Chapter 1
Port Dada Integration: Opportunities for Optimization and Value Creation

José Luís Cacho
https://orcid.org/0000-0001-7854-871X
Port of Sines, Portugal

Adalberto Tokarski
National Waterway Transportation Agency, Brazil

Elizabete Thomas
National Waterway Transportation Agency, Brazil

Valentina Chkoniya
https://orcid.org/0000-0003-1174-3216
University of Aveiro, Portugal

ABSTRACT

The maritime supply chain is growing in complexity. Ports are at the crossroads of many activities, modes, and stakeholders, and are actively becoming digital hubs. Today, digital and physical connectivity go hand in hand. The port could benefit from taping the opportunities arising from digitalization and data integration since it helps to leverage external knowledge, engage stakeholders, create new decision-making anchors, lower the risk of certain investments, boost productivity and cut costs, and accelerate greening and digital transition, generating possibilities for just-in-time operations and optimizations. The chapter aims to apprehend the use of data science in the port sector. The state of the art in Brazil and Portugal are different. Even inside Brazil, there is no homogeneity of ports in the usage of digital infrastructure, cloud computing, or artificial intelligence. The existing inequalities hinder general co-operation between nations but, at the same time, reveal opportunities to approach specific nodes in the international supply chain.

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INTRODUCTION

The present work is an exploratory study that aims to understand the application of data science in the port sector. The purpose, at first, is to provide information about the state of the art in two selected countries and then is to inform how it is possible to integrate data between ports from different nations to fill existing knowledge gaps. Information is currently generated in distinct regions or points in the supply chain, and it is necessary to identify a way to connect it systematically.

Another goal is to gather information about what would be the gains from these processes. Initially, the automation of routines with the integration of different systems is envisaged, which would result in resource savings, aid to decision-making processes, reduction of waiting time in ports, and the decrease of processes and goods costs. What other port challenges can be faced via data integration? Cooperation with other stakeholders will also be crucial to find workable solutions for issues like greening the shipping sector or the digitalization of the port ecosystem. According to European Sea Ports Organisation (ESPO), by teaming up, ports can leverage external knowledge or lower the risk of particular investments (Deloitte & ESPO, 2021). The study intends to trace a path that, later, can be followed.

After analyzing the trends on supply chains and the uses of machine learning in maritime logistics (which encompass Digital Supply Chain, Digital Ship, and Digital Prots), this chapter describes the current scenario in Brazil and Portugal. Survey the types of information produced by their ports and study the possibility of data exchange between them to identify the potential gains and challenges faced with data science.

This chapter aims to make an important locus in the global supply chain visible: the harbor. Several players operate in it, and it is hard to define, among the myriad of data produced, which ones can be made available and can optimize the system or bring tangible benefits to commercial exchanges. The scope of the present work is, therefore, bold. It is intended, in the end, to name the obstacles, assess their impact on the exchange of goods, and outline strategies to overcome them.

In summary, the authors seek to translate the complex reality of the sector into words and identify possible improvements resulting from data exchange in a systematic way. As a case study, the possibility of integration between selected Portuguese and Brazilian ports will be explored. Subsequently, future challenges in this context and possible lines of research will be outlined.

Background

There are more than 7500 ports worldwide that together accommodate the vast majority of world trade volumes. According to the United Nations Conference on Trade and Development (UNCTAD), maritime transport is the backbone of the global supply chain since the international shipping industry is responsible for the carriage of around 90% of world trade (UNCTAD, 2020). Shipping is a global service industry that, by general recognition, provides the lifeline of international trade. Suffice it to say that, due to the morphology of our planet, most international trade takes place by sea (Haralambides, 2019; Langen, 2020). However, essential to note that UNCTAD estimates that the operation of merchant ships itself contributes about US$380 billion in freight rates within the global economy, equivalent to about 5% of total world trade.

In this context, seaports are an essential spot in the global supply chain. Seaports are economic assets and value-adding logistics nodes with complex activity, comprising transactions related to cargo movement, whether in the transport or loading and unloading of vessels and which, if not responsibly

managed, can become a bottleneck in the supply chain. While cargo-handling operations form the core of ports, modern seaports have become logistics and industrial clusters, in addition to transport nodes (Langen, 2020; Parola, Satta, Notteboom, & Persico, 2020). As technological innovation, social transformation, and consumer behavior threaten firms' traditional boundaries, logistics need to adjust and adapt to new and emerging challenges, costs, and risks (Cacho, Marques, & Nascimento, 2020). Ports, however, are not an end but a means of passage. Being part of both more extensive transport and logistics supply chains and being a cluster of companies and businesses active in the sector, ports are in a unique position to fully grasp the potential generated by these new high-tech developments (Deloitte, 2021).

As long as humankind has been using water as a means of transportation, ports have served a critical purpose, permitting the transfer of goods and people from water to land. This unique role as a physical hub for freight flows has given ports a unique and longstanding role in information flow. In fact, Phoenician documents, dating from 1110 B.C., record trade transactions within the Phoenician network of Mediterranean ports (1). In many ways, this ancient network of ports coupled with a recordkeeping system could be considered an early form of geographically bounded information hubs in global supply chains (Srour, Oosterhout, Baalen, & Zuidwijk, 2008; Stopford, 2009). Ports are dynamic objects that constantly renew their technical systems according to the productive logic of each historical moment (Oliveira & Lima, 2016). Ports are growing in complexity. They are at the crossroads of many activities, modes, and stakeholders. They are essential multimodal nodes, hotspots for industrial activity, hubs for information, clusters for blue growth, etc. (Deloitte & ESPO, 2021). Modern maritime equipment constructors, ship owners and agents, transport and logistics companies, and port authorities collect enormous amounts of heterogeneous data at an unprecedented scale and pace (Herodotou, Aslam, Holm, & Theodossiou, 2020). Today port environments have become a locus of data generation and concentration. (Inkinen, Helminen, & Saarikoski, 2019). Technology is the most prominent force underlying change. Emerging trends – such as big data, data analytics, robotics, and artificial intelligence – show new means of supply chain coordination, other than the traditional hierarchical structure – in many instances, a chain of command – within the firm (Cacho et al., 2020). Areas of focus include establishing a vision for the future of maritime transport; identifying the innovative technologies, business models, and policies that will drive change; overcoming barriers to innovation; and establishing governance structures at the global and national levels to foster the innovations that our societies will need for a more sustainable and better performing future transport system (Rodrigue, 2010). Technology is the most prominent force underlying change. Ports dimensions have become intricate partner networks that include port authorities, terminals, shipping lines, trucking, logistics companies, and off-dock storage providers (Vanelslander & Sys, 2020). To be truly effective, stakeholders have to do more than adopt these technologies on their own. Instead, they must embrace platforms that make it easier for stakeholders to work together to promote the efficiency of the overall ecosystem (Delenclos, Rasmussen, & Riedl, 2018). "Platforms" are a term coined where many actors come together to share information and data on their activities. Within the port industry, 3 types of platforms can be distinguished (Deloitte & ESPO, 2021):

1. Port community systems
2. Cargo community systems
3. Terminal operating systems

Platforms increase efficiency by reducing paperwork and lowering the administrative burden. Nevertheless, producing and collecting data is not enough. In addition, by sharing real-time information, they

allow for increased transparency in the ecosystem and value chain, generating possibilities for just-in-time operations and optimizations (Deloitte & ESPO, 2021).

It is necessary to use them pragmatically to optimize flows, increase trade, and add economic value to related activities. For this, it is essential to connect, collect, monitor, monetize and optimize information (The Economist Intelligence Unit, 2020). Supply chain connectivity has the potential to become more robust. In this process, communication between different links in the supply chain is improved, processes are monitored more efficiently, and, consequently, operations are enhanced (Buxbaum, 2020). According to Ward and Bjørn-Andersen (2021), collecting and recording information that supports trade and the development of supply chains is not new: however, sharing that information is a much newer phenomenon (Ward & Bjørn-Andersen, 2021). Building a relationship with the maritime supply chain partners is imperative for organizations to survive and remain competitive (Osobajo, Koliousis, & McLaughlin, 2021).

Given their neutral position in both the supply chains and port ecosystem, ports are the perfect spider in the web to manage the digital oceans of platform data sharing (DNV GL, 2020). The amount of information generated by ports is constantly expanding as their applications. Data sharing between ports from different countries is still incipient and challenging (Lind, 2018). This challenge is also an opportunity for progress. Investing in digital infrastructure and new skills related to artificial intelligence, machine learning, and data science is a part of a new strategy in which new productivity levels can be achieved, contributing to improving efficiency at the various nodes along the maritime transport chain (Figure 1). Decision making in the industry can be improved by digital technology (Lind, Michaelides, Ward, & Watson, 2021)

Data use and sharing can engender significant opportunities to obtain new revenues, contribute to the identification of technological solutions to new or recurring problems and increase the competitiveness of the economic agents. With the generated knowledge, it becomes possible to identify choke points and business opportunities.

Creating value from data in maritime logistics depends on the data itself, the increasing maritime connectivity, the use of cloud computer algorithms, and the usage of machine learning. Data is the primary constraint to be faced: the data available must be sufficient in amount (quantity) and have a certain quality. Information will only create value if its amount is large and representative of the problem it is intended to solve (Kretschmann, Zacharias, Klöver, & Hensel, 2020).

Figure 1. The process of creating value from data

The use of machine learning in maritime logistics, in turn, comprises the advances in the Digital Supply Chain, the use of Digital Ships, and the improvement in Digital Ports (Kretschmann et al., 2020).

Supply chains are becoming more digital in recent years. The use of technological resources is being encouraged, and innovative ideas are being welcomed. Nowadays, it is possible to purchase raw materials, for example, without having to visit its producer, track the shipment throughout the supply chain, knowing in which container and in which vessel it is, its route, and its estimated time of arrival in each Port. Also, control and optimize stocks more efficiently through computer systems and benefit from more excellent connectivity between all stakeholders involved. This digitalization results in more transparency in the entire distribution network, taking full advantage of processes automation and cost reduction, providing better customer service, and providing digital data storage (Vieira & Fialho, 2020).

Shipping companies, in turn, are using more automated systems (Daniela, Calvert, Clark, & Parkhurst, 2019). Data is being collected during operations, and precise positioning systems are in use. These innovations help, for example, shipping companies optimize their fleet management through predictive maintenance since they have more information about cargo handling and fuel consumption. Data readings might suggest defects and alert the necessity of a certain kind of support. Besides that, routes can be better planned. Ultimately the decision-making process is optimized as well as the security at sea (T. E. Notteboom, Parola, Satta, & Pallis, 2017).

There are constraints to port management. The changing environment and the volatility in freight markets are stressing port operations, introducing structural changes in logistics and new distribution patterns. The large number of public and private stakeholders that interact in transport operations and the logistics of international trade generate coordination problems, requiring a considerable amount of information to be exchanged (Cacho et al., 2020)

A new logistics mantra could be spelled as "get the information flowing" (Cacho et al., 2020). Ports are only one node in the maritime supply chain, but an essential one (Brooks, Button, & Nijkamp, 2002; Carbone & De Martino, 2003). They must be able to adapt to the fast and changing conditions of international trade, ensure efficiency and safety in the handling and storage of cargo, enable the offer of value-added services, and be connected to other transport modes, such as highways, railways, and air transport in a cost-effective way.

Ports are evolving from traditional to digital ones. These last ones are converted into real technological parks and innovation environments (Heilig, Schwarze, & Voss, 2017). Nowadays, technology plays a significant role in them. The first step on becoming a digital hub is to promote intra-port coordination – through the adoption of computerized systems - and then build a connected network of ports within its country of belonging – through the systematic exchange of information. Ship to port and port to hinterland communication must be enhanced (Heilig, Lalla-Ruiz, & Voss, 2017; Kretschmann et al., 2020). Finally, connecting ports from different nations is an indispensable way to optimize and create value throughout the entire supply chain (Table 1).

The maritime industry is incrementally counting on the usage of data science. As impacts on the global supply chain, several benefits can be listed: new levels of efficiency, trade optimization, incident predictions, cost reductions, quality control improvement, reduced downtime and workloads, reliable forecasts of the movement of goods, simplification of information exchange, among others. Logistics then become more complex and dynamic.

Amidst this complexity, one cannot ignore the new realities that pressure economies like the pandemic or the growing consolidation of the Asian countries' productive sector. These changes in the contemporary world have repercussions on supply chains and logistics worldwide, motivated by people's heavy dependence on goods flows globally. Interruptions or changes in these flows significantly impact, demonstrating their vulnerability in an increasingly globally integrated world.

Table 1. Usage of machine learning in maritime logistics – loci of application (adapted from Kretschmann et al., 2020)

	Digital Supply Chain	Digital Ships	Digital Ports
What it is	• The evolution of the supply chain, adapted to technological resources and innovative ideas from the manufacture of a product to its delivery to the final consumer.	• A set of various trends in the digitalization of shipping companies.	• The evolution of traditional ports, which are converted into technological parks and innovation environments.
What it comprises	• Raw material purchase. • Movement of goods. • Storage. •Transportation. • Other support activities.	• The use of precise positioning systems. • Systematic data collection during operations.	• Coordinated action between government, companies, and universities. • Intra port coordination. • Enhanced ship-to-port communication. • Improved port to hinterland connection. • Connected network of ports.
Its benefits	• Greater connectivity between stakeholders. • Process automation. • Optimization of stock control. • Digital data storage. • Cost reduction, • Better customer service.	• Better fleet management. • Optimization of processes, such as fleet maintenance, cargo handling, fuel consumption, and route planning. • Optimization of decision-making processes and security.	• The possibility of port data sharing. • New levels of productivity. • Time reduction of operations. • Gains in safety and environmental sustainability. • Automated and data-driven decision-making.

As a result of all of this, it is possible to observe significant changes in consumer behavior, translated into a reevaluation of production and logistic processes and accelerating digital transformation processes. These changes will allow a more intelligent communication in a global network concept; there sharing, integration, and management of data throughout the chain will be one of the determining factors of change (Carbone & De Martino, 2003; Vanelslander & Sys, 2020; Venkatesh, Zhang, Deakins, Mani, & Shi, 2020).

THE USE OF DATA SCIENCE IN BRAZILIAN AND PORTUGUESE PORTS

The relationship between Portugal and Brazil is unique thanks to deep historical and cultural affinities. Its economic dimension - one of the ten largest economies in the world - makes Brazil one of the most important countries for the internationalization of Portuguese companies, but the volume of trade and reciprocal investments, while significant, still has excellent potential for further growth. In addition to being bound to each other by a common language, the two countries have a privileged relationship since it is in their mutual interest to reinforce trade and investment flows. The relationship between Portugal and Brazil is framed by the Treaty of Friendship, Cooperation, and Consultation (*Brazil Ctry. Rev.*, 2021; Portuguese Government Portal, 2021). Geographical distance plays a much lesser role today as a determinant of trade between countries, and it is being replaced in trade models by the concept of economic distance, as this is proxied by ocean freight rates (cf. transport costs). Ports today, technical-scientific-informational period, objects are essential to the smooth flow of goods across several territories and thus fundamental to the business enterprises and states. To meet the requirements of the globalized world

and the growing movement of goods in their docks, ports are modernized. In turn, the advancement of technical systems in ports contributed to greater flexibility in the movement of goods and the reduction of waiting time of cargo and ships on the docks (Oliveira & Lima, 2016). These developments have expanded the international markets and have improved the international competitiveness of exporting countries, and it has facilitated the industrialization of many of them around the world (Haralambides, 2019). Connected technologies are moving ports into the digital age and helping to boost productivity and cut costs (Delenclos et al., 2018). Digital and physical connectivity go hand in hand (UNCTAD, 2019).

The Brazilian Context

According to the Brazilian Infrastructure Ministry Homepage (Ministério da Infraestrutura, 2020), there are 36 public seaports and 39 public river ports in Brazil. Besides them, there are approximately 128 private use terminals. These last ones are port facilities operated under the government's authorization and located outside the public port area.

From north to south, the situation from these different ports varies a lot: there is no homogeneity between them. On the one hand, there are harbors devoid from the use of technology where humans carry out many manual steps and where data is only available in sparse documents. On the other hand, there are public ports and private use terminals that obtain productivity gains each year due to the massive use of technology and improve efficiency, speed, and accuracy. The reality along the coastline is quite complex (Mendes Constante, Langen, Vieira, Lunkes, & van der Lugt, 2018).

However, it is possible to state that all terminals that carry containers – regardless of whether they are public or private – have certain harmony among Brazilian ports. They are all automated and highly efficient. All of them invested, in recent years, in digital infrastructure, news skills and obtained new levels of productivity. In general, one may say that the treatment of containers is different from that of general cargo since the first ones are responsible for moving goods with higher added value. Therefore, Brazilian container terminals have stricter control over their cargo (Vedan & Thomas, 2019).

Because of this disparity between ports that handle containers and ports that handle other types of cargo, the existing data is not always good in terms of quantity or quality. Thus, it is hard to talk about an overall system that coordinates information between all the existing ports in Brazil, a country whose coastline is 7,491 kilometers long. Intra port coordination is still lacking (Rodrigues, Ferreira, Murta, & Murta, 2017).

In order to fill the present gap, there are initiatives promoted by the Federal Government that aims to collect data on port operations and their respective prices and generate information from them. One of these measures is promoted by the National Waterway Transportation Agency (ANTAQ - *Agência Nacional de Transportes Aquaviários*) - a Regulatory Agency - and consists of a system called "Port Performance System" which is considered as a strategic tool for planning and a significant data source for the generation of statistics and sector indicators (OECD, 2019). More than collecting data, the system aims to produce information that serves as a tool for a range of activities (Table 2).

Table 2. The purpose of the "Port Performance System"(adapted from ANTAQ, 2019)

Generate information that serves as tools for:
• Operational management at the terminals of each public Port or private use terminals, detecting possible deficiencies and dysfunctions and enabling diagnostic and correction actions. • Port development planning by comparing port cargo handling with capacity data and facility and equipment utilization levels, detecting trends and needs to promote expansions and improvements. • The monitoring of results derived from strategic measures and actions adopted by the Federal Government or by Port and terminal managers and operators. • Public knowledge and control of the performance and tariffs of port services offered, allowing a complete assessment of their quality and reflections on total transport cost. • Regulation of the economic activity. • The achievement of standards and comparative parameters of performance and tariffs between various facilities and terminals.

In this system, public ports and private use terminals provide data upon:

1. **Mooring:** place, International Maritime Organization (IMO) number, shipowner's nationality, operation type, etc.
2. **Temporal Data:** date/time of vessel's arrival, estimated date/time of mooring, date/time of mooring, date/time of unberthing, date/time of start/end of the operation.
3. **Stoppages:** date/time of start/end, reason (rain, anchoring without forecast of mooring, lack of electricity, strike, port equipment break, accident, tide, and others).
4. **Monetary Data:** amount paid for the use of waterway infrastructure, terrestrial infrastructure, mooring fare, equipment fare, the amount paid for internal transportation and labor, other rates.
5. **Cargo:** company responsible for the port operation, type of cargo (solid or liquid bulk, general cargo), full or empty (if containers), Bill of Lading number, the direction of cargo movement (loading or unloading), country of origin/destination, quantity, gross load weight.
6. **Types of Cargo Operation:** support, supply, long-distance navigation (between ports from different countries), short sea shipping (between ports in the same country), cargo transfer, etc.
7. **Containerized Cargo:** cargo code (related to the cargo moved inside the container), Bill of Lading number, net cargo weight, and container identification (alphanumeric field with 11 digits).

Another important initiative promoted by the Federal Government is the "Paperless Port" (PsP – *Porto sem Papel*) system, which automated the provision of information necessary for the stay of vessels in Brazilian public ports. The PsP aimed at improving port efficiency by reducing bureaucracy and the volume of redundant activities performed by agents involved in releasing, loading, and unloading operations (Governo do Brasil, 2021; Ministério da Infraestrutura, 2018).

Its main objective is to gather data and documentation to speed up the analysis and release of goods. Many different intervenient authorities are involved in using the system, such as the Port Authority itself, the National Health Surveillance Agency, the Maritime Police, the Ministry of Agriculture, Livestock and Supply, Brazil's Navy, and the Customs Authority. Among the advantages of its usage are standardization of information, reduction of bureaucracy, rationalization of procedures, agility, predictability, and transparency (Fioresi & Guimarães, 2016; Rodrigues et al., 2017).

As said before, a harbor is an important node in the supply chain and a great data generator. Although historically, traditional ports have been making decisions based on experience and the country's economic context, the value of data-based decision making is unquestionably and an essential component

to improving performance. Data-driven decision-making assumes the function of combining, analyzing, and visualizing data from different sources and providing it as an input for decision-making processes (Kretschmann et al., 2020).

There is, although, a considerable gap between theory and practice, especially in Brazil. With its vast coastline, there is a myriad of different economic agents involved in port activities. Public ports and private terminals and ports that handle containers and ports that handle other types of cargo present vastly different dynamics along the shoreline. It is not easy to homogenize and consolidate the distinct data provided (Vieira & Fialho, 2020).

If intra-port coordination is still lacking, there is a long way to go in order to promote a connected network of ports with a different country.

The Portuguese Context

Portugal has a long maritime tradition, and although its coastline is not as long as the Brazilian one, it is very well developed. Portugal has 14 continental ports divided between the ones dedicated to cargo handling and the ones dedicated to fishing and recreation. Among them, the Ports of Sines, Viana, Leixões, Aveiro, Figueira da Foz, Lisbon, Portimão and Setúbal are prominent. Besides these, there are important ports in the Azores Archipelago and the Madeira Archipelago.

In 2017, through Resolution of the Council of Ministers no. 175/2017, a national strategy was approved in order to increase the competitiveness of the continent's commercial ports network. With this program, the country intends to invest in the maritime economy, targeting boosting economic activities at sea, creating business opportunities that lead to job creation, and increased exports, maximizing the dynamics of maritime transport. This strategic vision is based on three pillars: i) Portugal as a global logistics platform that generates value; ii) creation of a business accelerating port hub capable of attracting investment and supporting the internationalization of the Portuguese economy; and iii) Portugal as a hub for liquefied natural gas (LNG) in the Atlantic (DRE, 2017).

In order to achieve this strategic vision, each Portuguese Port must combine data from different sources, systematically forecasting events or potential outcomes with predictive analysis, providing a new level of port management. Ports ought to become more digital and sustainable, abandoning their traditional profile. There is a large amount of data produced by Portuguese ports, and they can be divided into the following categories:

1. **Port System Assets:** comprising infrastructure, equipment, vehicles, buildings, vessels, communication networks, hardware, software, and other applications. These data characterize the assets that make up a port system.
2. **Cargo Operations:** data concerning the movement of goods and the information necessary to plan and control operations at the Port and between ports.
3. **Vessel Operations:** data concerning the information necessary to plan and control ship handling operations in ports.
4. **Access:** data related to the control and flow of people and goods in the port area.
5. **Multiple Statements:** general data corresponding to the necessary formalities for the entry and departure of ships and goods from the Port.
6. Maritime Traffic at and near the Port.
7. Meteorology, Waves, and Tides.

8. Energy Consumption and other utilities.

Table 3. Axes of action in the promotion of Digital Ports (adapted from Miranda, 2020)

	Axis 1	**Axis 2**	**Axis 3**
What it is	• Digitalization	• Decarbonization	• Accessibility
What it comprises	• The fifth generation of mobile communications (5G) applied to ports. • Better and faster connectivity.	• The replacement of traditional propulsion fuel with alternative energies.	• The strategy of gaining scale to receive larger ships and optimize the flow downstream.
Its application	• In the monitoring processes of containers and goods. • In loading and unloading operations.	• In ships. • In ports. • In general operations.	• In the navigation channels. • At terminals and road or rail access.
Its benefits	• Integrated information processing. • Efficiency gains in port processing. • The workforce may be progressively supplemented by port computer operators. • Stricter enforcement.	• The storage and processing of the generated waste will improve.	• Elimination of bottlenecks. •Better intermodality. • Simplification of the entire supply chain.

European Commission considers a need to promote high-performance seaport activities through strategic actions to connect seaports to the trans-European network, modernize port services, attract investment, promote social dialogue, improve the environmental profile, and encourage innovation. Furthermore, through the Directive 2010/65/EU, the EU aims to increase the opportunity to facilitate trade and administrative barriers through harmonization and standardization of the European Seaports Organization. Entities of the State sphere carry out the implementation of the Directive. Member States show a low priority to exchanging information between the Member States, and the majority has not taken any action in this direction. Concerning the Single Window Environment development model, the mixed model is adopted in most Member States (Jose & Fernandes, 2020; Linke, 2012).

The term Single Window Environment was introduced by World Customs Organization (WCO). Based on the definition presented in Recommendation No. 33, and is widely used in the area of international trade as "an 'intelligent,' facility that allows parties involved in trade and transport to lodge standardized information, mainly electronic, with a single entry point to fulfill all import, export, and transit-related regulatory requirements" (WCO, 2021).

It was decided that in Portugal, the Logistics Single Window (JUL - *Janela Única Logística*) would be developed considering all the necessary legal and operational requirements according to the EMSWe (European Maritime Single Window Environment) concept. The JUL is currently being developed by the Ministry of the Sea, through the Directorate-General for Natural Resources, Safety and Maritime Services (DGRM) and all the Portuguese Ports, together with a broad group of partners (Projeto JUL, 2021).

JUL is a digital ecosystem that allows data sharing between port authorities and other national authorities and organizations at the level of the European Commission. Port cooperation for the Portuguese is not something new. The platform is already contributing to making Portuguese ports less bureaucratic and paperless, with noticeable productivity gains. Moreover, as information is shared among different agents, a degree of data homogenization is achieved. Besides that, associated with the technological platform, a legal framework guarantees consistency, management, and operation in a coordinated and

harmonized way. It is possible to identify that intra-port coordination in Portugal and a connected network of European ports already exist.

Nowadays, the focus is on endow the country with "new generation ports" or Digital Ports, fully automated and environmentally friendly. According to Miranda (2020), to achieve so, actions must be focused on three axes (Table 3).

Portuguese ports are investing in digitalization, decarbonization, and accessibility (Portugal.EU, 2021). Through the first one, new investments are being made in telecommunication to achieve better and faster connectivity. The results are integrated informational processes, gains in efficiency, progressive replacement of human labor by port computer operators, and the possibility of carrying out more detailed and rigorous inspections (Czermański, Cirella, Oniszczuk-Jastrząbek, Pawłowska, & Notteboom, 2021; Notteboom, Lugt, Saase, Sel, & Neyens, 2020). Through the second one, Portugal is aligning itself with the trend of making ports environmentally friendly. This step is an important one to promote Portugal as a global logistics platform that generates value. The accessibility axis is intended to work on the existing supply chain's chokepoints, facilitate a better intermodality, and boost the simplification of the entire supply chain (DG MOVE, 2019).

The country wants to shift its port model from a traditional to a digital one and transform them into genuinely international ports. For this to happen, it is necessary to invest in technological infrastructure and new partnerships. In this context, it makes sense to search for partnerships with countries like Brazil, with which it shares a common history (in addition to the Portuguese language), and in which the largest Port in Latin America is located.

Other broader initiatives have already taken place, such as the "Portuguese Language Ports Association," which aims to ensure the defense and promotion of its members' interests and contribute to the port development and modernization. Its members are Angola, Brazil, Cape Verde, Saint Thomas and Prince, Guinea-Bissau, Equatorial Guinea, Mozambique, Portugal, East Timor, and Macau (China).

In this context, data is a strategic asset for the Portuguese ports. On the one hand, they constitute the basis of the information; on the other, the information constitutes knowledge. Its use in a broader way is already frequent in the country.

Given its unique nature, the data has assumed a predominant role in preparing information to support the decision and improve business processes. Many authorities take part in the process of data analysis and generation of information. Some of the information produced by ports is submitted to official entities in compliance with obligations. The National Institute of Statistics stands out, and the Budget Support Technical Unit, the Mobility and Transport Authority, the Transport Mobility Institute, and the General Direction of Natural Resources.

The Possibility of Port Data Integration

The world in which ports are tasked to facilitate global transport flows and create stable, resilient port infrastructure has become far more complex over the past decades. This has not lessened port authorities' core role and function but only added to their complexity. Port authorities are still neutral players in an increasingly competitive market environment, improving connectivity, facilitating private companies, attracting investments. However, they are also developing new roles to serve customers better, increase added value to customers, and meet general interest obligations. These evolved and new roles are sometimes a direct result of increased demand for public tasks, such as more focus on sustainability or a need for a neutral innovation facilitator. In other cases, they have become a business opportunity (although never

in competition with the port clients), for example, through investment in renewable energy generation or the development- and sale of in-house digital tools. (Deloitte & ESPO, 2021).

Traceability is at the core of modern supply chain management. For this to happen, information must be easily shared and freely exchanged amongst participants. The premise underneath the idea of port data integration is the hypothesis that a large amount of data is available. In a dynamic environment, intense IT technologies, standards, and harmonization processes are essential. In turn, better supply chain coordination requires further integration. This reorganization has substantial implications for management from risk exposure and cost efficiency (Cacho et al., 2020).

A multidimensional conceptual framework for port logistics integration is proposed to incorporate the role of the three infrastructural variables emerging from the recent developments in the port logistics environment (Grifoll, Ortego, & Egozcue, 2019). The literature review has found the logistics process and operations, information integration, value-added services, logistics practices, organizational activities, resource sharing, and institutional support as influential factors in logistics integration (Alavi, Sayareh, Fei, & Nguyen 2018).

In the case of Brazil, it was possible to detect that although ports are a spot in the supply chain that engenders lots of information, not all ports in Brazil are at the same pace. With a vast coastline, there are disparities between harbors, but there are initiatives from the Federal Government to homogenize and centralize information. It is crucial to notice that the process of port modernization in Brazil started to took place in 1993 with the new legislation on ports and, since then, the different harbors have been modernizing at a special rate (Rodrigues et al., 2017).

Portugal, in turn, is a much smaller country with a tremendous and traditional vocation towards the sea. The different continental ports already share information at the same time as they share information with European Authorities. The experience with cooperation seems to be more sophisticated. Meanwhile, Portugal considers South America a strategic region for its business and hopes to increase maritime trade with Brazil.

In order to achieve the intended port integration between countries, homework must be done before: the existing intra-port cooperation must be more elaborated. If, in theory, it all may seem simple and obvious, there are many to overcome in practice. One obstacle seems to be the absence of homogeneity between Brazilian ports, as said before. Another one is that many data provided by Brazilian ports to authorities are protected under business confidentiality. It means that not all information generated is available and can be shared.

Despite the constraints, Portugal can become Brazil its primary gateway to Europe. Located at the confluence of important international maritime routes, taking advantage of its Euro-Atlantic centrality, Portugal emerges as a hub for the European market with developed networks of logistics and transport infrastructures. It is also an alternative to other congested European ports. The European country can also contribute to Brazilian ports with its experience in terms of innovation.

Brazil, in return, is a much bigger economy, and this gap among countries can be seen as an opportunity (not as another obstacle) that can generate gains for both nations. Table 4 demonstrates the mismatch between the two economies.

According to data from UNCTAD, Brazilian ports process almost four times more containers than Portuguese ports (1.36% of world share against 0.36% in 2019). The Port of Santos, for instance, is the largest in Latin America and is the most important foreign trade route in Brazil. The South American country is also responsible for a much larger share of world exports (11.19% against 0.35% in 2019). There is still a disparity among economies in terms of merchandise imports, but not as big as the ones

Table 4. Comparison between Brazilian and Portuguese maritime economy in 2019 (adapted from UNCTAD, 2021a, 2021b)

	Brazil	Portugal
Container port throughput	10,982,131.00 TEU 1.36% of the world share	2,920,700 TEU 0.36% of the world share
Number of port calls	29,807.00	13,687.00
Merchandise exports in US$, in the world share	11.19%	0.35%
Merchandise imports in US$, in the world share	0.96%	0.47%
Top 5 partners	China United States of America Netherlands Argentina Japan	Spain France Germany United Kingdom United States of America

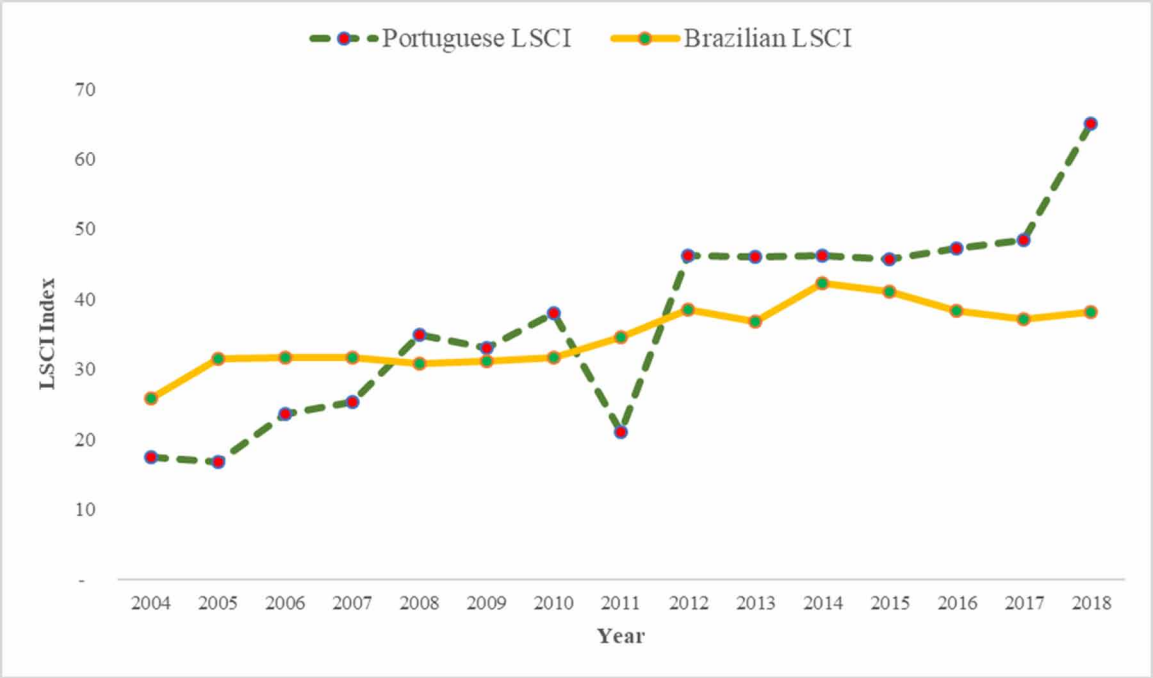
mentioned before. Brazil's economic prominence may be beneficial to the Portuguese and may also be an essential gateway to the regional market. A barrier that must be surpassed is the low connectivity between the two countries. In Europe, the Netherlands is the major Brazilian economic partner. Nevertheless, before it, China and the United States of America play a significant role. Portugal, in turn, has its most important economic partners centered in Europe (UNCTAD, 2021a).

Efficient and well-connected container ports enabled by frequent and regular shipping services are crucial to minimizing trade costs, including transport costs, linking supply chains, and supporting international trade. Thus, port performance is a critical factor that can shape countries' trade competitiveness. Every hour of port time saved by ships translates into savings in port infrastructure expenditure for ports, ship capital costs for carriers, and inventory holding outlays for shippers (World Shipping Council, 2021).

Recognizing the importance of measuring container port performance, UNCTAD developed the Liner Shipping Connectivity Index (LSCI) in 2004 to determine countries' positions within global liner shipping networks; the latest country-level LSCI statistics were published in July 2019. LSCI is generated from five components: (a) the number of ships; (b) the total annual container-carrying capacity of those ships; (c) the maximum vessel size; (d) the number of services; and (e) the number of companies that deploy container ships on services from and to a country's ports. The data are derived from Containerisation International Online (until 2015) and MDS Transmodal (from 2016 onwards). The index is set at 100 to the maximum value of the country's connectivity (UNCTAD, 2020).

Brazil's connectivity index has been constant since 2006. When it was created, as shown in the chart below, but always between 30 and 40 points. Their top ports are Port of Santos, Rio Grande, Rio de Janeiro, and Paranaguá. The Portuguese index had grown substantially since 2006, starting with a lower score than the Brazilian one, reaching 60 points in 2018, when it dropped due to the international economic crisis (Figure 2). Even after the crisis, Portuguese ports' connectivity is higher than Brazilian ports' connectivity. The top ports in Portugal are the Port of Sines, Leixões, Lisbon, and Setúbal. Once again, the inequality between the two countries takes place (UNCTAD, 2021a, 2021b).

Figure 2. Brazilian and Portuguese LSCI (adapted from UNCTAD, 2021a, 2021b)



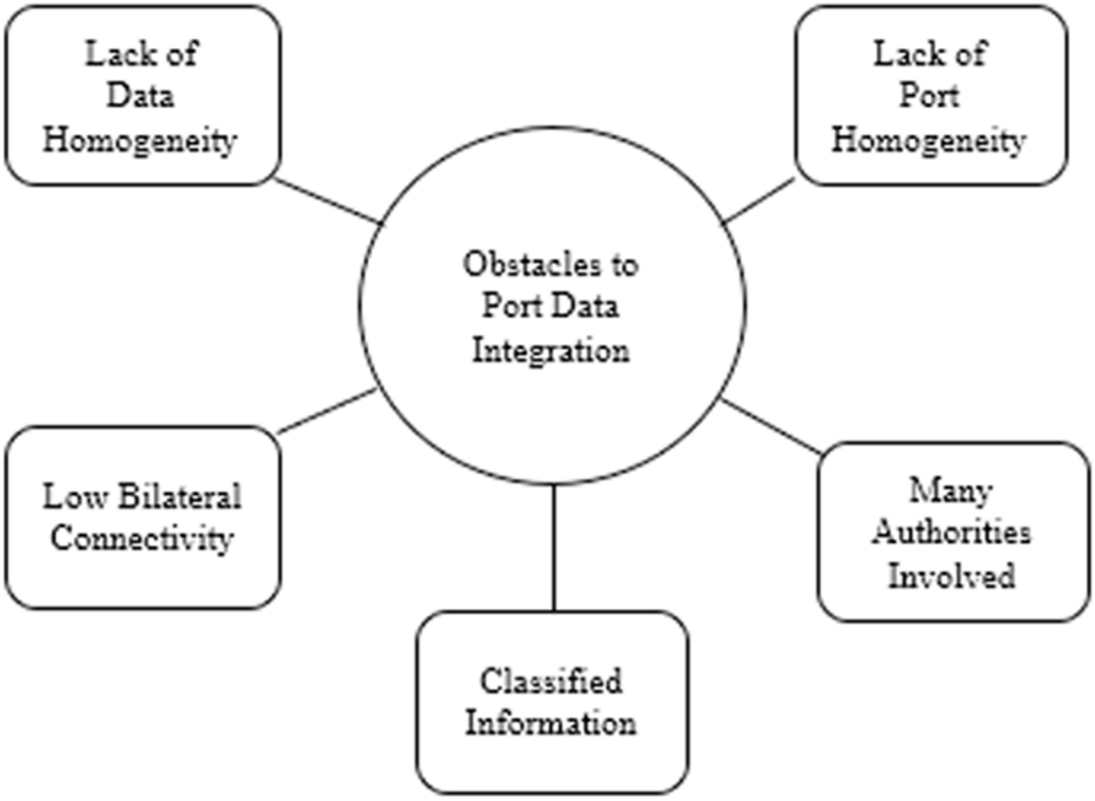
It seems that a vast program of port cooperation and data integration among Brazil and Portugal is still distant from happening since constraints were observed as summarized below (Figure 3). Even inside Brazil, there is no homogeneity of ports in the usage of digital infrastructure, cloud computing, or artificial intelligence. On the one hand, the existing inequalities hinder general cooperation between nations but, at the same time, reveal opportunities to approach specific nodes in the international supply chain. The research purpose is to start the debate about port data integration, its opportunities for optimization and value creation among these two Portuguese-speaking countries. Is it so straightforward to achieve it, or the reality poses obstacles to its realization? What can be accomplished at the current stage of data science application?

Suppose, at first sight, port data integration is seen as a challenge. In that case, it must also be seen as a business opportunity for new revenues, identifying technological solutions to new or recurring problems, and increasing economic agents' competitiveness (McKinsey, 2020).

A start on the way to overcome these difficulties is to start with a less bold project. One thing that can be done is to identify in each country its potentialities. It means: determine which particular Port can start the process. For example, Port of Sines in Portugal, for example, according to the LSCI, seems to be way ahead, with 45,20 points, from Port of Leixões (16,27 points) and Lisbon (16,12 points). In the Brazilian case, ports that handle containers, as Port of Santos (35,79 points), Paranaguá (32,22 points), Rio Grande (30,55 points), and Rio de Janeiro (29,16 points) emerge as promising candidates for a cooperation program.

What can be done to improve a port's connectivity? According to UNCTAD (2021b), "go digital" is essential to enhancing port connectivity since digital and physical connectivity go hand in hand. Just as trade benefits from the latest technologies such as artificial intelligence, the Internet of Things, and

Figure 3. Obstacles on Port Data Integration



blockchain, port and shipping operations would also benefit from taping the opportunities arising from digitalization (UNCTAD, 2021b).

After determining which ports in each country are data-rich and more connected with the international port network, it is possible to draw the desired outcome from the data integration process, frequently characterized as optimization in cost-efficiency, reduced response time, and increased safety. Data interchanging will provide digital intelligence storage for agents involved. From that point, they will detect trends, generate knowledge and identify chokepoints and opportunities.

One example can be sketched. Within the logistics industry, cargo community systems have been quite prominent in the past decade. A lack of relevant and accurate information in the supply of data can result in inefficient processes and other 'hidden costs' such as excessive inventories. By sharing more information, it is possible to optimize these processes and reduce costs. Fast and reliable cargo information systems have become increasingly indispensable for international transport hubs (Deloitte & ESPO, 2021). Imagine if Port of Sines and Port of Paranaguá sign a cooperation term to exchange information about cargo transacted between the two ports. The main objective of this cooperation is to guarantee a better integration among them, increase flow transparency, and ultimately reduce operating costs and time and increase operation security. It is well known that containers are scanned when exported and

imported. Port of Paranaguá inspects 100% of cargo that arrives at the Paranaguá Container Terminal (TCP) and enters the Port's public area.

The scanning operation brings safety to the process, but it requires time and money. The scanned images are sent directly to the Customs Service system, which crosses, in real-time, the captured image with data described in the invoice. In this way, the inspection process is faster and more accurate. The scanner can also detect any type of illicit or smuggled substance, such as chemicals, weapons, drugs, and radioactivity.

If there is an agreement that defines that the container must be scanned only in the Port of origin or destiny with image sharing between ports that subscribed to the cooperation agreement, there would be no need for a redundant operation in two points of the supply chain that costs time and other resources. Besides that, there can be gains in safety since there would be more time and scanners available to "read" other cargo than the same one for the second time.

Although difficult at first sight, port data integration opens opportunities for optimization (like the one described above) and value creation. However, it is vital to have in mind that the steps to be taken must be small and punctual at first.

SOLUTIONS AND RECOMMENDATIONS

The competitiveness of a seaport highly depends on its efficiency, especially in terms of logistics practices, functions, and activities and how all that is integrated with those of the other players in the supply chain (Alavi et al., 2018).

If, on the one hand, the Academy has been focusing on issues concerning data science, artificial intelligence, and cloud computing and there is a wide range of scientific articles and literature on these topics, on the other hand, it is possible to observe that there is still much to be done in this field in the port sector. There are successful experiences in the use of new information technology at specific points in the supply chain. Port of Sines in Portugal and container ports in Brazil are examples of supply chain nodes that use data science and can be considered true Digital Ports. Nevertheless, port data integration between ports from different countries is a more complex process.

Projects that aim for data integration should start more humbly. Instead of thinking big and try to connect two entirely different realities, it is essential to detect which actors can effectively make a difference and contribute to the progress. It is crucial to make an accurate diagnosis and start with a small-scale program. There will be no generic solutions, but each data exchange and integration process must be seen as unique and will face its obstacles and successes.

Furthermore, it is essential to coordinate action between government, ports, and universities to produce possible cooperation arrangements and find creative solutions.

FUTURE RESEARCH DIRECTIONS

Ports are growing in complexity. They are at the crossroads of many activities, modes, and stakeholders. Digitization allows them to cooperate and integrate along the supply chain and optimize, manage, and automate processes. Ports are actively becoming a digital hub, with port authorities as spiders in the web in which all stakeholders are connected and jointly collaborate. This is a central role for port authorities

as neutral players to facilitate data exchange between more commercial players. Dissemination of the effect of port activities and the sharing of data and insights will increase the engagement of the surrounding communities (including the academic and business community) and generate a competitive edge (Deloitte & ESPO, 2021).

The Academic community has already started studies on the applicability of data science, machine learning, cloud computing, and artificial intelligence in the port sector. Some theoretical and generic studies on the subject have already been published lately. What is needed is to start carrying out more practical studies, such as case studies. It is necessary to analyze in the specific case how this application happens.

Initially, it is necessary to carry out case studies of ports at the forefront of this process, such as the Port of Sines in Portugal. This type of empirical research must then be extended to bring state-of-the-art knowledge to different ports, such as those located in Brazil. What initiatives have these ports taken to become Digital Ports? How do they contribute to making digital supply chains more digital? What has been done to promote more excellent connectivity of these ports? These researches are yet to be done.

Only after getting to know the local realities can we outline models of cooperation. These models will be helpful in the sense that they will identify which results can be expected, achieved, and measured. In other words: what can be done in practice and what belongs to the world of theory. How to measure the gains on security, time, cost, and productivity derived from this integration process? What are the indicators to be used? They still need to be modeled. This is also a research direction on the topic.

CONCLUSION

The greening and digital transitions combined with the changing global political environment and the impacts of the pandemic create the perfect storm for the port industry. Ports are at the crossroads of these transitions and changing realities. The diverse challenges ahead, the increasing complexity and scale in the sector, push ports to cooperate with other ports: from coalitions on a single project to complete mergers. By teaming up, ports can leverage external knowledge or lower the risk of particular investments (Deloitte & ESPO, 2021).

The initial debates among researchers regarding the state of the art in applying data science in the port sector were marked by enthusiasm regarding its possibilities. When talking about technology, a new world unfolds. The reality is that different actors are at different stages of development concerning this subject: development is uneven. This inequality creates obstacles in cooperation, but it also generates opportunities, not only for business but also for learning.

An observer may think that Brazil and Portugal can quickly enter into cooperation agreements to exchange data and information since both countries speak the same language (Portuguese) and have a centuries-old connection. Nevertheless, when looking at a specific economic sector closely, such as the port sector, inequalities become apparent.

Initially, the coast size of both countries is too divergent: Brazilian coastline is 7,491 kilometers long, one of the longest in the world, while the Portuguese coastline is 943 kilometers long. Therefore, the Brazilian coast has many more ports than the Portuguese one. The rich Brazilian diversity in data homogenization and the construction of an efficient communication system between ports can hinder the process. Despite the size of the national port sector, it was observed that those ports that handle containerized cargo have massively invested in technological infrastructures, gained productivity, and

adopted new strategies for insertion in the global maritime network. These agents constitute a possibility for cooperation (Haralambides, 2019).

On the other hand, Portugal is a country with a small coastline, maritime tradition, and a strategic position, becoming a bridge between the Atlantic, the European continent, and the African continent. Their reduced number of ports compared to Brazil has made cooperation possible between them and other supranational authorities, such as the European Commission. The cooperative processes of which the country is a part already have a more sophisticated framework.

After the initial enthusiasm about the myriad of possibilities for applying data science in the port sector, it was observed that the development of the subject is uneven among the countries under study and within each of those countries (especially in the case of Brazil). It was concluded that a broad project covering all national ports would not be possible at the moment. It was necessary to realign expectations.

Any port data integration project will necessarily involve identifying those agents who can contribute to the process. In Brazil, for instance, it was observed that not all ports would be ready for this. After this delimitation, it is necessary to determine what is expected from this integration. Security gains? Gain in operational time? New recipes? From this specific cooperation, the process can expand and begin to face the identified obstacles: lack of data homogeneity, lack of port homogeneity, the fact that there are many authorities involved and it is necessary to find a way to cope with them, the use of classified information and the low bilateral connectivity. PsP and JUL are a good base for a start.

Portugal and Brazil have a privileged relationship. Considering that digital and physical connectivity go hand in hand, the process of port data integration has to be considered between the two countries since it is in their mutual interest to reinforce trade and investment flows. Just as trade benefits from the latest technologies such as artificial intelligence, the Internet of Things and blockchain, port and shipping operations would also benefit from taping the opportunities arising from digitalization (UNCTAD, 2019). Port data integration helps leverage external knowledge, engage stakeholders, create new decision-making anchors, lower the risk of certain investments, boost productivity and cut costs, accelerate greening and digital transition, and generate possibilities for just-in-time operations and optimizations.

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KEY TERMS AND DEFINITIONS

Bill of Lading: It is a document issued by the carrier that defines the contracting of the international transport operation and proves the receipt of the goods at the origin and the obligation to deliver them at the destination.

Digital Port: The evolution of traditional ports, which are converted into technological parks and innovation environments. Technology plays a significant role in them.

Digital Ship: A set of various trends in the digitalization of shipping companies.

Digital Supply Chain: The evolution of the supply chain, adapted to the use of technological resources and encouragement of innovative ideas from the manufacture of a product to its delivery to the final consumer.

IMO Number: Numeric field with seven digits corresponding to the code of the vessel according to identification from the International Maritime Organization (IMO).

Logistics Single Window (JUL – Janela Única Logística): This is a digital ecosystem that allows data sharing between port authorities and other national authorities and organizations at the level of the European Commission.

Paperless Port (PsP – Porto sem Papel): The initiative promoted by the Federal Government when the system automated the provision of information necessary for the stay of vessels in Brazilian public ports.

Port Authority: Or Port Administration. Is the entity with jurisdictional power in a specific location to operate ports.

Public Port: Public good built and equipped to meet the needs of navigation, passenger movement, or the movement and storage of goods, and whose traffic and port operations are under the jurisdiction of the port authority.

TEU – Twenty-Foot Equivalent Unit: Refers to the Equivalent Transport Unit. This transport unit has a 20-foot intermodal container size. A 40-foot container corresponds to 2 TEU.