



The impact of port community systems (PCS) characteristics on performance

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ARTICLE INFO

Keywords:

Port community system
Port performance
Effectiveness
Efficiency

ABSTRACT

The purpose of this study is to assess the effect of the port community system (PCS) and its influence on port performance. The techniques of principal component analysis and structural equation modelling are applied to 153 valid responses from a sample, obtained from Portuguese port community experts. The results identify and measure the factors that characterize the PCS and affects port performance. PCS characteristic, including service level, partner network, ship services, cargo services, logistics services and advanced services, affect port performance, defined as operational performance, effectiveness and efficiency. The primary contribution of this study is to show the mechanisms that allow ports to adjust and evolve the PCS characteristics and develop new features that affect port performance.

1. Introduction

Ports are key nodes in supply chains where physical and information flows and the requirements of transparency and identification of flows of goods are becoming increasingly complex. From ports, international supply chains can be structured based on the digitization of the supply and demand of logistics services and cargo information flows. Modern ports focus on increasing the efficiency and effectiveness of supply chains, developing PCSs that support information on demand forecasting and level of response to orders, and minimizing inventory costs. Online monitoring and transparency are increasingly critical to the success of supply chains and ports.

The modern scope of logistics entails greater complexity in port sector processes and a high number of stakeholders, which requires the innovation of port communication, information flows and documentation control. The maritime supply chain has evolved in recent years, supported by information and communication technologies (ICTs). This evolution has promoted a more intense integration of the port community and has imposed greater requirements on the provision of port services. Investment in ICTs for ports entails the adoption of paperless communication between members of the port community, integration with logistics partners and cooperation between different ports. This is a

necessary step towards competitiveness that ports must take.

Port Community System (PCS) is the technological platform that enables networking between the public and private agents and entities involved in the ship and cargo services offered by ports. Rondon & Ramis-Pujol (2007) described the PCS as an electronic platform that links multiple systems of several companies and entities, which constitute the port community, and whose main function is to digitize port operations. Few studies in the field of information systems have examined PCSs (Applegate, Siong, Bartlett, & Chang-Leow, 2001, pp. 1–34; Carlan, Sys, Calatayud, & Vanelslander, 2018; Carlan, Sys, & Vanelslander, 2016; Carlan, Sys, Vanelslander, & Roumboustos, 2017; Hock-Hai, Bernard, & Kwok-kee, 1997; King, Harsh, & Dobbins, 1990; McAfee, Ooms-Wall, & Al Qasimi, 2003, pp. 1–19; van Baalen, van Oosterhout, Tan, & van Heck, 2000). Moreover, most of these studies are only descriptive and do not assess the characteristics and performance of these systems or the integration with the existing systems of port authorities, entities and companies. Rondon & Ramis-Pujol (2007) theorized about the PCSs, which they identify as an electronic platform that connects multiple systems of several companies and entities, the port community, whose main function is to digitize the port operation.

PCSs are important to port performance, as noted by Meersman, Van de Voorde, and Vanelslander (2010). However, few researchers have

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<https://doi.org/10.1016/j.retrec.2020.100818>

Received 19 June 2019; Received in revised form 9 January 2020; Accepted 13 January 2020

Available online 23 January 2020

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systematically addressed the importance of PCS characteristics and the effect on port performance. Carlan et al. (2016). consider that the effect of information technology on port performance has not yet been sufficiently studied because PCS developments are usually analysed with regard to characteristics, without tackling how they affect port performance. Lee, Tongzon, and Kim (2015) used measures of customer satisfaction performance and port competitiveness to analyze the influence of container terminal management systems on port operations.

The SEM methodology is used to analyze the sample of 153 valid answers, collected using a survey addressed to managers from the main Portuguese ports. The purpose of this work is to identify, analyze and measure the characteristics of the PCSs and implications on port performance. The first objective is to analyze the characteristics of PCSs. The second objective is to identify the factors of port performance. The third objective is to analyze and measure the impact of the PCS characteristics on port performance factors.

The work contributes to a better understanding of role of PCSs and their effect on port performance. The study also contributes to PCSs development and reveals the main characteristics to be developed in the future.

The next section presents the literature review. The third section describes the method, research model, hypotheses, sample, measures, constructs and variables. The fourth section presents the results of the analysis. The fifth section discusses these results. Finally, the sixth section highlights the conclusions and contributions of the study.

2. Literature review

Supply chain integration ensures strategic partner collaboration and collaborative management in organizational processes. It involves the alignment and coordination of people, processes, information, knowledge and strategies throughout the chain. Its purpose is to facilitate efficient and effective material, financial, information and knowledge flows in response to consumer needs.

Vickery, Jayaram, Droge, and Calantone (2003) identified the attributes of an integrated supply chain strategy as technologies that facilitate integration and integration practices. Information technologies are considered important in the supply chain and include: (a) computerized production systems, integrated information systems and integrated electronic data exchange. Integration practices involve common objectives and rules, common information systems, and collaborative integration platforms. The objective is to create convergent interests amongst stakeholders in the port and logistics community to ensure reliability, continuous service and adequate levels of productivity. Visibility and transparency are crucial to efficient supply chains. Benefits of supply chain visibility include better inventory control, demand forecasting, fulfilment lead times, and flexibility (Closs & Swink, 2005).

The seaport has an important role in managing and coordinating flows of materials and information in the supply chain. De Souza, Carvalho, & Liboreiro (2006) and Radhika (2012), have highlighted the importance of ports as members of the supply chain. The performance of international maritime supply chain has become a crucial source of economies' sustainable advantage. The development of global supply chains has changed the traditional role of ports, from simple cargo loading and unloading service providers to a new role in the supply chain as logistic decoupling points and add value services providers (Dias, Calado, & Mendonça, 2010; Host, Skender, & Mirkovic, 2018).

An integrated port is characterized by efficient communications and operations. There is a shift in the role of ports as key points in a value-driven integrated supply chain. Real-time information is crucial for transport providers, shippers and logistics service providers (Aydogdu & Aksoy, 2015).

The focus of supply chain management is on integrating each component to achieve maximum efficiency and customer satisfaction, with the ultimate goal of increasing market share (De Souza et al., 2006). Flynn, Huo, and Zhao (2009) defined supply chain integration as

the level of strategic collaboration between producers and partners in the collaborative management of intra and interorganizational processes. Stevens and Johnson (2016) described supply chain integration as the alignment, linkage and co-ordination of people, processes, information, knowledge and strategies to facilitate efficient and effective flows of materials, money, information and knowledge in response to consumer needs. Carvalho, Dias, Martins, Menezes, and Ramos (2010) argue that the management of collaboration between multiple partners, involving different types of organizations, with their own resources and objectives, is a multi-step process that involves real-time cooperation in operations and decision-making. Vickery et al. (2003) identify the attributes of an integrated supply chain strategy, focusing on technologies that enable integration and integration practices. Information technologies support the supply chain. Such technologies include computer systems, integrated information systems and integrated electronic data exchange (Vickery et al., 2003). Chandra and van Hilleberg (2017) listed five roles in the collaborative networks of ports: members, PCS operators, supply chain partners, other partners and supply chain controllers in the port.

Bichou and Gray (2005) note that ports play a vital role in the management and coordination of material and information flows because transport is an integral part of the supply chain. The objectives are to create synergies and convergent interests amongst stakeholders in the port community to ensure reliability, continuous service and productivity. When integrating the maritime logistics chain, the ports are fundamental links in supply chains for international distribution (Palmieri, Parola, Song, & Baglieri, 2019; Radhika, 2012). The success of the port depends on the capacity to integrate the supply networks, and port community must generate synergies with the land transport nodes and other players in the logistics networks. Wang, , Olivier, , Notteboom, and Slack (2007) noted the prominent role of ports as members of the logistics supply chain as part of a coordinated and cooperative set of transport and logistics operators focused on creating value for customers.

Carvalho et al. (2010) reported that paper-based transactions and communications are time-consuming, unsafe and prone to multiple lapses, conditioning organizational effectiveness, efficiency and responsiveness to business opportunities. The commercial benefits of paperless transactions and communications include lower costs, better and faster information flows, fewer delays and costs at borders, greater supply chain accountability, and increased trade and transport security (El-Miligy, 2013).

To optimize business processes, maritime ports and transport companies provide electronic services. Electronic documents reduce operating and general costs and can be easily organized and quickly retrieved, archived and indexed. Information shared between organizations is primarily computer-processed, with data transferred between organizations. Electronic data interchange (EDI) technology using the United Nations commerce message standards for structured data exchange, allows the transfer of data between organizations' databases without printing (Keceli, Choi, Cha, & Aydogdu, 2008). Obara, Kiplagat, and Okidi (2010) affirmed that the EDI application provides advantages in faster and more efficient exchange of information, lead-time reduction, the lowering of costs through paper reduction, a decrease in errors, better data sharing and tracking, and increased rotation of stocks. Access time to specific information is crucial for transport providers and logistics service providers (Aydogdu & Aksoy, 2015). Ports can provide value-added services by improving information and reducing process time (El-Miligy, 2013). The use of electronic documents has an economic impact because it helps productivity and increases competitiveness (El-Miligy, 2013).

2.1. Port community systems

The success of a port is determined not only by infrastructure and superstructure but also increasingly by the way the port management

steers interactions between different stakeholders towards a common goal (Henesey, Notteboom, & Davidson, 2003). Martin and Thomas (2001) defined the port community as a commercial organization, in which combined services support the port in the transfer of cargo between maritime and land transport. The port community includes the provider of port facilities and infrastructure, cargo handling service providers, shipping operators and agents, land transport operators, and cargo representatives. The port community involves several private and public organizations, which traditionally operate in a fragmented way in processes related to port activity (Cordova & Duran, 2012; Sweeney & Evangelista, 2005; Tijan, Agatić, & Hlača, 2012).

Within the port community, Notteboom and Winkelmanns (2001) distinguished between internal stakeholders (groups within the port authority) and external stakeholders with formal and contractual relationships. For Tijan et al. (2012), the complexity of the port community and the massive exchange of data, messages and documents amongst the members of the port community highlight the need to implement integrated ICT systems to maintain competitiveness and achieve a high-quality service. The increased importance of communication between port stakeholders has transformed port information systems into port community systems (PCSs).

A PCS is usually based on electronic data exchange. According to UN/EDIFACT, EDI is the electronic transmission from computer to computer of commercial or administrative transactions using a common standard to structure the transaction or data message (Keceli et al., 2008). Most PCSs have different applications that integrate electronic data interchange. El-Miligy (2013) remarked that the integration of material and information flow with better external coordination, notably through functions such as shipping agencies, can lead to improvements in the supply chain but requires an integrated PCS. The integrated port system is essential to provide better services at a low cost (Miligy, 2013). Moros-Daza, Amaya-Mier, Garcia-Llinas & Voß, (2019) conclude that profits gained from the adoption of a PCS funded by the port community grand coalition are higher than those from pairs or individual members.

Rodon and Ramis-Pujol (2006) defined a PCS as an electronic platform that connects multiple systems, operated by a variety of organizations, which constitute a port community. For Srouf, Oosterhout, Baalen, and Zuidwijk (2008), a PCS is a holistic information centre, geographically limited in the supply chain, which primarily serves the interests of a variety of collective entities of a port community. It is also a commercial and logistics business-to-business (B2B) tool that is used to exchange messages in the port environment (Portel, 2009).

International Port Community System Association IPCSA, (2011) defined a PCS as an open and neutral electronic platform that enables a smart and secure exchange of information between public and private stakeholders to improve the competitive position of seaport and airborne communities; optimizes, manages and automates efficient port and logistics processes through a single presentation of data, linking transport chains and logistics. It is an effective, real-time, fast, focused, flexible and complex information system capable of improving efficiency at all stages of the cargo process in the unloading and loading of ships, customs clearance, port formalities, and delivery inside and outside the terminal. According to Dimitrios and Athanasios (2013), stakeholders generally include port authorities, port captains, terminal operators, shipping agencies, freight forwarders, towing services, pilotage services, mooring services, waste treatment companies, ship supply companies, customs authorities, dispatchers, police and fire departments, the port area security and concierge control, inspection services, and transport providers. There may also be process stakeholders related to non-customs inspections for health, animals and plants and for sanitary, phytosanitary, food and drug safety.

A PCS performs multiple functions. These functions are difficult to list in full because they are defined according to the specific needs of the stakeholders of each port community (Desiderio, 2011). The functionality of a PCS is aimed at using electronic data exchange to eliminate

unnecessary bureaucracy, which may interfere with cargo handling (European Port Community Systems Association, (EPCSA, 2011) and PCS have positive influence on the adoption of mandatory regulation (Fedi, Lavissiere, Russel, & Swanson, 2019). According to the MED-PCS Project (2013) the important aspects of the implementation of the PCS are represented by the following issues: the electronic and IT infrastructure adopted in the port, the information exchange protocols underlying the system and the type of transactions processed by the system.

According to Portel (2009), the services provided by the PCS include, amongst others, cargo loading and unloading, cargo declarations, bills of lading (BLs), dangerous cargo declarations, loading and unloading lists, transshipments, truck arrival notices/integration of national and international platforms, billing, documentation to customs, export reservations, ship information (ETA/ETD), reports of cargo operations, notices of arrival and departure, ship general statements, crew and passenger lists, and requests for towing services. A PCS should integrate services for importers and exporters (Moros-Daza, Nestor, Solano, Amaya & Paternina, 2018).

There has been a natural phasing in the development of general PCS. In an initial phase (establishment), in the 90's, the PCSs only included the basic notifications of the arrival of the ship and the goods, mainly for statistical purposes and response to external entities (Heilig, Lalla-Ruiz, & Vob, 2017). In the second phase (development), in the last 15 years, port systems begin to include the authorizations of port entities such as the port authority, customs, the border service, the maritime police, and health authorities and declarations. PCSs start to introduce the automatic billing of authorities and various automations of ship authorizations, leaving no paper in the port process. In a third phase (expansion), in the last 10 years, ports widen their scope. They begin to collect information from sensors embedded in the maritime logistics chains that pass through them. These chains include road and rail transport, dry ports, shipping lines and city entrances. There is information on the cargo situation for all logistics chains with a view to synchronisation, transparency and visibility of the processes and flows. (Heilig et al., 2017). In a fourth phase (public entrepreneurship), in the last 5 years which can be associated with the port PDC phase of de Langen and van der Lugt (2017), the most advanced PCSs are promoting new private start-up companies with advanced innovation and the development of artificial intelligence applications, robotization, port big data analysis, predictive analytics, probability-based cargo and ship advice, integrated flow and risk management, integrated multiple routing solutions, use of intelligent tags in the cargo units, internet of things, intermodal transport solutions, booking, physical internet, maximization of navigation information, autonomous navigation (Zerbino, Aloini, Dulmin, & Minnino, 2019). Irannezhad, Hickman, and Prato (2017) examined the advantages of using an intelligent agent in PCS cooperation with the advantages of sharing vehicle information and the common decision on optimizing transport in the supply chain and ports.

Not all ports develop all the phases and may adopt some systems of different phases. For example, the Portuguese system has advanced more rapidly in integrating the systems of the various ports, while the Spanish ports still maintain very different systems. Moreover, Portuguese ports integrated customs services from an early stage, which only recently most of the northern European ports have succeeded. There are several main services offered by PCS, with different evolution levels, and ports can be classified as to their evolution, within these levels and characteristics of their PCS.

2.2. Port performance

The benefits of PCS derive from the development of IT platforms. These benefits are proportional to the number of logistics agents in the system and are exponential in the case of a network Carlan et al. (2016). The information in the system is electronically managed, which avoids errors, drastically reduces paper, and facilitates the detection of any

inconsistent data (Diaz, 2009).

Aydogdu and Aksoy (2015) reported that there are indirect economic benefits in the form of decreasing information access costs, reducing communication costs and preventing smuggling. PCS increases the efficiency and effectiveness of port communication but differs between ports depending on their function (El-Miligy, 2013). According to Diaz (2009), PCS focuses on maximizing the operational use of port physical infrastructure and controls the efficiency of port operations in general.

PCS reduces paper-based documentation, improves information quality, enables data integrity between different related parties in the port, improves delivery times and allows the provision of a more user-friendly system by port (Posti, 2012). It allows users to request services and enter information directly into the port computer system (Zygyus, 2006). The PCS provides a single window that guarantees the safe exchange of electronic information by stakeholders involved in maritime transport and the logistics chain and the automation of typical port procedures (El-Miligy, 2013).

The implementation of the PCS provides benefits to the port authorities by supporting the coordination of port activity, improving the control of port operators' activities, setting up a real-time database for decision making and developing strategic plans (Tijan et al., 2012). Through a PCS, port and customs authorities control cargo handling information, reducing the risk of errors and time spent filling out forms (De la Guía, 2013).

With a common benefit for the port community, the advantages of using a PCS include providing critical information in real time due to the simplification of the regular flow of electronic data, ensuring compliance with national and international guidelines, norms and standards, improving a country's competitive advantage, increasing security throughout the supply chain, reducing waiting times and paper use, and enabling automation and acceleration of processes (Essay, 2017).

3. Methodology

This section includes a description of the research model, hypotheses and variables, as well as detail on sample, measures and methodology.

3.1. Research model, hypotheses and variables

The research model identifies the endogenous and exogenous latent variables of the PCS, regarding the literature review in the previous sections, consisting of: (a) Service level, that includes the entities respond in 24 h, the communication speed, the existence of 24-h technical assistance, the use of EDI and international standard messages, if the software is friendly and adaptable to any device and the level of errors and inoperative periods; (b) Partner network, including port authorities, customs, terminals and port services providers, shipping agents; (c) Ship service, including crew and passengers list, SafeSeanet notification, waste disposal notification and billing, collection of fees; (d) Cargo and port service, including the receipt of Bill of Lading documents, tug service requirements, pilots and mooring services and veterinary and sanitary inspection; (e) Logistics services, including integration with other ports, entities and logistic areas, road and rail operators, logistics companies and freight forwarders, industrial facilities and importers/distributors; (f) Advanced services, as providing information to users, including information from to road and rail transport, ship planning and terminal information, fleet control and scheduling system, terminal booking services and road traffic control, information on cargo state and control, tracking through the entire logistics chain, passing sensors, identification and state of charge (IoT - internet of things), containers scan information, services of bigdata, artificial intelligence, predictive algorithms to improve logistical decisions of ship owners, shippers, agents and freight forwarders, and the creation of integrative application development environment for customers (Fig. 1/Appendix 2).

The Port Performance construct is composed by: (a) Operational

performance, comprise the use of best procedural practices, prevention of smuggling and illegal revenues, port logistics integration, transparency, deduced waiting time, reduced lead time, reduction of logistic error rate, delivery time reliability, agility to changes in demand, creation of new logistical added value businesses, reduced personnel costs, improved control over the activities of port operators, increase in port activity and in productivity; (b) Effectiveness, regarding fast access to information, organizational integration of the port, fast response from entities, improvement of ship dispatch, increased customer satisfaction, ease reporting to authorities and historical data; and (c) Efficiency, including reduced communication costs, decreased use of paper, fast invoicing of port entities, increasing the level of port competitiveness and the general port activity (Fig. 1 and Appendix 3).

The research starts from three hypotheses, H1: Port Community System (PCS) is characterized by service level, partner network, ship services, cargo and port services, logistics services and Advanced services, H2: Port Performance is characterized by operational performance, effectiveness and efficiency and H3: Port Community System (PCS) influences port performance.

3.2. Sample, measures and method

A survey was used to collect the data. A questionnaire was sent by e-mail to 2000 senior managers of companies that use Portuguese ports. The questionnaire addressed the importance of the characteristics of the generic PCSs and the port performance measures. The sample consists of 153 valid answers divided by shipping agents (26), port authorities (42), terminal operators (19), freight forwarders (11) and others (55) and by (110) director/board/strategic and (43) operational functions. The main ports of respondents were from port of Setubal (34%), port of Lisbon (25.5%) and port of Sines (18.3%), followed by port of Leixões (12.4%) and then port of Aveiro/other ports.

A 7-point Likert scale was used to evaluate the PCS characteristics and port performance. Based on varimax factor analysis as a form of exploratory analysis, the factors were reduced to obtain constructs from the data and the scores for new constructs. Due to the sample dimension limitation, in a second step, structural equation modeling (SEM) was performed with exogenous and endogenous constructs scores, obtained in phase one. The model was tested for consistency, reliability, convergence and unidimensional validity (Hair et al., 1998).

The practical advantages of using SEM for this data analysis includes the possibility of strong validity testing, important in social sciences, like port management, when is no possible to observed directly the constructs, but that can only be inferred from observable variables. Survey data frequently contain measurement errors and this methodology can take measurement error into account by explicitly including measurement error variables. Theories in management frequently involve complex patterns of relationships and multitude of variables, and SEM allows to model and test complex patterns of relationships. Finally, SEM allows to test complex models for their compatibility with the data in their entirety and allows to test specific assumptions (Werner & Engel, 2009).

The survey consisted of questions for each variable of the model, corresponding to each characteristic of the PCS that most influence port performance (exogeneous variables) and to port performance factors

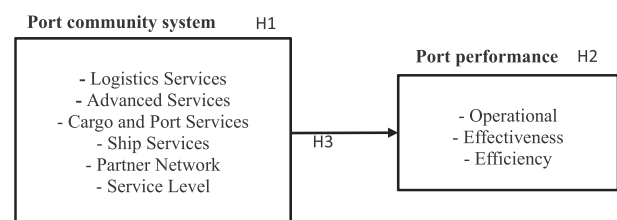


Fig. 1. Research model.

influenced by PCS (endogenous variables). A question was used for each exogenous and endogenous variable for general model and Portuguese case:

- (a) a first question about the importance of each variable regarding the general relation between PCS and port performance, aiming to confirm the research model: (a1) “What characteristics of the services should a port information system have, aiming a better port performance? (choose from 1-Strongly Disagree with to 7-Strongly Agree considering each PCS characteristic variable)” and (a2) “What should be the impact of a port information systems in the port? (choose from 1-Strongly Disagree with to 7-Strongly Agree considering each port performance variable)”;
- (b) And a second question regarding the current level of each variable in the case of the Portuguese port used by the manager organization, aiming to compare the real present status of the Portuguese ports: (b1) “What services your port information system provides? (choose from 1-Strongly Disagree with to 7-Strongly Agree considering each PCS characteristic variable)” and (b2) “What is the impact of your port information system? (choose from 1-Strongly Disagree with to 7- Strongly Agree considering each port performance variable)”.

4. Results analysis

The exploratory factor analysis of the data was performed for the research model and variable correlation were determined (Appendix 1). The reliability and internal consistency of the latent variables of the PCS model was tested and confirmed (α cronbach alpha coefficient > 0.8), regarding logistics services ($\alpha = 0.892$), advanced services ($\alpha = 0.939$), cargo and port services ($\alpha = 0.822$), ship services ($\alpha = 0.897$), partner network ($\alpha = 0.892$), service level ($\alpha = 0.896$) and the adequacy of the sample that was tested and confirmed by using Kaiser–Meyer–Olkin test (KMO) = 0.89). Six constructs were confirmed for the PCS characteristics. Regarding the port performance constructs, three were determined, with reliability and internal consistency, operational performance ($\alpha = 0.966$), effectiveness ($\alpha = 0.903$) and efficiency ($\alpha = 0.851$), with significant test results (KMO = 0.89).

The constructs scores resulting from the factorial analysis were applied in SEM methodology, but the observed variables were not used

directly in the SEM, only the scores of the factor analysis rounded un-correlated solution, with internal consistency. Significant results were obtained with the following measures of goodness-of-fit (GoF) of the model, χ^2 : 12,097.2; χ^2/df : 0.465; Root Mean Square Error of Approximation (RMSEA): 0.0 (<0.1), Normed Fit Index (NFI) 0.901 (>0.8) and Relative Fit Index (RFI) 0.863 (>0.8), indicating a good fit of the generic model (Fig. 2).

The results show the importance of advanced services such as the use of Big Data, traffic control systems, navigation planning and container scanning (β operational performance = 0.35, β effectiveness = 0.20), the partner network (β effectiveness = 0.22, β efficiency = 0.51), and ship services (β efficiency = 0.22). These variables were observed to influence operational performance ($R^2 = 0.17$), effectiveness ($R^2 = 0.10$) and efficiency ($R^2 = 0.35$).

The scores mean obtained in the survey for the actual level of each Portuguese port were used to compare each port phasing of development regarding the PCS characteristics and port performance (Fig. 3).

Port of Sines obtained higher level on all constructs, except for service level, dominated by port of Lisbon. Ports of Leixões, Lisbon and Sines have the highest values for partner network, ship services and cargo services. The exogeneous constructs, operational performance, efficiency and effectiveness are led by port of Sines. Portuguese ports must develop logistics and advanced PCS services, that are in an early stage at present time, comparing to some northern European ports, like Rotterdam, Antwerp and Hamburg.

The Portuguese ports have the same PCS designate by JUP (port single window in Portuguese) platform, except for the port of Sines which has advanced since 2013 to the creation of advanced logistics services, with the addition of a new module to JUP, for train detecting and road trucks locating, information that is available to customers and logistics operators.

However, the Portuguese government is currently developing, through the Portuguese Port Association, a new system that will apply to all ports, including the new logistic addon designated JUL (logistic single window) and other minor developments like terminal control and terminal planning, although this is a centralized and close solution, not including advances in the issue of bigdata analysis, use of artificial intelligence and automation of functions and decisions, or the possibility for startups to develop applications with access to mass data for port logistics customers.

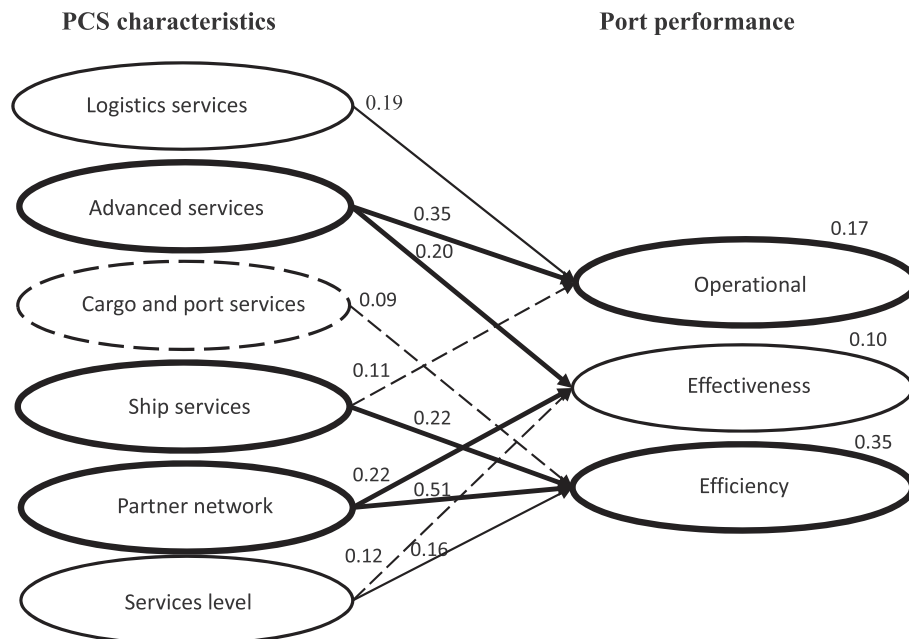


Fig. 2. Confirmatory model.

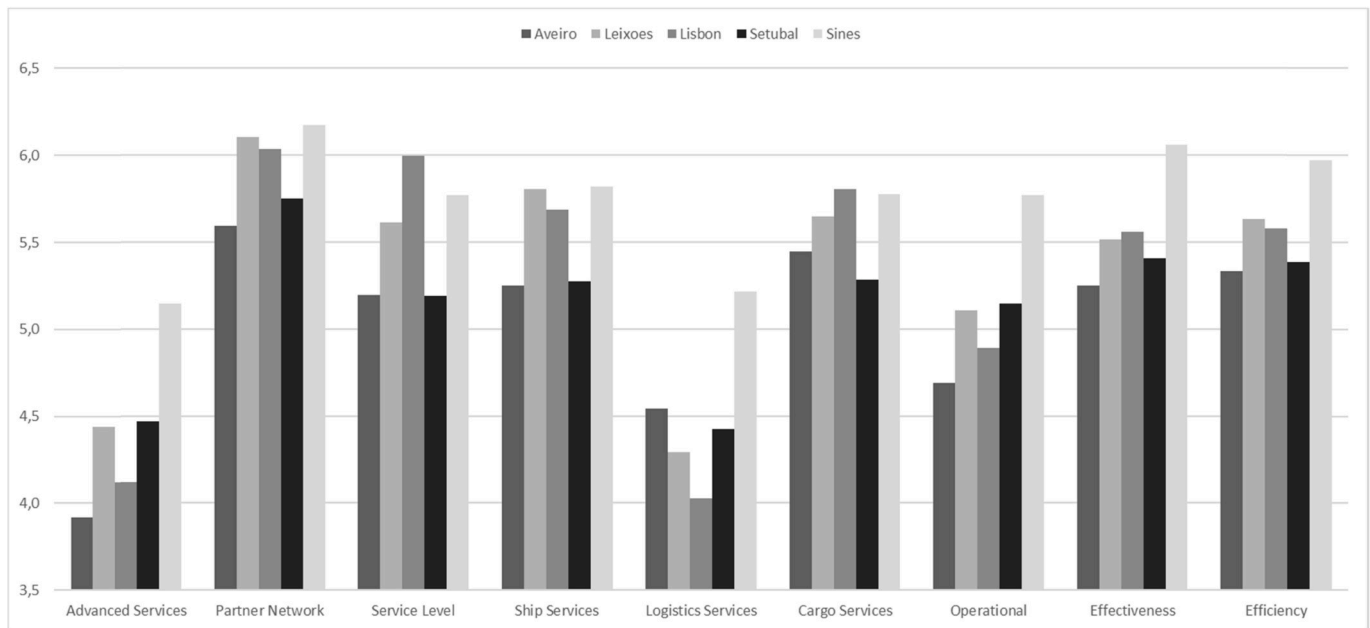


Fig. 3. Portuguese PCS comparison between ports.

Source: Authors

5. Discussion

The analysis of the results shows that PCS is identified by the factors: logistics services, advanced services, cargo services, ship and port services, partner network and services level. This confirms [Portel \(2009\)](#) conclusions, services provided by the PCS include: cargo services, ship billing, customs, ship information, crew and passengers list and port services request. The results also confirm [Irannezhad et al. \(2017\)](#) conclusions about the advantages of using an intelligent agent in PCS, and the inclusion of rail and road transport control systems, internet of things and terminal booking. Hypothesis 1 (H1) is confirmed - PCS is characterized by service level, partner network, ship services, cargo and port services, logistics services and advanced services.

Port performance is defined, as an example, by the improvement of service level provision and cost reduction. Results confirms that PCS port performance includes to avoid errors, reduces paper, and facilitates the detection of inconsistent data, as defended by [Diaz \(2009\)](#), and confirms the results of [Aydogdu and Aksoy \(2015\)](#), the reducing of communication costs, and prevention of smuggling by PCS. The PCS provides guarantees of safe exchange of electronic information as showed by [El-Miligy \(2013\)](#). PCS also increase security along the supply chain, reduce waiting time and enable automation and acceleration of processes, as defended by [Essay UK \(2017\)](#). Hypothesis 2 (H2) is confirmed - port performance is characterized by service operational performance, effectiveness and efficiency.

Of the six factors of the PCS model, only three have significant impact on port performance with different levels of importance for port performance. Advanced services (i.e., big data, container scanning and traffic control), specific services provided to shipping and the network of partners have the most influence on the performance of the port. Partner network is the main factor affecting port efficiency, but also affect port effectiveness. Collaboration and participation of port and logistic players, it is one of the most important characteristics of PCS, regarding a higher effect on port performance. Ship services are the basic and the first reason of PCSs development, and the dramatic improvement of port efficiency is one of the main result of PCS ship services feature. Advanced services and logistics services are very important for operational performance, and advanced features of PCS also influence effectiveness of ports. Service level have impact on port efficiency.

Both logistic services and Service level have less impact specifically on operational performance as well on efficiency. In the case of cargo and port services, the impact on cost reduction is weak. Effectiveness is a very relevant port performance indicator, influenced simultaneously by advanced services and partners network. Also, the efficiency is strongly influenced by ship services and partner network.

Results confirms that PCSs increases the efficiency and effectiveness of port communication ([El-Miligy, 2013](#)). And confirms that, according to [Diaz \(2009\)](#), PCS focuses on maximizing the operational use of port physical infrastructure and controls the efficiency of port operations in general. The results confirm that the implementation of the PCS provides benefits to the port by facilitating the coordination of port activity, improving the control of port operational activities ([Tijan et al., 2012](#)). Hypothesis 3 (H3) is confirmed - PCS influences the port performance.

6. Conclusions and contributions

The research model identifies the factors of the port community system and analyzes its nexus with port performance. The main conclusion is that there is a strong relation between port community system and port performance, but performance factors have different weights. The port community system is very relevant to port performance and involves as main constructs the advanced services, ship specific services and partners network.

Another important contribution accentuates the specificity of port performance factors, to understand the development conditions of the ports and the port system. It is considered important for port managers to analyze the conclusions of the research and develop new logistic and advanced services, since they are important as determinants of port performance. In most cases, the port services included in the port community system are limited to the digitization of ship and cargo paper processes, not by redesigning and simplifying processes, nor by creating new services that add value to modern logistics chains and fulfill their needs for transparency, automation and decision-based algorithms and large amounts of information available.

Port managers should focus the energy on creating a partner network, collaborating for common goals and sharing the cargo and ship information in port community system. This network should include not only the port agents, but also the enlarge supply chain partners.

The port community system is very relevant to port performance and involves advanced services, ship specific services and partner network. Another important contribution accentuates the specificity of the port performance factors to understand the development conditions of the ports and the port system.

It is considered important for port community system managers to analyze the conclusions for the research model and development advanced and logistic services as determinants of port performance.

The main limitation is the application to the Portuguese port reality, the sample dimension, the dominance by port authorities and the need to extend the sample to other countries. For future research, it is relevant to analyze different port systems and different continents.

CRedit authorship contribution statement

Vítor Caldeirinha: Conceptualization, Methodology, Software, Formal analysis, Writing - original draft. **J. Augusto Felício:** Validation, Resources, Writing - review & editing. **Antónia Sena Salvador:** Conceptualization, Methodology, Formal analysis, Investigation, Writing - original draft. **João Nabais:** Validation, Resources, Supervision, Project administration. **Tiago Pinho:** Validation, Supervision.

Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.retrec.2020.100818>.

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