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Original Article

Developing a comprehensive approach to port performance assessment

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ABSTRACT

This paper investigates the port performance assessment and proposes a comprehensive framework with various perspectives as well as priority distributions of stakeholders' expectations in port business and operations. One fundamental questions in port performance studies is how to evaluate and quantify intangible indicators on performance. There are definitely inputs and outputs, which may be measured and evaluated through conventional instruments. However, each instrument deals with a particular aspect of whole performance problem (e.g. port efficiency, port productivity,), and many of these instruments are limited to 'measurable' data on port management and operations. In this paper, these two common problems are put under the scope, and a comprehensive port performance assessment scheme is established by gathering various perspectives. Quality function deployment (QFD) approach is preferred to formulize the problem and define priority ratings of expectations by each stakeholder in the port domain. The framework can contribute to a broader understanding of ports as business units, its development drivers and interaction with community neighbors, and to shed light to port performance assessment considering both public and private entities.

1. Introduction

Port performance indicators is not a new topic for port managers nor maritime scholars. In the late 1970s, the UN agency UNCTAD proposed that signatory countries should adopt and follow certain port performance indicators (UNCTAD, 1976; UNCTAD, 1987). The idea behind it was straightforward: to be able to measure in order to improve port performance. This fell immediately within UNCTAD's mission of promoting trade facilitation that enhances economic development. Ports are a key element for merchandize trade transaction to take place. In this sense, UNCTAD has dedicated a specialized team of experts to follow up on the port performance indicators. More recently, UNCTAD has proposed a port performance scorecard as part of their port training program to combine a set of indicators to refine assessment and benchmarking capability for senior port managers. The main idea of this program is to bring the industry and academic perspectives together in terms of port performance in order to share best practices among port managers, particularly from developing countries (UNCTAD, 2012). Those indicators were predominantly associated with terminal operational efficiencies generally based on volume throughput (movements per crane, per hour; berth utilization rates; labor ratio per TEU are some of the main indicators). Some of those terminals, given the nature of the capital structure also allowed for some financial performance analysis generally based on annual statement and reports. Although insightful for terminal managers, those indicators focused a specific aspect (Economic) of port performance, not including other dimensions equally important in the port activity, such as the social, environmental and political.

Brooks and Cullinane (2007) have argued that port performance has a strong correlation with the concepts of governance and devolution programs. Further, Brooks and Cullinane (2007) have made an effort toward a clear cut of port performance measurements and definitions for port managers and scholars under the business perspective. More recently Brooks, Cullinane, and Pallis (2017) have revisited the port governance issues with focus on the port reform processes and less on port efficiency measurements. Furthermore, various studies and investigations have aimed to measure and to access port performance. In maritime business,

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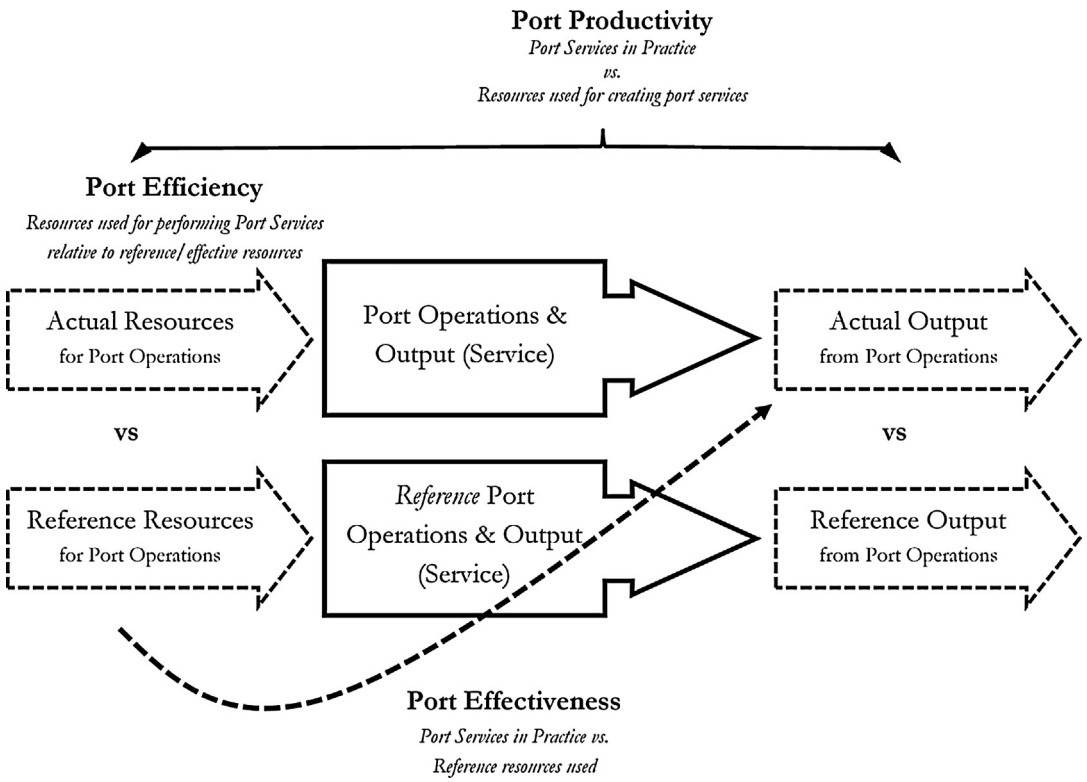

Fig. 1. Port efficiency, effectiveness and productivity.

Source: (Esmer et al, 2019)

the typical performance measures approach takes in consideration the economics only. The economic operational level typically uses static indicators to measure performance such as: *Utilization* (= Actual Input/Design Input Capacity, Max. Input); *Port Productivity* (= Actual Output/Effective Input Capacity); *Port Efficiency* (= Actual Input/Effective Input Capacity). *Port Effectiveness* (= Actual Output/Effective Input Capacity); *Port Effectiveness (management)* (= 'Qualified' Actual Output/Effective Input Capacity) (Fig. 1). One of the main issues that rise from these definitions is related to the data availability. That is, in the absence of actual input, researchers end up using capacity figures (Esmer et al, 2019aaaaaaaaaaa). Another consequence of the lacking data is that a great share of the research is done based on containers volumes throughput, however still two-thirds of world merchandize trade is of bulk cargo (UNCTAD, 2016).

Thus, if port performance measures are concentrated in efficiency measurements and are predominantly using the economic approach with using static data, how could the port performance be measured using a more comprehensive approach with multiple lenses (not only economic)? How does port performance follow the port strategy? Are there inconsistencies between efficiencies and effectiveness? These are some of the orientation questions for this study.

In this study, we argue that port performance assessment should be done under multiple lenses for three main reasons. First, based on the evidences we have observed in an in-depth literature review the economic perspective. Second, the predominant business orientation in the port performance assessment. And third, considering more recent issues in port developments, such as the need for port expansion due to increasing volume throughput; the complexification of logistics' networks; and the changes in the governance. That is, beyond the microeconomic aspects, the development of a comprehensive approach to port performance assessment should be able to include other strategic dimensions such as social, political and business ethics. This framework can be applied in different levels of analysis, which are from the strategy, to operational and technical levels. In the port reality, these levels would correspond to city/region, port and terminals.

In this sense, this paper objective is to identify conceptual gaps in the literature and with a theoretical approach, assessing it with different perspectives about the concept of port performance. In order to propose a more comprehensive framework this paper consider four main forces corresponding to strategic dimensions (social, economic, political and business ethics, which included the environmental dimension). The study methodology is based on three steps. First, we conducted an in-depth literature review studies about port performance, analyzing and investigating their main approaches and methods. Second, we deploy a comprehensive assessment instrument is developed by using the quality function deployment (QFD) methodology. The QFD method is a diagnostic toolbox generally used in manufacturing industries; however, it is also applied to services sectors identifying possible threats and opportunities (or gaps) about design, production and operation processes regarding overall expectations of customers. QFD, in a port context, can also be defined as a system for translating customer (public and private agents/users) requirements/expectations into appropriate port (entity) deliverables at each stage from research and service development to engineering and operation and finally to marketing/sales strategies. Third, a pilot study is used to illustrate the application of the QFD principles as a more comprehensive method to access port performance beyond the static data.

2. The port performance overview in the research agenda

The literature review conducted focused on two main aspects. First, we situate port performance as a topic on Maritime Transportation literature. Second, we identify the typical port performance measurements in seminal contributions of researchers in the field.

Pallis, Vitsounis, and De Langen (2010), Pallis, Vitsounis, De Langen, and Notteboom (2011) have considered the research on economics, policy and management of ports published from year 1997 to 2008. In their classification study they found that "port competition and competitiveness" were prevalent in the period 2002–2006, while the themes of "port governance", "port planning and development" and "port policy and regulation" were most studied in 1997–2001. In the 2007–2008 period it was also noted that there was a rise of "ports in the transport and supply chain." The results shown three main conclusions: First, almost half of the studies are focused on the containers and/or container terminals, while other goods (bulk, vehicles, and passenger) are not represented or are five percent of published papers. Second, the ports studies within the logistics chain has grown considerably; and thirdly, the academic community is characterized by being in a pre-paradigmatic stage, which consist of a set of small groups of researchers with limited references to each other's research. The research of Pallis et al. (2010) also indicated that in the period from 1997 to 2008 almost half of the papers on ports were published in a limited venue through to *the International Association of Maritime Economists* (e.g. *Maritime Policy and Management* and *Maritime Economics and Logistics*).

The research of Woo, Pettit, Beresford, and Kwak (2012) aimed at presenting a structured literature review on ports studies for the period from 1980 to 2009. The research used content analysis techniques to classify the eight hundred and forty papers identified in eight major themes. The authors concluded by stating that the future of the ports research agenda should be guided not only by the demands of the industry, but by development of methodologies and theories, in view of the complexity of port management.

Woo, Bang, Martin, and Li (2013) as well as Notteboom, Pallis, De Langen, and Papachristou (2013) had similar research objective which was to analyze the content of papers published over the forty years of the journal, *Maritime Policy and Management*, (1973–2012). Woo et al. (2013) stems from the assumption that the issues related to shipping were initially dominant while the issues of ports were of increasing interest to researchers later. The authors divided the time frame in four periods (1973–1979; 1980–1989; 1990–1999 and 2000–2012). The results highlight the followings. First, Economics remains as predominant field with about thirty-five percent of all the published papers, but Management field has greatly increased, particularly in the 2000s. Second, "*conceptual work*" has the largest share in methodologies applied (35.1% or 345 of the 984 papers). However, authors noted that the methodologies applied were becoming more sophisticated with advancing computer techniques that allowed usage statistics and mathematical models, with number of publications growing in the 2000s.

In second part of our literature review, we have identified the researchers that have presented seminal contributions in the study of port efficiency measurements. Efficiency remains a priority for port managers even though a port's performance is multifaceted and is no longer limited to internal processes (Woo, Pettit, and Beresford, 2011). Roll and Hayuth (1993) are pioneer in establishing research efforts to identify and execute port efficiency performance benchmarking. In Roll and Hayuth (1993) research, DEA is presented as new methodology for measuring port performance, as it provides a relative efficiency rating in the analyzed units and no 'standard references' or indexes are required. The paper however, works with hypothetical data and not real port cases.

Liu's (1995) study compares public and private enterprises in the UK port using the Stochastic Frontier analysis (SFA) model referencing the port efficiency measured by a frontier production function. The results did not show clear-cut ownership (private or public) as relevant factor in the efficiency outcome for the period of analysis.

In the case of Tongzon and Heng (2005), they have also studied the relationship of ownership and efficiency adding to the stochastic frontier model a principal component analysis (PCA) so that the key factors on port competitiveness could be examined. The results indicated that private sector participation can improve the operational efficiency. The limitations of the paper include the fact that only container terminals were studied.

Talley (2006) showed that port performance should be measured also by the economic perspective (cost function) rather than the engineering (volume throughput) as volume is limited by the technical efficiency. The author points out that DEA is a consolidated technique to measure the relative technical efficiency of ports, applied in different cases around the world. Talley (2006) also called attention to the importance of measuring port performance over time (single port) and in relative terms (multi ports analysis). The efforts of Cullinane and Wang (2006a) were dedicated to demonstrating the relevance of DEA in the port industry. Their scope of analysis was also the container terminals, but the most interesting result of their investigation was that "*the optimum efficiency levels indicated by DEA results might not be achievable in reality, because each individual port has its own specific and unique context (2006, p. 517).*"

Bichou (2006) recognized that despite all the advances made in port performance metrics, there was still a big gap in measuring the ports performance's integration in the supply chains they are inserted. The paper presented a tested model and other cases are offered as illustration. The investigation by Brooks (2006) is a genuine in presenting the links between port performance and the devolution process in the literature with strategic management insights.

The study from De Langen et al. (2007) is authentic in the sense that they also criticize the traditional performance indicator using volume throughput, and they give a concrete contribution pointing out alternative PPI (*port performance indicator*) that can be used. They also indicate ports that are already collecting data for these alternative PPI, as well as they name the interest of stakeholders and benefits for the port authorities in analyzing these alternative indicators. Relevant for this study is the new PPI they suggest for socio-environmental stakeholders.

The investigation by Gonzalez and Trujillo (2009) is perhaps one of the most comprehensive review on port efficiency measurements. The paper's scope is limited to economic productivity and efficiency of ports and as such, the authors give a great contribution to show the dominance of the Economics (as field) and Statistics (as methodology and model) of port performance analysis in the 1995–2006 period. The authors give also a relevant insight for policy makers, pointing the need of closer follow up of corresponding authorities of port data collection.

Port efficiency is also studied at the operational level. For example, multiple papers have focused on the use of operations research models for handling (containerized) cargo (Gharehgozli, Roy, & De Koster, 2016; Gorman et al., 2014). In general, the business literature covers the strategy levels, while the port literature is dominated by the economic operational level. In this sense, the research from Notteboom et al. (2013) gives another relevant contribution, as in their aim to understand the extend and scope of port research agenda, their conclusions go toward overcoming three challenges pointed out by the authors. First, avoid fragmentation of the studies that generate lack of consistency and breakdown of long-term research agenda; Second, overcome the tendency to neglect the construction of theories that is to deal with the

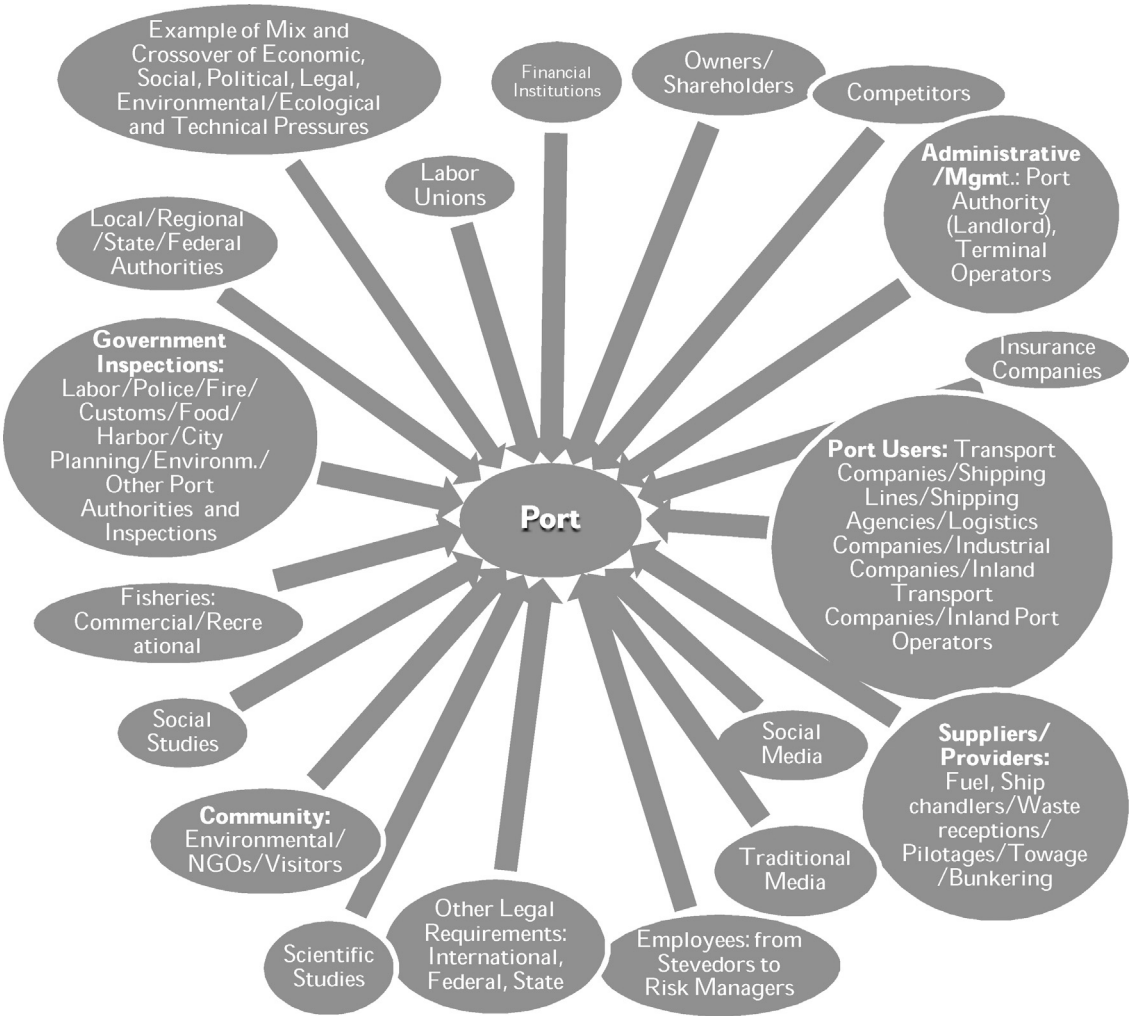

Fig. 2. Stakeholders: Mix and cross-over of economic, social, political, legal environmental/ecological, and technical pressures for seaport resilience.
Source: Gharehgozli, Mileski, Adams, and Von Zharen (2017c).

pressure for publication that direct the research for applied or cases studies. Third has to do with the relationship of researchers and policy-makers bearing in mind the relevance and rigor of port related research: "*Scholars tend to focus on making progress in specific research disciplines whereas decision and policy-makers are interested in the overall operation of ports,* i.e. *in economic, land-use planning and environmental aspects.*" (2013, p. 651)

The brief literature review performed here shows that there is gap in the literature in a sense that there exists no paper with a comprehensive approach to discuss whether efficient ports are also effective. Until recently, the only research done on port focused was from a decade ago on port choice (Hao, 2007). This is surprising, since research on effectiveness has a long history beginning with research on transport carrier choice using service attributes in the 1970s and early 1980s (see, for example, Saleh and LaLonde (1972); McGinnis (1978); Brooks (1985); LaLonde and Cooper (1989)). Furthermore, the handful discussions on port effectiveness do not specify whether the criteria considered are at the strategic, tactical or operational level. In fact, a quick review of the efficiency literature shows that they have been focused on the operational level. Finally, the papers which focus on the differences of port effectiveness and efficiency tend to focus on a specific stakeholder and dismiss the other ones.

The research efforts leave us with three key points for our investigation: there is an increasing interest for port performance indicators and assessment; port performance is predominantly measured within the economic parameters; and there is a chronic lack of data availability on the port level, as the information is typically provided by the individual terminals.

From the literature it is well documented that the port reform wave of the 1990s has led scholars to seek for performance indicators focused on efficiency. However, how is it possible to measure port efficiency if the full data set is not available and if multiple stakeholders are involved in the process? What if the multiple KPIs (key performance indicators) have incompatible (or even controversial) reference indexes? What if the efficiency optimization is not leading to port effectiveness?

These are just some of the common questions that arise from a more critical perspective of port performance analysis. Port effectiveness is out of the scope of this paper, but is a good example of a relevant topic that has received much less attention than port efficiency, as evidenced in the recent research from Brooks, Schellinck, and Pallis (2011a, 2011b); Brooks and Schellinck (2013); and Schellinck and Brooks (2014), Schellinck and Brooks (2016).

3. The port performance in four dimensions: The theoretical background

The stakeholders' literature is not new in corporate governance (Freeman & Reed, 1983), the incorporation of the stakeholders in

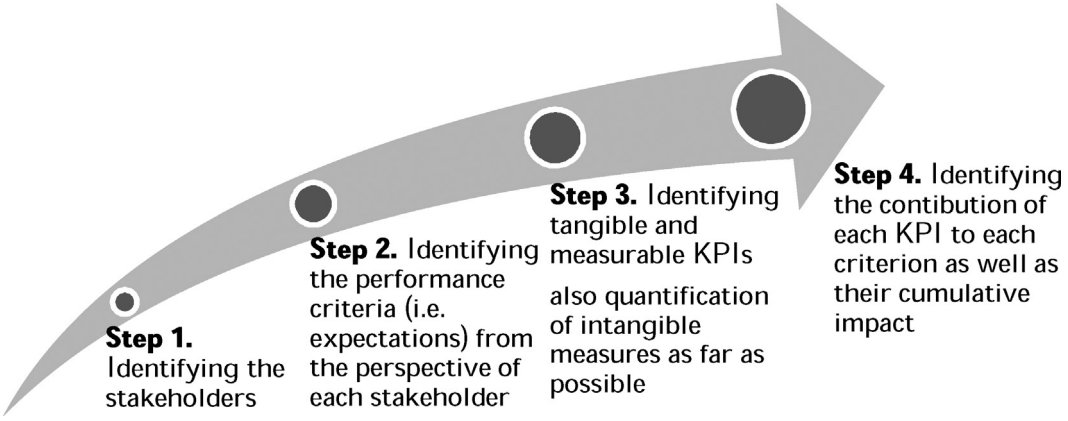

Fig. 3. An overview of the port performance assessment process.

Source: Authors' own elaboration.

the port governance studies is relatively new if comparted to port performance indicators as reviewed in the previous section.

The port stakeholders' studies have in general the focus on the stakeholders' management, considering their different interplay forces (Notteboom & Winkelmans, 2003) or their conflicting interests (De Langen, Nidjam, & Van der Horst, 2007; Galvao, Wang, & Mileski, 2016; Parola & Maugeri, 2013). In the cases of Lam, Ng, and Fu (2013); Cruz, Ferreira, and Azevedo (2013) and Dooms (2014) the authors have built on the stakeholder analysis to provide a framework of analysis that links stakeholders to governance issues.

Within a port, two different sets of people act as stakeholders: those who directly use, regulate, maintain, and police the port, and those who indirectly benefit or are otherwise affected by the activities of the port.

Fig. 2 provides an example of some of the stakeholders in the analysis that may influence or exert pressure on. Port performance must be analyzed by keeping in mind both the stakeholders inside and outside the port perimeter.

In any of those cases studied in our review of port stakeholders' literature we could notice that researchers have not necessarily found new stakeholders in the port context, but their interrelation became more complex as the port business developed to integrate supply chains and robust logistics operations. In this sense, our study has considered that besides the economic dimension, which shall remain as the main driver, there are at least three other dimensions that should be incorporated for a more comprehensive port performance assessment. The novelty we present here is the link between port stakeholders' expectations and the port performance measures and concepts. The 'comprehensive' framework refers to encapsulating of various aspects as well as a compromised assessment. Building a 'stakeholder neutral' perspective is obviously impossible. None of assessments would satisfy all stakeholders for all of their desires.

A performance assessment is conventionally expected to represent a certain point of view. From the perspective of a terminal operator, any strategies that reduces costs may be feasible while some of these strategies may dissatisfy e.g. society (e.g. environmental concerns originated from cheap but harmful equipment). However, a compromised assessment can be developed based on a predefined priority degree of major stakeholders while the debate raises on the definition of priority. The pilot study in Section 5 illustrates two cases including priority-based and priority neutral assessment, so one may compare both types of allocation.

Based on the initial discussions of Notteboom and Winkelmans (2003) on stakeholders' management and, also on the more recent research of Dooms (2014) about integrating the three "Ps" (profit, people and planet) in the performance bottom line, we consider that social and environmental aspects have to be part of the port performance assessment considering the nature of port activities and the ethics that its business should follow in an international competitive environment. In addition, the port reform 'wave' from the 1990s with subsequent changes in the governance (Brooks & Cullinane, 2007) leave no doubts that regulation and legislation have to be considered in any performance assessment of ports.

In other words, this means while the economic dimension includes any financial and operational efficiency measurements, the social, ethic and political dimensions have to take into account the port as a dynamic activity that brings impact to the location (environmental and community) at the same time it is impacted by national and international circumstances (trade, regulation and development). At a glance, we have that: The Social dimension is related to labor, impact on community, people and culture; the Political dimension has to do with regulation, law, policies and governance; the Ethics dimension can consider many different aspects of the social and environmental responsibilities; and Economics is related to the profit and resources required in the port business. These four dimensions (economic, social, political and ethics) can be applied in different levels of analysis, that is from the strategy, to operational and technical levels. In the port reality, these levels correspond to city/region, port and terminals.

As such, our hypothesis is that a port is performing well when these four dimensions are fulfilled. The next questions are then, what are the indicators to examine in each dimension? What are the parameters to consider and how to balance them? In order to be able to answer these questions, we have to bear in mind the different groups of stakeholders and their specific interest in the port performance.

4. Measurement and quantification in port performance

The assessment process consists of four main steps as parts of the QFD approach. In the first step, the stakeholders were identified. In the second step, the criteria that satisfy performance perception of each group were defined. Those criteria must be comprehensive and independent. If two criteria are dependent, then they have to be combined and labeled again. In the third step, the technical measures corresponding to the criteria were identified. Technical measures must be "measurable", "tangible" and must have a unit (i.e. KPIs). Furthermore, a technical measure can be a binary question such as quality management system exists or not. Finally, the level of contribution of each technical measure to each criterion were estimated. Furthermore, the importance level of each criterion were identified (priority of each criteria). As a result, we will see how each technical measure contributes to

Table 1
Stakeholders & expectations in port and terminal business.

S1	Terminal Operators (incl. Owners and Investors)	Notes
E1.1	Profitability/Earnings	Higher operating returns, less operating cost
E1.2	Customer Loyalty (Business Sustainability)	Customer commitment and long-term contracts
E1.3	Credibility/Financial Reputation	Financial strength and higher credit rating
E1.4	Publicity/Brand Value	General reputation, brand equity, goodwill
E1.5	Responsive and Professional Public Institutions	Port authority, landlord, public administration
E1.6	Safe and secure cargoes and their contents	
E1.7	Safe and secure on board operations at berth	Operations managed by ships and their officers
E1.8	Proper pilotage/tug services	7/24 service, proper number of tugs
E1.9	Hinterland/Foreland architecture and plasticity	Flexibility of backyard for development prospects
S2	*Cargo owners*	
E2.1	Safe and secure handling of cargo	
E2.2	Less transit time (quick service)	
E2.3	Cheaper service (right pricing)	
E2.4	Smooth and quick customs procedure	
E2.5	Convenience/Flexibility of storage facilities (early drop-off and late pick-up)	
E2.6	Less and reduced carbon footprint	
S3	*Shipping firms (shipowners)*	
E3.1	Less transit time (mooring, cargo handling)	
E3.2	Safe cargo handling	
E3.3	Lower terminal fees	
E3.4	Convenient/safe terminal location	
E3.5	Less and reduced carbon footprint	
S4	*Inland carriers (incl. Logistics firms, trucking and rail transport firms)*	
E4.1	Less transit time (handling, gate operations)	
E4.2	Convenience/flexibility of parking facilities	
E4.3	Smooth and quick customs procedure	
E4.4	Convenience of transport infrastructure	
S5	*Local and national government (incl. landlords/port authorities)*	
E5.1	Terminal security	
E5.2	Safe terminal operations	
E5.3	Social responsibility	
E5.4	Compliance with labor standards	
E5.5	Responsiveness to government inquiries (e.g. data sharing)	
E5.6	Transparency and proper communication	
E5.7	Competitiveness and growth (developmental attitude)	
E5.8	Less and reduced carbon footprint	
S6	*Global and supra-national regulators*	
E6.1	Terminal security	
E6.2	Safe terminal operations	
E6.3	Compliance with labor standards	
E6.4	Less and reduced carbon footprint	
S7	*Society/citizens*	
E7.1	Terminal security	
E7.2	Safe terminal operations	
E7.3	Social responsibility	
E7.4	Compliance with labor standards	
E7.5	Transparency and proper communication	
E7.6	Less and reduced carbon footprint	
E7.7	Positive and adaptive port-city connection	
S8	*Workers/labor (internal customer)*	
E8.1	Compliance with labor standards (working environment)	
E8.2	Higher salary scale and benefits	
E8.3	Social security	
E8.4	Relevant facilities and training opportunities	

Source: Authors' own elaboration.

satisfaction/dissatisfaction of a particular stakeholder or its expectation. Fig. 3 gives an overview of the framework (QFD method and its application will be discussed below with the pilot study).

In the first phase of this study (i.e. Step 1 and 2), an extensive content analysis process was followed mainly with in-depth systematic literature review (as built in sections 2 and 3) and authors' assessment of contents (keyword based) of port performance studies (PPRN, 2019),[1] and finally a list of major stakeholders and their expectations from port services were gathered in Table 1.

In this paper, a more functional classification as presented on Table 1 was preferred considering latter part of the study in which we investigated interactions and cause-effect linkages between measures/indicators and stakeholders' interest. In contrast to previous studies, this paper goes a step forward and classifies major expectations of each stakeholder to clarify the subset of requirements. Expectations of each stakeholder (coded as E*x.x*) also rephrase the definition and attributed meaning which eliminates the semantic miscommunication. For example, instead

[1] PPRN (Port Performance Research Network) is a group founded within the IAME (International Association of Maritime Economists) to investigate port performance in focus. It was created in 2001 by academic researchers and its meetings and author publication include maritime industry members and practioners.

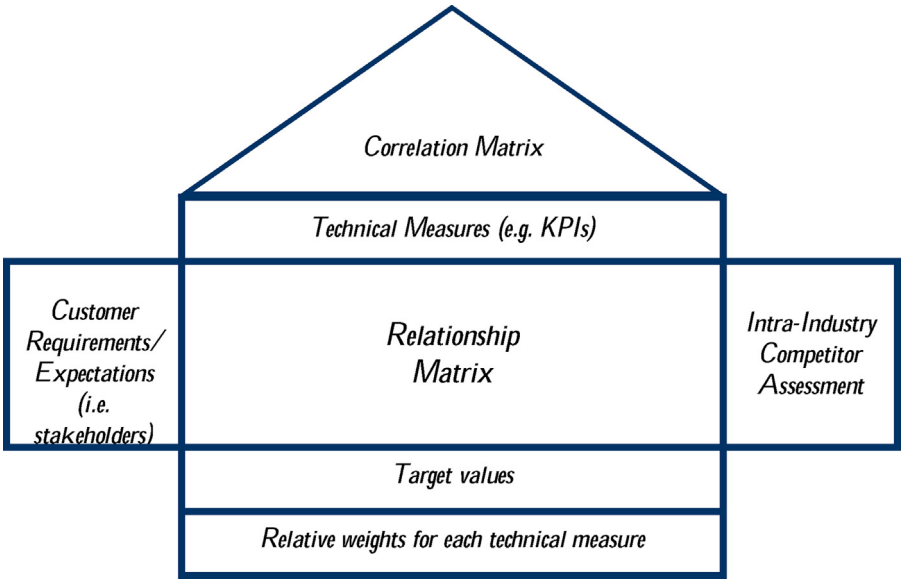

Fig. 4. Traditional format of *the House of Quality* (HoQ).

Source: Akao (2004).

of using "safety" or "location" a general expectation of all stakeholders, we have phrased them to meet each stakeholder point of view associated with that variable.

4.1. The Hinterland and Foreland Plasticity

In this paper, we propose a new concept in port studies, *the Hinterland and Foreland Plasticity* (*See* E1.9). Hinterland conventionally refers to all transport facilities and industrial end users (i.e. stakeholders) behind ports while foreland refers to maritime transport networks and connections in the sea side of ports. The first conventional use of the term, *foreland*, goes back to 1950s (Weigend, 1956, 1958). Weigend (1958) investigated the term from a semantic and bibliometric perspective and distinguished hinterland and foreland through their fundamental differences. The modern interpretation of the foreland concept was investigated in Notteboom and Rodrigue (2005) as well as Rodrigue and Notteboom (2010) based on the port regionalization problem. According to Rodrigue and Notteboom (2010), port regionalization is not only a process in hinterland, but it is also the evolution of foreland through cooperation among regional ports.

The concept of the hinterland and foreland plasticity refers to three fundamental features. First, ports extend their operations and business backward to intermediate hubs and hinterland in general. Many ports have been built in developing stages of their regions and countries, and cities behind those ports have enlarged and spread out through the connection between ports and hinterlands. Eventually, ports have significant difficulty to find suitable land and facilities to expend their operations and business. In this circumstance, plasticity refers to the capacity and flexibility of hinterland for expansion without tackling with the city at the background. Second, the plasticity of hinterland may refer to intermodal capacity and flexibility. Development and expansion of ports typically need the development of transport infrastructure between hinterland and ports as well as other destinations in the network (i.e. foreland). In some cases, port development is restricted by inability to develop transport infrastructure, and that is classified as another dimension of the plasticity. In addition to above mentioned costs of inaccurate city and port planning, the plasticity of hinterland in terms of political and social aspects is the third fundamental feature of the term.[2] Although the third dimension is more about the hinterland, it emphasizes the adoption and tolerance by local community and public policy.

4.2. Defining customer and seller (service provider)

Regarding a comprehensive port performance framework, there is no 'port-centric' definition of service provider which externalizes all other stakeholders and labels as 'customer' (stakeholder neutrality principle). The society and citizens of a region or country definitely value and benefit themselves from port services due facilitated trading activities and contributions to the region. Therefore, the relationship between stakeholders is not unidirectional from all stakeholders to ports and terminals, but it is actually multifaceted and it can be seen as a web of interactions. For example, citizens would require landlord and national government to facilitate hinterland operations as well as making proper plans to ensure safe, secure and lean transport. From citizens' perspective, local and national government is also a service provider or facilitator. Considering the entire concept of ports and terminals, port performance inquiries are a more complex web of relationships.

4.3. Quality function deployment and expectations matrix

The quality function deployment (QFD) (Akao, 2004) method is an instrument to find a final cumulative impact of a technical measure (e.g. KPIs) on particular aspects of customer satisfaction (i.e. expectations). The motivation behind the methodology arises from the fact that there is no direct link between a final product or service and various segments of the organization. In other words, expectations of customer cannot be reflected in different agents and departments of the product/service provider. For example, it is quite difficult to translate requirements of shipping firms into environmental or financial apparatus (i.e. technical measures) while same translations need to be performed many other stakeholders too. In this regard, the QFD methodology helps to translate requirements into measurable and tangible instruments as well as to

[2] The term, the hinterland and foreland plasticity, may be extended with other aspects of port/terminal operations and management.

Table 2
Impact of performance indicators on stakeholder satisfaction (Sample: Portugal, S.Pore, U.S.A., Turkey).

Ø (empty) – No impact
● – Weak impact /1 pt.
■ – Moderate impact /3 pts.
⬤ – Strong impact /5 pts.
■ – Very Strong Impact /7 pts.

		Stakeholders and Priority Degrees (% est.)	Market Indicators (Ex. % market share)	Financial Indicators (Ex. Return on equity)	Operational Indicators (in-terminal) (Ex. Ships/Day, Hours/Ship)	Technology Indicators (equipment-technology) (Ex. Type or age of gantry cranes)	Port/ Harbor Indicators (seaway) (Ex. No. of marine accidents)	Environmental Indicators (Ex. Volume of CO_2 Emission)	Social Indicators (public relations, CSR) (Ex. $ spent for local community)	Gate/Hinterland Indicators (border and out-terminal) (Ex. Average gate time per truck)	Macro-Economic and Political Indicators (Ex. Volume of regional trade, economic climate)
2	0.16	Terminal Operators	⬤	■	■	■	●	●		⬤	⬤
1	0.17	Cargo Owners	●	■	⬤	⬤	■	●		⬤	⬤
3	0.15	Shipping Firms	■		■	⬤	■	■			
4	0.13	Inland Carriers			■	■		■		■	⬤
5	0.12	Local and National Government				⬤	⬤	⬤	■	⬤	⬤
6	0.08	Global and Supra-National Regulators				⬤	⬤	■	●	●	
5	0.12	Society/Citizens				■	⬤	■	■		■
6	0.08	Workers	■	⬤	●	⬤			●		■
		Sum product (Priority degree × Perceived Correlation/Impact)	*1.645*	*2.008*	*3.446*	*4.750*	*3.264*	*3.132*	*1.785*	*2.875*	*3.909*
		% Cumulative Contribution	0.06	0.07	0.13	0.18	0.12	0.12	0.07	0.12	0.14
		% Cumulative Contribution (priority neutral)	0.06	0.07	0.11	0.18	0.12	0.13	0.08	0.11	0.14
		Rank	8	6	3	1	4	4	7	5	2

Source: Authors' own elaboration.

calculate the equilibrium among stakeholders as well as prioritizing instruments in terms of their cumulative impact on costumer's satisfaction. When only one type of customer is present, such translation should show an equilibrium among technical measures and highlighted measures of the greatest impact. A production unit may have so many technical measures to manage and to improve the product while ensuring certain internal criteria (e.g. breakeven, profitability, manpower security). The QFD approach helps organizations to identify technical measures with the greatest impact for better utilization of resources.

The house of quality (HoQ) is an essential component of the QFD, and it is a matrix of customer (i.e. stakeholder) expectations vs. technical measures (e.g. KPIs) (Fig. 4). The function of HoQ is to clarify and quantify the contribution of each technical measure to the improvement of the stakeholders expectation as well as the cumulative improvement of the objective phenomenon (Akao, 2004). An expert panel (e.g. experts, engineers, consultants, researchers) estimates the level of relationship between technical measures and their corresponding technical/management apparatus and customer requirements based on a scale of 0/1/3/5/7 or 0/1/3/5/7/9 (higher the rating, stronger the impact). When the relationship can be estimated numerically, corresponding rating can also be reflected based on a correlation index. However, it is most probably mentally calculated by subject matter experts. In contrast to traditional surveys, subject matter experience is much valuable and essential than the number of people in this exercise. A few subject matter experts would be sufficient than hundreds of less qualified people with limited experience. Therefore, the QFD should not be confused with conventional surveys and their sample size requirements. The legitimate population of the QFD is already very small due to the limited number of subject matter experts with broader understanding, experience and technical credentials.

It is a very natural argument that customer requirements are not equally important. Therefore, customer requirements need to be prioritized too. The prioritization of customer requirements can directly be asked to a sample of customers. However, this paper has slightly different objectives and structure. In this paper, the relationship between groups of respondents (e.g. cargo owners and shipping firms) and groups of technical measures are compared. This paper does not attempt to investigate the relationship between requirement of a specific customer and a technical measure at the micro level. Instead, this paper investigates macro relationships between stakeholders and groups of technical measures to shed light to future research. In other words, future research may focus on a specific customer group (stakeholder) and its expectations (listed in Table 1) and technical measures for a given port or terminal. For the purpose of this paper, the significance of each stakeholder is investigated through independent subject matter experts. If this question would be asked to specific stakeholder, each stakeholder would naturally prioritize its own requirements.

Table 3
Impact of performance indicators on stakeholder satisfaction (Sample: Brazil).

Ø (empty) – No impact
● – Weak impact /1 pt.
■ – Moderate impact /3 pts.
⬤ – Strong impact /5 pts.
▬ – Very Strong Impact /7 pts.

		Stakeholders and Priority Degrees (% *est.*)	Market Indicators (Ex. % market share)	Financial Indicators (Ex. Return on equity)	Operational Indicators (in-terminal) (Ex. Ships/Day, Hours/Ship)	Technology Indicators (equipment-technology) (Ex. Type or age of gantry cranes)	Port/ Harbor Indicators (seaway) (Ex. No. of marine accidents)	Environmental Indicators (Ex. Volume of CO_2 Emission)	Social Indicators (public relations, CSR) (Ex. $ spent for local community)	Gate/Hinterland Indicators (border and out-terminal) (Ex. Average gate time per truck)	Macro-Economic and Political Indicators (Ex. Volume of regional trade, economic climate)
2	0.16	Terminal Operators	●	▬	▬	▬	▬	■	■	▬	▬
1	0.17	Cargo Owners	●	▬	▬	●	●	■	•	●	▬
3	0.15	Shipping Firms	●	▬	▬	▬	▬	■	•	●	▬
4	0.13	Inland Carriers	■	▬	●	■	■	■	•	▬	●
5	0.12	Local and National Government	■	●	■	■	■	●	●	■	▬
6	0.08	Global and Supra-National Regulators	●	●	■	●	■	▬	▬	■	▬
5	0.12	Society/Citizens	•	■	•	■	•	▬	▬	■	■
6	0.08	Workers	•	■	●	■	●	■	▬	●	●
		Sum product (Priority degree × Perceived Correlation/Impact)	*3.711*	*5.810*	*5.083*	*4.157*	*4.488*	*4.025*	*3.463*	*4.950*	*5.843*
		% Cumulative Contribution	0.09	0.14	0.12	0.10	0.11	0.10	0.08	0.12	0.14
		% Cumulative Contribution (priority neutral)	0.09	0.14	0.12	0.09	0.10	0.10	0.10	0.12	0.14
		Rank	5	**1**	**2**	4	**3**	4	6	**2**	**1**

Source: Authors' own elaboration.

Therefore, participants should be impartial or reflect the impartial standpoint. Priorities can be extracted in various ways and then normalized. In this paper, we asked a few experts with broader views and without direct connection to any interest group as well as collecting opinions among scholars (including authors). A rank-rate approach was followed in which stakeholders are put in order of importance (for the port ecosystem) at the first stage, and then, assuming the top stakeholder as 100 points, remaining stakeholders are given points in 0–100 scale considering the indifference value with the top choice. Median responses are normalized to define priority degrees. For example, 'Terminal Operators' has been given 95 points just below the top choice, 'Cargo Owners', with 100 points. It is normalized priority calculated at 0.16 (=95/605 sum of given marks) while 'Cargo Owners' has 0.17 (=100/605 sum of given marks).

The HoQ may also represent the relationship between technical measures. The correlation matrix above technical measure row can be utilized for this purpose (as in Duru, Huang, Bulut, & Yoshida, 2013). On the other hand, this paper does not attempt a micro analysis and correlation assessment. A sample of technical measures in each group is provided to participants while this paper does not investigate each technical measure. Micro level assessment may be conducted for the case of a specific port or terminal, and technical measures are actually different for various types of ports and terminals (e.g. dry bulk terminal vs. container terminal).

Similar to the correlation matrix, intra-industry assessment is not performed in this paper. Intra-industry assessment section is a useful component in which the target organization is compared to its competitors in terms of each customer requirement. Since there is no target organization and micro level analysis, competitor section is also irrelevant. Future research at the micro level may also consider reflecting competition analysis.

The expectations of stakeholders have already been discussed and listed in Table 1. The definition of technical measures is another fundamental question to develop practical strategies to improve port performance. Considering authors in-depth analysis of technical papers, case studies and various publications of UNCTAD (as refereed on Sections 2 and 3), the technical measures of port services in its wider meaning are classified in nine groups of indicators as follows:

- *Market Indicators* (e.g. *% market share)*
- *Financial Indicators* (e.g. *Return on equity)*
- *Operational Indicators (in-terminal)* (e.g. *Ships/Day, Hours/Ship)*
- *Technology Indicators (equipment-technology)* (e.g. *Age of gantry cranes)*
- *Port/Harbor Indicators (seaway)* (e.g. *No. of marine accidents)*

- *Environmental Indicators* (e.g. *Volume of CO2 Emission)*
- *Social Indicators (public relations, CSR)* (e.g. $ *spent for local community)*
- *Gate/Hinterland Indicators (border and out-terminal)* (e.g. *Average gate time per truck)*
- *Macro-Economic and Political Indicators* (e.g. *Volume of regional trade, economic climate)*

In this paper, the stakeholder expectations are represented by each stakeholder group as a cumulative means of requirements and expectations to be satisfied. Technical measures are also represented by each group of indicators. In this research track, future studies will search for the relationship between each expectation of stakeholder and each technical performance measures.

5. Testing the concept of a comprehensive framework: a pilot study

As a pilot study, Table 2 introduces an estimated matrix of stakeholders (as representative of unique expectations) vs. technical performance measures (as representative of micro level indicators behind them). The objective of this pilot study is to represent potential gross interactions between stakeholders and groups of technical measures of port operations and connected activities. A group[3] of operational executives from port business and logistics company representatives as well as a few researchers are invited (in Brazil, Portugal, Singapore, Turkey and USA, whose profile is summarized in Annex I) to participate to the pilot study. The pilot study is a rough estimation for an average response, and Table 2 presents the median response for each group of data. The slight difference between priority-based and priority-neutral analysis reflects the approximation.

The distribution of the impact of stakeholders could be monitored through the density of symbols in the matrix. The direct stakeholders of port/terminal operations (terminal itself, cargo owners, shipping firms) cluster around the operational and technological indicators while the rest of the stakeholders lay through the right of the matrix which represents hinterland, society and macro-economic and political aspects of the port business. Based on pilot study entries, the priority of each stakeholder is presented with normalized priority degrees (ranking and standard scoring are utilized for the pilot study). Below the matrix, the level contribution (sum-product of priority and size of impact; normalized values) and ranking of technical measures are calculated (the conventional arithmetic operations of the QFD method are utilized).

Fundamentally, two groups of technical measures stand out in the entire sample of indicators. Macro-economic and political indicators represent the bird's eye view to the problem and emphasize the higher-level factors while technology indicators are more about the internal capacity (also operational indicators). However, the pilot study just deals with the gross impact of groups (stakeholders and technical measures) which is definitely an overview of the entire problem. Furthermore, there are special circumstances to be considered regarding the different contexts of each respondents' countries. In Brazil, for instance, respondents have emphasized the operational and financial indicators as per rank results shown in Table 3 (bottom line). This could be explained by the country regulatory framework, specifically as the concession processes are implemented by government agencies (centralized and long lasting). Still in Table 3, we can see that in Brazil, the respondents rank to indicate that Brazilian government should focus on facilitating and developing trade and national economy as well as building financially feasible ports/terminals to satisfy/support these stakeholders. The terminal operators ranked 2, indicating that terminal operations must be improved as well. In such a way, we consider that these results are consistent with some major issues identified at Brazilian large infrastructure projects such as lack of funds for new building; and government policies discontinuity both impacting the operational and economic efficiencies of ports (Galvao et al, 2017)(Galvao et al., 2016). In the case of public ports, the port governance structure centralizes decisions at the Federal Government level, there is actually a lack of autonomy, i.e., dependence of public funds transfer for facing investment, debts services and even operational expenses.

6. Conclusions

Overall, we consider that the paper has accomplished its objective of reviewing in-depth the international literature of port performance and based on a critical view on them, we have studied an alternative more comprehensive framework for port performance assessment covering four dimensions (economic, political, social, ethics). The stakeholder impact matrix shows that it is possible to have different expectations from different stakeholders being assessed at the same time, which support our original hypothesis of "a port is performing well when these four dimensions are full filled". The pilot study has validated the original idea of sector need of a more comprehensive analysis of port performance indicators. As such, this conclusion should provide insights to port managers and policy makers in how to integrate the QFD in their bench makers. The continuation of this research requires systematic input collection from a larger sample of stakeholders' groups aiming to provide an amplified pool of data that could sustain cross country managerial recommendations for the port stakeholders in addition to improve mutual understanding and interaction.

In an ongoing research, much sensitive and detailed analysis of those interactions are investigated through a wider group of representatives which will reveal more practical and insightful results about the comprehensive port performance framework.

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[3] The participants have agreed to provide their answers on a volunteer based and have received no monetary compensation for their time.

Annex I.

Summary of profile operational executives and researches who volunteered to collaborate in the pilot study

Country	Gender	Sector	Main expertise	Years of experience in the maritime sector
Brazil	Female	Public/regulatory	Port development/Investment	20+
Brazil	Male	Container Shipping	Container terminals	15+
Brazil	Male	Environmental impact	Ports and terminals	10+
Brazil	Male	Dry Bulk terminals	Port development	5+
Portugal	Female	Marine services and Shipping	Training and performance assessment	25+
Singapore	Male	Terminal Equipments	Container terminals	25+
Singapore	Male	Terminal/Yard Operations	Container terminals	10+
Singapore	Male	Third Party Logistics	Logistics (Land+Water)	10+
USA	Male	Third Party Logistics	Logistics (All modes)	20+
USA	Male	Container Shipping	Logistics (Inland Water)	25+
Turkey	Male	Third Party Logistics	Logistics (All modes)	10+
Turkey	Male	General Cargo Terminal	Break bulk	5+
Turkey	Male	General Cargo Terminal	Break bulk	20+

Source: authors' own elaboration.

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