Ocean and Coastal Management 202 (2021) 105435

Contents lists available at ScienceDirect

Ocean and Coastal Management

journal homepage: http://www.elsevier.com/locate/ocecoaman

Role of sustainability in global seaports

Tahazzud Hossain [a], Michelle Adams [b,*], Tony R. Walker [b]

[a] Service Newfoundland and Labrador, Corner Brook, Newfoundland and Labrador, Canada
[b] School for Resource and Environmental Studies, Dalhousie University, Halifax, Nova Scotia, Canada

ARTICLE INFO

Keywords:
Seaport sustainability
Sustainability initiatives
Sustainability scale
Environmental management
Sustainability approaches

ABSTRACT

Seaports are integral hubs of maritime supply chains and contribute to socio-economic development for communities. However, seaports can create negative impacts on host communities. Adopting sustainability initiatives within seaport operations is growing rapidly, and while many seaports claim to operate green or sustainably, sustainable port initiatives and approaches are poorly described in the academic literature. This research explores relationships between existing seaport sustainability and the current narrative that exists related to sustainability improvements. Thirty-six seaports were selected from North America (NA), Europe (EU) and Asia Pacific (AP) for analysis. Twenty-five (25) pre-defined indicators were used to identify operational trends linked to sustainability claimed by seaports. Each operation was assessed using publicly available data; using a mixed methods approach, descriptive statistical analysis for sustainability initiatives was performed to assess seaport sustainability efforts. Results show that EU seaports have made more progress in adopting various sustainability initiatives compared to NA and AP seaports, despite the public narrative of most seaport executives about their commitment to manage environmental impacts, and being good corporate citizens. Initiative most widely adopted include: greater emphasis on internal environmental policy and management – including third-party certification; investment in proactive environmental solutions; and enhanced stakeholder engagement.

1. Introduction

Maritime shipping is considered an economically and environmentally efficient mode of transport. The United Nations Conference on Trade and Development (UNCTAD) reported that global seaborne trade exceeded 10 billion tons by volume in 2015, up almost 400% since 1970 (UNCTAD, 2016; ICS, 2017). The shipping industry carries about 90% of global trade (Panayides and Song, 2012; ICS, 2017; Walker et al., 2019). Seaports (hereafter "ports") are critical gateways of international trade involved in loading and unloading cargoes and providing value-adding services like storage, warehousing, packing and arranging inland transport (Pettit and Beresford, 2009; Nam and Song, 2011; Nagle, 2013).

Port activities contribute significantly to maritime transport development, regional economic growth, and direct and indirect employment, but can also impose adverse effects on the host community (Gupta et al., 2005; Dinwoodie et al., 2012). Environmental impacts can be linked to internal port activities, shipping traffic, and emissions from intermodal transports (OECD, 2011; Lam and Notteboom, 2014; Walker et al., 2019; Chen et al., 2020; Hua et al., 2020). Responses from a 2004 study revealed that water quality, waste disposal, air quality, habitat conservation and noise were the top five environmental issues (Comtois and Slack, 2007). More recently, in 2016 the European Sea Ports Organization (ESPO) and EcoPorts reported that officials identified ten pressing environmental issues (Supplementary material Fig S1) (EcoPorts, 2016a). EcoPorts is the main environmental initiative of the European port sector. It was initiated by a number of proactive ports in 1997 and has been fully integrated into ESPO since 2011. The overarching principle of EcoPorts is to raise awareness on environmental protection through cooperation and sharing of knowledge between ports and improve environmental management (EcoPorts, 2016a). Puig et al. (2015) cited similar environmental issues to ESPO including air emissions, discharges to water/sediment, emissions to soil, resource consumption, and biodiversity conservation (Winnes et al., 2015; EcoPorts, 2016a). Localized water pollution has also been a significant issue as ballast water releases (Kröger et al., 2006; Grifoll et al., 2011; Hua et al., 2020). Additionally cargo residue, fuel oil residue, waste discharges and oil spills are routinely observed (Ng and Song, 2010; Lam and Notteboom, 2014; Walker et al., 2019; Chen et al., 2020; Hua et al., 2020).

Waste management has been an ongoing issue. However, since many

* Corresponding author.
E-mail address: adamsm@dal.ca (M. Adams).

https://doi.org/10.1016/j.ocecoaman.2020.105435
Received 19 November 2019; Received in revised form 27 October 2020; Accepted 28 October 2020
Available online 14 November 2020

jurisdictions require ships and ports to comply with regulations (e.g., IMO 73/78 Annexes I-V) for waste disposal and management, there has been improvement (Trozzi and Vaccaro, 2000; OECD, 2011; Chen et al., 2020; Hua et al., 2020). Alternatively, noise pollution complaints have risen (Khoo and Nguyen, 2011; Mustonen, 2013; Witte, 2016). ESPO prioritized noise as the third most impactful environmental effect on marine ecosystems (EcoPorts, 2016a). A related issue is that low-frequency underwater noise can adversely affect marine mammals and other marine life (Jasny, 2005). Port development and expansions poses major challenges. Land reclamation, habitat loss and further exacerbate existing issues (Del Saz-Salazar et al., 2012). However, growth in the port industry is expected to continue. This growth will intensify adverse environmental effects on marine ecosystems and coastal communities (Yim Yap et al., 2013; Walker et al., 2019; Hua et al., 2020). As society becomes increasing aware of environmental issues, effective environmental management in port operations becomes essential (Morris and Gibson, 2007; Puig et al., 2014; Ashrafi et al., 2019; Hua et al., 2020).

1.1. Environmental management in ports

Ports undertake environmental management initiatives not only for maintaining social license to operate and grow (Van Den Bosch et al., 2011) but also for international competitiveness (Lam and Notteboom, 2014; Hollen et al., 2015). However, the primary purpose of port environmental management is still to mitigate adverse effects (Walker, 2016). While some ports adopt environmental management initiatives for regulatory compliance, others go beyond compliance viewing sustainability as a key element of their operational strategy (Hua et al., 2020). The Port of Vancouver (POV), Port of Long Beach (POLB), Port of Los Angeles (POLA), Port of Rotterdam (POR), and the Port of Antwerp (POA) all claim to become more sustainable than their competitors (POV, 2018; POLB, 2018; POLA, 2018; POA, 2018).

Since the early 2000s Europe has noticeably developed environmental management via collaboration among ports, research institutions, and specialist organizations (ESPO, 2012). An effective port environmental management system (EMS) identifies environmental issues that can be mitigated by appropriate environmental management. Many researchers have emphasized engaging stakeholders to identify significant environmental components to measure port environmental performance (Dinwoodie et al., 2012; Denktas-Sakar and Karatas-Cetin, 2012; Adegoke, 2018). Puig et al. (2014) concluded that adopting Environmental Performance Indicators (EPI) provides measurable benefits to ports. The same researchers proposed nine management and three operational indicators (Table 1).

EcoPorts is a European port sector based environmental initiative under the European Sea Ports Organization (ESPO), which aims to cooperate and share knowledge among ports. The Self Diagnosis Method (SDM) was developed to assess environmental management performance (Darbra et al., 2004) and the Port Environmental Review System (PERS) was developed by ports through an ESPO initiative and both are available online from EcoPorts (Ecoports, 2017a,b). Ports can also support performance objectives by earning ISO certifications such as ISO 50001 (Energy Management), ISO14001:2015 (Environmental Management System), or the Eco-Management and Audit Scheme (EMAS) certification (Darbra et al., 2005; Peris-Mora et al., 2005; Puig et al., 2014; Ecoports, 2017a,b). North America also has an environmental program to establish sustainability in marine transportation. Green Marine is an environmental certification program for maritime companies in North America (Walker, 2016; Hossain et al., 2019). Alternative, some port authorities such as those found at Zhuhai port in China have sought to create their own set of "green port" indicators that would underpin the governance of environmental management strategies (Hua et al., 2020).

Table 1
Environmental performance indicators.

Management Indicators	Operational indicators
Environmental management system	Carbon footprint
Environmental monitoring program	Waste management
Inventory of significant environmental aspects	Water consumption
Environmental policy	
ESPO code of practice	
Inventory of environmental legislation	
Objectives and targets	
Environmental training	
Environmental report	

1.2. Defining "sustainable ports"

According to the American Association of Port Authorities (AAPA), port sustainability is defined as strategies and activities that meet current and future needs of port stakeholders while protecting and sustaining human and natural resources (AAPA, 2007). Similarly, green ports are defined as those engaged in the proactive development, execution, and monitoring practices targeted at reducing environmental effects beyond compliance (Acciaro, 2015). However, Lu et al. (2016) differentiated port sustainability and green ports. Sustainability considers social, economic and environmental issues, whereas green is solely focused on environmental issues (Ashrafi et al., 2019, 2020). Lam and Van De Voorde (2012) proposed a combined framework that included stakeholder involvement, green market development, cost-effective environmental policy, and sustainable operations and development, as major elements of a sustainable port strategy.

2. Methodology

2.1. Port sampling locations

A web-based data collection method was chosen. This study assesses sustainability initiatives adopted in global ports, using publicly available data. According to Becker et al. (2012), there are 1056 seaports ranging in size around the world. To assess initiatives and approaches adopted by ports to achieve port sustainability, 36 global ports were selected to be representative of three regions. Specifically, twelve ports were selected each from North America (NA), Europe (EU), and Asia Pacific (AP) (Table 2). Ports were selected to be regionally representative, and priority was given to ports with claims or pledges to be green/sustainable. Availability of data and information from port websites and secondary sources were also considered. Ports from Africa or South America were not selected due to lack of publicly available environmental data. Port location and relative size by cargo volume handled (in 2015) are shown (Fig. 1). Data were collected from January to April 2017.

Sample ports in this study are among the top ports in the world, and all of the ports are major ports in their representative countries. Where possible, sample ports were chosen from the top 250 ports according to the AAPA (World Shipping Council, 2017); 17 from the top 100, and 27 from the top 250. According to Santos et al. (2016), larger ports are more likely to publish and/or disclose their sustainability performance data. One large port from each region (POV, POR, and Port of Kaohsiung [POK]), with a history of environmental management or sustainability initiatives, was selected for more detailed analysis case analysis.

2.2. Sustainability indicator criteria

Similar to the methodological approach used by Hossein et al. (2019), 25 indicators were selected to assess the sustainability initiatives adopted by ports. Three steps were followed to select the 25 indicators. Firstly, relevant literature was reviewed to determine port-related social, economic and environmental issues. Secondly, the researcher categorized the ports' initiatives linked to achieving port sustainability

Table 2
Ports selected for analysis.

No.	Ports	Regions	Country
1	Port of Vancouver	NA	Canada
2	Port of Montreal		Canada
3	Port of Prince Rupert		Canada
4	Port Quebec		Canada
5	Port Saint John		Canada
6	Port of Sept-Iles		Canada
7	Port of Long Beach		United States
8	Port of Los Angeles		United States
9	Port of New York and New Jersey		United States
10	Georgia Port		United States
11	Port of Seattle		United States
12	Port of Houston Authority		United States
13	Port of Rotterdam	EU	Netherlands
14	Port of Antwerp		Belgium
15	Port of Bremen		Germany
16	Port of London		United Kingdom
17	Nantes Saint Nazaire Port		France
18	Port of Venice		Italy
19	Port of Valencia		Spain
20	Port of Copenhagen		Denmark
21	Port of Helsinki		Finland
22	Port of Igoumenitsa		Greece
23	Dublin Port		Ireland
24	Port of Gothenburg		Sweden
25	Port of Singapore Authority	AP	Singapore
26	Jawaharlal Nehru Port		India
27	Busan Port		South Korea
28	Port of Hong Kong		China
29	Port of Kaohsiung		Taiwan
30	Port of Keelung		Taiwan
31	Aqaba Container Terminal		Jordan
32	Fremantle Port		Australia
33	Port Hedland		Australia
34	Port of Hay Point		Australia
35	Port of Brisbane		Australia
36	Port of Auckland		New Zealand

by evaluating corporate websites of ports. Finally, 25 indicators were selected based on this literature review to measure and compare port sustainability. Each indicator represents an initiative of the port to be green or sustainable. Data were accessed from online sources publicly available sources such scholarly literature, third-party assessments and sustainability reports. Indicators (Table 3) were developed after review of various initiatives, strategies and operational norms of some of the worlds most sustainable ports.

Sustainability frameworks and guidance documents available during the research period were also assessed, examining re-occurring themes that could be applied to port operations. These included materials such as: the Global Reporting Initiative (GRI); World Port Sustainability Program; and Global Compact. As outlined in Hossein et al. (2019), port corporate websites were also reviewed to identify common claims, or similar initiatives and strategies linked to sustainability. Final indicators reflect synthesis of this analysis, incorporating those factors which were considered to be a true reflection of operationalization of sustainability for the port sector.

A structured evaluation matrix was created including each indicator, whereby each was assigned a 'Yes' or 'No' value based on the available

Table 3
List of sustainability initiatives (indicators) adopted by ports.

No.	Indicators
1	Environmental Policy (EP)
2	Publicly availability of EP
3	Environmental Management System (EMS)
4	EMS Certification (ISO 14001)
5	Air Quality Monitoring
6	Water Quality Monitoring
7	Noise Level Monitoring
8	Sediment Quality Monitoring
9	Wildlife Protection
10	Energy Efficiency and Conservation (EEC)
11	Renewable Energy (RE) Use
12	Emissions Inventory
13	Shore Power
14	LNG Facility
15	Green Incentives
16	Green Infrastructure Development/LEED building
17	Availability of Environmental Monitoring Report
18	Sustainability Reporting
19	Sustainability Reporting with GRI Guidelines
20	Community Engagement
21	Environment Menu Bar on port website
22	Environmental Professional
23	Research and Development (R&D)
24	Climate Change Adaptation
25	Port Environmental Review System (PERS)

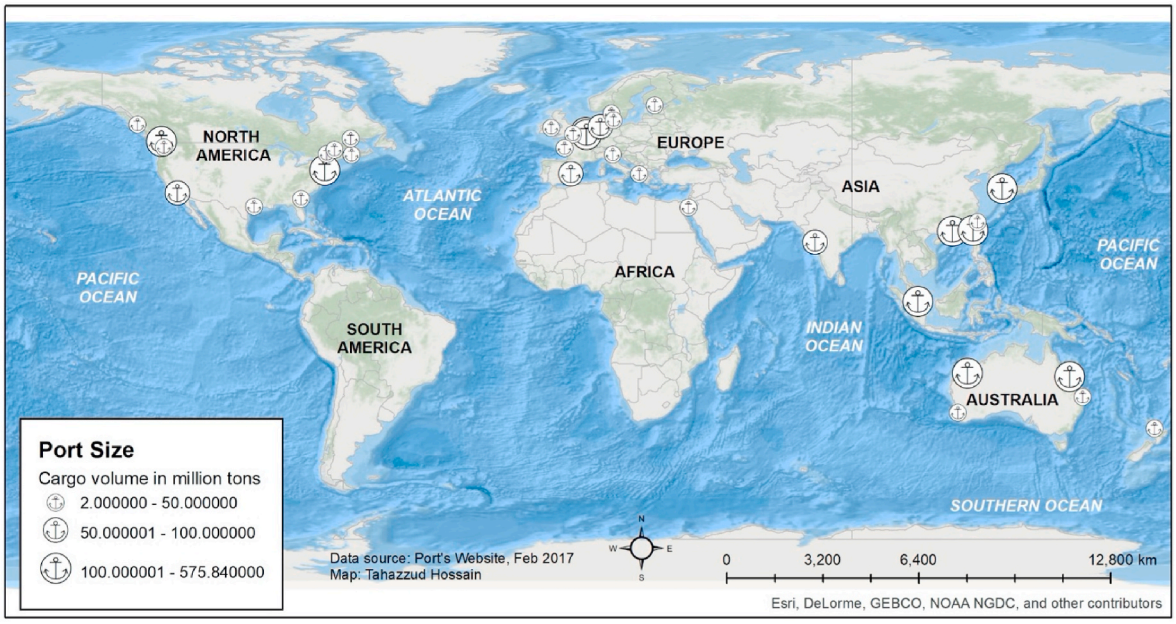

Fig. 1. Geographic location and relative size of ports by cargo volume.

data. The answers were entered into Statistical Package for Social Sciences (SPSS); value '1' if the answer was 'Yes' and value '0' if the answer was 'No' (meaning the port had not adopted that particular initiative). The dataset was used to do the descriptive analysis for each indicator for all 36 ports. To compare extent of sustainability initiatives adopted by the ports, a sustainability scale (1–10 initiatives = low; 11–21 initiatives = moderate; 22–23 initiatives = high) was developed by summing all 25 indicators. This sustainability scale was developed based on one standard deviation (SD) above the high sustainability mean (22–23 initiatives), and one SD below the low sustainability mean (1–10 initiatives), in between one SD above and below is moderate sustainability (11–21 initiatives). Cronbach's alpha was used to test the reliability of established indicators to assess sustainability. An alpha value between 0.6 and 0.7 is considered the lower limit of acceptability (Lun, 2014). Cronbach's alpha was tested for 25 indicators using SPSS to verify the internal consistency of indicators to measure sustainability scale. SPSS and Microsoft Excel were used to do the descriptive statistical analysis; ArcGIS 10.2 was used to present results spatially. Descriptive statistical analyses were used to evaluate variation in sustainability initiatives of ports in NA, EU, and AP. Strategies for improving port sustainability are discussed with the intent of generating new knowledge to contribute to port sustainability research.

2.3. Limitations

Most of the data were collected from port corporate websites. It is likely that some ports may not have published their environmental performance information on their corporate websites. However, large ports endeavour to maintain higher levels of sustainability communication through disclosing information to the public (Santos et al., 2016). Ports from Africa or South America were not included in the study due to lack of publicly available environmental data.

3. Results

3.1. State of sustainability initiatives in global ports

Results indicate that 92% ports have established EPs that are publicly available (Table 3), a written statement from port executives that includes commitment to manage port environmental impacts and to comply with laws and regulations. All EU and AP ports had EPs, while 75% of NA ports had them (Fig. S2). Establishing an EP is the first step in developing a robust EMS (Le et al., 2014). Over half the ports had an EMS (Table S1). EU ports appear to be the most likely to have an EMS. In AP and NA, less than half had implemented such programs. Of the various protocols, Green Marine is reported to be widely adopted by NA ports (Walker, 2016; Hossain et al., 2019). However, PERS and ISO 14001 certifications are more common within EU ports, whereas AP ports favour ISO certification (Darbra et al., 2009).

Of the 36 ports, 64% reported emissions inventories, although 80% of EU ports completed emissions inventories compared to 67% of NA and 42% of AP ports (Fig. S3). The larger percentage may be because member ports of the ESPO regularly monitor and report emissions; emissions inventories are a common measure of environmental performance (Puig et al., 2017). Many ports conduct annual emissions inventory to determine the source, composition, and level of air pollutants, to track air quality improvement initiatives and GHG emission reductions, and health risks to stakeholders. Port emissions inventory is an activity-based accounting of emissions from different significant sources (including buildings, cargo-handling equipment) (McEwen, 2012). Berthed ships are significant emitters, representing >50% of port-related emissions (Winnes et al., 2015).

Over 70% of ports had implemented wildlife habitat protection measures. Measures adopted by NA and EU ports are slightly (75%) higher than AP ports (67%) (Fig. S4). Wildlife habitat protection is considered by some authorities to be among the top environmental issues (Comtois and Slack, 2007). Under such strategies, ports take measures to control invasive species, reduce wildlife mortality, and create or restore habitat for local threatened species (Vincent, 2014). For example, POV (2017) reported implementing their Enhancing Cetacean Habitat and Observation (ECHO) program in 2015 to assess impacts of shipping on whales in port areas.

Shore power has been implemented by ports to reduce environmental impacts of berthed ships. Fig. 2 shows global ports providing shore power facilities and/or green incentives. Shore power facility allows ships to plug into the port provided electricity network instead of using auxiliary engines. Researchers found such facilities deliver environmental and economic benefits to the ports and ships (Hall, 2010; Winkel et al., 2015; Sciberras et al., 2016). Half the ports provided shore power facilities (Table S2) although there are considerable regional differences in uptake (Fig. S5). Compared to AP ports, NA and EU ports were more likely to offer a green incentive program as well as maintain shore power facilities. For example, the EU has made it mandatory for member states to install shore power facilities in ports by 2025 (WPCI, 2017). Green Marine (GM) has included shore power as a criterion under the *Environmental Leadership* to measure environmental performance of the ports in the Green Marine nvironmental Program (GMEP) since 2016 (Green Marine, 2016; Walker, 2016).

Energy management and GHG emission mitigation is considered one of the most important environmental strategies (Lam and Notteboom, 2014). Acciaro et al. (2014a,b) argued that both improving energy efficiency and conservation (EEC) and integrating renewable energy (RE) into port electrical systems can offer significant economic gains. Thirty ports have adopted some element of EEC. Twenty have integrated renewable sources into their energy mix (Table S3). Most EU ports adopted EEC initiatives; likewise over 80% AP ports and 75% NA ports have adopted EEC initiatives (Fig. S6). However, AP ports have been pro-active with RE initiatives compared to EU and NA ports (67%, 58%, and 42% respectively). Installation of solar panels in many AP ports has been one of the key initiatives.

Alternative fuels can reduce emissions in port areas. Liquefied Natural Gas (LNG) can be used by ships to reduce emissions and to meet environmental regulations (Schnurr and Walker, 2019). More than half support alternative fuels (Fig. S7). LNG has foreseeable economic viability and good environmental performance (Wang and Notteboom, 2015). Winnes et al. (2015) illustrated that the transition to alternative fuels could significantly reduce emissions from berthed ships. Others have reported that LNG presents an opportunity for ships to meet MARPOL Annex VI regulations to reduce particulate matter (PM) emissons (Xu et al., 2015; Walker et al., 2019; Schnurr and Walker, 2019). Some ports have suggested that being able to provision alternative fuels can attract (or retain) clients (POR, 2018).

The number of ports with certified environmental management systems (EMSs) is growing (Puig et al., 2014). PERS is the only port-sector specific standard for environmental management, although ISO 14001 has also been widely recognized and implemented by ports. EMAS is another certification system adopted by European ports that has also been demonstrated to improve an organization's environmental performance (Iraldo et al., 2009). In NA, the GMEP is a comparable certification system (Walker, 2016). Nineteen (of 36 ports) have ISO 14001 certification; nine have PERS certification, six have both certifications and 14 lack any certification (Table S4). Port of Valencia and Port of Igoumenitsa in the EU have ISO 14001, EMAS and PERS certifications (Fig. 3). Regionally, EU ports appear to be more proactive but also more diversified in their approach having recognized and implemented all three systems (Fig. S8). Some suggest that EU ports are more advanced because of the EcoPorts initiative, the practice of cooperation and knowledge sharing, and individual ports' willingness to improve environmental performance (EcoPorts, 2017b).

Many ports prepare annual sustainability reports and/or standalone environmental reports. These reports are often published on corporate websites (Santos et al., 2016). Corporate sustainability reporting is

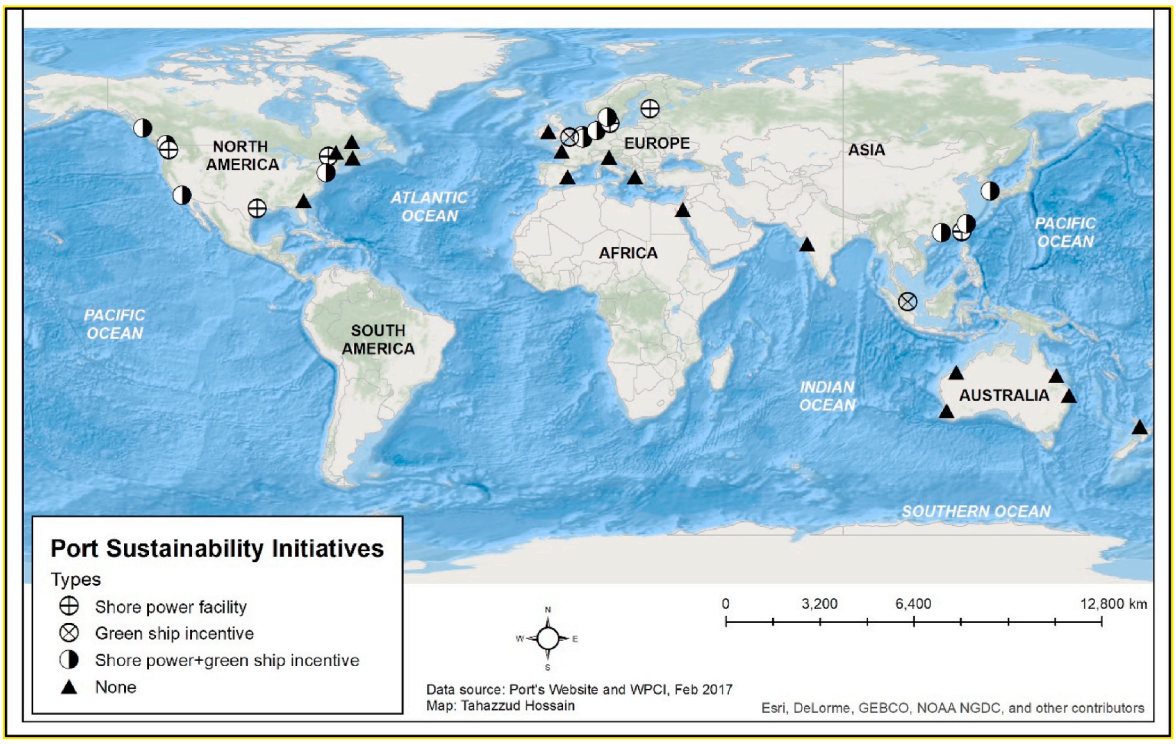

Fig. 2. Ports with shore power facilities and/or incentive program.

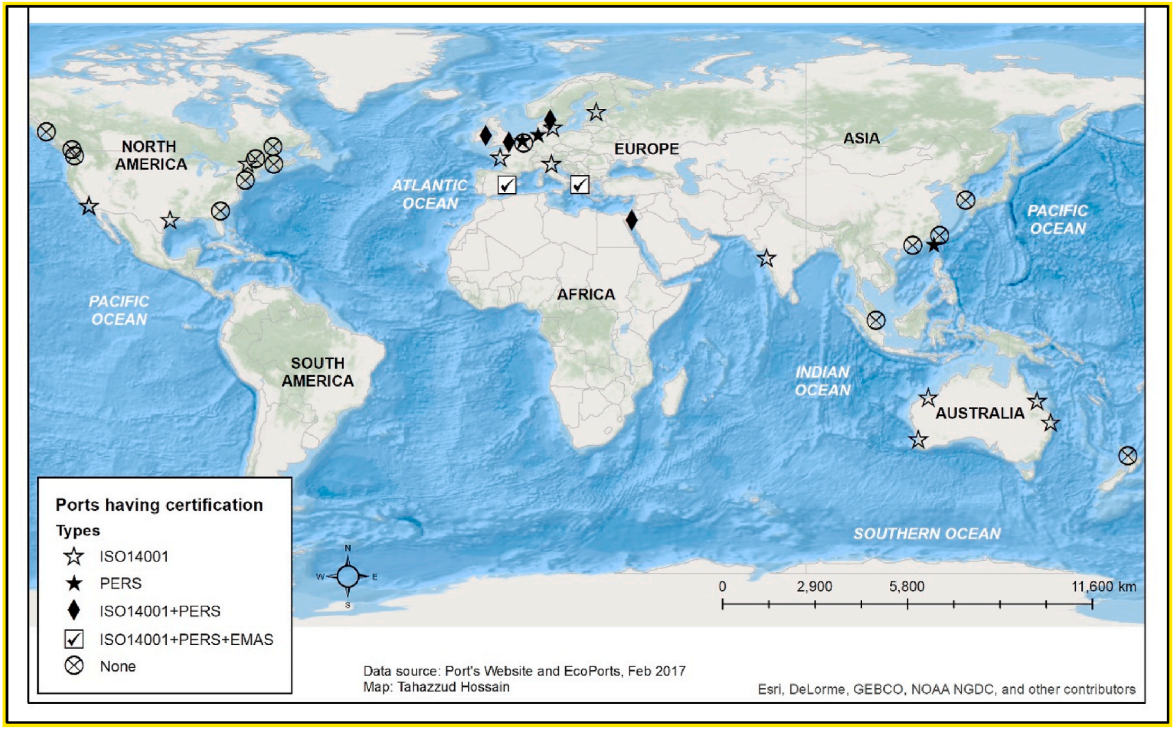

Fig. 3. Environmental certifications across global ports.

usually voluntary (unless mandated by certain certification programs) and suggests an organizations willingness to be good corporate citizens (Piecyk and Björklund, 2015). Some ports have used the GRI guidelines to frame the environmental elements of their sustainability reporting (Table S5). Regionally, 67% of EU ports, 50% of NA ports and 42% of AP ports prepared annual sustainability reports (Fig. S9). Moreover, sustainability reporting among the EU ports is on the rise, especially among EcoPorts members (EcoPorts, 2016b). Fig. 4 shows ports that publish annual sustainability report and follow GRI standards.

The public disclosure indicator is intended to highlight online accessibility of information (regardless of quality or rigor), related to environmental performance or sustainability initiatives; implying

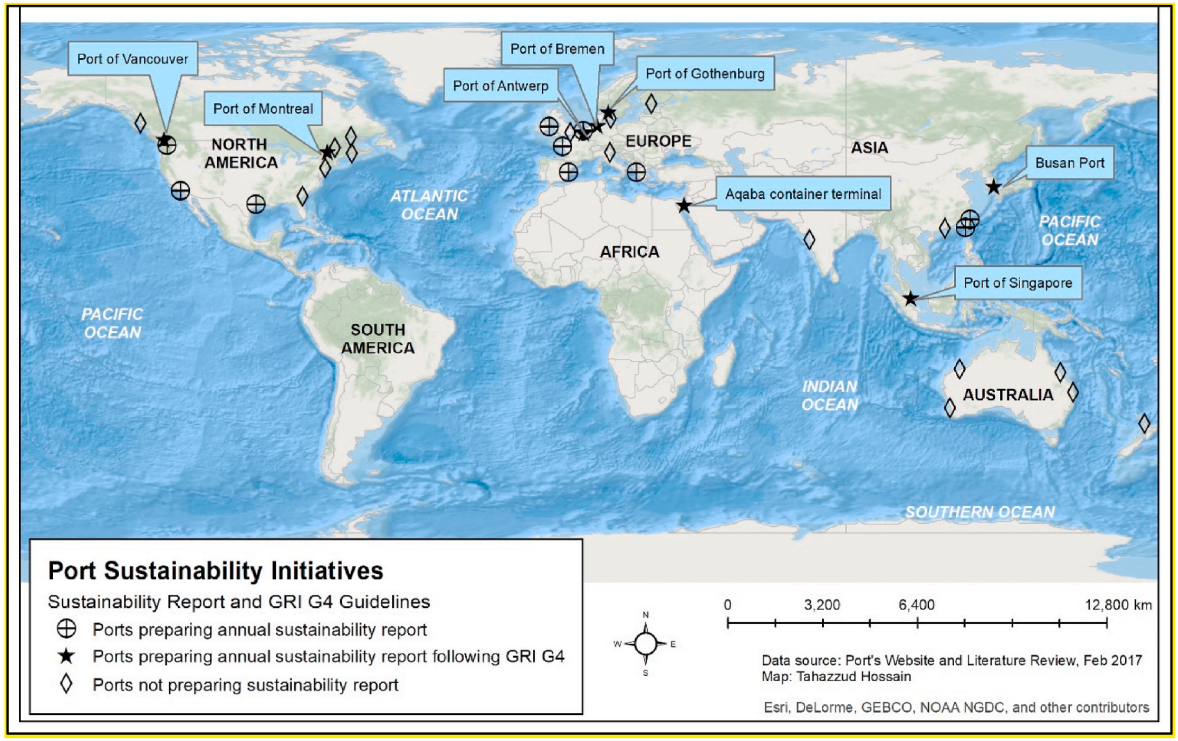

Fig. 4. Ports publishing annual sustainability reports.

transparency. Corporate websites are widely used for ports to disclose environmental information (Wanderley et al., 2008). Twenty-seven ports have an 'environment' menu bar on their corporate websites (Fig. S10). EU ports (92%) provide transparency by disclosing information to the public through systematic environmental reporting and online report availability. This transparency is likely due to EU directives and ESPOs requirements (EcoPorts, 2016b). Santos et al. (2016) found that larger ports were more likely to communicate sustainability information online.

Ports are at considerable risk to climate change-induced effects (Nursey-Bray et al., 2013). Port infrastructure and port-based economies are expected to be disproportionately affected by climate change impacts; ports need to adapt (Becker et al., 2012, 2013). Many ports have adopted both mitigative and adaptive strategies. Adaptative measures include relocating marinas and wharves, renovating infrastructures, and considering new climate-sensitive designs. Many researchers have argued that such proactive adaptation is far more cost-effective than reactive response (Pielke, 2007; Hallegatte, 2009). Only 25% of ports have climate focused adaptation initiatives implemented. EU ports were the most proactive, and AP ports were the least (Fig. S11). Differences could be due to many factors. For example, ESPOs initiative includes *climate change* as one of the top 10 environmental priorities for 2017 and 2018. Additionally, the 2013 EU Adaptation Strategy and Paris Agreement might have influenced EU ports to address climate change and adaptation measures more urgently (European Commission, 2018; Christodoulou and Demirel, 2018).

Most (90%) of ports had implemented some kind of stakeholder engagement process (Fig. S12). Engaging local stakeholders in port operations, planning and development is an important aspect of port sustainability initiatives (Hendricks, 2017). Port operations have both positive and negative consequences on host communities; efforts to maintain a strong relationship with host communities are important (Adams et al., 2009). EU ports employed the most environmental professionals (92%), followed by AP and NA (83% and 58%, respectively).

3.2. Summary of the state of sustainability initiatives in global ports

Overall, EU ports have adopted more sustainability initiatives compared to NA and AP ports (Fig. 5). The number of sustainability initiatives (indicators) adopted by ports vary widely from 1 to 23 (mean $= 15.58 \pm 6.03$ standard deviation). The Cronbach's Alpha for 25 indicators was 0.899. A Cronbach's alpha $\geq$0.9 is excellent according to Matkar (2012), suggesting that indicators are strongly internally consistent to measure port sustainability. Cronbach's alpha is widely used to assess consistency of selected variables to measure a scale. Results show 23 (out of 25) initiatives were adopted by Port of Los Angeles (POLA) (NA port) and Port of Gothenburg (POG) (EU port) (Table 4).

Three NA ports and four EU ports had high sustainability scores (Fig. 6). Five NA, eight EU, and 10 AP ports fall under the moderate sustainability scale, although no EU ports were found to have low sustainability scores (Fig. 17). EU ports lead in sustainability. Researchers have linked this proactive behaviour to increased rigorous monitoring and measurement of environmental performance influenced by the initiatives and efforts of ESPO and EcoPorts network in the last 20 years (Puig et al., 2017).

3.3. Case analysis: ports of vancouver, Rotterdam, and Kaohsiung

3.3.1. Port of Vancouver (POV)

POV is Canada's largest port; in 2016 it handled ~150 million tons of cargo involving 170 countries. POV's objective is to be "the most sustainable port in the world" (POV, 2017). In addition to adopting many initiatives, POV undertook a two-year stakeholder consultation process involving over 100 interest groups. The result was a designated *Port 2050* (POV, 2017). Port 2050 comprises a comprehensive set of metrics for air emissions, water quality, noise levels, habitat and wildlife impacts to be monitored and reported upon annually. Such programs include the real-time monitoring of ambient noise levels around the port. POV also measures underwater noise to assess impacts on at-risk whales. In this latter case, results prompted POV to undertake mitigative measures to reduce underwater noise levels. To engage clients with

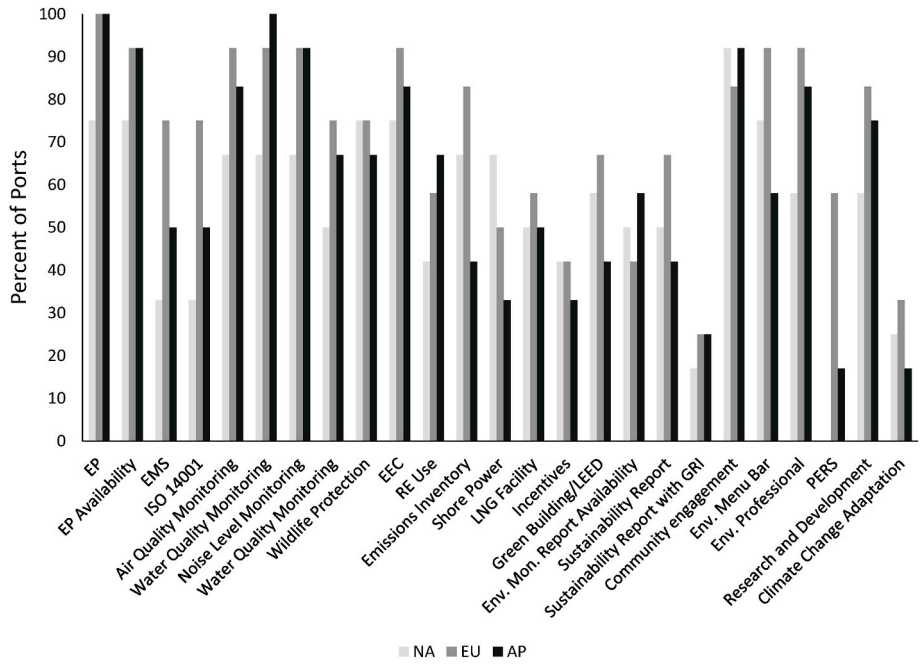

Fig. 5. Summary of port sustainability initiatives (by region).

Table 4
Sustainability initiatives adopted by ports. Red indicates low (1–10 initiatives), yellow indicates moderate (11–21 initiatives) and green indicates high (22–23 initiatives).

Sum of Initiatives (Indicators)	Number and Name of Ports Adopted the Initiatives	Number of Ports (Regionally)		
		NA	EU	AP
1	1 (Quebec)	1		
2	1 (Saint John)	1		
3	1 (Sept-Iles)	1		
5	1 (Georgia Port)	1		
8	1 (Jawaharlal Nehru)			1
10	1 (Hong Kong)			1
11	2 (Auckland, Fremantle)			2
12	2 (Igoumenitsa, Prince Rupert)	1	1	
13	1 (Helsinki)		1	
14	1 (London)		1	
15	1 (Nantes Saint Nazaire)		1	
16	1 (Hedland)			1
17	7 (NY-NJ, VEN, COP, SIN, KEE, HP, BRI)	1	2	4
18	2 (Seattle, Busan)	1		1
19	4 (Vancouver, Valencia, Dublin, Aqaba)	1	2	1
20	1 (Houston)	1		
21	1 (Kaohsiung)			1
22	5 (Montreal, Long Beach, Rotterdam, Antwerp, Bremen)	2	3	
23	2 (Los Angeles, Gothenburg)	1	1	
Total	N = 36	N = 36		

Note: NY-NJ (New York and New Jersey), VEN (Venice), COP (Copenhagen), SIN (Singapore), KEE (Keelung), HP (Hay Point), BRI (Brisbane).

their sustainability initiative, POV offers incentives to ships that have implemented measures to reduce emission and environmental effects (POV, 2017). POV published its first sustainability report in 2011 (POV, 2017). In 2016 GMEP awarded POV a five (out of five) for the POVs environmental performance (Green Marine, 2016).

3.3.2. Port of Rotterdam (POR)

POR, in the Netherlands, is the largest seaport in Europe handling 508 million tons in 2016 (POR, 2018). POR endeavors to be the worlds most sustainable port. Energy transition is a key focus as POR strives for net zero emissions by 2050 (POR, 2018). POR supplies LNG to clients, incentivizes the use of shore power facility, and includes of renewable energy in its electricity mix (POR, 2018). POR is pioneering the use of the Environmental Shipping Index (ESI) to provide other incentives (e.g., ESI performance certification) to clean vessels for emission reduction (Lam and Notteboom, 2014). Along with the city of Rotterdam, POR has invested in an *innovation hub* initiative, providing support for those developing innovative low-carbon and clean technologies (POR, 2018). POR holds port-specific PERS certification, addressing its environmental management and sustainability initiatives through its Corporate Social Responsibility (CSR) program. POR publishes sustainability-related data and its annual reports on the corporate website.

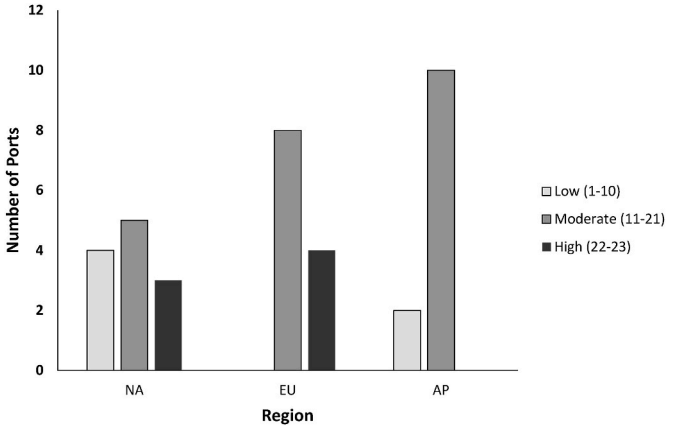

Fig. 6. Variation of sustainability across three regions.

3.3.3. Port of Kaohsiung (POK)

POK, in Taiwan, is one of the worlds 50 largest ports, handling about 121 million tons in 2015 (World Shipping Council, 2017). POK was the first port in Asia to received EcoPort Certification (POK, 2017). POK's ten specific environmental objectives and the related monitoring data are publicly available on the corporate website. (POK, 2017). POK has

adopted an adaptive approach to its environmental management, using monitoring data to inform and amend strategies to reduce resource consumption. POK has guided initiatives such as habitat restoration solar initiatives, improved management of dredged material, and has invested in green building infrastructure (POK, 2017). All environmental performance data are presented with POKs annual, publicly available environmental report. Researchers made not the level of environmental management and performance of POK even before it received EcoPorts certification in 2014 (Lirn et al., 2012; Chang and Wang, 2012; Lu et al., 2016; Papaefthimiou et al., 2017). POK is one of the leading ports in AP in terms of adopting various environmental initiatives and maintaining corporate environmental stewardship.

4. Discussion

This paper highlights various initiatives adopted by 36 key global ports. Yet initiatives have varying strengths and weaknesses. For example, when operationalizing commitments to environmental performance. It is best practice to formally develop and follow a meaningful Environmental Management Plan (EMP) regardless of the specific certification. Establishing an EP is the first step for developing and implementing EMS, but the key to the successful integration of such policies and frameworks is a firm commitment from upper management in the form of a specific strategy that includes specific objectives and clearly defined (and measurable) metrics. Potential impacts must first be identified to be managed, such that metrics to be monitored can be developed. Monitoring data must be regularly reviewed as it provides the foundation for any mitigation measure and demonstrates its effectiveness (or lack thereof) to have adaptive management. Regular monitoring informs port officials of any amendments or modifications necessary to the existing measures to achieve their expressed objectives. We cannot manage what is not measured. Finally, the original "potential impacts" should be revisited regularly to ensure that port authorities are not overlooking key problems (Puig et al., 2015).

External environmental certifications or membership programs are voluntary. Such programs are not specifically required for a port to maintain a robust, internal EMS initiative, but third-party influence may reflect both internal and external motivations on the part of the port; internal in that they seek continuous improvement, but also external in they view such participation as important for their reputation within their broader community of stakeholders (Prajogo et al., 2016). Open and transparent reporting is an important element of port sustainability, ensuring positive [and possibly negative] information is communicated to key stakeholders. Both annual sustainability reports and standalone environmental reports are increasingly found on corporate websites (Santos et al., 2016). Piecyk and Björklund (2015) linked robust (and transparent) environmental reporting with an organization's consciousness, maturity, and willingness to be good corporate citizens.

Port stakeholder engagement is a key practice within ports identifying as "sustainable" (Lam et al., 2013; Puig et al., 2017). Open and ongoing communication enables port authorities to respond to stakeholder concerns and/or pressures from customers, and competitors (Dinwoodie et al., 2012). Such engagement is also key maintaining the port's 'social license to operate' (Adams et al., 2009) which also plays well with local officials and regulators (Acciaro et al., 2014a,b; Kim and Chiang, 2014). Committed investment in 'green' innovation is an important component of a port's sustainability strategies. Results revealed a considerable number of ports had developed of innovation and investment. Specific examples include alternative fuels/LNG facilities, green buildings, renewable energy development, energy efficiency, and low emission transportation technologies. In addition, the integration of climate change considerations into investment decisions is an increasing trend. Both GHG emission mitigation and improving infrastructure resiliency are hallmarks of many *green ports* and are directly linked to the willingness of port officials to invest in the necessary responses (Lam and Notteboom, 2014; Acciaro et al., 2014a,b; Acciaro, 2015; Hua et al., 2020).

Ports use incentive programs to encourage ship owners, port users, and tenants to adopt innovative measures. This approach has typically incentified improved emissions performance of berthed ships. Lam and Notteboom (2014) noted that incentives could be an effective approach to reducing pollution, while also engaging port users to consider their environmental performance (Lam and Van De Voorde, 2012; Winnes et al., 2015). POV, for example, offers discounted port fees to vessels that connect to shore power and reduce underwater noise. We found a correlation between incentive program and other approaches. For example, this study found that ports which adopted incentive approach, have also adopted innovation and investment and stakeholder engagement approaches.

Despite numerous international conventions, ports are responsible for implementing policies and regulations to mitigate environmental pollution locally. Ports can impose penalties on users, vessels, and tenants for pollutant release (Acciaro et al., 2014a,b). Lam and Notteboom (2014) agreed that imposing penalties and/or providing incentives can be effective motivation. However, Winnes et al. (2015) suggested more strict international policies and regulations are also important. The top ports (e.g., POV, POR, POLB) applied various policy instruments such as incentive, community engagement, research & development and environmental control and enforcement instrument for the environmental management in port operations.

Greater inter-agency collaboration and knowledge exchange was observed of those ports with higher sustainability scores. Acciaro (2013) reported that both internal collaboration and external collaboration have been positively associated with improved sustainability performance. For example, seven American ports collaboratively developed the Sustainable Design and Construction Guidelines with the intention of providing guidance during the design and construction of industrial maritime development; and many other such examples exist (I2S2, 2013; POV, 2017b). Ports with higher sustainability scores adopted collaboration approach. POR and POA have been working collaboratively to tackle local ecological issues (Lam and Notteboom, 2014). EU and NA ports also collaborated to address environmental issues. Leading ports have partnered to work together to address the issue of global warming (POR, 2018).

5. Conclusions

With increasing socio-economic and environmental pressures, port authorities are taking various measures to improve the sustainability of port operations. This study evaluated initiatives of 36 global ports in NA, EU, and AP. Results indicate that most ports have emphasized the identification, mitigation, and monitoring of impacts, as well as improved energy management, and stakeholder engagement – particularly linked to environmental policy development. Many ports were found to progress on research and development, stakeholder participation, wildlife protection, environmental performance disclosure, and providing a green incentive to port users for the better environmental performance of port operations. However, many ports are still lagging behind in taking initiatives related to energy management, certification, sustainability reporting, and climate change adaptation.

EU ports have made greater progress in adopting sustainability initiatives as compared to the NA and AP ports. This could suggest that the European Union directives and the influence of the ESPO may have motivated improved port performance and a willingness to adopt more ambitious sustainability targets and initiatives. In North America, the GMEP launched by GM in NA has been assisting maritime industries in greening port operations, but GMEP is not as robust as Ecoports of ESPO. Organizational guidance and framework might help AP ports improve their environmental performance.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgments

This study was supported by the Social Sciences and Humanities Research Council (SSHRC) of Canada funded project "Green Shipping: Governance and Innovation for a Sustainable Maritime Supply Chain" and the Nova Scotia Research and Innovation Graduate Scholarship (NSGS).

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ocecoaman.2020.105435.

References

AAPA, 2007. Sustainable Port Development: a Practitioner's Perspective. Retrieved from. http://aapa.files.cmsplus.com/SeminarPresentations/08FINANCE_Degens_Sebastian.pdf.

Acciaro, M., 2013. Corporate responsibility in the port sector: the institutional theory perspective. In: Fu, X., Li, C.L., Luo, M., Ng, A.K.Y., Yip, T.L. (Eds.), IFSPA 2013: Trade, Supply Chain Activities and Transport: Contemporary Logistics and Maritime Issue. The Hong Kong Polytechnic University, Hong Kong, pp. 522–535.

Acciaro, M., 2015. Corporate responsibility and value creation in the port sector. International Journal of Logistics Research and Applications 18 (3), 291–311.

Acciaro, M., Ghiara, H., Cusano, M.I., 2014a. Energy management in seaports: a new role for port authorities. Energy Pol. 71, 4–12.

Acciaro, M., Vanelslander, T., Sys, C., Ferrari, C., Roumboutsos, A., Giuliano, G., et al., 2014b. Environmental sustainability in seaports: a framework for successful innovation. Marit. Pol. Manag. 41 (5), 480–500.

Adams, M., Quinonez, P., Pallis, A.A., Wakeman, T., 2009. Environmental Issues in Port Competitiveness. Dalhousie University, Halifax. Atlantic Gateway Initiative Centre for International Trade and Transportation Working Paper 7.

Adegoke, A., 2018. Benchmarking Sustainability Performance of Ports. Concordia University. Retrieved from. https://spectrum.library.concordia.ca/984075/1/Adegoke_MASc_F2018.pdf.

Ashrafi, M., Acciaro, M., Walker, T.R., Magnan, G.M., Adams, M., 2019. Corporate sustainability in Canadian and US maritime ports. J. Clean. Prod. 220, 386–397.

Ashrafi, M., Walker, T.R., Magnan, G.M., Adams, M., Acciaro, M., 2020. A review of corporate sustainability drivers in maritime ports: a multi-stakeholder perspective. Maritime Policy & Management, pp. 1–18.

Becker, A., 2013. Building Seaport Resilience for Climate Change Adaptation: Stakeholder Perceptions of the Problems, Impacts, and Strategies. Stanford University. Retrieved from. https://stacks.stanford.edu/file/druid:ft948cq5546/BECKER_DISSERTATION_FINAL_FORMATTED_3-augmented.pdf.

Becker, A., Inoue, S., Fischer, M., Schwegler, B., 2012. Climate change impacts on international seaports: knowledge, perceptions, and planning efforts among port administrators. Climatic Change 110 (1–2), 5–29.

Chang, C.C., Wang, C.M., 2012. Evaluating the effects of green port policy: case study of Kaohsiung harbor in Taiwan. Transport. Res. Transport Environ. 17 (3), 185–189.

Chen, J., Zheng, H., We, L., Wan, Z., Ren, R., Li, J., Li, H., Bian, W., Gao, M., Bai, Y., 2020. Factor diagnosis and future governance of dangerous goods accidents in China's ports. Environ. Pollut. 257 https://doi.org/10.1016/j.envpol.2019.113582.

Christodoulou, A., Demirel, H., 2018. Impacts of Climate Change on Transport- a Focus on Airports, Seaports and Inland Waterways. Retrieved from. http://publications.jrc.ec.europa.eu/repository/bitstream/JRC108865/jrc108865_final.pdf.

Comtois, C., Slack, B., 2007. Restructuring the Maritime Transportation Industry : Global Overview of Sustainable Development Practices. Québec. Retrieved from. http://www.bv.transports.gouv.qc.ca/mono/0938424.pdf.

Darbra, R.M., Pittam, N., Royston, K.A., Darbra, J.P., Journee, H., 2009. Survey on environmental monitoring requirements of European ports. J. Environ. Manag. 90 (3), 1396–1403.

Darbra, R.M., Ronza, A., Casal, J., Stojanovic, T.A., Wooldridge, C., 2004. The Self Diagnosis Method: a new methodology to assess environmental management in sea ports. Mar. Pollut. Bull. 48, 420–428.

Darbra, R.M., Ronza, A., Stojanovic, T.A., Wooldridge, C., Casal, J., 2005. A procedure for identifying significant environmental aspects in seaports. Mar. Pollut. Bull. 50 (8), 866–874.

Del Saz-Salazar, S., García-Menéndez, L., Feo-Valero, M., 2012. Meeting the environmental challenge of port growth: a critical appraisal of the contingent valuation method and an application to Valencia Port, Spain. Ocean Coast Manag. 59, 31–39.

Denktas-Sakar, G., Karatas-Cetin, C., 2012. Port sustainability and stakeholder management in supply chains: a framework on resource dependence theory. Asian Journal of Shipping and Logistics 28 (3), 301–320.

Dinwoodie, J., Tuck, S., Knowles, H., Benhin, J., Sansom, M., 2012. Sustainable development of maritime operations in ports. Bus. Strat. Environ. 21 (2), 111–126.

Ecoports, 2017a. About - EcoPorts | ESPO. Retrieved from. https://www.ecoports.com/about.

Ecoports, 2017b. Self-diagnosis method (SDM). Retrieved from. https://www.ecoports.com/sdm.

EcoPorts, 2016a. ESPO/EcoPorts Port Environmental Review 2016. Brussels. https://www.ecoports.com/laravel-filemanager/files/common/publications/ESPO_EcoPorts_Port_Environmnetal_Review_2016_v1.pdf. Retrieved from.

EcoPorts, 2016b. ESPO/EcoPorts Port Environmental Review 2016. Retrieved from. https://www.espo.be/media/news/ESPO_EcoPorts Port Environmental Review 2016.pdf.

ESPO, 2012. ESPO Green Guide: towards Excellence in Port Environmental Management and Sustainability. Brussels. Retrieved from. https://www.espo.be/media/espopublications/espo_green guide_october 2012_final.pdf.

European Commission, 2018. ESPO Environmental Report. Retrieved from. https://www.espo.be/media/ESPO Environmental Report 2018.pdf.

Green, Marine, 2016. Performance report. Retrieved from. https://www.green-marine.org/wp-content/uploads/2017/05/2016_Performance_Report.pdf.

Grifoll, M., Jordà, G., Espino, M., Romo, J., García-Sotillo, M., 2011. A management system for accidental water pollution risk in a harbour: the Barcelona case study. J. Mar. Syst. 88 (1), 60–73.

Gupta, A.K., Gupta, S.K., Patil, R.S., 2005. Environmental management plan for port and harbour projects. Clean Technol. Environ. Policy 7 (2), 133–141.

Hall, W.J., 2010. Assessment of CO2 and priority pollutant reduction by installation of shoreside power. Resour. Conserv. Recycl. 54 (7), 462–467.

Hallegatte, S., 2009. Strategies to adapt to an uncertain climate change. Global Environ. Change 19 (2), 240–247.

Hendricks, K.R., 2017. How People Green the Port: Sustainability in Canadian Ports. Simon Fraser University.

Hollen, R.M.A., Bosch, F.A.J. van den, Volberda, H.W., 2015. Strategic levers of port authorities for industrial ecosystem development. Marit. Econ. Logist. 17 (1), 79–96.

Hossain, T., Adams, M., Walker, T., 2019. Sustainability Initiatives in Canadian Ports. Marine Policy 106, 103519.

Hua, C., Chen, J., Wan, Z., Xu, L., Bai, Y., Zheng, T., Fei, Y., 2020. Evaluation and governance of green development practice of port: a sea port case of China. J. Clean. Prod. 249 https://doi.org/10.1016/j.jclepro.2019.119434.

ICS, 2017. International Chamber of Shipping (ICS). Retrieved from. http://www.ics-shipping.org/shipping-facts/shipping-and-world-trade.

Iraldo, F., Testa, F., Frey, M., 2009. Is an environmental management system able to influence environmental and competitive performance? The case of the eco-management and audit scheme (EMAS) in the European Union. J. Clean. Prod. 17 (16), 1444–1452.

Jasny, M., 2005. Sounding the Depths II: the Rising Toll of Sonar, Shipping and Industrial Ocean Noise on Marine Life. Retrieved from. https://www.nrdc.org/sites/default/files/sound.pdf.

Khoo, I.H., Nguyen, T.H., 2011. Study of the Noise Pollution at Container Terminals and the Surroundings. Long Beach, California. Retrieved from. https://www.metrans.org/sites/default/files/research-project/09-09_Khoo_METRANS_final_report_0_0.pdf.

Kim, S., Chiang, B., 2014. Sustainability practices to achieve sustainability in international port operations. Journal of Korea Port Economic Association 30 (3), 15–37.

Kröger, K., Gardner, J.P.A., Rowden, A.A., Wear, R.G., 2006. Long-term effects of a toxic algal bloom on subtidal soft-sediment macroinvertebrate communities in Wellington Harbour, New Zealand. Estuarine. Coastal and Shelf Science 67 (4), 589–604.

Lam, J.S.L., Ng, A.K.Y., Fu, X., 2013. Stakeholder management for establishing sustainable regional port governance. Research in Transportation Business and Management 8, 30–38.

Lam, J.S.L., Notteboom, T., 2014. The greening of ports: a comparison of port management tools used by leading ports in Asia and Europe. A Transnational Transdisciplinary 34 (2), 169–189.

Lam, J., Van De Voorde, E., 2012. Green port strategy for sustainable growth and development. Transport Logistics for Sustainable Growth at a New Level, Proceedings of the International Forum on Shipping, Ports and Airports (IFSPA). The Hong Kong Polytechnic University, Hong Kong, pp. 417–427. Retrieved from. https://www.polyu.edu.hk/lms/ICMS/ifspa2012/Papers/M25.pdf.

Le, X.Q., Vu, V.H., Hens, L., Van Heur, B., 2014. Stakeholder perceptions and involvement in the implementation of EMS in ports in Vietnam and Cambodia. J. Clean. Prod. 64, 173–193.

Lirn, T., Jim Wu, Y.C., Chen, Y.J., 2012. Green performance criteria for sustainable ports in Asia. Int. J. Phys. Distrib. Logist. Manag. 43 (5/6), 427–451.

Lu, C.S., Shang, K.C., Lin, C.C., 2016. Examining sustainability performance at ports: port managers' perspectives on developing sustainable supply chains. Marit. Pol. Manag. 43 (8), 909–927.

Lun, Y.H.V., Lai, K.H., Wong, C.W.Y., Cheng, T.C.E., 2014. Green shipping practices and firm performance. Marit. Pol. Manag. 41 (2), 134–148.

Matkar, A., 2012. Cronbach's alpha reliability coefficient for standard of customer services in Maharashtra state cooperative bank. IUP J. Bank Manag. 11 (3), 89.

McEwen, B., 2012. A port energy and emission inventory model. Green Tech, Green Marine Annual Conference, Quebec. Retrieved from. http://www.green-marine.org/wp-content/uploads/2015/02/Bryan-McEwen.pdf.

Morris, R.K.A., Gibson, C., 2007. Port development and nature conservation- experiences in England between 1994 and 2005. Ocean Coast Manag. 50 (5–6), 443–462.

Mustonen, M., 2013. Noise as an Environmental Challenge for Ports. Stockholm. Retrieved from. http://projects.centralbaltic.eu/images/files/result_pdf/PENTA_result4_noise.pdf.

Nagle, K., 2013. Seaports: Essential to Our Economic Prosperity. Retrieved from. http://www.pnwa.net/wp-content/uploads/2013/03/Nagle-2013-Mission-Slides.pdf.
Nam, H.S., Song, D.W., 2011. Defining maritime logistics hub and its implication for container port. Marit. Pol. Manag. 38 (3), 269–292.
Ng, A.K.Y., Song, S., 2010. The environmental impacts of pollutants generated by routine shipping operations on ports. Ocean Coast Manag. 53 (5–6), 301–311.
Nursey-Bray, M., Blackwell, B., Brooks, B., Campbell, M.L., Goldsworthy, L., Pateman, H., et al., 2013. Vulnerabilities and adaptation of ports to climate change. J. Environ. Plann. Manag. 56 (7), 1021–1045.
OECD, 2011. Environmental Impacts of International Shipping : the Role of Ports. OECD Publishing.
Panayides, P.M., Song, D., 2012. Introduction. Maritime Logistics : Contemporary Issues. Emerald Group Publishing Limited, Bingley, U.K, p. 1.
Papaefthimiou, S., Sitzimis, I., Andriosopoulos, K., 2017. A methodological approach for environmental characterization of ports. Marit. Pol. Manag. 44 (1), 81–93.
Peris-Mora, E., Diez Orejas, J.M., Subirats, A., Ibáñez, S., Alvarez, P., 2005. Development of a system of indicators for sustainable port management. Mar. Pollut. Bull. 50 (12), 1649–1660.
Pettit, S.J., Beresford, A.K.C., 2009. Port development: from gateways to logistics hubs. Marit. Pol. Manag. 36 (3), 253–267.
Piecyk, M.I., Björklund, M., 2015. Logistics service providers and corporate social responsibility: sustainability reporting in the logistics industry. Int. J. Phys. Distrib. Logist. Manag. 45 (5), 459–485.
POA, 2018. Sustainability. Retrieved from. https://www.portofantwerp.com/en/sustainability.
POK, 2017. Environmental Report. Retrieved from. https://kh.twport.com.tw/en/cp.aspx?n=5DC7E9FCB54DF8F4.
POLA, 2018. Environment. Retrieved from. https://www.portoflosangeles.org/environment.
POLB, 2018. Environment. Retrieved from. http://www.polb.com/environment/default.asp.
POR, 2018. Leading Port Authorities Combine Forces in Climate Action Program. Retrieved from. https://www.portofrotterdam.com/en/news-and-press-releases/leading-port-authorities-combine-forces-in-climate-action-program.
POV, 2017. Sustainability Report. Vancouver, BC. https://www.portvancouver.com/about-us/sustainability/. Retrieved from.
POV, 2018. Environment. Retrieved from. https://www.portvancouver.com/environment/.
Prajogo, D., Castka, P., Yiu, D., Yeung, A.C.L., Lai, K.H., 2016. Environmental audits and third party certification of management practices: firms' motives, audit orientations, and satisfaction with certification. Int. J. Audit. 20 (2), 202–210.
Puig, M., Michail, A., Wooldridge, C., Darbra, R.M., 2017. Benchmark dynamics in the environmental performance of ports. Mar. Pollut. Bull. 121 (1–2), 111–119.
Puig, M., Wooldridge, C., Casal, J., Darbra, R.M., 2015. Tool for the identification and assessment of environmental aspects in ports (TEAP). Ocean Coast Manag. 113, 8–17.
Puig, M., Wooldridge, C., Darbra, R.M., 2014. Identification and selection of Environmental Performance Indicators for sustainable port development. Mar. Pollut. Bull. 81 (1), 124–130.
Santos, S., Rodrigues, L.L., Castelo Branco, M., 2016. Online sustainability communication practices of European seaports. J. Clean. Prod. 112, 2935–2942.
Schnurr, R.E., Walker, T.R., 2019. Marine transportation and energy use. Reference Module in Earth Systems and Environmental Sciences. https://doi.org/10.1016/B978-0-12-409548-9.09270-8.
Sciberras, E.A., Zahawi, B., Atkinson, D.J., Juandó, A., Sarasquete, A., 2016. Cold ironing and onshore generation for airborne emission reductions in ports. Journal of Engineering for the Maritime Environment 230 (1), 67–82.
Trozzi, C., Vaccaro, R., 2000. Environmental impact of port activities. Second International Conference PORTS 2000. Barcelona, Spain.
UNCTAD, 2016. Review of Maritime Transport 2016. Retrieved from. http://unctad.org/en/PublicationsLibrary/rmt2016_en.pdf.
Van Den Bosch, F.A.J., Hollen, R., Volberda, H.W., Baaij, M.G., 2011. The Strategic Value of the Port of Rotterdam for the International Competitiveness of the Netherlands: a First Exploration. Rotterdam. Retrieved from. https://www.erim.eur.nl/fileadmin/default/content/erim/research/centres/smart_port/admin/c_book_releases/havenrapport engelse versie_0.pdf.
Vincent, R., 2014. Environmental Initiatives at Seaports Worldwide: a Snapshot of Best Practices White Paper. Retrieved from. http://aapa.files.cmsplus.com/AwardsCompetitionMaterials/Portland 2014 Stakeholder Awareness Education %26 Involvement.pdf.
Walker, T.R., 2016. Green marine: an environmental program to establish sustainability in marine transportation. Mar. Pollut. Bull. 105 (1), 199–207.
Walker, T.R., Adebambo, O., Del Aguila Feijoo, M.C., Elhaimer, E., Hossain, T., Edwards, S.J., et al., 2019. Environmental effects of marine transportation. World Seas: an Environmental Evaluation. Academic Press, pp. 505–530.
Wanderley, L.S.O., Lucian, R., Farache, F., José Milton De Sousa, F., 2008. CSR information disclosure on the web: a context-based approach analysing the influence of country of origin and industry sector. J. Bus. Ethics 82 (2), 369–378.
Wang, S., Notteboom, T., 2015. The role of port authorities in the development of LNG bunkering facilities in North European ports. WMU Journal of Maritime Affairs 14, 61–92.
Winkel, R., Weddige, U., Johnsen, D., Hoen, V., Papaefthimiou, S., 2015. Shore side electricity in Europe: potential and environmental benefits. Energy Pol. 88, 584–593.
Winnes, H., Styhre, L., Fridell, E., 2015. Reducing GHG emissions from ships in port areas. Research in Transportation Business & Management 17, 73–82.
Witte, J.R., 2016. Noise in ports. 2016 GREEN4SEA Conference & Awards. Retrieved from. https://www.green4sea.com/noise-in-ports-2/.
World Shipping Council, 2017. Top 100 Ports in the World in 2015. Retrieved from. http://www.worldshipping.org/about-the-industry/global-trade/ports.
WPCI, 2017. Onshore Power Supply. Retrieved from. http://www.ops.wpci.nl/implementation-1/legal-analysis/e-dot-u-dot–policy/.
Xu, J., Testa, D., Mukherjee, P.K., 2015. The use of LNG as a marine fuel: the international regulatory framework. Ocean Dev. Int. Law 46 (3), 225–240.
Yim Yap, W., Siu, J., Lam, L., 2013. 80 million-twenty-foot-equivalent-unit container port? Sustainability issues in port and coastal development. Ocean Coast Manag. 71, 13–25.