partners. Such an approach to increasing efficiency through digitalization has therefore improved operations and services, while also strengthening Maersk's credibility and trustworthiness. Through environmental performance measurement, Maersk positions itself as a responsible industry leader that connects profitability with environmental protection.

5.2.4 LESSONS LEARNED

Maersk’s experience highlights three critical lessons for digital transformation in shipping:

18. Digitalization must align with strategy. Technology alone does not create advantage; it must serve a clear business purpose.

19. Cultural change is essential. Maersk invested heavily in retraining its workforce and changing its mindset from operational to analytical.

20. Collaboration drives progress. Even unsuccessful initiatives like TradeLens contribute to collective learning across the industry.

In my opinion, Maersk’s example sets a benchmark for what large-scale, strategic digitalization looks like in practice.

5.3 CASE STUDY 2: NYK LINE - JAPAN'S SMART SHIPPING PIONEER

According to NYK Line (2023), the company's digitalization projects can be described as innovative in shipping, including Smart Ship Project and research and development into AI-assisted operation. In contrast to Maersk which has focused on supply chain and customer side digitalization, NYK Line is developing intelligence systems for vessels with particular focus on the role of crew and crew safety. The difference in calculated focuses illustrates how even global market leaders approach digital transformation in different ways and at different paces.

5.3.1 VISION AND STRATEGY

According to NYK Line (2023), "Digitalization Vision 2030" is a long-term vision for the NYK Group to build ships that are autonomous, safe, and environmentally sustainable through data analysis and artificial intelligence. By utilizing data analytics and artificial intelligence technology, the NYK Group seeks to transform ship construction and operation as well as maintenance. By networking the clever functions on board the ship and the operational network, NYK seeks to reduce the human error factor, ensure safety, and reduce environmental impact by optimizing fuel consumption and passage routes.

In practice, NYK seems to consider digitalization as a means to improve operational efficiency, rather than being a goal in itself. The company uses digital systems to complement decisions made by humans, and to ease better cooperation between ships and shore-based offices. While we shall continue to mechanize to the fullest extent, I believe that the true innovation in the shipping industry does not simply lie in the application of new technologies but in the creation of a corporate culture where precise and reliable management is paramount and that culture is deeply ingrained in the Japanese industrial system, which is based on precision, reliability and long-term planned conception. The result is less a break with tradition than simply an evolution of it, managed with a nod to maritime heritage.

The *Digitalization Vision 2030* rests upon several interrelated pillars that bring this philosophy to life.

- Smart Ship Project: Employs Internet of Things (IoT) technologies to continuously collect, transmit, and analyze vessel performance data in onshore operation centers, enabling predictive maintenance and enhanced navigational safety.
- Ship Information Management System (SIMS): Functions as an integrated digital platform that provides real-time operational insights to both shipboard crew and onshore management, thereby improving transparency and response times.

- MarCoPay Platform: A dedicated digital payment and financial management system for seafarers, designed to promote financial inclusion, security, and transparency within the maritime workforce.

Together, these initiatives illustrate NYK's holistic view of digital transformation—one that unites technological progress with human-centered values and a strong commitment to safety, sustainability, and operational integrity.

5.3.2 HUMAN-CENTERED DIGITALIZATION

What makes NYK stand out is that the well-being of seafarers is integral to its digital strategy. Crews are provided with data-based feedback on vessel performance via SIMS and enabled to upskill and improve their digital capabilities through training (ICS, 2023).

I find this philosophy inspiring, and instead of positioning technology as replacing human labor, NYK has a philosophy of empowering human capabilities through technology. I view this as aligning with a need to approach digital change in a human-centered, inclusive and transformative way for sustainability to thrive.

5.3.3 ENVIRONMENTAL IMPACT AND SMART NAVIGATION

NYK's shipping vessels have become more environmentally friendly, as advanced AI-enabled navigation navigates vessels with AI routing systems to emit an average of 6% less CO_2 compared to vessels that do not navigate with advanced navigation systems, according to its "Digitalization Vision 2030" report (NYK Line, 2023).

I think this shows that you can measure the link between digitalization and sustainability. NYK really is proving that if you optimize your processes, you can also optimize your carbon emissions.

5.3.4 COLLABORATION AND FUTURE PLANS

NYK is working with classification societies ClassNK and technology partner MTI Co on ship autonomy and digital security (DNV, 2022). The company is working with the Japanese government to test remote-controlled ship systems.

What I personally really admire about NYK is the focus on experimentation and building for the long term rather than optimizing for short-term wins. It could therefore be a good model for Greek companies that want to embrace the digital era.

5.4 THE GREEK SHIPPING SECTOR - TRADITION MEETS TRANSFORMATION

Greek shipping is probably one of the great paradoxes of the maritime world, at once the most customary and the most globalized. While Greek shipowners own about 20% of the world's deadweight tonnage, their approach to ship management has been cited as conservative (UNCTAD, 2023).

In my opinion, this makes Greece an ideal case for studying how digitalization interacts with deep-rooted traditions. The transition is happening, but it is gradual and pragmatic. Driven not by hype but by practical necessity.

5.4.1 ADOPTION TRENDS IN GREEK SHIPPING

Over the past five years, several leading Greek companies have embraced digital technologies:

- Angelicoussis Group has invested in METIS Cyberspace Technology's digital performance platform, enabling real-time vessel monitoring and predictive maintenance (METIS, 2023).
- Tsakos Energy Navigation (TEN) uses analytics for fuel optimization and regulatory compliance (DeepSea Technologies, 2023).
- Dynacom Tankers and Thenamaris are incorporating AI-based voyage optimization tools into daily operations.

The difference in the digital transformation of Greek shipping to me is that it is owner-driven rather than consultant-driven. The decisions are taken at the top level, by experienced shipowners who see the technology as a planned enabler rather than a cost.

5.4.2 BARRIERS AND CHALLENGES

Despite these advances, small and medium-sized shipowners may find digitalization too expensive or consider it unnecessary. In a survey by the Union of Greek Shipowners (UGS, 2023), the most frequently cited barrier was "high cost" (42%), followed by "lack of digital expertise" (28%).

This is less about technology and more about culture. Greek shipping has flourished for decades on the strength of entrepreneurship, personal connections and informal networks. Changing this mindset will take some time in the organization.

The young people joining the industry, most of them through Universities such as the University of Piraeus, will also have their own vision. This will accelerate Greece's digital maturity in the next 10 years.

5.5 THE ROLE OF MARITIME TECHNOLOGY COMPANIES

Revolutionary maritime technology startups in Greece close the divide between shipowners' challenges and solutions in the digital technology ecosystem.

5.5.1 DEEPSEA TECHNOLOGIES

DeepSea Technologies is a company headquartered in Athens that uses AI-powered energy efficiency software to aggregate data from ships and deliver actionable perceptions to find ways to reduce vessels' fuel use and emissions (DeepSea Technologies, 2023).

DeepSea is a perfect example of how a great Greek startup can compete on a world scale by combining our knowledge of the seas with technology. To have companies like Lloyd's Register, Shell and others come to us shows how effective we can be.

5.5.2 METIS CYBERSPACE TECHNOLOGY

Another Greek data analytics company is METIS, offering a one-click performance management tool for over one billion data points of vessel performance data per month (METIS, 2023) to support data-driven decision making, taking the operational constraints imposed by the IMO into account.

To my mind, METIS is the next stage in the evolution of Greek shipping, in building homegrown technology solutions that meet the needs of Greek shipping companies, reduce reliance on foreigners and strengthen the national maritime cluster.

5.5.3 OTHER PROMINENT STARTUPS

New companies such as Harbor Lab (port call management) and global vessel tracking company MarineTraffic indicate a potential for Greece as a maritime technology hub (MarineTraffic, 2023). Such new companies, together with established Greek ship owners, can create a new ecosystem, complementary to the customary players.

5.6 CULTURAL ADAPTATION AND ORGANIZATION CHANGE

Digital transformation in the maritime sector is not just a technological issue but also, following Acciaro and Wilmsmeier (2022), a process of Organizational Transformation, where the way decisions are made and shared within the organization may also need to change in order for digital systems to be adopted. In the customary Greek style of management organization, decision-making tended to be highly centralized in a small circle of trusted managers who also tended to be either family members or long-term company executives whose opinions and experience were regarded as the basis of the business. This has delivered great agility, responsiveness, and resilience in a volatile market.

However, because digitalization allows for shared databases and algorithm systems to analyze them, if decisions become a matter of data interpretation, transparency and collective access to data, it creates new forms of interaction and participation for organizations and individuals. At first, very uncomfortable for those who had grown up with the "captain's call" model of managing, this has gradually led to a culture of teamwork and cross-functional working. In recent years, a number of major Greek firms have created Chief Digital Officers, Data Analysts and IT integration specialists, roles virtually unknown five years ago in the sector. These developments signal a slow but deep change in the way Greek shipping understood knowledge, authority, and innovation.

Indeed, while this moves us toward a digital culture, it is important not to lose sight of the old values that have made Greek shipping successful, namely speed, responsiveness, and the human factor they all stand for. The challenge is not how to incorporate these cultural advantages into existing models such as Maersk or NYK. It is how to combine them with our access to technological advances to create a new Greek model of digital leadership. By eschewing the model of the global giants, the Greek shipping community has an opportunity to create a model of its own, adding to the human and relational capital of the Greek maritime legacy.

5.7 EMERGING DIGITAL STARTUPS IN GREECE’S MARITIME CLUSTER

In recent years, a younger generation of Greek ship owners has begun developing start-ups that combine customary ship owning expertise with technology. This has shifted the Greek shipping industry from one customarily dominated by individualistic, conservative family-owned shipping companies into one that is more collaborative, innovative, and technologically advanced. Not only do they offer hi-tech solutions to the domestic fleet, but they have turned increasingly towards the

international market, with Greece being established as a centre for shipbuilding and ship technology in Europe.

These include several companies that have already gained international recognition. For example, Harbor Lab has brought disbursement accounting and port-call cost management, previously done in a non-transparent way, into the digital age, providing a better perception to shipowners and their port agents around port-call costs. MarineTraffic, widely seen as the world's de facto standard for ship tracking, is one of the most visible success stories of maritime IT in Greece, with users around the world accessing its services from its headquarters in Athens. DeepSea Technologies focuses on artificial intelligence to help shipping companies reduce costs and greenhouse gases through energy consumption optimization and route planning. Advanced analytics for vessel performance and predictive maintenance have been developed by METIS Cyberspace Technology. Digital human resources and crew management systems were developed by SOFTimpact and Seafair, improving marine operations and safety in the process.

So I would hope that the growth of this community of maritime start-ups is one of the most positive things to happen to the Greek shipping industry in its history. It joins the long and rich maritime heritage of our country to the exponentially improving technological future and brings to our industry engineers, data scientists, IT people, and others who would otherwise go to another industry. This also relates academia and private industry more closely, as well as government, and develops a more integrated environment.

With the necessary funding, education, and policies put in place, this momentum could allow Greece to become a European center in maritime digital technologies. Greece, with its rich maritime heritage, entrepreneurial mindset, and an emerging technology sector, has the potential in order to build and maintain a competitive advantage in the global maritime sector.

5.8 COMPARATIVE ANALYSIS AND DISCUSSION

When comparing Maersk, NYK and Greek shipping, several insights emerge.

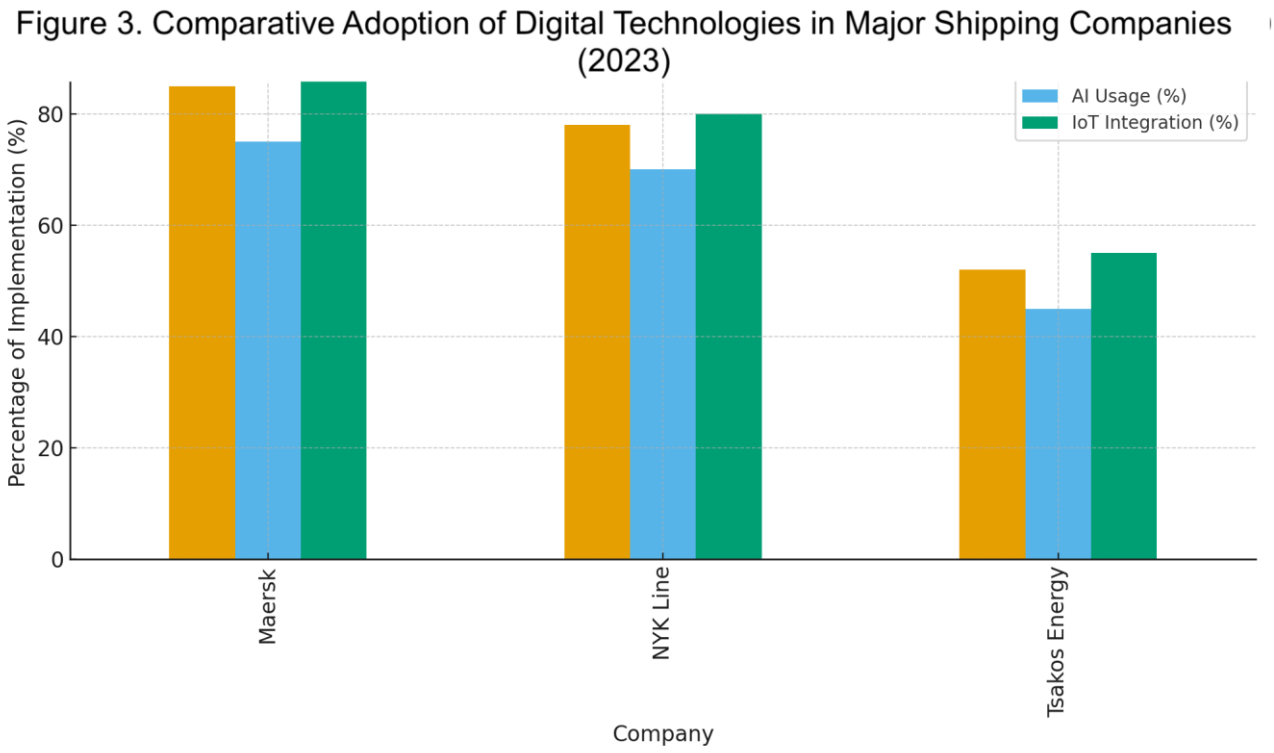
21. Strategic Approach:
    Maersk leads in global integration, NYK excels in operational intelligence, and Greece focuses on practical adoption. Each model reflects its cultural and economic context.

22. Human-Centric vs. Technology-Centric Models:
    NYK's approach is notably human-centered, integrating digital tools with crew training and wellbeing. Maersk's strategy, while highly efficient, is more top-down and business-driven. Greek companies fall somewhere in between, adapting digital tools without losing their personal management style.

23. Innovation Ecosystem:
    Japan and Denmark benefit from strong governmental and institutional support for R&D. Greece is catching up fast, with universities and startups forming a dynamic network that bridges academia and industry (EU Commission, 2023).

24. Cultural Factors:
    In my opinion, culture remains the invisible hand shaping digital transformation. Maersk's discipline, NYK's precision, and Greece's entrepreneurial spirit each produce different, but equally valuable, results.

Ultimately, I believe that there is no single model for digitalization in shipping. Each ecosystem adapts according to its values and resources. What matters most is vision, persistence and openness to collaboration.



CHAPTER 6 - CONCLUSIONS AND RECOMMENDATIONS

6.1 INTRODUCTION

The final chapter of the dissertation "Digitalization in Shipping: Technologies, Impacts and Case Studies" summarizes the theoretical, technological and empirical findings and analyzes, and discusses the implications of digitalization for the global shipping industry as well as for the Greek shipping industry.

In my opinion, the most important message of the whole study is that digitalization is not only about introducing new tools and technologies, but it is also a matter of changing the mindset of people. The shipping industry has always been conservative, based on trust, experience and human skills. What

Figure 3. Comparative Adoption of Digital Technologies in Major Shipping Companies (2023)
This figure compares the level of digital technology adoption among leading global shipping firms —Maersk, NYK Line, and Tsakos Energy Navigation. The comparison highlights the degree of implementation of key technologies such as Artificial Intelligence (AI) and the Internet of Things (IoT), demonstrating significant variations between international and Greek operators.
Source: Compiled by the author based on company annual reports and industry publications (2023).

we have now and what we have seen is the technology that is redefining how to run and operate a vessel in the 21st century.

6.2 SUMMARY OF KEY FINDINGS

6.2.1 THE NATURE OF DIGITAL TRANSFORMATION

The repercussions of digitalization should not be underestimated. Digitalization is not only a technological upgrade but a systemic change, where virtually all parts of the maritime industry are impacted with effects on efficiency, costs, environmental performance, navigational safety and even the labor market organization (Acciaro & Wilmsmeier, 2022). In practical terms, digitalization impacts the flow of information, the decision-making process, and the role of actors within the overall shipping and maritime system. Digitalization is therefore an integrated change to both the technical and social dimensions of the shipping and maritime sector.

In this context, a key finding of the research is that digitalization is a great equalizer. Smaller shipping companies, thanks to their better use of data, can now compete on more equal terms with larger and well-capitalized companies. This democratization of information allows agility (and niches) to substitute for scale. Those who cannot follow the shift may be left behind in the global networked economy. They will not lag behind because of their age, size, or customary industry status. No, they will lag because they refuse to embrace data-driven and organizational learning. Shipping's digital divide is considered a behavioral divide between those with leadership vision and those who adapt their management.

6.2.2 THE INTERPLAY OF TECHNOLOGY AND CULTURE

Conclusively, the case studies showed that it is not the technology itself that makes the difference, but how it is leveraged and embedded culturally into the relevant system or situation. Maersk has made strides with a common vision of digitalization throughout all business model dimensions, and NYK Line has made strides on a perhaps more human-centered level based on collaboration and crew empowerment. The Greek version could be called pragmatism with an entrepreneurial flavor. Instead of striving for innovation as an end in itself, one strives for innovation in response to the demands of the market. In this respect, the case studies illustrate the decisive influence of the organizational culture.

Whilst intuition, personal relationships, and informal communications have served the Greek shipping industry well for many years, the future of Greek shipping will need to embrace a more open, cooperative, and data-informed decision-making mentality. Only those companies that are able to combine Greece's long history of maritime tradition with its technological and entrepreneurial flexibility will be able to improve the country's competitive position in the international shipping market by combining an extraordinary maritime tradition with the most modern analytical tools. Greek shipping will continue to grow, not just in experience but in innovation and entrepreneurship.

6.2.3 ECONOMIC AND ENVIRONMENTAL GAINS

Ultimately, digitalization makes things more efficient and productive. These advances in IoT and AI will optimize fuel consumption, emissions, and routing according to DNV (2022). Together, smart systems and big data analytics are seen to be able to improve productivity and reduce costs, to also help to achieve the "IMO 2030" decarbonization targets (IMO, 2021).

What this convergence between profit and sustainability means to me, is that doing the right thing by the environment also means doing the right thing for the bottom line.

6.3 THE GREEK PERSPECTIVE: BALANCING TRADITION AND INNOVATION

The shipping industry in Greece is at a crossroads. Despite having the largest merchant fleet of any nation, it has been one of the most customarily managed. So marked is this duality of the old and the new, the instinctual and the data-driven,

6.3.1 STRENGTHS AND OPPORTUNITIES

The main comparative advantage of Greek shipping is flexibility and global reach. Greek shipowners are famous for their entrepreneurship, flexibility and ability to assume risks, particularly in relation to rapid technological change (UNCTAD, 2023).

The development of Greece's digital economy depends on maximizing its human resources. Today's Greek workforce is college-educated, tech-savvy and international in outlook. It is a great asset for a digital economy. This talent can be fostered, and customary companies can adapt, making the country a European digital maritime hub.

6.3.2 WEAKNESS AND CHALLENGES

Yet, several difficulties remain, including regulatory fragmentation, small operators' lack of access to affordable digital tools and a culture that often resists transparency (OECD, 2022).

In fact, it seems that in many Greek companies, digitalization is still considered a “project” and it is understood as a need for an action with limited benefits. What is needed, therefore, is for Greek shipowners to see the technology to be their own.

6.4 BROADER IMPLICATIONS FOR THE GLOBAL MARITIME INDUSTRY

Digitalization is transforming the entire maritime ecosystem, including shipping lines, ports, logistics chains and regulators.

6.4.1 INTEGRATION AND COLLABORATION

These will be integrated ecosystems in which ships, ports and cargo owners will exchange information with each other via what DNV (2022) calls “integrated maritime networks”, leading to better efficiency. Developing these networks will require common standards for cybersecurity, data ownership and interoperability.

The biggest challenge and the greatest opportunity exist for me. The industry has to learn to work together, even alongside competitors. Technology works only with everyone's participation, similar to Maersk's TradeLens (IBM, 2023).

6.4.2 POLICY AND GOVERNANCE IMPLICATIONS

Governments and international organizations, such as the IMO and the EU, can develop policies for digitalization, guide data-sharing, ensure cyber resilience and assist small operators with finances under policies (EU Commission, 2023).

I opine that regulation and innovation balance perfectly. Too many regulations stifle innovation. Very few regulations lead to anarchy. The maritime sector requires regulation rooted in principles that flex to keep pace with technological developments.

6.5 HUMAN AND ETHICAL DIMENSIONS

6.5.1 THE FUTURE OF SEAFARERS

Automation and remote operation are changing the role of the seafarer. While some fear this could lead to job losses, I believe the role will transform into that of data manager, system supervisor and problem-solver (ICS, 2023).

It needs to be ensured through education and training, and it is, in my opinion, the most reliable way to secure the benefits of digitalization by investing in people. Without digitally savvy professionals, technology would be underutilized.

6.5.2 ETHICAL AND SOCIAL RESPONSIBILITY

Other ethical issues related to digitalization involve surveillance, concern privacy, and create inequality. An automated system could monitor everything that happens on board in operation, potentially impacting the crew's trust. What I think businesses should be doing is valuing the data and promoting the human experience.

They also mentioned the need to tackle global digital inequality in the digital divide, with developing countries and small operators left behind. Personally, I believe that we need international cooperation and technology-sharing programs to ensure such a digital transition.

6.6 RECOMMENDATIONS

Drawing on the key findings presented in this dissertation, several practical recommendations can be proposed for shipping companies, policy makers, and maritime education institutions. These suggestions aim to bridge the gap between technological potential and real-world implementation across the sector.

6.6.1 FOR SHIPPING COMPANIES

25. Adopt Long-Term Digital Strategies:
    Treat digital transformation as a continuous journey. Align digital initiatives with corporate strategy and measurable goals.

26. Invest in Human Capital:
    Provide regular training programs in data analytics, AI literacy and cybersecurity. In my view, a well-trained workforce is more valuable than the most advanced software.

27. Prioritize Integration and Interoperability:
    Use open-source systems and standards to ensure seamless data sharing across fleets and partners (OECD, 2022).

28. Foster a Culture of Innovation:
    Encourage experimentation and accept occasional failure as part of learning. Innovation in shipping requires courage.

6.6.2 FOR POLICYMAKERS AND INSTITUTIONS

29. Support SMEs in Digital Adoption:
    Offer financial incentives or public-private partnerships to help smaller operators digitalize cost-effectively (EU Commission, 2023).

30. Promote International Standards:
    Strengthen collaboration between IMO, ISO and regional authorities to develop unified data exchange protocols.

31. Invest in Maritime Education:
    Update academic programs to include AI, digital logistics, and environmental analytics (Lyridis & Zacharioudakis, 2020).

32. Encourage Collaboration between Academia and Industry:
    Research institutions should act as innovation accelerators, connecting startups and traditional shipowners.

6.6.3 FOR THE GREEK MARITIME SECTOR SPECIFICALLY

33. Build a National Maritime Digitalization Strategy:
    Establish a roadmap linking shipowners, startups and universities to promote coordinated innovation.

34. Develop Maritime Innovation Hubs:
    Expand initiatives like the “Blue Lab Piraeus” to create physical and virtual spaces for experimentation.

35. Encourage Generational Transition: Empower younger professionals to take leadership roles in digital transformation.

I believe they will allow Greek shipping to remain on top of things and to pass smoothly into the digital age.

6.7 FUTURE RESEARCH DIRECTIONS

This dissertation provides a broad overview of the digitalization of shipping, but several topics need further research:

- Quantitative Analysis: Measuring the direct financial impact of digital adoption on profitability.
- Sociological Research: Understanding how digital tools affect seafarer wellbeing and identity.
- Comparative Policy Studies: Evaluating how different nations regulate digital transformation in shipping.

Personally, I hope future studies will tell us not only how technology changed the work, but how it changed the people, their values and how they relate to the sea.

Based on my research, I can conclude that through digitalization, shipping continues on the path of seeking efficiencies, security and discovery that started centuries ago. Just as the steam engine and container shipping changed world trade, digitalization is now changing the management of shipping itself.

The future does not stem from the technology. It comes from visionary thinking, ethical consideration and collaborative implementation. The development of tomorrow's shipping technology will not be driven by hardware and software, but by leadership, education and a common goal.

6.8 FINAL REFLECTIONS

As someone deeply passionate about the maritime field, I believe digitalization is not the end of seamanship, but a way for us to modernize an old profession, while keeping the humanity within it. We should strike a balance, and the next generation of global shipping will be built upon this principle.

References

Acciaro, M. & Wilmsmeier, G. (2022). *Digital transformation and maritime logistics: Drivers and impacts. Maritime Economics & Logistics,* 24(3), 431–456.

BIMCO. (2022). *BIMCO Shipping Market Analysis 2022.* Bagsværd: Baltic and International Maritime Council.

Clarkson Research. (2023). *Digitalization in Shipping: Trends and Insights.* London: Clarkson Research Services Limited.

DeepSea Technologies. (2023). *AI-driven optimization for shipping.* Available at: https://www.deepseatechnologies.ai.

DNV. (2022). *Maritime Forecast to 2050.* Oslo: Det Norske Veritas.

European Commission. (2023). *Digital Transport Corridors and Horizon Europe Initiatives.* Brussels: European Commission.

ICS (International Chamber of Shipping). (2023). *Maritime Workforce Report 2023.* London: ICS Publications.

IBM. (2023). *TradeLens discontinuation statement.* Available at: https://www.ibm.com/tradelens.

IMO (International Maritime Organization). (2021). *Guidelines on Maritime Cyber Risk Management (MSC-FAL.1/Circ.3).* London: IMO.

Lyridis, D. & Zacharioudakis, P. (2020). *Digital Transformation in Maritime Transport.* Piraeus: University of Piraeus Publications.

Maersk. (2023). *Sustainability and Digitalization Report 2023.* Copenhagen: A.P. Moller–Maersk Group.

MarineTraffic. (2023). *Maritime intelligence and analytics.* Available at: https://www.marinetraffic.com.

METIS Cyberspace Technology. (2023). *Smart data analytics for shipping.* Available at: https://www.metis.tech.

NYK Line. (2023). *Digitalization Vision 2030.* Tokyo: Nippon Yusen Kaisha.

OECD (Organisation for Economic Co-operation and Development). (2022). *The Digital Transition of Maritime Transport.* Paris: OECD Publishing.

Stopford, M. (2020). *Maritime Economics.* 4th edn. London: Routledge.

UGS (Union of Greek Shipowners). (2023). *Annual Report on Digital Innovation in Shipping.* Athens: UGS Press.

UNCTAD (United Nations Conference on Trade and Development). (2023). *Review of Maritime Transport 2023.* Geneva: United Nations.