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Port Sustainability Performance: A Systematic Literature Review

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Abstract

Motivated by a lack of research on port sustainability performance and assessment, this paper uses a systematic literature review to identify trends, measurement methods, and mechanisms for the implementation of strategy and policy in this area. The paper provides a comprehensive and critical evaluation of port operational sustainability, focusing on ascertaining the impact of its implementation. The study analysed and synthesised established characteristics in the current literature regarding the performance of port sustainability and its evaluation in terms of operations and management. Successful performance measurement in port sustainability is driven by the dependence on establishing accurate indicators as the basis for measurement. Our clustering of analytical sustainability indicators reveals that environmental research is focused on pollution, social research is mainly focused on human resource management, while economic research is mainly on port management and borderline investment. Findings are discussed in four key areas of port sustainability performance and assessment: existing trends, implementation of measures, mechanisms for implementation, and assessment gaps and challenges. For existing trends, attempts to evaluate the applicability and practicality of green operations have improved the awareness and promotion of governmental green policies. Implementation measures relate to the utilisation of techniques that reveal optimal practices for practical sustainable operations while mechanisms largely relate to establishing indicators which increase understanding of performance. Finally, challenges in this field include achieving consistency among ports in how sustainability is measured. Future research should incentivise improvements in port operational practice and encourage self-examination in order to prioritise activity.

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The review allows both academics and practitioners in the port industry to build a better understanding of port sustainability performance and discover useful evidence when implementing initiatives to fulfil sustainability goals.

Keywords: *Port sustainability, Port sustainability performance, Port sustainability performance evaluation, Systematic literature review, Sustainable port, Port management*

Port Sustainability and Performance: A Systematic Literature Review

1. Introduction

Maritime transport plays a pivotal role in international logistics chains, and acts as a facilitator of economic growth between regions and countries (Clark et al., 2004). Fuelled by globalisation and containerisation, international seaborne trade volumes reached 10.7 billion tons in 2017, with a growth rate of 4 per cent over the last five years. Shipping also accounted for more than 80 per cent of the world's merchandise trade transport (UNCTAD, 2018). Even though maritime transport has been regarded as an environmentally-friendly mode of transport in terms of emissions per kilometre, given the share of maritime transport in total world trade, its impacts on the environment are not negligible. Furthermore, port authorities have extended their port infrastructure in order to satisfy the growing demand for the maritime transport and logistics services, and to accommodate the wide range of container vessels size (Notteboom and Rodrigue, 2005; Yang and Chen, 2016). Thus, increased international seaborne trade and port expansion have led to significant adverse effects on the environment including increased noise, reduced air quality, biodiversity loss, and water pollution, as well as impacts on public health and safety (UNCTAD, 1993; Endersen et al., 2003; Corbett and Winebrake, 2007).

With global regulations regarding environmental issues in maritime transport being developed and enacted, for example the MARPOL regulations (Zhang, 2016) and the Kyoto Protocol (Bodansky, 2016), ports are facing greater pressures to comply with regulatory and societal requirements for operational sustainability. Ports have had to take progressive action in this area because it has become a paramount consideration when shipping companies are determining which port to use (Thai, 2016; Parola et al., 2017; Ding et al., 2019). A port which is operating at a high level of sustainability is more likely to attract support from the government, communities and the public, as well as potential investors in the maritime industry (UNCTAD, 2015). Ports have thus increasingly had to make costly investments to achieve regulatory compliance and improve their Corporate Social Responsibility image (Acciaro, 2015). However, given that port operators will ultimately aim to increase profits and only invest where necessary, whereas sustainable port development strategies potentially require heavy financial investment, it is still unclear if the concept of port sustainability is successful or has yielded positive outcomes.

As incompatibility between sustainable management and economic advantage continues to emerge in ports and related activities (Yang et al., 2013; Hou and Geerlings, 2016), previous literature on sustainability performance in ports has reflected understanding of global sustainable development issues in the context of ports, for example, incorporating sustainability challenges into operational practices and strategies and increasing sustainability performance capability from a management perspective. Research has delivered insights into

practices and operations regarding port sustainability performance, which have mainly been addressed from three perspectives; performance measurement (Peris-Mora et al., 2005; Chiu et al., 2014; Asgari et al., 2015; Shiau and Chuang, 2015; Lu et al., 2016a); performance management (Videira et al., 2012; Hiranandani, 2014; Lam and Notteboom, 2014; Le et al., 2014; Kim and Chiang, 2017); and the relationship between the three aspects of sustainability examining the effects of environmental or social management on economic performance in the context of ports (Anne et al., 2015; Laxe et al., 2016; Cheon, 2017; Cheon et al., 2017).

Notwithstanding significant relevant contributions and insights into port sustainability performance from the growing body of literature, further questions emerge; how does the literature on port sustainability performance and its evaluation contribute to fulfilling the goals of sustainability?, and what are the managerial implications of sustainability performance within ports? Further, reflecting on sustainability in port performance identifies a gap in the literature; a comprehensive review of port sustainability performance and assessment does not exist.

This study aims to provide a synthesised view of sustainability performance in the context of ports by understanding operational and managerial implications with a specific focus on assessing sustainability performance from both methodological and empirical perspectives. Performance evaluation plays a strategic role in all areas of business management, helping to explain to what extent they have reached their goals (Dyson, 2000). Therefore, improving understanding through a systematic analysis of the existing literature is a suitable approach to assess the current situation and provide evidence for future port sustainability approaches. However, although this study is not the first to examine the concept of port sustainability using a systematic literature review (see Hakam and Solvang, 2013; Sislian et al., 2016; Davarzani et al., 2016), it is the first to use such an approach to consider port sustainability performance and evaluation.

This study is distinct in two ways from previous systematic literature reviews in this area. First, the focus of this study is on port sustainability in terms of its performance and evaluation, which has, to date, not been covered. Second, in contrast to previous studies which focused on environmental aspects of sustainability, this study covers port sustainability performance from three perspectives; environmental, social, and economic, and categorises aspects of sustainability using clustering of sustainability analytical indicators. Another important contribution of this study is that it covers a period of significant increase in publications on this topic between 2005 and 2018, with 2017 accounting for approximately 29% of the total. Table 1 positions the contribution of this research against other studies that focus on reviewing port sustainability research.

[Insert Table 1 here]

Table 1: Position of this study in the context of port sustainability research

Using a rigorous review approach, this paper provides (1) overall knowledge regarding the current state of port sustainability performance and its assessment, (2) useful evidence of key indicators to decision makers in implementing port sustainability, and (3) suggestions where academic research has the potential to make new contributions in the field of port sustainability performance. The subsequent sections cover the following: first, the definition and scope of

port sustainability and a literature review on port sustainability are presented; second, the research methodology adopted for the research is addressed; third, a discussion about the research questions is conducted; and lastly, conclusions are drawn and contribution outlined.

2. Literature Review

Many publications have considered sustainable management in the port industry, although many of them discuss sustainable management of ports as one part of maritime logistics, shipping, and supply chain management (e.g. Ng and Song, 2010; Berechman and Tseng, 2012; Bergqvist and Egels-Zandén, 2012; Hou and Geerlings, 2016). Therefore, in line with the research aim, this section provides a considered review aimed at addressing sustainability in the context of ports.

2.1 Port sustainability

The increase in volumes carried by maritime transport has led to the expansion of port facilities and resources related to port activities, often causing severe environmental pollution (e.g. Rao et al., 2000). Operational outputs in port areas including water discharge, effluent discharge, noise, dust, greenhouse gas emissions, and dredging spoil disposal, have had detrimental environmental consequences as well as creating security, safety, and health issues for employees (UNCTAD, 1993; Peris-Mora et al., 2005; Acciaro et al., 2014). These issues have increased the need for consideration of a sustainability concept in the port sector.

Port sustainability is rooted in the three pillars of sustainable development that embrace environmental, social, and economic goals (AAPA, 2007). Its main purpose is to seek a safe, socially acceptable, energy-efficient, and environmentally friendly port management approach while at the same time maximising profits (AAPA, 2007; Hakam and Solvang, 2013). Practical and multidisciplinary management techniques are required to integrate the socio-economic, legal, technical, and environmental practices, and to analyse the performance of sustainable responsibilities with appropriate data of components of sustainability (Wooldridge et al., 1999). Figure 1 illustrates the three pillars of port sustainability.

[Insert Figure 1 here]

Figure 1. The three pillars of port sustainability (Source: Authors)

The goals of each of the three pillars from a port perspective can be summarised as follows:

- **Environmental sustainability:** minimising the negative impacts engendered by a wide range of operational and shipping activities within the vicinity of ports (Narula, 2014; Shiau and Chuang, 2015).
- **Social sustainability:** contributing to the enhancement of people's quality of life by supporting port activities to satisfy socio-economic priorities such as employment opportunities, education for employees and communities, and improving social stability of the area surrounding ports (Narula, 2014).

- Economic sustainability: maximising the economic performance resulting from implementing sustainable development initiatives, without adversely affecting social and environmental development (Cabezas-Basurko et al., 2008).

2.2 Port sustainability literature

Ports are inherently complex systems interlinked with numerous internal and external factors together with broader port functions such as, for example, socio-economic issues (Parola and Maugeri, 2013). Indeed, each port establishes and implements individually different operational management strategies depending on the characteristics of geographical position, size, ownership, policy, administration, and stakeholder (Abood, 2007; Li and Yang, 2010; Dinwoodie et al., 2012).

Academic interest in port sustainability has been addressed from a variety of viewpoints: the ecology of port logistics system (see Li and Yang, 2010; Martinsen and Björklund, 2012; Psaraftis, 2016); the environmental impact costs of shipping operations (see Ng and Song, 2010; Lun et al., 2016a); the analysis of exhaust emissions from vessels activities (see Abrutyte et al., 2014; Winnes et al., 2015; Papaefthimiou et al., 2016); and the viability of regulatory and political frameworks in terms of environmental port management (see Wooldridge et al., 1999; Gilman, 2003).

Ports need to consider the integration of environmental concerns into their activities (Beleya et al., 2015; Roh et al., 2016). Environmental sustainability is an essential component of sustainable business strategies and operations in the port sector, in order for them to comply with sustainable development regulations, policies, and guidelines (Puig et al., 2015; Kim and Chiang, 2017; Rocha et al., 2018). This is particularly evident in port activities such as dredging, material disposal, and cargo loading and unloading. In this sense, research related to port sustainability has been focused on such daily port activities in order to promote environmental port performance including, for example, waste oil processing, exhaust emissions reduction, renewable energy generation, energy efficiency initiatives, and noise, waste, and other polluting substances reductions (e.g. Bateman, 1996; Rao et al., 2000; Joseph et al., 2009; Lashin and Shata, 2012; Beleya et al., 2015; Di Vaio et al., 2018).

Research has demonstrated sustainable port operational approaches in a number of ways. (e.g. I2S2, 2010; Homsombat et al., 2013; Shiau and Chuang, 2015). For example, Abood (2007) investigated sustainability initiatives featuring port development and operational activities, and categorised them using a green rating system. More recently, Kim and Chiang (2017) conceptualised the structures and attributes of sustainability practices related to port operations through semi-structured interviews. Regarding research on port sustainability practices, most try to understand their complexities, and in many cases the various conceptual frameworks have been presented in order to realise sustainable port development (e.g. Acciaro et al., 2014; Hou and Geerlings, 2016). More recently, there has been a surge in port sustainability research which in itself demonstrates the importance of port sustainability (e.g. Park and Yeo, 2012; Liao et al., 2016; Puig et al., 2015; Wan et al., 2018). Aregall et al. (2018) address port sustainability in the context of port hinterland interactions by identifying individual green strategies and measures taken at 76 ports. The authors emphasise the importance of environmental measures taken within hinterland activities to achieve successful sustainable development approaches.

Globally, ports are operated and managed under the different forms of port administration and ownership. Some ports are controlled by central government in a way that includes all

regulation and landlord functions; some are operated under mixed public and private service provision. In the western world, ports are, in many cases, private organisations being fully privatised with all regulatory and operational functions transferred from the public to the private sector and aiming to maximise profits with reduced financial investment (Van den Berg and De Langen, 2017; Baird, 2000; Cullinane and Song, 2002; Brooks, 2004). Regardless of the governance structure of ports, the ultimate aims of any port are to maximise operational productivity and efficiency, and to optimise overall direct and indirect economic benefits. The mechanics of this lie in achieving operational efficiency and financial stability, and in building sustainable revenue streams within a specific resource base and budget. (World Bank, 2007; Van den Berg and De Langen, 2017). On the one hand, the concept of sustainability has been identified as one of the key factors influencing the improvement of port competitiveness (Woo et al., 2011; Park et al., 2015; Parola et al., 2017), on the other hand sustainability is required to remove or minimise risk, abandoning short-term gains inherent in, for example, committing to additional investment, and bearing additional external costs such as environmental costs related to CO₂ emissions (EC, 2003; Tichavska and Tovar, 2015). Hence, sustainable economic growth is one of the critical agendas for port authorities, and an ongoing debate has been focused on the balance between environmental and social concerns, and economic importance (Nebot et al., 2017).

However, it is a complex task to assess sustainability performance or establish evaluation criteria in that sustainability itself is entwined with a multitude of internal and external factors (Robert et al., 2005; Magee et al., 2013). This complexity has contributed to developing diverse quantitative indicators to assess sustainability performance in the context of ports (see Lirn et al., 2013; Puig et al., 2014; Roos and Neto, 2017; Oh et al., 2018), and to weight them via tools and evaluation methods including Environmental Management Systems (EMS), Analytic Hierarchy Process (AHP), and synthetic index calculation methods (see Chiu et al., 2014; Le et al., 2014; Liao et al., 2016; Lu et al., 2016b; Laxe et al., 2017; Jiang et al., 2018). In addition, assessing port sustainability performance has had to account for complementary and multidimensional approaches with view to determining the economic effectiveness of sustainability objectives. For example, Cheon (2017) focused on the socio-economic impacts of port activities, while Asgari et al. (2015), Laxe et al. (2016), and Cheon et al. (2017) analysed the relationship between economic and environmental performance.

Although sustainable port development appears to have increased in importance, there remains only a limited amount of literature addressing sustainability issues in port operations, compared to the other modes of transport such as road and urban transport systems (Cabezas-Basurko et al., 2008). As highlighted earlier it is clear that systematic literature review papers, even up to the present time, in the area of port sustainability have not extended to cover social and economic aspects, an issue which this paper now addresses. Besides, the difficulty in understanding the structure of port sustainability performance has been highlighted because port sustainability faces complex decision-making processes (Mansouri et al., 2015). Even though a variety of aspects have been covered, and valuable insights have been provided in the literature, an integrated framework for evaluating port sustainability performance has not yet been developed.

3. Methodology

A systematic literature review methodology was used in order to gather and explore literature addressing the theme of evaluating port sustainability performance. The port sustainability research field has been regarded as being at a relatively early stage in its evolution (see, for

example, Asgari et al., 2015). Petticrew and Roberts (2008) suggested that conducting exploratory research through systematic literature reviews was appropriate when a phenomenon was at the developmental stage and research questions were unclear. In this section, the application of each steps of review process is described in detail.

3.1 Systematic literature review

A systematic literature review is defined as ‘a systematic, explicit and reproducible method for identifying, evaluating and synthesising the existing body of completed and recorded work produced by researchers, scholars, and practitioners’ (Fink, 2013). It is a scientific method designed to investigate and classify large bodies of information, contribute to exploring the frontiers of research, and establish and expand background knowledge (Gu and Lago, 2009). A systematic literature review provides an evidence-informed approach which highlights relevant research studies and questions (Denyer and Tranfield, 2009), and identifies, appraises, and synthesises existing original data from primary research with explicit search strategies and procedures in order to answer particular questions (Petticrew and Roberts, 2008).

Nonetheless, insufficient attention has been given to the systematic literature review as a research method in the field of port sustainability research. An integrated review of the evaluation of port performance and assessment in the context of sustainability has not, to date, been undertaken. The following literature studies focused on one topic (port sustainability or the evaluation of port performance) and provided fragmentary evidence; Hakam and Solvang (2013) adopted a systematic literature review in order to understand the issues and patterns in sustainability of container ports; and Dutra et al. (2015) attempted a more methodical systematic literature review by using a bibliographic portfolio, ‘ProKnow-C’ (Knowledge Development Process – Constructivist) for the purpose of analysing elaborate future research streams on the evaluation of seaport performance.

The use of a systematic literature review in this study is supported by Dutra et al. (2015). They show that a critical analysis of the literature around performance evaluation in port management can support the decision-making process to establish sound policies for port development. Also, Tranfield et al. (2003) highlighted that a systematic literature review enables the identification of effective and efficient evidence based on policy and practice in many disciplines. Therefore, this study, synthesises the evidence of port sustainability performance, and contributes by providing ideas and recommendations for practice.

This study adopts a review protocol proposed by Denyer and Tranfield (2009) for conducting a systematic literature review in the field of management studies. The review protocol involves five major phases: 1) Question formulation; 2) Locating studies; 3) Study selection and evaluation; 4) Analysis and synthesis; and 5) Reporting and using the results. Each step contributes to minimising errors and bias in appraising the review. The review in this paper uses the methodological features and contributions previously defined by researchers in this field.

As pivotal players in international trade and logistics, the important roles of ports cannot be overstated. Despite periodic variations in the performance of the global economy, ports consistently handle over 80 percent of global trade, realising market access, links to industrial activities, support to supply chains, and a range of wider economic benefits (UNCTAD, 2018). Depending on location, function, and the types of ship served, ports are classified into various types such as cruise ports, inland ports, and dry ports. Globalisation and integration of transport networks in the maritime logistics industry have led to the rise of containerised cargo (Chen, 2009), and therefore container ports handling cargo containers, in particular, have become

central to maritime transport activities. World seaborne container trade accounts for approximately 60 percent of the value of total world seaborne trade (Statista, 2018) which stood at 752 million TEUs in 2017 (UNCTAD, 2018). However, with the constant expansion in container trade volumes, container ports are also known to be significant contributors to environmental impact through operational activities (Lam, 2011).

The anthropogenic impact of container ports has motivated many researchers in the port industry to re-examine the role of container ports in sustainable maritime logistics beyond traditional performance levels such as operational efficiency, cost reduction, and the increase in trade volumes and to re-evaluate performance challenges for container ports in terms of environmental and social issues. In this sense, it was considered to be reasonable to delimit the scope of the research to container ports to facilitate information gathering on port sustainability and to provide an integrated analysis on a common basis. The term “ports” in this paper is henceforth taken to mean “container ports”, and sustainability is bounded on port operations and management. Hence, the focus of the review is on the investigation of port sustainability performance from operational and managerial aspects regardless of the characteristics and functions of those ports.

3.2 Research question formulation

Determining the focus of research by formulating clear research questions is essential in all disciplines, but is of paramount consideration in conducting a transparent and rigorous systematic literature review. This is due to the fact that it reflects a variety of approaches, assumptions, and methodological implications from primary research. The appropriate research questions are established before starting the review because the major components of a systematic review such as eligibility criteria, and search strategies are contingent on research questions. An approach called PICO (Population, Intervention, Comparison, Outcomes) has been developed to help to establish definite research questions at an early stage of the review and to preclude inefficient effort that refines them repeatedly during the review process. Denyer and Tranfield (2009) restructured the approach into CIMO (Context, Interventions, Mechanisms, Outcomes) to accommodate the research domain of business management and organisation.

The main aspects of this study were identified by the CIMO as: performance of sustainability operations in ports (C), methods of the assessment of port sustainability performance (I), indicators and tools regarding port sustainability performance (M), and the effectiveness, efficiency, positive and negative results of implementing port sustainability (O). Based on this, the research questions were defined as following.

- *RQ1*: What are the existing trends in port sustainability performance and assessment research?
- *RQ2*: How are port sustainability performance and assessment measures implemented?
- *RQ3*: What are the mechanisms that exist for the implementation of port sustainability performance and assessment?
- *RQ4*: Which gaps and challenges in this research field can be identified?

3.3. Identifying Studies

After establishing the specific research questions, the next step was to locate the existing works which were relevant to answering the research questions by identifying search databases and search strings (Smith et al., 2011). Locating studies involved three search strategies: search terms, databases for literature search, and inclusion and exclusion criteria.

3.3.1. Search terms

Based on the research questions and the main topics defined earlier by the CIMO, the initial search strings included the following key terms: “port sustainability”, “performance”, and “evaluation”. According to an iterative process for a keyword structure presented by Davarzani et al. (2016), and previous literature review studies of port sustainability (see Gimenez and Tachizawa, 2012; Reim et al., 2015; Wong et al., 2015; Centobelli et al., 2017), the structured keywords were determined: “*port*” OR “*container port*” OR “*seaport*”; “*sustainability*” OR “*sustainable development*” OR “*green*”; and “*performance assessment*” OR “*performance evaluation*” OR “*performance measurement*” OR “*green port performance*”.² Figure 2 illustrates the iterative procedure to establish keyword for effective searches.

[Insert Figure 2 here]

Figure 2. Redesigned iterative procedure with the search keywords process of Davarzani et al. (2016)

The searches were run using all possible combinations between the three types of keywords. An asterisk was used at the end of the keywords to expand the range of possible studies (Gimenez and Tachizawa, 2012), considering different derivatives for the same terms, e.g. “sustainable” is derived from “sustainability”. Additionally, the advanced search used Boolean logic: “AND” to connect the two key terms; and “OR” to allow synonyms (Gu and Lago, 2009). In order to thoroughly explore the relevant literature, the keywords focusing on each of the three aspects of port sustainability were additionally searched, for example, “*container port*” AND “*environmental OR social OR economic*” AND “*performance assessment*”.

3.3.2. Database for literature searches

The initial online searches were conducted using the Scopus database (Elsevier). Additionally, iterative literature searches were conducted to reduce the risk of missing literature (Barnett-Page and Thomas, 2009), and enhancing the sensitivity of the review process. Thus, an exhaustive search of a wide range of databases was also conducted (Petticrew and Roberts, 2008). Various electronic international journal databases available were used including EBSCO, Emerald Insight, Google Scholar, Web of Science as well as a university library database, which provides a comprehensive and diverse database in business and management disciplines (Wong et al., 2015). In the same vain, as the published literature is to a considerable degree interlinked (Srivastava, 2007), a manual search of the reference lists of reviews was necessary in order to ensure a more comprehensive landscape of literature review that could be obtained (Schryen et al., 2015).

3.3.3. Inclusion and Exclusion criteria

Only peer-reviewed articles published in academic journals were included in the study (Colicchia and Strozzi, 2012). The exclusion criteria encompassed conference articles, book chapters, dissertations and theses, and other ‘grey literature’ (Petticrew and Roberts, 2008) including reports, working papers, government documents, and white papers (Boland and

² Based on a suggestion from an anonymous reviewer we added the key word “green port performance”.

Dickson, 2013). Often the contributions of such work can be found in the completed version in academic journals (Davarzani et al., 2016). Given that discussions on sustainability in maritime logistics have gradually developed since 1990 (Hakam and Solvang, 2013), the period of time considered by the study was therefore determined to be from 1990 to the present. Also, only articles available in full-text in English were selected in this study. Furthermore, since the focus of this study is on port sustainability performance and assessment, only articles covering the methods or measures for performance assessment were included. In other words, those focused on establishing a conceptual approach and frameworks were excluded from the study. Summaries of the inclusion and exclusion criteria are detailed in Table 2.

[Insert Table 2 here]

Table 2. Inclusion and exclusion criteria (Source: Authors)

3.4. Study selection and evaluation

Using the keyword combinations detailed in section 3.3.1, an initial search identified a total of 704 papers. The results of the search through individual electronic databases are illustrated in Figure 3.

[Insert Figure 3 here]

Figure 3. Number of articles identified through initial database search (Source: Authors)

This study's inclusion and exclusion criteria were based on the recommendations of Pittaway et al. (2004) and Petticrew and Roberts (2008). Three filtering processes were established for the purpose of increasing the reliability of article selection. First, refining based on the scope of the papers was accomplished using the context provided by the abstract together with the keywords. Since it is unlikely that the paper title adequately reflects the papers relevance to the research questions, the abstract provides a broader summary of the paper (Gu and Lago, 2009). Papers not falling within inclusion criteria such as non-accessibility to full text, articles, conference paper, book chapters, and non-English papers were filtered at this stage. The research scope was also considered in this step. Since this study was concerned on the area of ports, articles covering irrelevant subjects, for example, shipping, ship-related, supply chain management, maritime logistics, logistics, climate change, transport, marine environment, international trade, education, were excluded even if they covered the concept of sustainability. Also, a large number of duplications resulting from the repetitive search using the electronic databases were eliminated. On this basis, the number of articles was reduced to 68.

Second, the papers were categorised using the following quality criteria (Pittaway et al., 2004; Petticrew and Roberts, 2008; and Easterby-Smith et al., 2012).

- List A: Papers whose abstracts/contexts focus on both port managerial sustainability and performance assessment (32 papers).
- List B: Papers whose abstracts/contexts mainly focus on performance assessment but cover scarce or insignificant reference to port managerial sustainability (25 papers).
- List C: Papers whose abstracts/contexts mainly focus on port managerial sustainability but cover scarce or inconsistent reference to performance assessment (11 papers).

The 36 papers contained in List B (25 papers) and List C (11 papers) were determined to be extraneous to the central research and questions and excluded since this study focuses on the performance evaluation of port managerial sustainability. The 32 papers identified in List A using the second filtering process were included due to their consistency with the scope of the research.

Last, a thorough examination of the context was carried out separately with a focus on the inclusion and exclusion criteria as well as the research questions specified earlier. After assessing the full context of the papers, a further 11 articles were excluded, and consequently a total of 21 articles containing useful information for answering the research questions were selected. Through the iterative filtering process, the number of papers reduced from 704 to 21, primarily for two reasons; redundancy and duplication identified using the iterative process from the previous steps in finding studies; and a lack of literature covering empirical evidence of sustainability performance in the context of general operation and management of ports (Hakam and Solvang, 2013). The complete filtering procedure for selecting papers is shown in Figure 4. All reviewed papers are listed in Appendix A.

[Insert Figure 4 here]

Figure 4. The procedures of selecting and filtering of the articles (modified from Abidi et al. 2014)

The final sample size of 21 papers (a 97% reduction from the original 704 papers) is consistent with other studies of this type. Although, 13% higher than Davarzani et al.'s (2016) study on greening ports and maritime logistics, which started with an initial sample of 2,180 papers and finished with a final sample of 228 papers (84.4% reduction), this study aligns with other literature review studies in supply chain management. On average the decrease in sample size in such studies from initial to final samples is between 95% and 98% (see Miemczyk et al., 2012; Abidi et al., 2014; Gimenez and Tachizawa, 2012; Tachizawa and Wong, 2014). A further example, is a study in software engineering (Kitchenham et al., 2009) where they analysed only 18 papers a decrease from original sample size of 99.3%.

3.5. Analysis and synthesis

This section provides a descriptive overview of the information obtained from the papers dealing with the research questions established in the review process. Further important evidence in relation to port sustainability was identified and synthesised.

3.5.1. Descriptive analysis

Number of articles

The 21 papers identified between 2005 and 2018 relate to sustainability performance and assessment in the context of port management and operations. However, there has been a significant increase in the number of published papers covering these areas in the last four years, with 6 being published in 2017, accounting for approximately 29% of the total.—This suggests that evaluation studies on port sustainability performance represent an emerging field of research, showing a gradual increase in academic interest. In fact, the recent growth in the number of articles published is plausible because the concept of sustainability within the maritime and transport industry has developed, particularly since the United Nations Conference on Environment and Development (UNCED) (Earth Summit) in Rio de Janeiro in 1992, where the concept of sustainability concerning maritime transportation was reinforced, and governments agreed and adopted a comprehensive programme, the so- called “Agenda 21”

(UN, 1992). This summit emphasised the need for comprehensive impact studies and assessment of sustainable development.

Geographical scope

Geographical location was analysed in order to identify the distribution of academic interest. Ports that have been the focus of the most research were in Taiwan (5 articles) and China (5 articles), followed by ports in South Korea (3 articles) and Spain (3 articles). Figure 5 illustrates the proportion studies relating to a ports' geographical location. The greatest density was found in Asia (62% of the total): Taiwan (24%), China (24%), and Republic of Korea (14%).

[Insert Figure 5 here]

Figure 5. Distribution of the ports' geographical locations (Source: Authors)

Assessing green port performance in Asian ports has been growing since the region has the largest and busiest ports which handle the highest container volumes globally, and regulations addressing the environmental impact caused by their activities have been strengthened (Chen and Pak, 2017). Furthermore, increasingly studies have been conducted on the effectiveness and feasibility of port sustainability implementation in the Asian region (Asgari et al., 2015; Chen and Pak, 2017) reflecting the pervasive perception among Asian ports that the benefits of sustainable practices are not sufficient to cover the costs of their implementation (Yang et al., 2013; Acciaro, 2015).

Dimensions of sustainability

Papers on the dimensions of sustainability can generally be split into three aspects and, taking possible overlaps into account, six categories were used for this review: (1) environmental; (2) social; (3) economic; (4) environmental and social; (5) environmental and economic; and (6) social and economic. Figure 6 shows the number of articles by category.

It is worth noting that 8 articles focused on the social aspect with environmental and economic aspects, and none of the articles only focused on social aspects. Similarly, 5 articles focused on economic aspects along with social and environmental issues, but none focused solely on economic considerations. On the other hand, 10 articles investigated the sustainable performance of ports from an environmental perspective. Including papers whose foci overlap with social and economic aspects, environmental issues in ports were addressed by a total of 19 articles.

[Insert Figure 6 here]

Figure 6. Number of articles by the category of sustainability (Source: Authors)

Research methods and data analysis techniques

In order to classify the articles based on their characteristics and purposes of methods, this study adopted the categorisation provided by Wacker (1998), which has been used by researchers in operations management in order to detect certain patterns in the literature (Burgess et al., 2006; Woo et al., 2011). Wacker (1998) divided research methods into two

groups: analytical research conducted using deductive methods; and empirical research using induction methods applied to external data from organisations or businesses. Further, each major classification can be divided into three sub-categories: conceptual, mathematical, and statistical for analytical approaches; and experimental, statistical, and case studies for empirical approaches. Empirical research methods (12 papers, 57%) were used more extensively than analytical research methods (9 papers, 43%). All empirical research has been undertaken using statistical approaches which analyse data gathered from external sources such as interviews, surveys, archival research, and Delphi techniques. In other words, neither empirical experimental research ('field experiments') demonstrating causal relationships under controlled environments (Meredith et al., 1989) nor empirical case studies which investigate a limited number of samples to generalise theoretical ideas, have been used. Contrary to empirical research biased towards one methodology, analytical research methods were used evenly across the three sub-categories. One paper (5%) using analytical conceptual research aimed to add new insights to traditional problems, illustrating developed concepts by case study. Four papers (19%) using mathematical research studied the relationships of concepts based on numerical examples. Finally, four papers (19%) used analytical statistical research which measures the relationship of variables and develops integrated models for empirical statistical tests (Wacker 1998). Table 3 reports the proportions of type of research methods in six categories.

[Insert Table 3 here]

Table 3: The different types of research methods in port sustainability and performance studies.

Most researchers used Analytic Hierarchy Process (AHP), a Multiple Criteria Decision Making (MCDM) method, followed by the Delphi method, and Data Envelopment Analysis (DEA) in order to evaluate and measure port sustainability performance, conducting not only case studies but also survey-based research. This is primarily because each port is influenced by different characteristics such as geography, regulations, size, and the different types of cargo handled, and thus it is easy to understand certain relationships and potentials with survey-based MCDM methods. Figure 7 illustrates the number of articles included in the data analysis techniques.

[Insert Figure 7 here]

Figure 7. Number of articles by data analysis techniques (Source: Authors)

3.5.2 Synthesis of empirical evidence

The purpose of synthesising empirical evidence is to describe existing data and findings identified through the previous phase which was the process of analysing the main patterns of the articles. The focus here is on the similarities within diverse evidence in order to understand the mechanism of port sustainability evaluation and to provide a fresh understanding and direction for future research.

Based on a "Plan-Do-Check-Act" management model for environmental performance evaluation presented by Scipioni et al. (2008), the evaluation approaches in terms of port sustainability performance in the articles were sorted into five processes: Identification of indicators; Prioritising key indicators; Assessment of port sustainability performance; Comparison of sustainability performance among ports; and Development of a tool for assessment of port sustainability. The most common approaches for evaluating port

sustainability were the ‘Identification of indicators’ (18 articles) and ‘Assessment of port sustainability performance’ (13 articles). This implies that successful performance measurement depends on establishing accurate indicators as a criterion for measurement. The study analysed the type of participants in order to explore who are regarded as major and potential stakeholders in port sustainability performance. The articles referred to in the analysis utilised the views of experts involved in port sustainability in order to establish the indicators and confirm the relative importance and weights of green port performance indicators. The experts’ viewpoints were gathered through surveys and interviews. Puig et al. (2014) argued that potential users of sustainability indicators such as port authority, port users (e.g. terminal operators or shipping agencies), policy makers, and public organisations (e.g. NGOs or local communities) should be considered.

In accordance with the principle outlined above 13 different perspectives of experts were considered in the identified papers in order to collect information on establishing the indicators and their priorities: Terminal operators, Shipping companies, Academic Researchers, Ship owners, Port managers, Port Authorities, Port consultants or Supervisors, Government representatives, Legislators, Industry representatives, Employees in a port, Forwarder or Cargo owners, and Local communities and Organisations. ‘Port managers’ were integrated into ‘Port authority’ in that they mainly work for and with port authorities (van der Lugt et al., 2017). Accordingly, the surveyed experts who have played key roles in implementing port sustainability were commonly ‘Researchers in academia’, ‘Port authorities’, and ‘Terminal operators’.

Identifying effective and pertinent indicators is necessary in order to analyse, assess, and control port sustainability tasks (Hughes and Bartlett, 2002) due to the fact it is a difficult task for complex and dynamic entities such as seaports to consider all variables affecting an environmental analysis (Peris-Mora et al., 2005). In the same context, the majority of the articles (18 articles) undertook the process of identifying indicators before embarking on the measurement of port sustainability performance. The accepted opinions of the experts by the articles confirmed the relative importance and weights of performance indicators regarding three dimensions of port sustainability. The purpose of prioritising indicators was to provide evidence to decision makers in establishing key indicators for the evaluation of sustainability performance as well as for green operations.

3.5.3 Clustering of analytical sustainability indicators

The most frequently studied environmental indicators were ‘Water pollution management’ (16 articles), ‘Air pollution management’ (14 articles), ‘Energy and resource usage’ (11 articles), and ‘Noise pollution’ (9 articles). These can be considered as key environmental indicators in measuring the environmental impacts or sustainability performance of port operations (GEMI, 1998). Most environmental indicators prioritised by experts were associated with port operational aspects, encompassing products and services resulting from port activities (Puig et al., 2014). Multiple indicators related to port operations in the articles were identified including inputs such as resource consumption, and outputs such as noise reduction, waste production rates and waste water recycling. Further, atmospheric pollution is acknowledged as a salient indicator with most experts agreeing that port operational activities should pay more attention to enhancing the quality of the atmosphere in order to meet sustainability goals.

In terms of the social aspect, there were very few articles dealing with the concept of sustainability and thus the variety of indicators established was limited. Eight indicators were

consistently identified from the articles: ‘Health and safety’, ‘Job generation and security’, ‘Social image’, ‘Public relations’, ‘Quality of living environment’, ‘Social participation’, ‘Job training’, and ‘Gender equality’. ‘Health and safety’ (7 articles) was not only the most interesting indicator for researchers, but also a priority for experts. The scope of ‘Health and safety’ includes ‘Employee job security and safety’, ‘Ensuring cargo handled safely and effectively’, ‘Port area safety and orders’, ‘Low frequency of accidents’, and ‘Occupational health and safety’.

The most frequently identified economic indicator was ‘Foreign Direct Investment’ (4 articles) which is considered as one of the key components of growth performance in that the implementation of port sustainability has positive impacts on national and international economy and prosperity by leading the creation of jobs, promoting exports, and the expansion of income and employment (OECD, 2013). Table 4 reports this study clustering of analytical sustainability indicators from the environmental, social, and economic aspects. Where 64% of environmental sustainability research is focused on pollution and 78% of social sustainability research is focused on human resources management. While 38% and 19% of economic sustainability research is focused on port management and investment, respectively.

[Insert Table 4 here]

Table 4: Literature classification of aspects of sustainability using clustering of sustainability analytical indicators.

4. Discussion

Using a systematic literature review, this study has addressed the structure and patterns of port sustainability performance and assessment in the existing research, and provided synthesis of empirical evidence. In this section, the findings from the analysis and synthesis of papers are summarised in relation to the four research questions, focusing on managerial implications.

4.1. What are the existing trends in port sustainability performance and assessment research?

According to the overall analysis of publication trends in this field, it is clear that only recently has there been serious interest in the evaluation of port sustainability performance. However, given the fact that the number of publications has been steadily increasing over the past few years, sustainable development has become more established within port industry research. Research in this field has been increasingly focused on the link between environmental or social impact and economic performance, as well as port competitiveness. Definitive positive links between environmental, social and economic issues have increasingly been highlighted, consistent with findings from a wide range of studies on sustainability performance (see Christmann, 2000; Filbeck and Gorman, 2004; Lun, 2011). Specifically, the benefits of sustainability implementation have contributed to service quality and operational efficiency enhancement. These both involve the drive for continuous improvement in the areas of port performance and port distribution network effectiveness over the longer term (Kim and Chiang, 2017).

There is, however, a clear difference between views expressed in the existing literature and the findings of this review. Taking a geographical perspective, Davarzani et al. (2016) show that many studies of green ports and maritime logistics have come from researchers in western Europe and the United States, while research into east Asian ports has been less common. There have been significant advances in the management of port sustainability, most notably in Europe, with the development of the Ecoports system for environmental management adopted by the European Seaports Organisation in 2011. This system allows ports to measure their environmental performance and compare themselves to standard criteria. The guiding principle is ‘to raise awareness on environmental protection through cooperation and sharing of knowledge between ports, and to improve environmental management’. Currently the Ecoports network covers 113 ports primarily in Europe (ESPO, 2019).

Where the focus of research is on the assessment of port sustainability performance, Asian ports feature more prominently. In this context the ports of Taiwan and China, have featured regularly in studies of international environmental responsibility, auditing and compliance. In this way, the Ecoports management system has been adopted beyond Europe and the ports of Kaohsiung, Keelung and Taichung were certified as EcoPorts in 2014 and 2015. This has encouraged Asian ports to investigate their port sustainability performance more thoroughly in order to achieve the long-term goals of sustainable development for the future (Liao et al., 2016; TIPC, 2017). In China, there has been a widespread perception that the guidelines and processes of green port management promoted by the government have led to a decline in port profitability. This is seen to be due to the additional investment costs required, despite the expansion of grants and funds from the Chinese government for the participation of ports in green initiatives (Chen and Pak, 2017). In this sense, attempts to evaluate the applicability and practicality of green operations have improved the awareness and promotion of governmental green policies.

4.2. How are port sustainability performance and assessment measures implemented?

Overall, quantitative assessments of port sustainability performance are seen in the study of financial measures such as operational efficiency, container throughput, costs, and economic impact on measures such as Gross Domestic Product. Given that many ports operate as private enterprises (Brooks, 2004), performance assessment using a quantitative approach is reasonable for understanding the relationship between profits and costs. Additionally, scientific evidence through the process of quantifying actions is required for decision makers in order to validate the substantial investment required for the implementation and tracking of progress towards port sustainability.

The conflicting aims between the economic and environmental dimensions – cost-efficiency in port operations and additional investment for managing environmental impacts – seem to contribute to considerable utilisation of MCDM methods in research. Particularly, AHP has been the most preferred technique by researchers with a view to revealing the best and most optimum practices for practical sustainable operations. However, there are difficulties in measuring the performance of port sustainability. For example, the individual nature of each port in terms of their resources and unique operating environments have made the consistent assessment of port sustainability performance elusive. In this respect, there have been efforts made to reflect geographical similarities in measuring green performance through conducting case studies, focusing on ascertaining differences in the eco-friendly levels between ports in a similar geographic area.

4.3. What are the mechanisms that exist for the implementation of port sustainability performance and assessment?

It has been shown that indicators should be established for the assessment of port sustainability performance in order to understand the structure for the implementation of green port management and its evaluation. In this review, a wide diversity of indicators was identified from the environmental, social, and economic aspects of green port issues. Typical indicators for the assessment of port sustainability from an environmental perspective are related to water management, air pollution management, energy and resource use, and noise control. In terms of the social aspects health and safety is important while for economic aspects Foreign Direct Investment and efficient port operations are primary issues.

From an environmental perspective it can be seen that there is a slight difference between indicators used by researchers for assessment and those appreciated as important and prioritised by the practitioners such as port authorities, port managers, and port operators. The most frequently mentioned indicators in the reviewed studies for the assessment of port sustainability are associated with water pollution management. However atmospheric pollution management and energy consumption are regarded as more important indicators, than water quality when making decisions on successful environmental performance of ports.

From an operational perspective, the amount of energy usage within a port area, including fuel consumption, is high but unavoidable for ongoing port operations. As practitioners have recognised, and underlined, the importance of the efficiency of overall port operations and management, efficient energy management is assumed to be the most salient factor for practitioners, enabling them to comply with environmental requirements while achieving economic growth.

4.4. Which gaps and challenges in this research field can be identified?

The analysis of the surveys in the reviewed studies show that few reflect the opinions of local groups regarding port sustainability. This implies that even though the majority of reviewed studies have verified that public relations have been positively associated with port economic performance, the weak power of local stakeholders in green port planning and management has been still detected as a barrier against the achievement of port sustainability.

External cooperation with green activities is underlined by the several studies reviewed as one of the mediums for the goal of efficient port operations since port systems are engaged in various functions and relations, for example, green road systems linking to the port to its hinterland, and green actions of shipping companies (Cheon, 2017). Public participation also plays an important role in embodying a specific sustainability scheme of ports, for example, the engagement of local governments which have responsibility in enacting legislation to promote eco-friendly industries located near the port, allowing them to comprehensively control air and water quality in surrounding port areas. Thus, in order to fulfil the successful implementation of port sustainability, communities, groups, and organisations affected by port activities should be taken into consideration in the decision-making process of port sustainability operations.

Furthermore, a system of integrated performance measures is required for the purpose of supporting practical and balanced implementation of port sustainability with consistent and meaningful evidence of evaluation over time (Puig et al., 2014). However, the difficulty in establishing an integrated evaluation standard is another conundrum in measuring port

sustainability performance. Ports are complex organisations which have been affected by economy, culture, policies, local communities, geographical locations, and administrations (Chiu et al., 2014), taking their own positions with regard to port sustainability operations and management. Indeed, depending on the size and type of port, organisational structure, location, the level of environmental impact from port activities may vary from port to port. Hence the criteria for performance evaluation may not be consistent among ports. The issue of sustainable development for ports is not limited to one country, nor is it easy to conduct an integrated evaluation of sustainability performance for ports due to the distinct nature of port administrations. Therefore, a model or tool which can reflect both the international evaluation criteria and the characteristics of each port should be developed in order to overcome the challenge of the conflicting claims.

5. Conclusion

The systematic literature review adopted in this study was used to understand the existing academic characteristics of port sustainability performance and assessment and to provide useful insights for future research. The main contributions of this study emanate from an overview of managerial performance of ports from the perspective of sustainable development and its assessment, being recognised in the reviewed studies.

The contributions of this study can be summarised as follows. First, it contributes to the expansion of the overall knowledge of port sustainability performance and its assessment by articulating economic effects and applicability. Second, this study clearly shows the key indicators for the assessment of port sustainability performance for each of the three dimensions of sustainability. This is useful evidence for decision makers in implementing sustainability operations and management. Last, the findings of this study provide insights for future research for the successful implementation and evaluation of sustainability in port operations and management by identifying the crucial challenges that need to be overcome.

This systematic literature review provides insights into the idea of performance management and measurement regarding port sustainability from an economic perspective, and leads to new research directions. Three future research directions are identified for the analysis of economic effects of port sustainability performance. First, this review has confirmed that sustainability performance has had a positive impact on port economic growth, and future research needs to investigate enablers and drivers which accelerate and maximise such impacts of sustainability performance as well as inhibitors which obstruct the successful implementation of sustainability performance. By exploring the dynamics of port sustainability operations and management, the mechanisms whereby environmental and social values, and economic performance are simultaneously realised, can be clear, contributing to the evaluation of more accurate port sustainability performance. Second, with the increasing awareness of social responsibility, future research should focus on developing key social indicators for ports. The lack of research on social impacts of port operations may be attributed to the ambiguous boundaries and subjective interpretations of social indicators, obscuring the measurement of the effects of port social performance. Therefore, there is an opportunity for research to establish key indicators by expanding the scope of social indicators with clear definitions in the context of green port operation. Third, future research should investigate whether the impacts of sustainability collaboration with internal and external stakeholders are positive or negative for port economic performance. The stakeholders should include different organisations, communities, companies, and carriers who are involving in port sustainability

performance. In general, the collaboration with other organisations has been seen as having positive impact on the sustainability performance of ports, and the need for such cooperation has been emphasised. However, deeper investigation into the economic effects from the sustainable development collaboration is still lacking. Therefore, future research focusing on the effects of collaboration with external stakeholders can be addressed in two directions: the collaboration mechanism with intra-and inter-organisations to resolve effectively the conflicting interest; and the effect of costs and social benefits on the collaboration with external stakeholders, for example, in terms of the reduction of risks in uncertain port environments and the improvement of social legitimacy and reputation.

There are important policy implications that emerge from this review. These are in the areas of environmental management trajectories for ports, and the extent to which governments proactively determine environmental sustainability in port development. Parallel areas of potential research involve the role of academia in capturing key performance metrics in a way that best fits the practical requirements of the ports themselves, and at the same time also fits the needs of the academic world to usefully reflect the tensions between commercial and sustainability objectives as they evolve through time.

Both academic research and policy making is likely to follow two main paths. The first path is to stimulate, through both controlling legislation and incentivisation, the progressive improvement of port operational practices. Such a 'top-down' approach would lead to both immediate and long-term gains through the introduction of more efficient machinery, better space utilisation, wider use of modern technologies, and the implementation of technological improvements, especially those which themselves encourage a move towards sustainable practices. The second path is that which encourages port businesses and the wider port community to self-examine and to reorder priorities so that environmental, social and economic sustainability become a leading part of corporate behaviour and development, and employees' thinking. This is essentially a 'bottom-up' approach. This paper has identified a number of potentially valuable policy pointers especially in the areas of environmental pollution and management, occupational health and safety, social aspects of employment, and job satisfaction and training.

Finally, there are some limitations to this study. Technical aspects of port sustainability, capturing metrics such as equipment utilisation, terminal efficiency, and labour productivity, do not fall within the scope of this paper and have been addressed in previous studies (e.g. Woo et al., 2011). The analyses and contributions of this study are based only on 21 academic journal papers due to scarcity of literature covering empirical evidence of sustainability performance in the context of general operation and management of ports. This might limit evidence of the scientific relationship between the findings of the reviewed articles, because the selection of the articles included in this review and their analysis are based on subjective interpretations. Furthermore, this study focused on the performance and evaluation of sustainability in terms of general operational aspects of ports. In other words, studies which cover specific port activities, such as vessel operations or energy management, are excluded from this study, which may also limit the insights for the implementation and evaluation of port sustainability.

Appendix A. Reviewed papers

- Asgari, N., Hassani, A., Jones, D., Nguye, H.H., 2015. Sustainability ranking of the UK major ports: methodology and case study. *Transportation Research Part E: Logistics and Transportation Review* 78, 19-39.
- Chen, Z., Pak, M., 2017. A Delphi analysis on green performance evaluation indices for ports in China. *Maritime Policy & Management* 44(5), 1-14.
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Reference	Title of Study	Period Covered by the Study	Scope of Research	Focused Aspect of Sustainability
Hakam and Solvang 2013	Container port sustainability	1985-2012	Port sustainability and related initiatives	Environmental aspects
Sislian et al. 2015	A literature review on port sustainability and ocean carrier's network problem	1987-2013	Port sustainability and Ocean Carrier's Network Problem	Environmental aspects
Davarzani et al. 2016	Greening ports and maritime logistics: A review	1975-2014	Green ports and maritime logistics	Environmental aspects
This study	Port sustainability performance: A systematic literature review	1990-2017	Port sustainability performance and evaluation	Environmental, social, and economic aspects

Table 1: Position of this study in the context of port sustainability research

Inclusion criteria	<ul style="list-style-type: none"> · Research published in academic journals · Full access to full-text · Peer-reviewed research articles · Research published since 1990 · Research covering port sustainability performance and assessment
Exclusion criteria	<ul style="list-style-type: none"> · Research not covering port managerial sustainability · Non-English · Research focusing on conceptual approach and frameworks · Gray literature, conference articles, working papers, commentaries, editorials book review articles, dissertations, and books

Table 2. Inclusion and exclusion criteria (Source: Authors)

Types of research method (proportion)	
Analytical research (43%)	Mathematical research (19%)
	Statistical research (19%)
	Conceptual research (5%)
Empirical research (57%)	Statistical research (57%)
	Experimental research (None)
	Case study (None)

Table 3: The different types of research methods in port sustainability and performance studies.

Aspect of Sustainability	The Most Identified Indicators by Researchers (Number of Papers)	Dominant Research (%)
Environmental (10 Indicators)	Water pollution management (16) Air pollution management (14) Energy and resource usage (11) Noise pollution (9) Green port management (8) Ecosystem and habitats (6) Soil pollution management and occupation (5) Waste pollution management (4) Green construction and facilities (3) Odour pollution management (1)	Environmental Pollution (64%)
Social (8 Indicators)	Health and safety (7) Job generation and security (5) Job training (4) Public relations (2) Gender equality (2) Social image (1) Quality of living environment (1) Social participation (1)	Human Resources Management (78%)
Economic (11 Indicators)	Foreign direct investment (4) Value generated productivity (2) Port operational efficiency (2) High quality business services (2) Benefits from external stakeholders (2) Port development funding (2) Port infrastructure construction (2) Port throughput (2) GDP (1) Operating costs/revenue (1) Cost-efficiency (1)	Port Management (38%) Investment (19%)

Table 4: Literature classification of aspects of sustainability using clustering of sustainability analytical indicators.













