Chapter 21
Green Port Indicators: A Review

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Abstract Unlike the shipping sector that has witnessed concerted international efforts to address sub-standard ships, similar action has not been seen in the port sector. Other than the efforts taken by the European Sea Ports Organisation that has produced various environmental guidelines to seaports located in the European Union, most efforts to become green or environmentally sustainable are arguably unilateral in nature. As interest in ensuring greener shipping began to accelerate after the implementation of Annex VI of the International Maritime Organization's MARPOL Convention in 2003, the interest to extend its effect on greener seaports has begun to be seen. This resulted in an increase on green port studies beginning 2010. Therefore, the aim of this paper is to review the accessible literature on green ports and to identify the indicators or determinants that were normally addressed to ensure their green performance. Literature search was done through the google scholar search engine using the keywords "green port" and "sustainable port" to identify the relevant literature. Subsequently, a qualitative content analysis technique was used on the 27 identified articles in order to merge the various findings into suitable categories.

Keywords Green port · Sustainable port · Marine environment · Coastal environment

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21.1 Introduction

More than 80% of global trade are carried on board ships and handled through seaports of the world. Therefore, without an efficient seaport and shipping network, the continually increasing demand to move international trade would not be effectively met. As port traffic continues to grow, the question of how to ensure long-term sustainability of the port sector is becoming an important issue at international level. Responding to the sustainability and environmental challenges, many developed economies have taken unilateral actions to implement green port policies and legislation in their countries and it has been argued that since 2010, the green port concept has been applied as a new paradigm that has become synonymous with sustainable port [1]. It has also been argued that ports and their stakeholders can use their associations with green improvements to explore commercial benefits through positive branding and corporate savings. Therefore, developed economies such as Europe have translated their environmental concerns into the European Sea Ports Organisation (ESPO) Environmental Code of Practice in 1994 that was subsequently enhanced into the ESPO Green Guide in 2012 [2].

A Green port is defined as a product of the long-term strategy for sustainable and climate-friendly port infrastructure development [3]. Similarly, it can also be defined as those that place priorities on pollution prevention, clean technology, clean shipping and clean port services [4]. It is a contemporary trend of port development. Sustainability in terms of the green port concept consists of three key elements: ecological balance, port economic stability and social development [5]. The concept of green ports advocates with port to minimise or eliminate harms to the environment and to improve the port's efficiency. All of these positive effects will eventually affect worker's health and social stability, and also increase economic development. For a port to achieve green port status, it has to adhere to the green port concept and measure the port's green performance.

There are many negative impacts from port operations. These negative impacts come in various forms such as pollution and environmental degradation. As the operations are continuous, the ports are generally aware of the pollutions that are emitted to the natural environment [6]. These negative effects can be mitigated by implementing the concept of green port. A green port uses systems and technologies that prevent the environmental pollution and enable to eliminate or reduce the negative impact of port activities on the environment [5]. Despite the awareness, most port systems use outdated energy consumption measurement technology that does not contribute to energy efficiency, environmental protection and sustainable development [6]. Nowadays, a port requires an updated or advanced technology to measure the port energy consumption. Energy and environmental management systems enrich business processes with new knowledge about energy consumption and allow stakeholders to better understand their activities and processes [3]. Scarcity of resources is a challenge in the development of green port since ports require more resources to develop or improve. According to [5], the concept of sustainable port rationally uses natural resources of the environment. Therefore, the development of green port

is beneficial to the environmental resources in the foreseeable future. Environmental planning is important in determining how sustainable seaports are built and developed [6].

21.2 Aim

Studies on green ports seem to increase after 2010. Most green port studies have generally focused on evaluating the benefits of green port implementation, identifying managerial and policy tools required for green ports, transnational initiatives and strategies to improve the green port performance and determining priority green port determinants in order to improve green port performance. The aim of this review paper is to identify the main determinants for improving the green port performance, thus contributing to the fourth category of green port literature. Since ports are involved in activities that are not exactly similar to each other, the presentation of a general list of main determinants or indicators will assist the port management to select those that can provide a significant impact towards achieving a green port status.

21.3 Identification of Important Green Port Indications

Green port indicator is used to measure the port's green performance. The indicators can be identified through several methods. The indicators can form a significant measurement avenue to evaluate the port's status. There are several indicators in ports and it varies depending on the characteristics of ports such as the types of cargo handled, size and locality. At present, the number of research concerning green port indicators is still limited although research on green port has generally increased after 2010. In an earlier study, [7] argues that detrimental effects on the port environment are caused by identified port activities, which include oil spills, waste dumping in the water, cargo spills by chemical carriers and tankers, air pollution from bulk cargo handling, noise and vibration from cargo handling activities, ballast water discharge, collision and stranding of vessels. Hence, necessary measures must be taken to minimise the detrimental effects of those activities. A study by [8] has identified the green criteria of a seaport (GCS) using the Factor Analysis (FA) to evaluate port's green performance. The study was conducted on five ports in Korea. The factor analysis was conducted based on the criteria suggested in other previous research. The research has resulted in the development of green criteria of a seaport (GCS) to evaluate the port's green performance. The GCS consists of fifteen indicators grouped into five main categories. Category one is easing the environmental burden; involving the utilisation of alternative fuels, incentives of pollution reduction, using renewable energy, and recycling of dredging sand recycling. Category two involves environmental friendly method and technology development of construction, whilst

the third category involves utilisation of resources and wastes inside a port. The fourth category deals with efficient planning and management of port operation involving the introduction of a port environment management system, expansion of prevention facilities of ocean pollution and an efficient construction plan. The final category is port redevelopment with the introduction of a waterfront concept which involves the introduction of environmental impact assessment (EIA), and creation of artificial sandbars and wetlands.

A year earlier, the authors of [9] espouse determinants to consider for Greece to develop a port with green status. The first determining factor involves measures to prevent air pollution such as fully comply with regulations, installing air monitoring station for monitoring pollution emitted, modernise cargo handling equipment, using filters and friendly fuel to reduce fuel emission, provide shore power and used wet suspension. The second factor is to reduce soil and sediment pollution followed by an improvement in water quality through development of a storm water pollution prevention program, cleaning the paved roads, connect the contaminant water to the sewage treatment plant and installing sensors for pollution risk. The fourth factor is improving the marine life through periodical environmental studies and tracking indicators of habitat quality. The fifth factor is the reduction in energy consumption by enforcing energy efficiency policies, installation, maintenance, usage and storage of renewable and eco-friendly forms of energy, and conduct energy consumption studies. The sixth factor is the reduction of noise pollution followed by an improved weather monitoring by establishing weather station networks. The last two factors are modern environmental perspectives for green ports by using geographic information system (GIS) environmental monitoring and adopting sustainable practices through recycling, using solar energy or hydroelectric power and applying energy efficiency plans [9].

The authors of [10] in their case study on the Kaohsiung harbour argue that by adopting an onshore power supply (or known as cold ironing) system and speed reduction to 12 knots within a 20 nautical mile zone could reduce nitrogen oxide (NO_x) by 49.2%, sulphur dioxide (SO_2) by 63.2% and particulate matter (PM) by 39.4%. Moreover, by preventing ships at berth from using their auxiliary engines, greenhouse gas (GHG) emissions involving carbon dioxide (CO_2) and hydrocarbon (HC) would also be reduced by 57.2 and 29.2%, respectively [10]. [10] also argue that green port concept requires an efficient leadership, relevant policies and regulations, innovations, and an environmental energy efficient and sustainable development management system. A subsequent study by [11], has evaluated port's green performance on three major ports in Asia, which are Shanghai, Hong Kong and Kaohsiung. The study identified 17 green port indicators through a brainstorming session with academicians. The indicators were later reviewed and grouped into five areas namely air pollution management; aesthetic and noise pollution management; solid waste pollution management; liquid pollution management and marine biology preservation. By applying the analytical hierarchy process (AHP) method to identify the weightage of each indicator, the research results indicate that the top three important actions to improve the green performance are air pollutant avoidance, using electrically powered equipment, and encouraging the use of low-sulphur fuel [11].

In another study, [12] have investigated the factors for operating a green port. The study evaluated three ports in Taiwan namely Kaohsiung, Taichung and Keelung. The authors referred to previous studies and have identified 13 factors based on five dimensions for green port operations. The five dimensions are environmental quality; use of energy and resource; waste handling; habitat quality and greenery and social participation. The results of the empirical study from the research show that the top five attributes of green port operations are hazardous waste handling, air pollution, water pollution, port greenery and habitat quality maintenance. The result is then used to evaluate the three ports green performance. Additionally, by referring to a study by [11], authors of [13] have successfully discovered 15 key performance indicators that can be used to evaluate the green performance of Egyptian ports. Using the AHP method, top four indicators identified are air pollution avoidance, oil spill contingency plan, reducing road vehicle CO_2 emissions and hazardous cargo management. The authors propose a Green Port Performance Index (GPPI) that was subsequently used to evaluate the ports performance based on the top indicators. Additionally, it was argued that the proposed index can be used on ports of any country to ensure compliance to their environmental law [13].

In another study, authors of [14] conclude that energy management is important in achieving sustainability, and more attention must be paid on energy issues in port management. The researchers highlight the importance of renewable energy and encourage the installation of equipment to generate renewable energy. They also emphasise on the development of biofuels in ports as it can be seen as an opportunity for the ports since the world demands eco-friendly fuels. They argue that energy management is important to achieve port sustainability. Therefore, port management must give more attention on energy matters. The researchers express their views towards the importance of renewable energy and encourage the installation of equipment for generating renewable energy from the wind, wave and geothermal energy. Based on a case study on the European ports of Genoa and Hamburg, the researchers encourage installing solar panels on the wide flat surface such as storage areas and warehouses to generate solar energy. They argue that these installations and commitment towards renewable energy can leave a positive impact on ports. Additionally, carbon capture and storage (CCS), material recycling and waste disposal may influence the port's reputation. The production of biogas and electricity can be obtained from waste by converting it into thermal energy. The development of biofuels in ports is also an opportunity for the ports as the world demands eco-friendly fuels [14].

In a research published in 2014, the authors of [3] espouse the problem in achieving green port status is because the majority of the workers tend not to see or feel the link between their action or behaviour and their companies' energy performance and impact on the environment. They argue that energy efficiency is largely linked to investments in new equipment [3]. In their case study on the Port of Koper, Slovenia they discovered that in order to be successful in achieving green port status, a proper selection of the initial projects is vitally important in order to make the green concept alive. Additionally, the involvement of a multi-disciplinary team from all departments in the port is also crucial. The implementation of the green port projects must be supported by an intelligent energy and environmental management system to enable

those involved are updated with previous and present performance to ensure their effectiveness [3]. In their evaluation of two Asian and two European leading ports, authors of [4] argue that the most common green tools used by port authorities and public regulators are managing ship traffic, cargo handling and storage activities, as well as port expansion and industrial activities. This is because ports are driven by international conventions that place a higher weight on curbing pollution from ships. They argue that less initiatives were seen in the area of intermodal hinterland connections [4].

Authors of [15] investigated the status and trends in the environmental performance involving 79 European ports on issues related to environmental management, environmental priorities and current environmental monitoring practices. Based on their survey to support their "Port Performance Indicators: Selection and Measurement" (PPRISM) project in 21 European countries, it was discovered that the top five environmental priorities among European ports are air quality, garbage/port waste, energy consumption, noise and ship's waste. Other priorities are relationship with local community, dredging operations, dust, port development (land work) and water quality [15]. Although, some of the priorities have shifted as compared to earlier surveys conducted by the European Sea Ports Organisation beginning 1996, it has been argued that dredging operations, dust, port development and water quality have consistently appeared as the top priorities among European ports[15]. Authors of [16] propose the data envelopment analysis (DEA) and panel data estimation models as an approach to assess the efficiency of green ports. They also argue that the deployment of computer and control systems within vehicles laid the foundation for an emission reduction strategy. Additionally, the advance of intelligent logistics and smart transportation will improve the fuel economy that will lead to the choice of cleaner energy [16].

Authors of [15] have identified ten specific components of environmental management and eleven environmental monitoring indicators. The eleven environmental monitoring indicators are air quality, water quality, soil quality, sediment quality, terrestrial habitats, noise, marine ecosystems, energy consumption, water consumption, carbon footprint and waste management. The three indicators of green shipping obtained from the results are onshore power supply, differentiated fees for clean shipping and LNG bunkering. Two techniques were used in this research to identify and select the indicators. Firstly, a bottom-up method was used to assess the current indicators applied by the ports. Secondly, a top-down approach mainly focused on legislation and regulations as well as valuable opinions and suggestions from port communities. According to [17], Vietnamese ports need to emphasise on sustainable development for their expansion and improvement projects. They argue that the criteria for environmental management should be divided into two dimensions, which are internal and external. Ports should use integrated technology equipment for efficiency and reduce cost and time. Collaboration with business partners in computer aided operations is necessary to reduce time and supply chain collaborations to improve stakeholder relations. Furthermore, the utilisation of cleaner port technology equipment is necessary. Periodic collaboration through business meetings

with shipping companies for environmental issues is necessary. Port expansions activities should consider sustainable projects with urban authorities to evaluate projects and effects on inhabitants around the ports area. Internal social programs proposed are employee welfare, education and training for management that are related to reduction of potentially damage environmental practices and lead for environmental performance improvement [17].

According to [18] in their study involving Brazilian public ports, there are four main innovations in port environmental management. The first is cooperation with external parties such as UNESCO and specialised companies. The second innovation is improving the internal pipeline of the port, followed by marine biology preservation at port entrance sediment and coastal erosion control, as well as wetland and marine habitat preservation in the port area. The fourth factor is organisation and management training or education for employees and working level, good communication with the local government, establishing managerial organisation for green port development and regular and exclusive budgets for green port performance [18]. On the other hand, author of [19] conducted a review on 18 articles involving green port and condensed green port performance criteria into five groups namely air pollution management, liquid pollution management, solid waste and other pollutants management, aesthetic and noise control management, and lastly marine biological preservation.

In a research done by [6], the modernisation of the waste management system is one of the methods to develop a green port. Examples of green measures mentioned by the researchers are the use of renewable energy for port operations and activities; recycling and reuse of materials; implementation of policies similar to the reduction of the emissions of harmful substances; and landscape design of a port, which includes the plantation of trees to absorb noise and pollution. It has also been argued that the importance of open discussions such as forums with environmental organisations related to environmental activities in order to obtain efficient, high quality guidelines and management recommendations. Moreover, the researchers suggest to establish networking among the ports to exchange experience and knowledge regarding green development. The researchers utilised the qualitative content analysis method to complete their research [6]. Additionally, author of [20], argued that environmental aspects play a vital role for ports as they can gain support from the community and attract trading partners and potential investors. They suggested three approaches to reduce maritime GHG, namely through technical measures, market-based instruments measures and operation options measures. The researchers also argued that on-road and off-road vehicles are the major emissions contributor of the terminal. Technical measures composed of efficient ship hulls, energy-saving engines, more efficient propulsion, use of alternative fuels such as biofuels, scrubbers to trap exhaust emissions and onshore power supply. Market-based instruments are divided into two main categories, namely; carbon levy schemes and emission trading. Operational options measures comprised speed optimisation, optimised routing and improved fleet planning. Based on the outcome of their research on the port of Long Beach and Istanbul's Marpot terminal, they concluded that the major contributors to the total emission in terminal are on-road and off-road vehicles [20].

Authors of the study [9] have listed 21 indicators for green performance evaluation with six sections, which are liquid pollution management air pollution management, noise control, low carbon and energy saving, marine biology preservation and organisation and management for three major China's ports. Among the 21 indicators are a fuel spilling contingency plan, sewage treatment, hazard waste management, ballast water polluting control and waste dumpling management. They are followed by dust control and encouraging use of low-sulphur fuel, cold ironing, regulation on the emissions of toxic gas, annual plan for air pollution management, reducing noise and vibration from cargo handling, equipment and the vessels and using renewable energy resources such as solar heat and wind power. Additionally, using substitute energy and energy-saving devices, applying new energy-saving working processes, using on deck power, port entrance sediment and coastal erosion control, wetland and marine habitat preservation, training or education for employee at working level, good communication with the local government, establishing managerial organisation for green port development, and finally regular and exclusive budgets for green port performance. Recent studies indicate that government guidelines in terms of training and education are the most significant and essential components to evaluate the green port performance. The problems are lack of access to collect data from the ports and also information on guidelines of green port criteria evaluation for becoming "green". Hence, the ports have to get a better understanding on the method to implement a comprehensive approach for Chinese port sustainability practices to improve green performance. Government can take initiatives to promote sustainability by allocating special grants and funds to encourage and motivate Chinese ports for better green performance [9].

According to [21], in their study involving the handling of bulk cargo, the use of technological measure for prevention of the dust emanation during dust material transportation is unavoidable. Dust prevention by perforated wind dust screens is used in Canada, China and several other countries. Depending on the direction of the wind, it functions as wind protection when located upwind from the stack, whilst it functions as dust prevention when located downwind from the stack [21]. The dust problem can also be reduced by using standard container for handling bulk cargo. The box type bulk cargo handling reduces missing cargo compared to open storage. Five indicators are proposed for green operations in dry bulk terminals, namely treat dust production materials at dispatch point with special liquid solutions, watering stacks at open handling points of materials, frequent dust removing and area cleaning, installing wind dust protection screen at port area and container cargo handling system of delivery materials [21]. Additionally, author of [22] in their study on toxic air pollution in United States' 20 biggest container ports discovered many challenges in the measuring port efficiency due to the heterogeneity characteristics of port activities. They argued that although ships are becoming more efficient, they are the largest in port source of toxic air pollution contributing about 70% of sulphur oxide (SO_x) and 50% of PM [22]. Author of [23] espouse six green port concepts based on their study on six ports in Turkey, Europe and the United States.

The first concept is air quality that aims to reduce air pollution and improve the air quality at the port areas by using the shore electricity as power source. Next is

monitoring the wildlife by tracking several indicators of habitat quality including the abundance of birds and the number of fish species found in the harbour during periodic biological surveys. Hence, ports also have to plan for restoration programs for rehabilitation area and should conduct a biological periodic survey after every construction. Third, the water quality needs to be measured by its own parameters for water quality study. Fourth, the community relation for sustainable environment must be improved in order to complete for EIA. Public broadcasting can be used as a channel to gain awareness for the public on the protection of the environment. Managing waste material by recycling and reuse is also important as another strategy to protect the ecological environment. Finally, sustainability should be adopted as a new concept to reduce pollution through the recycling method. According to [5], the green port concept will contribute towards the concept of sustainable development, which means a port development that meets the needs of the present and future generations. They espouse efficiency of resources, low emission of dusts and other harmful substances, low emission of noise and economy of land use as the contributors to green ports. Additionally, they propose eight important assumptions to achieve a sustainable port concept as addressed in Table 21.1. Meanwhile [2] utilised the drivers, pressures, states, impacts and responses (DPSIR) framework to integrate different perspectives on environmental, social and economic issues in their study on green port. In addressing the pressures on green ports, they argue that dust pollution, water pollution, solid waste pollution and noise pollution are the main stress inflicted by ports daily operations [2]. Therefore, in order to identify the pressures, ports must be able to identify volume of waste gas emission involving SO_2, NO_x and inhalable particles. Similarly, volume of waste water discharge per throughput, amount of solid waste residual per throughput and average noise level of port need to be considered [2].

A more recent study by [24], propose the environmental performance indicators (EPIs) to access to the environmental aspect of a container seaport through their evaluation of Laem Chabang port in Thailand. According to the authors, green port becomes a trendy seaport activity, and EPIs are important for the assessment of environmental criteria. The authors propose several green port indicators by applying the entropy method in support of the efforts by the Port Authority of Thailand in promoting green ports. The top five indicators are total Kjeldahl nitrogen (TKN) in wastewater, chromium in soil and sediment, total suspended particles (TSP) in the air, phytoplankton biodiversity and zooplankton biodiversity. The authors argue that the EPIs can be used as a tool for green port evaluation that could be applied not only to Laem Chabang port but also to any container port that is interested in achieving the green port status [24]. Additionally, [1] in their examination of green port practices by the port of Bremen and the main ports of West Africa shortlisted 12 green practices implemented by the ports as highlighted in Table 21.1. In their study on the challenges faced by cruise ports, [25] identified waste management and various forms of emissions that include air and noise since cruise ships are large emitters due to their large hoteling loads. Therefore, they espouse on the concept of cold ironing, utilisation of diesel oil to replace heavy fuel oil, renewal energy sources

Table 21.1 Summary of greenport research

No	Author	Research area	Findings	Method	Region
1	[12]	Port planning and development	Activities the cause detrimental effects to port environment are: a. water pollution (oil spills, waste dumping, cargo spills by chemical carriers and tankers) b. air pollution through bulk cargo handling c. noise pollution (vibration from cargo handling) d. collision and stranding of vessels	Not revealed	General
2	[9]	Green port	Factors to achieve green port: a. Air pollution prevention (compliance with regulations, air monitoring stations, modernise cargo equipment, use filters and friendly fuels, shore power and wet suspension) b. Soil and sediment pollution prevention c. Improvement in water quality (storm water pollution prevention, cleaning paved roads, connect contaminant water to sewage treatment plant and sensor for pollution risk d. Improvement of marine life (periodical environmental study and habitat quality tracking) e. Reduce energy consumption (energy efficiency policy, renewable and eco-friendly forms of energy, energy consumption studies) f. Reduction of noise pollution g. Improve weather monitoring, GIS environmental monitoring and adopting sustainable practices	SWOT analysis	Europe
3	[14]	Green port	Development of Green Criteria of a Seaport (GCS) to evaluate port performance with 15 indicators grouped into five categories: a. Easing environmental burden (utilise alternative fuels, incentives for pollution reduction, renewable energy and recycling of dredged sand) b. Environmental friendly method and technology for construction (improvement of port facilities and equipment, breakwater system, less noisy construction method) c. Utilisation of resources and wastes (resources recycling and development of industries in ocean waste disposal) d. Efficient planning and management of port operations (prevention of ocean pollution and efficient construction plan) e. Port redevelopment with waterfront concept (EIA and creation of artificial sandbar and wetland)	Factor analysis	East Asia

(continued)

Table 21.1 (continued)

No	Author	Research area	Findings	Method	Region
4	[8]	Green port	Actions to achieve green port: a. Provision of onshore power supply (cold ironing) b. Speed reduction to 12 knots within 20 nautical miles from port c. Efficient leadership, relevant policies/regulations, innovations, energy efficient and sustainable development management system	Case study	East Asia
5	[11]	Green port	Identified 17 green port indicators divided into five groups: a. Air pollution management b. Aesthetic and noise pollution management c. Solid waste management d. Liquid pollution management e. Marine biology preservation	Brainstorming session	East Asia
6	[22]	Green port	Identified 13 factors as guidelines for green port operation. Top five factors are: a. Hazardous waste handling b. Air pollution c. Water pollution d. Port greenery, and habitat quality maintenance e. New measures to reduce port service time through minimising disruption and maximising efficiency	Fuzzy AHP	East Asia
7	[24]	Green port	Four top indicators for green port: a. Air pollution avoidance b. Oil spill contingency plan c. Reduce road vehicle CO_2 emission d. Hazardous cargo management	Fuzzy AHP	Africa (North)
8	[18]	Energy management in port	Factors for efficient energy management: a. Installation of equipment for generating renewable energy from wind, wave and geothermal energy b. Wide flat surface such as storage areas and warehouses that can be used for the installation of solar panels c. Carbon capture and storage, material recycling and waste disposal d. Conversion of waste into thermal energy or used to generate biogas and electricity e. Development of biofuel	Case study	Europe

(continued)

Table 21.1 (continued)

No	Author	Research area	Findings	Method	Region
9	[4]	Green and sustainable port infrastructure	Factors to ensure success of initial green port projects a. Development awareness among the workers on the relationship between their actions and the environment b. Proper selection of initial projects to make green concept alive c. Involvement of multi-disciplinary teams in green projects d. Green port projects to be supported by intelligent energy and environmental management system	Case study	Europe
10	[16]	Green port	Main activities performed: a. Managing ship traffic b. Cargo handling c. Storage activities d. Port expansion e. Port Industrial activities Neglected important activity: a. Managing intermodal hinterland connections	Case study	East Asia and Europe
11	[19]	Green port	Top five environmental priorities among European ports: a. Air quality b. Garbage/port waste management c. Efficient energy consumption d. Noise management e. Ship's waste management Other priorities: a. Relationship with local community b. Managing dredging operations c. Dust prevention d. Sustainable port (land work) development e. Water quality	Survey questionnaire	Europe
12	[13]	Energy Efficiency for Green Port	1. Propose DEA and PDE models as an approach to assess the efficiency of green port 2. Deployment of in-vehicle computer and control system laid the foundation of emission reduction strategies 3. Advance of intelligent logistics and smart transportation improve the fuel economy	Data Envelopment Analysis (DEA) and Panel Data Estimation (PDE)	East Asia

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Table 21.1 (continued)

No	Author	Research area	Findings	Method	Region
13	[20]	OSH and Environmental performance in ports	Identified 11 environmental monitoring indicators: a. Air quality b. Water quality c. Soil quality d. Sediment quality e. Terrestrial habitats f. Noise control g. Marine ecosystem h. Efficient energy consumption i. Efficient water consumption j. Carbon footprint management k. Waste management	Bottom-up and top-down methods	Mostly Europe
14	[25]	Sustainable port development	Criteria for environmental management: a. Use integrated technology equipment for efficiency, reduce cost and time b. Collaboration with business partner in computer aided operations c. Utilise cleaner technology equipment d. Port expansions should consider effects on inhabitants e. Training of employees that lead towards improvement in environmental performance	Semi-structured interview	East Asia
15	[6]	Port environmental management	Main innovations in port environmental management: a. Cooperation with external experts b. Improving internal pipelines c. Marine biology and marine/wetland habitat preservation d. Sediment and coastal erosion control e. Training and education of employees at working level f.. Establish green port organisation	Qualitative and quantitative analysis	Latin America
16	[5]	Green port performance criteria	Main performance criteria: a. Air pollution management b. Liquid pollution management c. Solid waste and other pollutants management d. Aesthetic and noise control management e. Marine biology preservation	Qualitative content analysis	General

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Table 21.1 (continued)

No	Author	Research area	Findings	Method	Region
17	[21]	Green port	Methods to develop green port: a. Modernisation of waste management and facilities (e.g. use of renewable energy and recycling and reuse of materials) b. Policy on reduction of the emissions of harmful substances into the atmosphere c. Landscape design which includes trees that absorb noise and pollution d. Engagement with experts and networking with other ports to obtain efficient, high quality guidelines and management recommendations	Qualitative content analysis	Croatia
18	[3]	Green port	Three approaches to reduce maritime greenhouse gases: a. Technical measures—efficient ship hull, energy-saving engines, efficient propulsion, alternative fuels, scrubbers and onshore power supply b. Market-based measures—Carbon levy scheme and emission trading c. Operation options measures—speed optimisation, optimised routing and fleet planning including management of on- and off-road vehicles	Case study	Asia (Turkey) and North America
19	[26]	Green port (performance evaluation)	21 indicators divided into six sections: a. Liquid pollution management (oil spill contingency plan, sewage treatment, waste management, ballast water control, waste dumping management) b. Air pollution management (dust control, use of low-sulphur fuel, cold ironing, control of toxic gas emission annual air pollution management plan) c. Noise control (noise reduction and vibration from activities, equipment and ships) d. Low carbon and energy saving (renewable energy resources through solar heating and wind; substitute energy and energy-saving device; apply energy-saving work processes; use on deck power) e. Marine biology preservation (protect port entrance sediment, coastal erosion control, wetland and marine habitat preservation) f. Port organisation and management (training and education for employees, communication with local government, green port development organisation, exclusive budget, grant/fund from government)	Delphi	East Asia

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Table 21.1 (continued)

No	Author	Research area	Findings	Method	Region
20	[6]	Bulk cargo handling	Five methods to minimise dusts in bulk cargo handling: a. Treatment of dust materials at despatch point with special liquid solutions b. Watering stacks at open handling point c. Frequent dust removing and area cleaning d. Installing wind dust protection screen in port e. Utilise container cargo handling system for bulk	Not revealed	Europe
21	[17]	Air Pollution in ports	Ships are main contributor of air pollution in ports consisting: a. 70% of SO_X b. 50% of PM	DEA	North America
22	[23]	Green port	Six green port concepts: a. Air quality (using shore electricity) b. Wildlife monitoring (tracking indicators of habitat quality e.g. birds and fish species) c. Water quality (establish parameters for water quality study) d. Community relations (improve public awareness) e. Reuse of waste material f. Adopt recycling concept to ensure sustainability	Not revealed	Asia (Turkey), Europe and North America

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Table 21.1 (continued)

No	Author	Research area	Findings	Method	Region
23	[15]	Green and sustainable port	Main factors for green port concept: a. Efficiency of resources b. Low emission of dusts and harmful substances c. Low emission of noise d. Economy of land use Conditions for sustainable port: a. Actions to prevent/reduce air pollution b. Actions to prevent/reduce sludge and soil contamination c. Effective improvement of water quality d. Limiting the impact of port activity on aquatic and land ecosystem involving fauna and flora e. Effective technology that limits energy consumption or/and using renewable energy sources f. Real reduction of noise and vibration g. Monitoring and analysis of weather changes affecting port operations and environment h. Research and Development to expand green growth prospect for port	Qualitative content analysis	East Asia
24	[7]	Green port development	Stress created by port activities: a. Dust pollution b. Water pollution c. Solid waste pollution d. Noise pollution Responses: a. Volume of waste gas emission (SO_x, NO_x, PM) per throughput b. Volume of waste water discharged (treated or not) per throughput c. Waste residues (solid and semi-solid) produced from port activities d. Average noise level of port	DPSIR framework, AHP, evidential reasoning	Asia

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Table 21.1 (continued)

No	Author	Research area	Findings	Method	Region
25	[2]	Green port	Five main indicators to evaluate green port performance: a. Total Kjeldahl nitrogen in waste water b. Chromium in soil and sediment c. Total suspended particles in the air d. Phytoplankton biodiversity e. Zoo plankton biodiversity	Entropy method	East Asia
26	[10]	Green Port	Green strategies: a. Establishment of Office of Environment and Sustainability Affairs b. Nature conservation c. Improving water quality d. Reduce air emissions e. Reduce impact on climate change f. Waste reception facility g. Environmental Ship Index (Discount 15% for ship that meets ESI) h. Paperless port policy to expedite processes i. Adoption of ISO 140,001 EMS j. Port dues and fines k. Oil spill management l. Ballast water management	Interview	Europe and Africa (West)
27	[1]	Green Cruise Ports	Externalities for cruise shipping: a. Waste reception for waste and garbage – Oily bilge water – Sewage – Solid waste – Non-sewage waste water b. Control of emissions in port: – Diesel generator exhaust – Ventilation inlets/outlets – Pumps and reefers	Not revealed	Europe

and LNG as alternatives [25]. A summary of 27 previous studies that were published mostly between 2011 and 2019 is condensed in Table 21.1.

Gleaning through Table 21.1, it can be observed that a variety of research methods have been utilised for green port research. Among the most popular methods are case study, AHP/Fuzzy AHP, DEA, interview, content analysis and survey. Most of the research is also focussed on findings in container and general cargo terminals with only one research that is focussed on dry bulk terminals and another research on passenger terminals. Most of research studies are focussed on a particular geographical region whilst four studies focus on two or three regions. From the 27 papers reviewed, 13 papers focus on Asia involving ports in East Asia and Turkey. 11 papers address the ports in Europe and three papers cover ports in North America. The coverage for ports in other regions are barely minimum and present an excellent gap that can be explored for future research.

21.4 Most Research Green Port Indications

In order to determine suitable indicators for green ports, a qualitative content analysis was performed on the 27 selected publications. The text identified has been coded into a suitable number of categories or themes that can assist in a better understanding of the main green port determinants. Based on the content analysis, the most popular determinant covered by green port research is air pollution management, which was addressed in 25 publications that were reviewed. Among others, this category deals with dry bulk cargo handling, modernisation of cargo handling equipment, on- and off-road vehicles management, cold ironing, use of scrubbers and alternative fuels for ships, electrical powered land vehicles, control of speed and effective control of toxic gas emission. On the other hand, water pollution management was addressed in 16 publications. This category covers sub-categories such as handling of oil and cargo spill, sewage treatment, handling of ballast water, liquid waste management, maintenance of water quality. The third most frequently covered category is preservation/improvement of marine life with 11 publications. It covers areas that include periodical environmental study, habitat tracking and preservation, preserving marine ecosystem, wetland habitat conservation, and monitoring of phytoplankton and zooplankton biodiversity.

The next popular research area in the green port study is noise pollution management that was covered in 10 publications. This is followed by soil and sediment preservation (nine publications), management of solid waste and garbage (nine publications), utilisation of green technology (eight publications), preservation/improvement of coastal habitat (seven publications) and cooperation with external parties (six publications). Next areas that received coverage in five publications are effective coordination and regulatory measures, efficient port development, and environmental awareness and training. Other areas that were covered in more than one publications are recycling/management of wastes and resources (4), monitoring changes in weather/climate (3), incentives and fines (3), landscape design

(2), measures to reduce port service time (2), adoption of quality standard (2) and management of hazardous cargo (2).

21.5 Conclusion

In retrospect, it is easy to comprehend why air pollution management is the most frequently research green port indicator in the recent years. This is because, it coincides with the current research in green shipping especially on the various initiatives to adhere to Annex VI of the Marine Pollution (MARPOL) Convention. Besides air pollution, the other popular indicators or determinants that are commonly studied in green port research are water pollution, preservation/improvement of marine life and noise pollution. Water pollution and noise pollution are also two common areas that are generally studied in environmental research. It is also interesting to note that soil and sediment preservation, management of solid waste and garbage, the prospect of utilising more green technology, as well as the preservation and improvement of coastal habitat have also been considered by many researchers as among the important factors that must be addressed by ports in order to become more sustainable in the long run. Notwithstanding the preceding arguments, it is worthy to note that although the other indicators did not receive much coverage in the contemporary green port literature, it does not in any way signify that those indicators are less important. In fact, it presents green port researchers with an opportunity to further explore into those indicators and contribute towards the enhancement of green port as a body of knowledge.

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