Lisbon School of Economics & Management
Universidade de Lisboa

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MASTER

MANAGEMENT AND INDUSTRIAL STRATEGY

MASTER´S FINAL WORK

DISSERTATION

THE IMPACT OF TECHNOLOGIES OF INDUSTRY 4.0 AND SUSTAINABILITY ON MARITIME CONTAINER TRANSPORTATION NETWORK

MARIANA VALY MAMEDE CALHEIROS AGUIAR

NOVEMBER – 2024

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SUPERVISION:

PROFESSOR JOSÉ NOVAIS SANTOS

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ABSTRACT

The container, defined as “the box that changed the world”, has accelerated the process of globalization, making it possible to reduce distances between countries with disparate geographies. In recent years, maritime transportation has had to reinvent itself through the use of new technologies and the search for sustainable solutions. Therefore, technology and sustainability are themes that are becoming increasingly important within the sector.

This study aims to understand the impact of technologies of Industry 4.0, from an interaction and network approach, on containerized maritime transportation and to understand the sustainable practices that should be considered for the growth of the network as a whole. For the purpose of this study, an exploratory study was carried out and a case study was developed with companies in the sector, with seven semi-structured interviews being conducted with a total of six companies.

The results of this study suggest that technology is a disruptive factor in establishing business relationships between ocean carriers, port infrastructures, port service providers and customers. But, certain characteristics such as trust, loyalty, collaboration and commitment are essential pillars not only to foster relationships and partnerships, but also to fight one of the serious problems we currently face, climate change and global warming caused by high amounts of greenhouse gases. Therefore, the use of technology, the use of clean fuels, the adoption of retroffiting, the practice of slow-steaming and the use of digital documentation are solutions for achieving carbon neutrality.

Keywords: Technologies, Industry 4.0, Network, Greenhouse Gases, Sustainability.

RESUMO

O contentor definido como “a caixa que mudou o mundo”, acelerou o processo de globalização permitindo reduzir distâncias entre países com geografias díspares. Nos últimos anos, o transporte marítimo teve de se reinventar através da utilização de novas tecnologias e pela busca por soluções sustentáveis. Portanto, a tecnologia e a sustentabilidade são temáticas que estão a ganhar cada vez mais importância dentro do setor.

O estudo apresentado pretende compreender o impacto que as tecnologias da Indústria 4.0, a partir de uma abordagem de interação e rede, afetam o transporte marítimo contentorizado e compreender as práticas sustentáveis que devem ser consideradas para o crescimento da rede num todo. Para o objetivo deste estudo foi realizado um estudo exploratório e desenvolvido um case study com empresas do setor, tendo sido realizadas sete entrevistas semiestruturadas a um total de seis empresas.

Os resultados deste estudo sugerem que a tecnologia é um fator disruptivo para estabelecer relações comerciais entre armadores, infraestruturas portuárias, prestadores de serviços portuários e clientes. Mas certas características como a confiança, a lealdade, a colaboração e o compromisso são pilares essenciais não só para fomentar os relacionamentos e parcerias, mas também para combater um dos graves problemas que atualmente temos de lidar, as alterações climáticas e o aquecimento global causadas pelas elevadas quantidades de gases com efeito de estufa. Portanto, a utilização de tecnologia, a utilização de combustíveis limpos, a adoção de retroffiting, a prática de slow-steaming e a utilização de documentação digital são soluções para alcançar a neutralidade carbónica.

Palavras-chave: Tecnologias, Indústria 4.0, Rede, Gases com Efeito de Estufa, Sustentabilidade.

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GLOSSARY

IMO – international maritime organization

RFID – radio frequency identification

AIS – automatic identification system

I4.0 – industry 4.0

IoT – internet of things

CO2 – carbon dioxide

SOX – sulphur oxide

NOX – nitrogen oxide

PM – particulate matter

GHG – greenhouse gases

LNG – liquefied natural gas

VES – voyage efficiency system

LR – lloyd´s register

3BL – triple bottom line

OBL – original bill-of-lading

E-BL – electronic bill-of-lading

EDI – electronic data interchange

1. INTRODUCTION

1.1. Context of the problem

As the IMO explains, "The maritime transportation industry because of its globalized nature has no specific home and tends to be "invisible" in people's lives... a relatively "invisible" service, but one which is, nevertheless, an indispensable component of the world economy' (IMO, 2013, p. 6). Therefore, maritime container transportation is characterized by being the "backbone" of global trade. According to available data from the United Nations Conference on Trade and Development, no other mode of transport is more important for global trade than maritime transport (IMO, 2013, p.1; UNCTAD, 2022). This is justified by carrying about 90% of goods by ships (Fruth and Teuteberg, 2017).

Due to the importance of maritime transportation on international trade and given the current worldwide economic situation, COVID-19, the war in Ukraine, conflicts in the middle east and climate change, several challenges emerged on maritime container transportation network such as congestion of some ports, maritime freights have skyrocketed, reconfiguring new existing shipping routes, delays to deliver the cargo to customers and the pressure to guarantee an agile and reliable supply chain. Thus, these disruptions are accelerating the use of technologies of Industry 4.0 to navigate through the complexities of maritime transportation. But also are being reshaped for other factors such as decarbonization and energy transition (UNCTAD, 2022).

1.2. Research problem

The application of technologies of Industry 4.0 are a disruptive factor to solve several problems associated with shipping activity namely concerning communication, integration of actors within the network, processes and operations and environmental concerns (Rojko, 2017; Durlik et al., 2023). Thus, new technologies have encouraged a paradigm shift on maritime container transportation network. From a network perspective, firms are embedded in a network of connected business relationships that enable companies to learn, share information and resources to raise joint productivity (Anderson et al., 1994; Holm et al., 2015). Hence, decisions and actions of the firms and all changes, occur within the context of the business network, as it influences "what can be done" and "how can be done" (Håkansson and Ford, 2002, p. 135).

Therefore, this research aims to understand the impact of technologies of Industry 4.0 and sustainable solutions on maritime industry, from an interaction and network approach, by considering the following research questions:

RQ1: How are technologies of Industry 4.0 affecting the maritime business network?

RQ2: How are sustainable solutions affecting the maritime business network?

1.3. Relevance of the study

Ships produce high emissions, generating negative externalities. The use of new technologies such as Internet of Things (IoT) provides great benefits for the entire maritime container transportation network, including in the environmental field. Therefore, the concepts "technologies of Industry 4.0" and "sustainability" have become central themes for companies and consequently for the context of academic research.

Despite the existing literature on the impact that technologies of I4.0 have, particularly in terms of promoting sustainability, improving communications, greater efficiency in operations, improving data storage capacity, greater connectivity, greater integration of actors, it is still little explored as it is a topic that has only gained some relevance in recent years. Furthermore, the present study is also relevant for shipping companies, especially the larger ones known as ocean carriers, which in a certain way impact not only national trade but also international trade and which can establish more efficient strategies, become even more competitive in the market and within their business relationships.

1.4. Work structure

This work is divided into 6 parts. Regarding, Chapter 1 - Introduction explains the research context, the research problem and the relevance of the study. Following, Chapter 2 - Literature Review addresses the literature relevant to the research, in which the subtopics covered are Networks and Business Relationships, Industry 4.0 and Digital Transformation on Maritime Container Transportation Network and Sustainable Practices on Maritime Container Transportation Network. In terms of Chapter 3 - Methodology, it explains which techniques are used in the research process and data collection. Furthermore, in Chapter 4, case studies were carried out, the chosen research strategy. In

Chapter 5 - Discussion of Results, focus on analyzing the data obtained through interviews. Finally, in Chapter 6, are presented the final conclusions, main limitations and suggestions for future research.

2. LITERATURE REVIEW

2.1. Networks and Business Relationships

Over the last decades, the concepts "relationships" and "networks" have gained a lot of attention and interest from academics and business experts (Håkansson and Ford, 2002). From the point of view of Häkansson and Snehota (1995, p. 26), a relationship is defined as "a result of an interaction process where connections have been developed between two parties that produce a mutual orientation and commitment". Usually, a relationship represents a link between a customer and a seller which consist of some phone conversations or an email for a product or service (Ford et al., 2011).

On the other hand, Anderson et al. (1994, p. 2) defined a network as "a set of two or more connected business relationships", in which companies are capable to learn, are able to share information and resources to raise joint productivity (Holm et al., 2015). Therefore, the development of relationships depends on what happened in the past of each relationship, what each company learned in previously relationships and what are the future expectations of each company to achieve desired goals (Håkansson and Ford, 2002).

"All decisions, all actions and all changes occur within the context of the structure of the network" that influences "what can be done" and "how can be done" (Håkansson and Ford, 2002, p. 135). According to Axelsson and Easton (2016), relationships are important in determining network properties for enabling partners to access to new technologies; provide a range of products and services together; access to knowledge and resources; obtain economies of scale and sharing risks (Mohr and Speckman, 1994).

Studies have highlighted that understanding the nature of business relationships is complex and have effects in several dimensions. From the point of view of Häkansson and Snehota (1995), the ARA model highlights the importance of networks as sets of connected business relationships by focusing on the three components: actors, resources and activities.

A network is characterized by actors, these can be individuals and companies, that manage resources and perform activities (Koporcic, 2017). On this way, as the greater importance of business relationship, actors become more linked and as a result may affect their activity structures, the set of resources and the perceived goal of the actor within the context of the network (Häkansson and Snehota, 1995). Nevertheless, as a business relationship develops consequently the activity structures of both companies change over time and the interaction activities between actors may need to be adapted (Ford et al., 2011).

Concerning resources, these include tangible and intangible such as human, knowledge, financial and technological assets (Häkansson and Snehota, 1995). These are managed by one or several actors with other business actors within the network as "no company has sufficient resources itself to satisfy the requirements of any customer" (Koporcic, 2017; Håkansson and Ford, 2002, p. 137). Constantly, companies are involved in efforts to "alter their resource base – acquire and shed resources, integrate them together and recombine them". In this line, interaction in business relationships plays an important role as companies "are increasingly dependent on access to the resources of their business partners" (Gade et al., 2011, p. 210). Even more, business relationships are recognized as resources, according to Håkansson and Snehota (1995, p. 31), "A relationship is a resource which ties together various resource elements".

Activities are performed by the actors. As the capabilities of actors develops, new resources are created, and existing resources are enhanced (Håkansson and Snehota, 1995; Koporcic, 2017). Even more and according to Koporcic (2017, p. 3), activities represents "the performance of two or more companies, where resources are mutually utilized and where actors are learning and developing through cooperation and shared network perceptions".

Companies have the capability to connect different actors, resources and activities operating in a context of interdependencies like technology, knowledge, social relationships, administrative routines, legal ties. These interdependencies are linked to business activity and affect network and business relationships (Häkansson and Snehota, 1995). Consequently, companies need to choose correctly their business partners and "manage their relationship effectively" (Ford et al., 2011, p. 4). In this line, there are

involved three important behavioral characteristics such as trust, commitment and conflict resolution (Mohr and Speckman, 1994).

Commitment is seen as the “exert effort on behalf of the relationship” in which companies makes short-term sacrifices to achieve desired goals (Mohr and Speckman, 1994, p. 137). An analysis of Friman et al. (2002) found that if business relationships are perceived as valuable, high levels of commitment are involved. Committed partners drive partnership success (Mohr and Speckman, 1994). On the other side, if business relationships are recognized as less important, commitment is expected to decrease (Friman et al., 2002).

Trust plays a crucial factor in business relationships. It represents the capacity of think is common interests and not in a particular interest (Hosmer, 1995). In addition it is associated with the other party's word being reliable. Generally arise from business partners actions with the goal of producing positive effects to the network (Schurr and Ozanne, 1985; Anderson and Narus, 1990).

As pointed out by Zand (1972), the level of trust is associated with the success of the business relationship. The greater the trust between business partners, the better the performance of companies and the greater the collaboration between partners, the greater the incentive for communication and information sharing (Zand, 1972; Ratnasingam, 2005). Thus, and as Bencsik (2022) argued, technology is one of the drivers that improve trust within business relationships.

Digital transformation and digitalization are transforming business in terms of strategies, processes, skills, interaction between actors and shaping the structure of business relationships (Bencsik, 2022; Pagani and Pardo, 2017).

The improvement of communication and information sharing, through the use of new technologies, allows for greater transparency and traceability of information, and the connectivity of actors in the business network. Therefore, transparency and traceability of information are the way to establish greater levels of trust between business partners (Bencsik, 2022; Pagani and Pardo, 2017). Trust plays a central role not only for business relationships but also for companies as a whole, so according to Bencsik (2022, p. 5), "lack of trust is clearly a key challenge for organizations struggling to make the transition to the digital age”.

Digital transformation plays a crucial role in business from value creation, configuration and value capture, according to Bresciani et al. (2021). The use of technology is associated with improving business decision-making, user experience and consequent customer loyalty, according to Pagani and Pardo (2017). Artificial intelligence is an example that enhances decision-making capacity, reinvents new business models and improves the consumer experience (Duan, 2019).

According to Handfield and Bechtel (2002), new digital technologies are "enablers", as they can help to optimize information, improve processes by reducing the use of paper and improve organizational efficiency. But to this happen, partners must be aligned, share resources and information, be committed and work cooperatively towards innovative solutions and by achieve the goals of the business relationship or partnership in which they are involved (Handfield and Bechtel, 2002; Bresciani et al., 2021). In this way, the entire network must be integrated into this new digital world, be aware that a new set of skills are necessary, and as Bresciani et al. (2021, p. 206) argued, "The digital transformation era thus evokes a need for more digital skills and if the introduction of new technologies was pushed by the advancement of innovations before, now it is possible to emphasize the importance of digital and human skills for business growth".

On the other hand, when the level of trust is low that are involved implications such as, partners will not have the capacity to share important information and resources, vulnerability will increase and misunderstandings will occur with more frequency (Schurr and Ozanne, 1985; Zand, 1972). Thus, will “destroy” and reduce joint goal-settings and problem-solving effectiveness (Zand, 1972).

According to Gadde and Snehota (2000), in any business relationship as commitment and trust arise, conflict may arise too. Conflict is defined as the “disagreement of differences between two or more people” (Plank and Newell, 2007, p. 59). Conflict is characterized as “natural part of social behavior” in which is “endemic to any human relations” (Plank and Newell, 2007, pp. 59-60). However, the main causes that may push up the conflicts result namely from incompatible goals and misunderstood communications (Rosenberg and Stern, 1970). Finding the cause of conflict may be the solution to understand why the conflict occurred (Tidström, 2012). According to Tidström (2012, p. 127), a conflict is considered “destructive if actors are dissatisfied with the outcome and is constructive if actors are satisfied with the outcome”. Furthermore, by

anticipating conflict, companies are able to introduce more inputs, will be more innovative and construct interesting solutions to produce mutual goals. This will impact directly network and business relationships (Håkansson and Senhota, 1995; Håkansson and Ford, 2002).

2.2. Industry 4.0 and Digital Transformation on Maritime Container Transportation Network

According to Schwab (2016, p. 6), "the word revolution denotes abrupt and radical change". During the past, goods were manufactured through manual work. However, in the beginning of the 19th century, manufacturing development brought the transition from manual work to the first manufacturing processes (Thangaraj and Narayanan, 2018; Rojko, 2017). First industrial revolution, known as Industry 1.0, began with the mechanization and the invention of the steam engine (Schwab, 2016; Rojko, 2017). According to Yin et al. (2017, p. 1), this period was characterized by product volume, meaning that "if supplies were smaller than demands, prices rise and if supplies were larger than demands, prices fall".

The second industrial revolution, also known as Industry 2.0, occurred into the early 20th century. Was fostered by the advent of electricity and the advent of mass production (Schwab, 2016; Thangaraj and Narayanan, 2018). According to Yin et al. (2017, p. 2), this period was characterized by two dimensions - volume and variety, where "the pressure was how to increase product volume with low cost". In this context, by using mass production, Henry Ford – the father of mass production, combined high volumes with its Model T assembly line (Yin et al., 2017). This period is associated to famous quote about Model T "You can have any colour as long as it is black" (Rojko, 2017, p. 79).

The third industrial revolution, also known as Industry 3.0, started in the last few decades of the 20th century. It emerged with invention and manufacture of electronic devices, automation and flexible production (Rojko, 2017; Thangaraj and Narayanan, 2018). According to Yin et al. (2017), this period was characterized by matching three dimensions – volume, variety and delivery time.

The XXI century was marked by fourth industrial revolution, also known as Industry 4.0. The concept was presented for the first time at Hannover fair in 2011 by German government, to sustain strong competitiveness of German manufacturing industries, since "Germany has one of the most competitive manufacturing industries all over the world" (Kagermann et al., 2013; Rojko, 2017; Yin et al., 2017). Industry 4.0 represents a new paradigm where business activity, manufacturing processes and all actors are integrated (Birkel et al., 2019; Rojko, 2017). Nadeem et al. (2024) argue that I4.0 is intrinsically linked to digital transformation where traditional business processes are being transformed with the use of digital technologies such as Cyber-Physical Systems (CPS) and Internet of Things (IoT) (Shahbakhsh et al., 2021). This period is characterized by the following dimensions: digitalization, automation, robotics, customization, optimization, improved human-machine interaction, data-sharing, new types of services and business models, which are supported by latest digital technologies (Nadeem et al., 2024; Posada et al., 2015). However and according to Tijan et al. (2021, p. 1), "Integrating and exploiting new digital technologies is one of the biggest challenges that companies currently face". For this reason, selecting the right suitable technological solution is an advantage to internalize new digital tools within business structure (Büyüközkan and Göçer, 2018).

Industry 4.0 is generating huge volumes of data. Therefore, the ability of store and transform huge volume of data is a great challenge of Industry 4.0 (Costa et al., 2019). In this line, IoT has become one of the most important technologies to face challenges concerning data storage. Internet of Things (IoT) refers a network of physical devices incorporated by wireless communications, sensors and software that exchange data with other devices and systems (Lu and Cecil, 2015). Use IoT applications enable rapid data generation contributing to information flow and to reliable communication networks (Costa et al., 2019; Khan and Yuce, 2019). Even more, IoT context brings together the physical world and cyber world "transforming the focus of business processes from physical products to data-driven services" (Pflaum and Gölzer, 2018, p. 87). IoT is a catalyst to link actors, activities and resources, covering several fields like health, education, industrial, transport, defense (Anderson and Mattsson, 2015; Khan and Yuce, 2019).

Digital transformation is shaping the maritime industry. It represents a new turning point in which digital technologies are capable to generate value to the chain and produc-

ing network effects (Büyüközkan and Göçer, 2018). Maritime transportation is recognized as one of the key sectors for digital transformation (Fruth and Teuteberg, 2017). But hardly can be considered as a pioneer where "deep-seated traditions" and "operational complexities" makes maritime transportation a conservative sector when it comes to use new technologies (Raza et al., 2023; Durlik et al., 2023, p. 2). The adoption of IoT is still at an initial stage. However, in recently years, the Internet of Things (IoT) has attracted interest of maritime transportation sector (Belfkih et al., 2017; Hiekata et al., 2019).

According to Sullivan et al. (2020), ships are complex structures that produce and require huge amounts of data. Analyse, manage and process data generated from IoT devices, can be considered a difficult task because are involved multiple and different sources, are huge in volume and high in speed (Noto et al., 2023; Durlik et al., 2023). So, and according to Durlik et al. (2023), analyzing such data needs high skills and advanced capabilities to handle with different type of data.

"IoT technologies have emerged as potential game-changers" (Durlik et al., 2023, p. 2) and are impacting and transforming three major application fields in maritime activity: ships, transportation and ports. IoT devices are used on ships for data storing, reporting and monitoring. For example, Automatic Identification Systems (AIS) and Radio Frequency Identification (RFID) are examples of IoT devices that allows ships traffic tracking, monitoring and information, which through the diffusion of local and ship information, provide real-time updates about direction, location and speed. IoT applications are also capable to monitor a lot of parameters such as equipment status, environmental conditions, fuel consumption, maintenance cargo conditions and storage capacity. Concerning IoT devices installed at ports, allows to monitor cargo handling, track containers and vehicles, control operations and containers movements (Arifin, 2023; Durlik et al., 2023; Mudra et al., 2023). The use of IoT devices allows reducing delays in operations; increase transparency and visibility of information; increase efficiency and control of operations; enhanced cargo turnover and minimize human errors (Durlik et al., 2023).

A study conducted by Durlik et al. (2023, p. 6) revealed in 2020 that "global maritime IoT market valued at $4.15 billion and is projected to reach $21.36 billion by 2027". This suggests that the growth of IoT devices in the maritime transportation sector have potential and is expected to increase in the coming years. Despite the relevance of

IoT in this sector, the adoption of IoT devices has some challenges namely concerning sensitive data and security (Durlik et al., 2023).

2.3.Sustainable Practices on Maritime Container Transportation Network

The United Nations Conference on the Human Environment recognized on 1972 that suitable measures should be implemented for the preservation of the human environment (United Nations, 1972, p. 3). Over the years, "sustainability" gained recognition with the emergence of the concept "sustainable development". The Brundtland Report in 1987 defined "sustainable development" as "the development that meets the needs of the present generations without compromising the ability of the future generations to meet their own needs" (Brundtland, 1987, p. 24). Driven by the evolution of sustainability, the notion of Tripple Bottom Line – 3BL emerged. According to Norman and MacDonald (2004), this concept defines that the success of a company should be measured by social and environmental dimension, not only by financial component.

The economic line of TBL is defined as the ability of companies to generate positive results contributing to the economic growth (Alhaddi, 2015). According to Alhaddi (2015), the social line of TBL focuses on the impact that organization has on society´s welfare by address social equity such as fair wages, health and safety, non-discrimination and appeal to social responsibility inside and outside the business (Goel, 2010). Lastly, the environmental line represents the impact that companies have in the environmental field. The goal is to establish good practices and strategies in order to reduce environmental impact without compromising the use of resources for future generations (Alhaddi, 2015; Goel, 2010).

Over the last years, maritime transportation is being pressured to address sustainability standards (Justavino-Castillo et al., 2022). However, is still recognized as "one of the biggest challenges of 21st century" (Yuen et al., 2017, p. 18). In this line, the emission of greenhouse gases (GHG) from maritime transportation has attracted attention as a global issue (Mansouri et al., 2015). GHG emissions in the maritime container transportation are closely associated with air pollutants such as SOx, NOx, PM and CO2 (Justavino-Castillo et al., 2022; Kim and Seo, 2019). The IMO, as responsible for regulating emissions of maritime sector, showed that GHG emissions resulting of maritime activity has increased from 977 million tonnes to 1,076 million tonnes in the

period recorded between 2012 and 2018, this is justified by the continuous increase of global maritime trade (IMO, 2020). The most recent studies revealed that maritime transportation in 2012 contributed to 2,76% of global CO2 emissions and in 2018 increased to 2.89%. These emissions could represent by 2050 “in the absence of policies, may grow up by 150% to 250%” (IMO, 2009, p. 7; Zhang et al., 2024; IMO, 2020).

During the last decade, to handle with issues associated with GHG emissions, several solutions emerged, for example, the use of alternative energy sources, the use of low-carbon fuels or carbon-free fuels, the use of technology for emissions reduction, retrofitting existing ships and documentation used on a shipment (Zhang et al., 2024; Fahnestock et al., 2021; Lai et al., 2011).

Alternative energy “is an energy source that is naturally regenerated faster than it is used, constantly replenished without being exhausted” (Zhang et al., 2024, p. 11). These include solar energy, wind energy, wave energy and geothermal energy. According to Wang et al. (2023), by using solar energy the potential CO2 reduction could achieve between 0.2% and 12%. Despite their GHG and fuel reduction, the application of solar energy is feasible just if ships has the capacity to store energy (Shi and Luo, 2018). Many studies defends that is not a viable option, meaning that “the shift from fossil fuels to renewable ones is still far from being achieved” (Serra and Fancello, 2020, p. 9).

According to Zhang et al. (2024), to support the fuel transition LNG, methanol, hydrogen, ammonia emerged as an alternative to traditional fuels. LNG represents a new paradigm to a new carbon-free future, with a potential of reduce CO2 emissions by 10%. However, “LNG bunkering infrastructure is still currently limited”, according to Eide et al. (2013, p. 277). Hydrogen, for instance, can be a better alternative to LNG in the future, “if hydrogen has lower production costs and higher yields” (Zhang et al., 2024, p. 11). Compared with other fuels, hydrogen bunker infrastructure is the highest, the “only defect of hydrogen is lack of global availability, but it does not affect the final result of durability evaluation of hydrogen” (Zhang et al., 2024; Wang et al., 2023; Cheliotis et al., 2021; Deniz and Zincir, 2016, p. 447). Furthermore, ammonia when compared with hydrogen can be cheaper due to its properties like high energy density, low flammability, ease storage and low production cost. Still, comparing with hydrogen there are already existing infrastructures namely concern in terms of handling and transportation and the availability in some ports around the world (Cheliotis et al., 2021; Mallouppas et al.,

2022). A recent study done by Lloyd's List and Lloyd's Register (LR) identified ammonia as one of the important cleaner fuels to achieve carbon neutrality by 2050 (Adamopoulos, 2021).

Furthermore, several authors have identified that the application of biofuels or called low-carbon fuels, including bioethanol and biodiesel has great potential, e.g., availability and diversity of feedstocks for their production, the simplicity of handling and storage, high energy density (Wang et al., 2023). On the other hand, biofuels presents complex characteristics, current limited availability, high maintenance costs, needs and costs for scaling up production (Wang et al., 2023; Kass et al., 2018).

According to Serra and Fancello (2020), ahead of the question of alternative traditional fuels, there is an operational technique that allows to reduce fuel consumption as well the amount of CO2 emissions, named it slow steaming. Slow steaming is a technique applied by larger ships to sail at a reduced speed. Have several benefits including that "is considered the most economical method since its implementation is flexible, almost free and it greatly reduces ship operating costs" (Kim et al., 2014, p. 109).

Concerning mitigating the ecological impact through technology, adopting "scrubber" technology may be a way of controlling emissions. This allows to reduce as much 98% sulphur oxides (SOx) and particulate matter (PM) (Kristensen, 2012). Additionally, adopting technologies can have an impact on real-time monitoring during navigation as well route optimization. For instance, Maersk it has a software toll installed on ships called Voyage Efficiency System (VES) that during navigation allows to identify "the most fuel-efficient route and pursue a just-in-time steady running strategy" (Wang et al., 2023; Lai et al., 2011, p. 635).

To decarbonize maritime transportation, recently studies have highlighted the importance of retrofitting. Retroffiting emerged from the need of traditional fuel costs be very high. It is a strategy that is possible to use at the same time fossil fuel and carbon-free fuels like hydrogen, ammonia or green methanol, "without building new ships" (Kolios, 2024; Mahmoudi et al., 2024, p. 2). Implementing this strategy have several benefits like energy efficiency, reducing operational costs as well increasing competitiveness on maritime market (Kolios, 2024).

A typical shipment involves various procedures such as booking request, booking confirmation, shipping instructions, invoice, packing list, bill-of-lading (Lai et al., 2011). The original bill-of-lading is a physical transport document representing the ownership of the cargo (Raposo et al. 2023). The original bill-of-lading (OBL) is characterized by paper format and there are many implications of using transport document in paper format, like, can be lost or be falsified, the time involved in handling transport document and costs in terms of printing a set of OBL. Consequently, the importance of creating an electronic format emerged. The adoption of electronic bill-of-lading (E-BL) represents a significant milestone in the context of international maritime transportation by offerings several benefits such as cost-effectiveness, security, cutting down paperwork, more trust and reliability, less complexity of operations and great visibility and transparency of operations (Raposo et al., 2023; Lai et al., 2011). However, the implementation of E-BL may create obstacles to bankers, insurers, credit agencies, economic agents, business partners and namely when are involved countries that only accepts conventional OBL. To replace paper format to electronic format there has to be harmonization and integration between all parties "to treat the electronic document exactly the same way with the paper one" (Zhu et al., 2022, p. 24).

3. METHODOLOGY

This dissertation aims to understand how maritime container transportation network is affected by technologies of Industry 4.0 and sustainability, from a business network perspective. The purpose of the study is characterized as being exploratory as it aims to "gain insights about a topic of interest, to investigate a problem that is not clearly defined, has been under-investigated, or is otherwise poorly understood" (Nand et al., 2023; Saunders et al., 2019, p. 186).

Regarding the research strategy, case study was considered the most appropriate. It is an empirical method that involves a detailed investigation of a phenomenon of interest (Yin, 2018). The case was selected purposely considering the research objective and the case revelatory potential.

This study employs a qualitative study, using interviews and secondary data (Creswell, 2015). Data collection was done mainly through the use of primary data, more specifically semi-structured interviews. Seven online interviews were carried out with

people from different positions and who belong to Portuguese larger companies in the maritime container transportation sector. However, as at the end of the 7th interview the information was saturated, no further interviews were carried out. Each interview lasted approximately 1h30 and was recorded with the permission of each interviewee.

Company Name	Date of Interview	Job Position	Years in the maritime sector	Time of Interview
Alfa	20th May	Operational Manager	16 years	1h30min
Alfa	12th June and 18th June	Sales Manager	24 years	2h00min
Beta	29th May	Business Director	23 years	1h20min
Charlie	10th June	Export Customer Care Supervisor	27 years	46 min
Delta´s Manager A	18th June	Manager Agent Customer Experience	7 years	33min
Delta´s Manager B	25th June	Portugal Country Representative & Head of Direct Transport	2 years	35min
Echo	27th June	Export Documentation Manager	10 years	1h15min

Table 1: Interviews details

Furthermore, they were conducted in Portuguese and online and took place between May 20th and June 27th. To maintain the anonymity of each interviewee and each company, a name corresponding to the phonetic alphabet was assigned. The questions can be seen in Annex II – Interview Script and in some cases the order of the questions found in the script was not followed so that each interviewee was open to talking about new subjects, contributing with more inputs to the objective of the study (Saunders et al., 2019, p. 439).

Regarding the secondary data, documents and reports from each company were used, along with the respective recordings and notes during each interview, in order to complement the collection of primary source data.

4. CASE STUDY

Last events as COVID-19 caused great disruptions in global maritime network, but maritime industry is still expected to grow in the coming years. The main reasons for this growth are associated with advances in technology and according to Lars Jensen, CEO of Vespucci Maritime Consulting and a leading expert with 20 years inside the container shipping industry, "The shipping industry is facing a profound change in the next 10-20 years– and the key driver for the change is namely the need to digitalise and automatize" (Eronen, 2018). Apart from this, there are other factors that are accelerating this industry like decarbonization and the need for energy transition (UNCTAD, 2022).

Maritime business network is characterized by being a dynamic environment influenced by the number of actors involved like ocean carriers, shippers, freight forwarders, port service providers, customers, customs broker, road hauliers. These actors manage resources and perform activities particularly in terms of maritime transportation and logistics services.

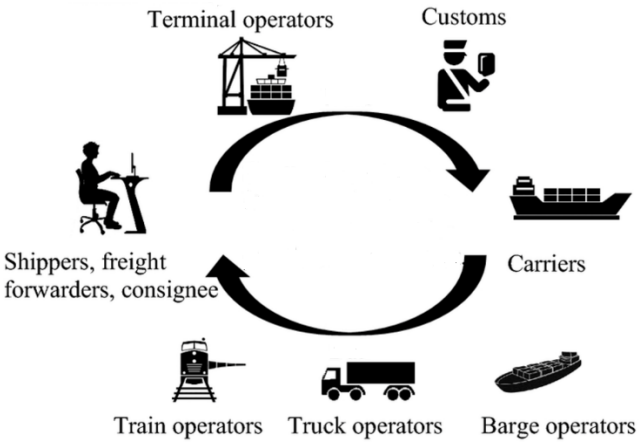

Figure 1: Network structure of maritime container transportation

4.1. Main characteristics of maritime business relationships

Globalization would not have accelerated if was not maritime transportation providing a cheap cost for moving goods between continents. One of the drivers that allowed the operation to become more extensive and cover smaller countries, was the improvement of relationships within maritime network between ocean carriers, forwarders, consignees, notifies, port authorities, terminals, road hauliers, shippers,

freight forwarders and namely the creation of "Ocean Alliances". "Ocean Alliances" represents a set of two or more relationships in which in each alliance occurs space sharing on ships. As Alfa's Sales Manager pointed out "if there weren´t alliances, containers would have to deconsolidated to other ocean carriers because there was no capacity to establish a service network (...), the costs would be very high for the consumer and the operation would be much slower".

Businesses are based on numbers, profitability and the relationships also "lives" on that. To establish a successful relationship there are some relevant features that should be taken into account. As result, all interviewed highlighted relevant characteristics like trust, commitment, loyalty, work together towards common goals, openness and sincerity and conflict resolution.

Trust in business partners means that they will support and incorporates company´s strategy. Beta´s company represents two companies. Currently, they are passing for an internal change, that is, one of the companies will be responsible for the transit and logistics activity and the other company will be responsible for dedicating itself entirely to the management and expansion of services of shipping agency. This particular case can impact business partners if there is no trust. But, as Beta shared "if I am careful to communicate what the strategic reason is behind of this transformation, if I am careful to keep people in touch and assure them that there will be no conflicts of interest and that I will continue to be ethically correct in my relationships with them. The partners will face this internal change with more confidence, with much more lightness and accept this transformation more quickly".

Concerning commitment, represents the promise in which our business partner will not fail with us. In general, developing a reciprocal and solid relationship presupposes that commitment is the basis of a recommendable, reliable and stable partnership. According to Alfa´s Operational Manager, road hauliers represents a fundamental part of the maritime network that can compromise the entire logistics chain. For example, the maritime transportation service has fixed slots, e.g. Port of Rotterdam has "working slots", if the fixed time slots are lost, maritime transportation fails, road hauliers stay compromised, containers will not pick up and consequently customers will not receive their cargo.

The maritime container transportation network is defined as a competitive environment. Thus, looks always for a competitive partner. Alfa's Operational Manager shared a situation where commitment failed, mentioned that there was a strike at the port of Lisbon and the road partner ensured that the service would be fulfilled. At the end of the day, also due to a union strike in the terminal, the road partner refused to carry out the services. According to the interviewed, "if we need their services exceptionally, we will always be wary of whether or not they will fail, and the relationship will end up being damaged and will never be the same again".

Despite the importance of trust and commitment, one of the interviewed referred that directing towards "common goals" is an essential characteristic. For instance, Delta´s company shared that they have a partnership that will end next year, due to both companies have different strategies like one wants to have the world's largest fleet and the other company wants to be the world's largest logistics operator. Also adds that there will be a new partnership with other ocean carrier that have the same strategic objectives that Delta´s company. To support this idea, mentioned that ships' space management is a critical and sensitive topic to sustain business relationships. The partnerships are crucial in this way "If I have x ships of a certain characteristic and y ships of another certain characteristic and this determines how I create my networks between ports globally, if I add characteristics and numbers of other ships from another ocean carrier who has the same objectives as our company and works in similar ports, we can even share space and optimize services" (Delta´s Manager A).

More openness and sincerity on businesses is possible to gain loyalty and overcome obstacles together with business partners. As mentioned by Alfa´s Sales Manager, when there is a problem, generally it is associated with externalities, such as, "difficulties in releasing the cargo at the origin, difficulties in getting more space, some flexibility for certain types of circumstances with free days at destination", it is essential to create a background that favors this relationship. Despite the difficulties that may exist in a business relationship, customers will not change the service by less than 100$ or over than 100$, because "if he feels that our company always giving the best, you give a good service, will always end up coming back". Price is not the only factor that determine a relationship it is important firstly to create and strengthen ties through an environment of openness and sincerity.

Moving to the last attribute, conflict resolution. There is always conflict when one of the parties places their interests above the interests of the partnership. Therefore as Charlie shared "there must always be concessions from each party". Business partners have to be on the same wavelength, there has to be a balance between individual interests and the interests of the partnership (Alfa's Sales Manager). Thus, in critical and in unpredictable situations, which is when conflicts generally occur, "having the ability to reach an agreement" that does not harm either party is crucial to fostering relationships within the maritime transport network (Echo). In this line, one of the crucial tools is communication, that is, the clearer and more visible the communication, the greater the likelihood of mitigating conflict, according to Beta.

4.2. Using technologies of I4.0 to improve business relationships

Shipping industry represents the main “fuel” that boost free trade between disparate geographies. Without maritime transportation, how could we have a global maritime network? Without technology, how could maritime transportation be enhanced? (Alfa´s Operational Manager).

The synergies lead to improved conditions and strategies inside maritime network. According to one of the interviewees, "if it weren't for this technological leap, there wouldn't be interconnectivity and synergy between partners in a much simpler way". Nowadays, synergies between ocean carriers, customers, terminals using I4.0 technologies allows greater proximity and connectivity between all parties involved in a network. By developing more technological capabilities, technological interfaces between ocean carriers and services providers (e.g. terminals) will have greater productivity gains.

The development of common technological tools increases synergies and fosters partnerships and relationships within the maritime container transportation network (Alfa's Operational Manager). For example, through technology the information transmitted began to flow much more quickly and on the other hand, in terms of communication, technology has made it possible to shorten distances, bring all the business partners closer together and improve relations within the network, since in the past the way of communicating was extremely time-consuming (Charlie).

Technology brings disruptions. In the past, the programmes used by each ocean carrier were very archaic and there were many people doing just one task. Today, each ocean carrier's programmes are intuitive and many of them are already incorporated with technology. For example, Delta's Manager B pointed out that the platform the company uses, through the incorporation of artificial intelligence, has a virtual assistant that makes it possible to interact in a more integrated way, improving communication between partners, achieving gains in terms of productivity and process efficiency, but also allowing employees to focus on more complex tasks by guiding the simpler tasks to the virtual assistant.

Relationships are generally created when there are strategies that match between different companies. For example, if two companies in the shipping industry get together and "if there was a large technology gap, the companies could not have a common long-term strategic goal and possibly the relationship would end up being harmed". Therefore, technological investment is determinant for establishing and maintaining partnerships (Delta´s Manager A).

4.3. Barriers to digital transformation and benefits of using technologies of I4.0

There are risk factors concerning geopolitical nature that can delay plans associated with digital transformation. Also, ocean carriers are very conservative entities where are perfectly aware of the trends and risks they are running, can be slow down this digital path (Alfa´s Sales Manager).

Shipping industry represents an industry that moves a lot of money and in which there are "some ocean carriers have revenues greater than the GDPs of some countries", according to Alfa´s Sales Manager. The basis of maritime transport are ships and support infrastructures, where are associated very high investments. Although the industry generates a lot of money it is crucial to check the viability of the investment, whether or not it is worth investing, as transforming ships and support infrastructures in something autonomous cannot occur overnight (Beta).

Despite the geopolitical factors, high investments, the fact that ocean carriers are quite conservative, there is another barrier that can delay plans regarding advances in technology, which is the requalification of people in the shipping industry. That is, people have to be trained, they have to meet the technologies, things are happening at such a fast

pace that it is difficult to enable people to change. Beta shared that the challenge is people embracing to change because human beings don't like change, e.g. for people who are already in the career last phase, it is difficult to get them to master it, because they think it will not bring any benefit, and it requires a lot of effort and time. Technology is increasingly fast paced, so it is crucial that people and companies follow this change because according to Alfa's Sales Manager "it will not be a low skills industry".

Not only the shipping industry but also the transportation industry are important sectors for digital transformation, but they are not considered pioneers sectors. As interviewees shared, it is not considered the main industry to sustain this transformation due to is still characterized by following and seeing what other industries do. However it is a determining sector that impacts the movement of goods.

Processes had to be dematerialized to move on to the digital transformation. As one of the interviewees shared "90% of goods are transported by sea, this is a decisive and large-scale factor in considering that it an important sector in this transformation". The trend in the future will be increasingly guided and influenced by integration of information and simplification and digitalization of processes. This has already been accelerated by COVID-19 and will continue as new increasingly sophisticated and efficient forms of digital technologies are developed.

Digital transformation has driven digitalization. Digitalization allows gain scale and have lower costs, from a micro business perspective. As Alfa's Sales Manager shared "digitalization is a function of obtaining advantages of economies of scale", that is, if the information is processed much faster, more efficiently, with less costs, it will bring scale and numerous advantages like " how to be efficient concerning managing the route of the ship, how to better manage networks and what level of bookings allows prices to be raised" (Alfa's Sales Manager).

The use of new technologies such as Blockchain, Artificial Intelligence and Internet of Things have generated several important changes in maritime business. In the past, ships loading plans were made manually. Nowadays, through the application of Electronic Data Interchange (EDI) it is possible to provide a better ship loading plan but also allows the exchange of information and an increase of communication between various actors (Alfa's Operational Manager).

In terms of documentation used in shipments, during the past, the bill-of-lading was done manually with the help of "needle printers". Some ocean carriers already has the original bill-of-lading in paper. However, there are several disadvantages to having the shipping document on paper, such as its ability to be tampered with, which can lead to great losses for the seller, buyer of the cargo or the cargo carrier, the loss of OBL and the costs of printing the OBL. As Alfa's Sales Manager pointed out, "this is why the shipping industry is not a pioneering industry for digital transformation because nowadays we still have the bill-of-lading in paper".

Some ocean carriers have already adopted the electronic bill-of-lading (E-BL). The E-BL is encrypted by Blockchain technology in which there is no risk of document loss, forgery or fraud, it is accessible from any device, it focuses on reducing paper and is no longer a physical document and it is considered as “cost-efficient”, since it is no longer necessary to print the document, as Echo shared. Many maritime companies are not yet adopting the BL in digital format because many shipments work with credit letters issued by banks which require the issuance of an original physical BL, according Delta's Manager A. Furthermore, Echo shared that the issue of regulation and "the fact that not all countries yet have approval from the Government and local authorities makes it difficult to apply this solution". Thus, as shared by Alfa's Sales Manager "credit entities, economic agents who buy and sell and ocean carriers must be interested and together they must seek to accelerate the digitalization of the bill of lading".

Driven by the COVID-19 pandemic and the resulting disruption of maritime supply chains, there was a need to improve cargo information to deal with longer and more unpredictable transit times. There are some maritime companies that already have the functionality to track and monitor the container in real time through a locator device installed in the container. As Beta pointed out, it won't take long for it to be transversal to all shipping companies, as can be considered "one of the greatest agents of change in the shipping industry".

Another relevant aspect refers to the robotization of port infrastructures. There are several ports that are almost completely robotic. As Beta shared, the trend in the coming years or decades will tend towards smart infrastructures which will greatly increase the efficiency of ports, but "it depends on the degree of investment required and depends on

the locations where that investment is, that is, whether it pays off or not enter the port infrastructure".

In terms of automation, this implies a large investment, it will compensate the investment when we are dealing with large infrastructures e.g. Ports of China or Port of Rotterdam, which are among the ports with the most cargo and which in turn are those that have the most benefits because return on investment is faster, according to Beta. Automation has great advantages and does not involve losing human capital, because there will always be a need for people to control the machines. However, the COVID-19 pandemic, which caused major disruptions in the maritime logistics chain, people were sick and consequently could not leave their homes, cargo began to accumulate in ports and costs increased more and more. With introduction of automation, the situation could have been controlled by reducing the impact that it caused. As Beta shared, "automation first leads to work specialization, because it's not just knowing how to program a machine, it's knowing how to change the programming of a machine, it is knowing how to respond well to contingencies."

4.4. The trend of larger ships and dimensions that impact sustainable field

During the 1980s, ships known as Panamax had a capacity of around 3,000 TEU[1], were the ships that had the maximum limit for passing through the Panama Canal. Over the following years, emerged Post-Panamax ships with a capacity of 5,000 TEU, New Panamax ships with a capacity of 12,500 TEU and Triple-E with a capacity of 18,000 TEU. Today, the largest container ship in the world has 24,346 TEU, with a length longer than the Eiffel Tower as Echo shared. A question emerged from several interviewees that is, " Is there a limit to the size of container ships?".

The trend of ships becoming larger has been a controversial topic in current years not only for commercial reasons but also for operational issues intrinsic to maritime business. Ships are heavily dependent on port infrastructures, which is why port infrastructures have to keep up with the growth of ships to obtain benefits in terms of cost reduction, gains in efficiency and speed in operations, as Beta shared.

[1] One TEU represents an equivalent unit of 20 feet of a standard container

In the shipping industry, economies of scale determine the sustainability and competitiveness of a company. Making a comparison between a large ship with 24,000 TEU, in which each container has a net weight of approximately 28 tons and comparing it with an airplane that carries around 28 tons (is equivalent to the weight of a container). Even more, a container costs around 1500-2000$ and air freight costs over 3000$, airplane pollutes much more, pays much more and is less competitive, it only wins in speed as Delta's Manager A shared. Ships keep growing that consequently reduces environmental impact and costs are less. This determines the competitiveness and sustainability of the industry.

Transport and technology increasingly go “hand in hand” in order to reduce carbon footprint. As Beta shared, the adoption of technology takes sustainability to the level of 3 pillars: environmental, social and governance. Regarding environmental field, it implies developing technologies that pollute less and somehow finding more efficient alternatives. In social field, the adoption of technology can lead to a higher quality of life. Concerning governance field, in terms of company structure, the adoption of technology allows “greater visibility, greater validation and greater implementation of controls” (Beta).

Many efforts have been made to build ecologically sustainable ships and become existing ones “environmental friendly”. Before moving to ships powered by methanol, one of the interviewees shared that they are doing several studies and tests to verify if methanol is viable or not, before applying to large ships. Also adds that several tests are being done firstly in small ships through navigating between small ports in China entirely powered by electricity. As Beta shared, "in my perspective, studies involve using technology either alone or in combination with other technologies, helping to prepare the ground for research to begin to be explored in terms of larger ships".

Larger ships consume more fuel and consequently pollute more. One of the solutions found was the installation of “scrubber” technology, also known as exhaust gas cleaning systems. Like Echo pointed out, the installation of “scrubbers” is essential for filtering particles and consequently reducing polluting sulfur oxides found in ship engines. Due to the impact of this type of technology, the international shipping fleet fitted with “scrubbers” as increased in the last years (Echo).

Shipping industry is characterized by the excessive use of fossil fuels. With this, the need arose to explore other types of fuels such as LNG, hydrogen, biofuels and methanol. Despite the characteristics and limitations of each fuel, the main point is that it should be cost-effective: it may be a clean fuel, but if it is highly expensive, it will no longer make the operation profitable.

According to Beta, large ships can not only be prepared to receive a certain type of fuel because “certain type of fuel may not be available in certain ports”. By being a concern in this industry, a new technique emerged, called "retrofitting". Retrofitting means that ships are prepared to receive conventional fuel as well carbon-free fuels. Involves changing the "configuration of the engines" and the "ship structure itself". However, it is considered a “promising technique”, according Beta.

A theme that has promoted the decarbonization of the industry is the use of renewable energy. When talking about the use of renewable energy in larger ships, one of the limitations when using this type of energy arises when addressing the issue of storage capacity, as Alfa's Sales Manager shared. On the other hand, as Beta pointed out, they could be viable options if pilot tests are carried out to try to understand the impacts, advantages and limitations, and then apply them first to small ships and after that apply them to larger ships. Also adds that combining different types of renewable energy would be a viable option. But, as Alfa's Sales Manager mentioned, "the most obvious path is not the use of renewable energy, the path is centered on cleaner and low-carbon-free fuels like biofuels, hydrogen, ammonia or green methanol".

Finally, in response to economic pressures and environmental concerns, an operational technique called "slow steaming" emerged. According to Charlie and Alfa's Operational Manager, slow-steaming is applied "only from an economic-financial perspective intrinsic to the business", more from a cost control perspective, that is, "companies seek profit and will not harm their reputation or reliability by reducing the speed of ships". However, as most interviewees mentioned, this technique is also viable in the field of sustainability. Alfa's Sales Manager shared, for example, the Europe-Asia cargo and the direction of the Asia-Europe route, sea freight and the results are different depending on the demand that exists, that is, slow steaming is adopted in low seasons to keep ships busy not just to reduce emissions but to control the cost of fuel itself. Slow steaming does not solve the problem associated with emissions generated mainly by

larger ships. But according to one of the interviewees "it is another factor to help and to solve the problem, to make the operation more efficient".

5. DISCUSSION OF RESULTS

The phenomenon known as globalization was considered as one of the main drivers for accelerating trade exchanges, include more regions at a lower cost through the creation of “Ocean Alliances” but also for improving relationships within the maritime transportation network. The maritime transportation network is characterized by being a dynamic, competitive environment, strongly influenced by the “number of connected business relationships” (Anderson et al., 1994, p. 2) and the number of actors, including ocean carriers, shipping agents, consignees, port authorities, terminals, road hauliers, shippers and forwarders.

Therefore, within the structure of the maritime transportation network, business relationships are defined as “the result of a process of interaction” (Häkansson and Snehota, 1995), where trust and commitment are pillars for establishing long-lasting and successful relationships and partnerships (Zand, 1972; Häkansson and Snehota, 1995).

Based on Mohr and Speckman (1994, p. 137), commitment is seen as the “effort exerted on behalf of the relationship”. In the container shipping network, road hauliers represent the main link in the logistics chain. Therefore, by developing a reciprocal and solid relationship between carriers and ocean carriers, it is assumed that commitment is the basis of a recommended, reliable, stable partnership and the path to partnership success (Mohr and Speckman, 1994; Friman et al., 2002).

On the other hand, there are some reasons that can lead to situations of distrust in the maritime transportation sector, which is usually when there is a new acquisition or separation of activities. Generally in these situations, conflicts of interest can occur, commitment can diminish, and this has a negative impact on business partners (Friman et al., 2002). Therefore, conflict mitigation will only happen if communication is clear and visible between business partners.

The level of trust is associated with the success of the partnership (Zand, 1972). But for the level of trust to increase within business partners, it is crucial to move towards the goals of the partnership. In shipping industry, space management on ships is a critical and

sensitive matter. So the existence of partnerships, alliances and relationships are essential to create a more global network, optimize space on ships and share services. For this reason, the objectives and strategies must move in the same direction and as Hosmer (1995) recognized, it is to think about the common interests of the partnership and not the particular interest of each ocean carrier, there must be a balance between individual interests and the interests of the partnership.

Within maritime transportation context, relationships, partnerships or alliances are created when there are strategies that suit both companies. If there were a technological gap between the companies, they might not be able to achieve a common strategic objective in the long term. Therefore, technology is considered an essential mechanism for transforming the interaction between actors in the network and shaping the structure of business relationships (Bencsik, 2022; Pagani and Pardo, 2017). In the maritime transportation structure, the use of EDI is responsible for the high levels of interconnectivity, integration, interoperability between business partners and the improvement of synergies between actors such as maritime carriers, customers and terminals, ensuring a greater exchange of information, communication and proximity between business partners. Therefore, the more developed the technological interfaces, the better the productivity gains, the greater the sharing of information, knowledge and resources and the development of joint activities (Axelsson and Easton, 2016; Mohr and Speckman, 1994; Koporcic, 2017; Holm et al., 2015).

Technologies are disruptive and responsible for creating, configuring and capturing value (Bresciani et al., 2021), allowing traditional business models to be improved (Duan, 2019) and new working methods to be transformed and revolutionized. The container shipping industry, with its “deep-rooted traditions” and “operational complexities”, is considered a conservative sector when it comes to using and implementing new technologies (Raza et al., 2023; Durlik et al., 2023). For this reason, in the past, the sector was characterized by the use of highly archaic programs, where the connection between the various players was very time-consuming, communication failed, and the information transmitted was slow. However, today, many programs used by shipping companies have not only improved communication and information sharing, but have also ensured harmonization and improved user experience, leading to greater productivity and efficiency gains (Pagani and Pardo, 2017; Duan, 2019).

In the shipping network, information is a critical variable, given that the structure produces and requires large amounts of data (Sullivan et al., 2020), in which several actors are involved and the volume of information generated is high (Noto et al., 2023; Durlik et al., 2023). For this reason, and based on Costa et al. (2019), storing and transforming large amounts of data is a major challenge for Industry 4.0. Therefore, the Internet of Things (IoT) is emerging as one of the technologies associated with Industry 4.0 that enables the management and processing of large volumes of data. But as Durlik et al. (2023) introduced, managing and processing the large amounts of data produced by the maritime transportation will require specific skills that the industry will "demand", that will not be a "low skills" industry.

As Nadeem et al. (2024) and Posada et al. (2015) identified, two of the dimensions that Industry 4.0 is characterized is by automation and robotics. Therefore, ships and port infrastructures have enormous potential to incorporate this technology part. However, due to the high investment required, it would only be worth investing in, when it comes to ports with large volumes of cargo, where the return on investment is quicker. Then, one of the benefits of having robotic infrastructures is that they can respond to contingencies, enable remote control without the need for people to be present. During the COVID-19 pandemic, remote control could have been an asset, because people were at home sick and couldn't leave the house and many of the costs that occurred could have been avoided.

Digital transformation has driven the digitalization of processes. For digitalization and processes simplification to occur, a dematerialization of processes had to take place. Therefore, technologies of Industry 4.0 must also be applied from the perspective of improving operations, i.e. simplifying processes, particularly in terms of the documentation used in daily shipments. As Lai et al. (2011) mentioned, a shipment involves a series of procedures ranging from the booking request, booking confirmation, shipping instructions, invoice, packing list and bill-of-lading.

In many ocean carriers, the original bill-of-lading (OBL) it still presents as a paper document. According to a study done by McKinsey in 2022, the "bill-of-lading represents between 10-30% of total trade documentation costs". Due to this and the several constraints that the physical document presents, the need arose to create a more efficient, secure and sustainable alternative - the electronic bill-of-lading (E-BL). Through the integration of Blockchain, E-BL brings many advantages, including cost-effectiveness,

security, reduced bureaucracy, increased trust and reliability, less complex operations and great visibility and transparency of operations (Raposo et al., 2023; Lai et al., 2011). As defended by Zhu et al. (2022), it is crucial that all entities that buy and sell are interested in seeking to speed up the digitalization of conventional bill-of-lading.

Technology has become an essential part of maritime container transportation. Driven by the COVID-19 pandemic and consequent disruptions in the maritime supply chain, the need to improve cargo information has increased. Consequently, "smart containers" have been developed. Today, through technology known as the Internet of Things (IoT), containers are equipped with a locator that provides better visibility and traceability of cargo, ensuring integrity and safety not only for the crew but also for stakeholders. Additionally, it allows monitoring the container´s temperature and humidity levels (in the case of a refrigerated container) (MSC Sustainability Report, 2022). Some specialists of maritime sector state that will be "one of the biggest game changers in the shipping industry".

The basis of maritime transport are ships, and these are one of the main sources that emit high amounts of greenhouse gases such as SOx, NOx, PM and CO2 into the atmosphere (Justavino-Castillo et al., 2022; Kim and Seo, 2019). For this reason, in recent years, maritime transport has been a target and heavily pressured to comply with the requirements imposed by the International Maritime Organization (IMO) on issues associated with sustainability (Justavino-Castillo et al., 2022).

Given the trend of ships continuing to increase in size, sustainability becomes a central issue. If, on the one hand, larger ships allow for greater cargo capacity, and on the other, they help to reduce environmental impact by eliminating the need for smaller ships to navigate. Therefore, in order to support the field of sustainability, various measures have been developed to mitigate the impact of atmospheric pollutants, such as the use of emission reduction technologies, the use of alternative energy sources, the use of low-carbon fuels and the adoption of adaptation measures on existing ships (Zhang et al., 2024; Fahnestock et al., 2021; Lai et al., 2011).

In recent years, transport and technology have gone "hand in hand" in search for efficient and sustainable solutions. One of the technologies that has revolutionized the maritime transportation is the implementation of "scrubbers" or "exhaust gas cleaning

systems" on ships. Allows filtering out particles and also have the capacity to reduce polluting sulphur oxides and particulate matter found in ships' engines. As defended by Kristensen (2012), the use of scrubbers can reduce sulphur oxides (SOx) and particulate matter (PM) by up to 98%.

Sustainability is increasingly intrinsic to the shipping activity. The shipping industry is characterized by its excessive use of fossil fuels, which has led to the exploration of various cleaner fuel alternatives. A lot of research and testing has been done to assess the viability of these cleaner fuels, initially applying them to smaller ships and later to larger vessels. LNG, methanol, hydrogen and ammonia have emerged as the main substitutes for traditional fossil fuels (Zhang et al., 2024). Despite the characteristics and limitations of each fuel, the main point is that it should be cost-effective.

One of the limitations affecting almost all clean fuels is their availability, as they may not be accessible in every port. Due to this condition, especially for large ships, ships cannot be prepared to receive just one fuel. Consequently, the concept of "retroffiting" emerged. Retroffiting is a technique that allows the simultaneous use of both fossil fuels and low-carbon fuels, "without building new ships" (Kolios, 2024; Mahmoudi et al., 2024, p. 2). The application of this technique is mainly aimed at ships that already exist, so it requires the modification and configuration of the ships' engines and physical structure. Despite this, the implementation of this technique brings many benefits in terms of energy efficiency and environmental impact, as Kolios (2024) identified.

To accelerate the decarbonization of maritime transportation, the use of alternative energies such as solar energy, wind energy, wave energy and geothermal energy has been discussed. As identified by Wang et al. (2023), the use of solar energy have a potential to reduce CO2 emissions by 0.2% to 12%. However, renewable energy sources has several implications such as storage capacity, especially when applied to large ships. For this reason and as suggested by Serra and Fancello (2020), the path to decarbonization is not through the use of renewable energies, but through cleaner energy processes.

To meet the IMO's requirements for reducing carbon emissions, biofuels have emerged as a promising solution. According to Wang et al. (2023), biofuels namely bioethanol and biodiesel are considered major drivers of decarbonization. Their availability and diversity of raw materials for their production, simplicity of handling and

storage, and high energy density make them a viable alternative to traditional fuels (Wang et al., 2023).

Achieving net zero emissions by 2050 is the main goal for the maritime container transportation sector (MSC Sustainability Report, 2023). To accelerate the energy transition, an operational technique known as slow steaming has emerged. By reducing speed, there is a reduction in terms of fuel consumption and a CO2 emissions decrease, as Serra and Fancello, (2020) shared. Its application is seen also from a financial perspective intrinsic to the business, because companies are looking for profit and will not damage their reputation or reliability by reducing the speed of ships. However, slow steaming can be seen as a support tool in the field of sustainability. For example, during periods when cargo flow is lower, slow steaming is adopted not only to keep ships operational but also to reduce emissions and control fuel and operational costs (Kim et al., 2014).

Partnerships and business relationships are also important for achieving carbon neutrality. Collaboration, trust, loyalty, openness and sincerity, and a commitment to working together have become fundamental pillars for solving one of the major and serious problems we have to deal with today: climate change and global warming caused by high emissions of greenhouse gases (GHGs). Maritime transportation remains a significant concern in this domain, as IMO (2020) reported maritime transportation contributed to "2.76% of global CO2 emissions in 2012 and in 2018 it increased to 2.89%". Therefore, the decarbonization of maritime transport is urgently needed, towards energy transition and by protecting the planet without compromising the needs of future generations (UNCTD, 2022; Brundtland, 1987). Environmental concerns have been presented in terms of alternatives to traditional fossil fuels, the use of technology to reduce emissions, the use of alternative energies and the adoption of retrofitting on existing ships (Zhang et al., 2024; Fahnestock et al., 2021; Lai et al., 2011). However, it is crucial to "adopt climate regulations so that shipowners can operate with environmentally friendly fuels and to encourage fuel and energy suppliers to invest in new production capacity" (World Shipping Council, 2024).

6. CONCLUSIONS, LIMITATIONS AND FUTURE RESEARCH

6.1.Conclusions

The maritime container transportation network is being positively affected by the implementation of IoT in ships, ports and containers, as identified by Arifin (2023), Durlik et al. (2023) and Mudra et al. (2023). Through IoT, the diffusion of information takes place in real time, which allows a greater level of connectivity between ships, port infrastructures and port service providers. IoT devices ensure faster spread of information, reduce delays in operations, efficiently monitor operations and optimize decision-making in terms of route planning by evaluating certain parameters such as fuel consumption, direction, location and speed of ships.

Technologies of Industry 4.0 enable optimize business relationships by promoting information sharing between several actors in the maritime container transportation network. Recently, “smart containers” have emerged through the integration of Internet of Things (IoT) technology. These containers are equipped with location sensors inside the container allowing full tracking and visibility of the cargo. In addition, they enable the monitoring of temperature and humidity of the container in cases where the cargo has specific characteristics and nature (MSC Sustainability Report, 2023). The use of this type of container allows business relationships to be shaped and transformed, particularly between the ocean carrier and the entities responsible for the cargo, and consequently guarantees harmonization in the supply chain, offering greater security to the person responsible for the cargo and the other entities involved.

Information sharing fosters greater proximity, communication and connectivity between actors in the network. Electronic data interchange (EDI) simplifies the exchange of information between ocean carriers and service providers, such as terminals. Furthermore, it ensures better loading plans on ships, control errors in greater detail and enables faster communication and information flow.

Technologies are instrumental and disruptive in transforming work methodologies. Currently, many of the programs used by shipowners are integrated with technology from Industry 4.0. Through the incorporation of Artificial Intelligence, supported by a virtual assistant on ocean carriers' websites, it is possible to offer a

personalized experience to customers and consequently establish greater proximity between ocean carriers and customers.

In the context of the maritime container transportation network, automation and robotics are technological solutions derived from I4.0 that are linked to the improvement of ships operations and the port infrastructures. The feasibility and implementation of automation and robotics would bring enormous potential to the relationship between port infrastructure and ships. It wouldn't mean losing human capital, it would be applied with a view to responding to contingencies, increasing responsiveness and efficiency in operations. For example, if the main seaports had such technological component, the situation during the COVID-19 pandemic would have been managed in a more calculated way and many of the demurrage and storage costs that occurred could have been mitigated.

Enhancing and developing digital tools is the way to simplify processes and support the field of sustainability. A typical maritime shipment involves a series of procedures from the booking request, booking confirmation, shipping instructions, invoice, packing-list, bill-of-lading as Lai et al. (2011) identified. As argued by Raposo et al. (2023), the original bill-of-lading is a physical transportation document that represents the ownership of the cargo. Due to the various constraints presented by the paper bill-of-lading (OBL), the need arose to create a more efficient, secure and sustainable alternative. The electronic bill-of-lading (EBL), through the integration of Blockchain technology, offers numerous advantages, from reducing the use of paper and the costs of printing physical documents, security for all associated entities (e.g. shipowners, customers), greater trust and reliability, less complex operations, great visibility and transparency of operations (Raposo et al., 2023; Lai et al., 2011).

Technology is intrinsic to the concept of sustainability. One of the technologies that has revolutionized shipping activity is the use of “scrubbers” or “exhaust gas cleaning systems” on ships. The use of scrubbers allows ships to filter particles, reducing pollutants such as sulphur oxides and particulate matter. This reduction can reach up to 98% for sulphur oxides (SOx) and particulate matter (PM), as Kristensen (2012) has identified.

Apart from the use of technology that helps to promote green practices, as mentioned by Zhang et al. (2024), Fahnestock et al. (2021), Lai et al. (2011) and Serra

and Fancello (2020), there are other solutions to support the field of sustainability, such as the use of low-carbon fuels or carbon-free fuels, the adoption of retroffiting on existing ships and the adoption of slow-steaming.

The main low-carbon or carbon-free fuels are biofuels, LNG, methanol, hydrogen and ammonia, as identified by Wang et al. (2023) and Zhang et al. (2024). In order to replace traditional fossil fuels, it is essential to understand the characteristics and implications of each clean fuel. The key factor in choosing a particular fuel is that it must be cost-effective, i.e. it may be a clean fuel, but if it is excessively expensive, the operation will no longer be profitable.

Regarding the technique known as "retroffiting", as identified by Kolios (2024) and Mahmoudi et al. (2024, p. 2), retroffiting is a solution that allows the simultaneous use of traditional fossil fuels and low-carbon fuels "without building new ships". It enables ships to source different types of fuel from two different supplies, they are stored in different places and then there is the possibility that the ship can work with a cleaner fuel or with a traditional fuel. This is important because it is not always guaranteed that a certain fuel will be available at the ports where ships dock. It is designed from a sustainable perspective, aiming to promote the use of cleaner fuels.

Finally, another solution to support the field of sustainability is the practice of slow steaming. Slow steaming is a strategy, by reducing the ship´s speed, helps lower emissions, as argued by Serra and Fancello (2020). Furthermore, it is adopted to keep ships "busy" during low-demand periods, when cargo flow is reduced, and simultaneous helps to control fuel consumption.

6.2.Limitations and Future Research

This study includes six companies, specifically the largest ocean carriers located in Portugal. The main limitation of this study is related to the difficulty in assessing the impact that technologies bring to the interviewed companies in terms of the local context. Half of the shipping companies that participated in the study are agents who represent the company in Portugal, and because of this, it is difficult to measure the level of use and implementation of technology, as everything is practically controlled by the large international offices of each company. The data obtained may not accurately reflect the impacts from a national perspective, but rather from a global perspective.

In terms of future research, it seems that sustainability is considered a factor clearly related to the competitiveness of the maritime transportation but also it is associated with the trend of ships continuing to increase in size. Larger ships are capable of carrying much more cargo, but this can generate a strong impact on maritime container transportation network namely to cargo receiver. If receiver is waiting to receive a certain cargo, the ocean carrier can allocate more cargo of this receiver on a larger ship, and this can create major problems in terms of receiver´s warehouse storage capacity. Today, the world's largest container ship has a transport capacity of 24,000 TEU. Thus, due to this trend, studying the impact of ships continuing to increase in size to all actors involved in the network would be a “win-win” to future research.

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APPENDIX

Annex 1 – Interview Script

As part of the Master in Management and Industrial Strategy at ISEG and based on the master's thesis - "The impact of technologies Industry 4.0 and sustainability on maritime container transportation network", the primary data was collected through semi-structured interviews. The following interview script seeks to understand the impact of technologies of Industry 4.0 and sustainable solutions on maritime industry, from an interaction and network approach.

Networks and Business Relationships

1. What are the main characteristics that a partner should have when part of a relationship, in order to establish a sustainable long-term relationship? Why? Can you give examples of what made a partner continue to collaborate with your company? Have you ever felt distrust from one of your partners?
2. What are the biggest challenges associated with being part of an alliance, relationship or partnership? How did you manage to overcome these challenges? Give examples.
3. When one of the parties disagree with another, how can conflict be avoided? Can you give examples of a situation where one of the parties disagreed, and how they managed to overcome the situation.
4. Based on the company that you work for and considering that your company belongs to the 2M Strategic Alliance (MSC + Maersk), do you trust in the partner that belongs to the same alliance? Why? What are the positive and negative points that stand out?
5. Based on the company that you work for and considering that your company belongs to the Ocean Alliance Strategic Alliance (Cosco Shipping, OOCL, Evergreen, CMA CGM), do you trust in the partner that belongs to the same alliance? Why? What are the positive and negative points that stand out?
6. If you had the opportunity to choose a company from other alliance, which one would you choose? Or would you keep the same companies that belong to the same alliance? Why? What points do you consider relevant about the partners you choose or did not choose?

Industry 4.0 and Digital Transformation on Maritime Container Transportation Network

7. In recent years, maritime supply chains have become more interrelated and international, ensuring a greater proximity between all parties involved. Do you believe that technologies of I4.0 are an element responsible for leveraging this growth? How? Give examples.
8. Currently, technology and maritime transport go “hand in hand”. What are the critical factors or challenges that you consider fundamental to foster this relationship? Why? Give examples.
9. In your perspective, maritime transportation is one of the key sectors for digital transformation? Why? If yes, what are the positive points to consider that is a key sector for digital transformation?
10. Considering that the use of technologies of I4.0 will be a trend in this sector, what changes do you consider that will be necessary to implement? Why? Give examples.
11. Are technologies of I4.0 a factor that can enhance relationships, partnerships or alliances? Why?
12. What are the most promising technologies for the maritime container transportation network? How are these technologies being implemented in practice? Give examples.

Sustainable Practices on Maritime Container Transportation Network

13. Can technologies of I4.0 be used to promote sustainability of maritime transportation? Is there a relationship between technology and sustainability or they are independent variables? Give examples.
14. Is sustainability considered a critical issue in maritime container transportation sector? Why?
15. Maersk is considered a pioneer in the use of new technologies and responsible for adopting sustainable practices to support the reduction of greenhouse gas emissions (GHGs). Can you mention what your company is doing in terms of technological field to mitigate environmental impacts?
16. Maersk and Volvo Group came together to create environmentally friendly solutions (e.g. investment in Volvo electric trucks). Do you consider that

establishing this type of partnership is essential to support the industry in the field of sustainability and create new environmentally friendly solutions? How? Do these solutions involve incorporating I4.0 technologies? Give examples.

17. Ships emit various polluting gases such as SOx (sulfur oxide), NOx (nitrogen oxide), PM (particulate matter) and CO2. Is the adoption of renewable energies such as solar, wind energy and/or the use of biofuels, and the practice of slow steaming viable options for this sector? What benefits and challenges might be associated with this?
18. In this new digital world, companies need to adapt to this new paradigm. MSC, for example, believes that the electronic bill of lading (E-BL) are an original electronic document that offers a more efficient, safe and sustainable alternative. There are no longer any errors or delays between exporters, agents, banks. Do you consider that is a sustainable practice that should be reconsidered by all companies in the maritime container transportation sector? Mention advantages and disadvantages.
19. Regarding the future, what does the company propose in terms of sustainable solutions?