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Towards a Green Port Model: Helping Ports to Make Progress in the Direction of Sustainability

Rumo a um Modelo de Porto Verde: Ajudando os Portos a Progredir na Direção da Sustentabilidade

Hacia un Modelo de Puerto Verde: Ayudando a Los Puertos a Avanzar Hacia La Sostenibilidad

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ABSTRACT

Context: The SDGs highlight the need to make modes of transport sustainable. Ports are of significant economic importance, but th/ey must also be aligned with sustainability. To help solve this problem, green ports are an option. **Objective:** This research aims to propose an evaluation model for a green port, with indicators and sub-indicators. A total of 10 indicators were mapped from the literature, with a group of 45 sub-indicators. **Contribution:** This research contributes to this topic in the literature by presenting a set of relevant indicators and helping ports progress towards their sustainability-related objectives. **Conclusions:** It is concluded that the most relevant indicators in the literature are: Emissions reduction and efforts to ensure Energy Management; Air quality; Noise pollution; Water management; Cost and savings; Materials, inputs and resources; Indoor environmental quality; Construction project management; Social indicators; and Port operations management. Furthermore, the indicators and sub-indicators were verified by experts in the port sector and applied using documentary sources from internationally recognized ports.

Keywords: Green Port; Green buildings; Sustainable development of the ports.

RESUMO

Contexto: Os ODS destacam a necessidade de tornar os modos de transporte sustentáveis. Os portos são de importância econômica relevante, mas também devem estar alinhados com a sustentabilidade. Para ajudar a resolver esse problema, os portos verdes são uma opção. **Objetivo:** Esta pesquisa visa propor um modelo de avaliação para um porto verde, com indicadores e subindicadores. Um total de 10 indicadores foram mapeados na literatura com um grupo de 45 subindicadores. **Contribuição:** Esta pesquisa contribui para este tema na literatura ao apresentar um conjunto de indicadores relevantes e ajudar os portos a progredir com seus objetivos relacionados à sustentabilidade. **Conclusões:** Conclui-se que os indicadores mais relevantes na literatura são: Redução de emissões e esforços para garantir a Gestão de Energia; Qualidade do ar; Poluição sonora; Gestão da água; Custo e economia; Materiais, insumos e recursos; Qualidade do ambiente interno; Gestão de projetos de construção; Indicadores sociais; e Gestão de operações portuárias. Além disso, os indicadores e subindicadores foram verificados por especialistas do setor portuário e aplicados por meio de fontes documentais em portos reconhecidos internacionalmente.

Keywords: Porto Verde; Edificações Sustentáveis; Desenvolvimento Sustentável dos Portos.

RESUMEM

Contexto: Los ODS resaltan la necesidad de hacer que los modos de transporte sean sostenibles. Los puertos tienen una importancia económica significativa, pero también deben estar alineados con la sostenibilidad. Para ayudar a resolver este problema, los puertos verdes son una opción. **Objetivo:** Esta investigación tiene como objetivo proponer un modelo de evaluación para un puerto verde, con indicadores y subindicadores. Se mapearon un total de 10 indicadores de la literatura, con un grupo de 45 subindicadores. **Contribución:** Esta investigación contribuye a este tema en la literatura al presentar un conjunto de indicadores relevantes y ayudar a los puertos a progresar hacia sus objetivos relacionados con la sostenibilidad. **Conclusiones:** Se concluye que los indicadores más relevantes en la literatura son: Reducción de emisiones y esfuerzos para asegurar la Gestión de la Energía; Calidad del aire; Contaminación acústica; Gestión del agua; Costos y ahorros; Materiales, insumos y recursos; Calidad ambiental interior; Gestión de proyectos de construcción; Indicadores sociales; y Gestión de operaciones portuarias. Además, los indicadores y subindicadores fueron verificados por expertos en el sector portuario y aplicados utilizando fuentes documentales de puertos reconocidos internacionalmente.

Keywords: Puerto Verde; Edificaciones Sostenibles; Desarrollo Sostenible de los Puertos.

INTRODUÇÃO

The importance of transportation has been recognized in the United Nations (UN) Sustainable Development Goals (SDGs). Although none of the objectives are exclusively dedicated to means of transport, or maritime transport in particular, the sector is considered a critical factor for the effective achievement of eight goals, mainly SDG 11, referring to cities. The American Association of Port Authorities (AAPA) recognizes that ports have a critical role in transport, logistics and infrastructure development, and is aware that their activities can impact the environment. In this context, AAPA states that the existence of sustainability in ports is directly related to the defined strategies as well as the activities carried out by its structure and stakeholders (AAPA, 2020).

A port is a building, and green buildings are developed following environmentally friendly principles that seek to minimize the number of resources used in its construction and the operation of the activities carried out in it so that the least possible waste occurs (Ragheb et al., 2016).

Port consumers are not always close to ports, because for them, what is important is the efficiency in the transport of products and access to these services (Silva and Rocha, 2012). However, the impact of these services falls on the city where the port is located and therefore, environmental management of the surroundings is necessary. It can be challenging for port managers to be aware of global changes in trade, economy, technology and the environment (Parola, 2021).

So, this research aimed to propose an evaluation model for a green port, with indicators and sub-indicators mapped in the literature. This research aims to contribute to academic purposes, bringing a new set of indicators relevant to this theory. For practical purposes, the paper may assist ports to make progress with their sustainability-related objectives.

THEORETICAL FRAMEWORK

Green Building and Sustainable Building

Green buildings are buildings designed for the efficient use of resources, based on ecological principles that benefit the environment and human health, the concept of a green building must include the entire life cycle of the building (Chi et al. 2020). Lee and Burnett (2008) described performance criteria and credit scales for three methods of assessing a sustainable building, which are: Hong Kong Building Environmental Assessment Method (HK-BEAM); Leadership in Energy and Environmental Design (LEED); and Building Research Establishment Environmental Assessment Method (BREEAM).

Besides these, Nilashi et al. (2015) created a performance evaluation system for green buildings, organised into a set of criteria categories: Occupant satisfaction; Site selection; Quality of the interior environment; Waste and pollution; Externalities; Energy efficiency; Accessibility; Cost and savings; Material. Boca Santa et al. (2020) recently presented a certification model for green airports, a type of construction similar to ports in terms of receiving vehicles and having centralised transport constructions.

In recent years, the appearance of different Green Building Rating Systems (GBRSs) has been noted, in parallel with the accelerated development, over the last decades, of green buildings (Doan et al., 2017). In this sense, GBRSs are responsible for measuring the sustainability and greening of buildings, as a structure with a comprehensive character, represented by building authorities, international organizations, or private consulting companies (Lee et al., 2013, Toroghi et al., 2016). Therefore, considering the project teams' search for reaching performance limits, this measurement process is imposed on buildings to obtain certificates, consisting of performance limits and guidelines (Wu et al., 2014a, Wu et al., 2014b, Wu et al., 2017, Mattoni et al., 2018). Thus, the assessment of the sustainability of buildings is currently supported by the worldwide development of numerous GBRSs (Chen et al., 2015, Li et al., 2017, Mattoni et al., 2018).

Green Port and Sustainable Port

The ports are called facilitators because of the contribution that ports can make in helping the entire port community comply with legislation, reduce and mitigate environmental impacts, prevent pollution, promote sustainable development, and show satisfactory evidence of performance (ESPO, 2012).

In addition, a sustainable port must be economically and environmentally efficient (Chang, 2013). A green port proactively integrates adaptation and mitigation measures to climate change in its operations and plans (PIANC, 2014).

According to Antão et al. (2016), indicators are useful that assessing performance following low trends. Ports are encouraged to use indicators to monitor their performance. According to Mazon et al (2019), sustainability indicators are basic factors for the elaboration of sustainable performance assessment models.

In Brazil, the National Waterway Transport Agency (ANTAQ) aims to implement national transport policies, being responsible for regulating, supervising, and inspecting port activities. Aiming for the adoption of environmental practices, the Environmental Performance Index (IDA) evaluates national ports (ANTAQ, 2020a).

Housni et al. (2022) proposed a model that has a scale based on maturity, that is, success factors to achieve an Environmental management goal, to guide port managers. This System is guided by social, environmental and economic indicators.

Usually coastal cities have only one port and thus the port maintains the city. These cities provide resources for the operation of the port. On the other hand, the port attracts companies and investments in the city (Kong and Lui, 2021). Thus, the evolution of ports is constantly changing, according to their ecosystem, so disruptive technologies should mark the future of ports (Salsas et al., 2022).

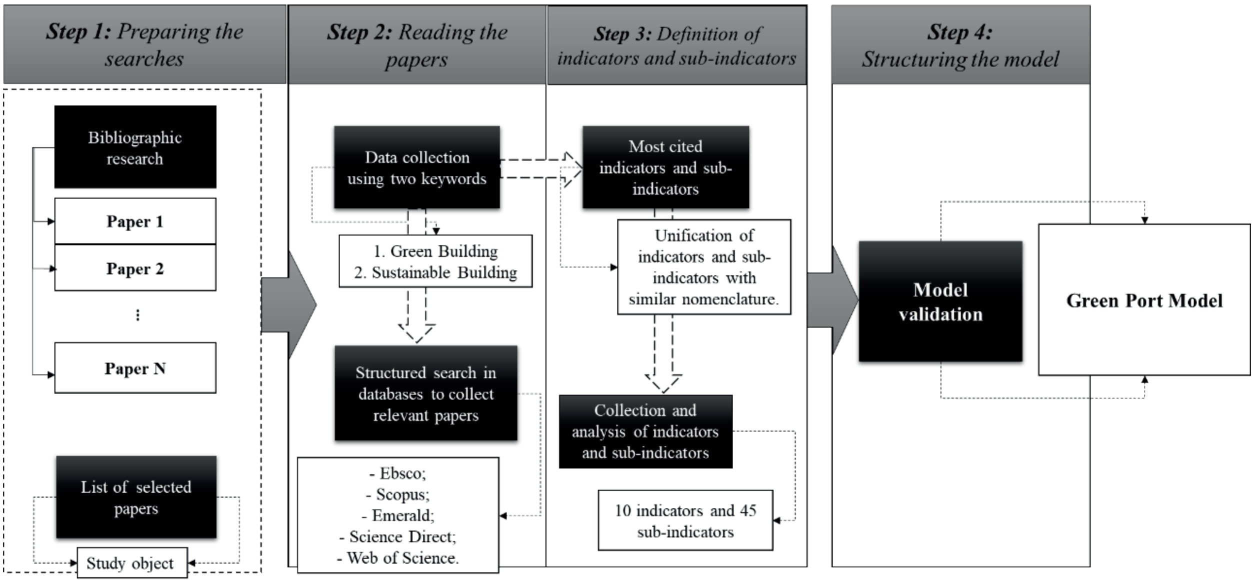
METHODOLOGY

The objectives of this research are descriptive, since they aim to study the characteristics of sustainable ports based on the literature. The study approach is considered qualitative since this methodology helps to understand the process of building a sustainable port model. Data collection took place taking into account two aspects that permeate the theme: Green Building and Sustainable Building; and Green Port and Sustainable Port.

So, the data processing and analysis procedures can be divided into four stages, as shown in Figure 1.

Figure 1

Data treatment and analysis procedures



According to Figure 1, the first stage refers to planning related to bibliographic research and, in the second stage of reading the papers, the objective is to verify the adherence to the theme. In the third stage of collecting indicators and sub-indicators, the data are shown in a spreadsheet for further analysis and regarding the indicators and sub-indicators analysis, the verification of the most-cited indicators and sub-indicators is done. In the fourth stage, the model is structured, and in this phase the indicators and sub-indicators are organized and duly referenced. Finally, and as a result of the last stage of research, 10 indicators and 45 sub-indicators related to the sustainable port model were established. The detailed results of the research are highlighted in the next topic.

Validation was carried out with port sector experts to verify if the indicators selected match the reality and need for sustainability of ports. Thus, a questionnaire was made available to 64 experts, so that they could assess the indicators and sub-indicators according to the Likert scale, ranging from 1 (irrelevant) to 5 (extremely relevant). Among the participating specialists, there were port managers as well as researchers and academics directly related to the port sector. After defining the indicators, ports were selected for evaluation through documentary information. Thus, obtained the information from the previous steps and identified three ports considered outstanding because of the implementation of sustainable ports. Chart 1 presents the selected ports, the countries, and the documents that were selected for the analysis.

Table 1

Ports selected for comparative study

Port	Country	Information
Port of Rotterdam	Holland	2017 Annual Sustainability Report
Port of Shanghai	China	2016 Annual Sustainability Report
Port of Santos	Brazil	2016 Annual Sustainability Report

These ports were selected for sampling because they are ports with a great movement of cargo in their respective continents. For the calculation of the global sustainability index, equation (1), from Pfitscher (2014), was used.

$$\text{Sustainability Index} = \frac{\text{Total of yes} \times 100}{\text{Total of questions} - \text{Total of "NA"}} \quad (1)$$

Based on the answers “Yes”, “No” and “Not applicable” it is possible to calculate the global sustainability index.

PRESENTATION OF THE GREEN PORT MODEL

Finally, the indicators and sub-indicators that make up the sustainable port model are shown in Table 2.

Table 2

Indicators and sub-indicators of the green port model

Indicator	Description	Authors
Emissions Reduction and Air Quality	Actions for reducing toxic emissions and controlling air quality	Abood (2007); Ali and Nsairat (2009); Chiu et al. (2014); Puig et al. (2014); Cerceau et al. (2014); Le et al. (2014); Shiau and Chuang (2015); Carić et al. (2016); Hou and Geerlings (2016); Yang et al. (2017); Roos and Kliemann (2017); Chen and Pak (2017); Shan and Hwang (2018); ANTAQ (2020b); Liu et al. (2021); D’Amico et al. (2021); Xie et al. (2022); Tai and Chang (2022); Housni et al. (2022)

Indicator		Description	Authors
Sub-indicators	1. Design infrastructure, buildings, and operations to minimize greenhouse gas and carbon emissions.	Prioritize material and equipment options that aim to minimize greenhouse gas and carbon emissions.	Abood (2007); Pavlic et al. (2014); Chen and Pak (2017); ANTAQ (2020b)
	2.lanting/Preserving trees/vegetation in port areas	Actions aimed at protecting the environment in the vicinity of port areas.	Chiu et al. (2014); Chen and Pak (2017)
	3. Emission of toxic substances into the air	Monitoring aimed at measuring gas emissions and actions to reduce these emissions.	Abood (2007); Chiu et al. (2014); Chen and Pak (2017); ANTAQ (2020b)
Energy Management		Control of energy expenditure, targeting all equipment, processes, and services for energy savings.	Abood (2007); Lee and Burnett (2008); Ali and Nsairat (2009); Alyami et al. (2013); Le et al. (2014); Chiu et al. (2014); Pavlic et al. (2014); Nilashi et al. (2015); Mat et al. (2017); Pilouk and Koottatep (2017); Shan and Hwang (2018); ANTAQ (2020b); Hua et al. (2020); Kong e Liu (2021); Salsas et al. (2022); Xie et al. (2022)
Sub-indicators	1. Total amount of energy consumed	Management focused on monitoring the amount of energy needed to operate port activities and how to optimise this expenditure.	Chiu et al. (2014); Pavlic et al. (2014); ANTAQ (2020b)
	2. Total amount of renewable energy consumed	Monitoring the renewable energy consumed and how to reuse it.	Pavlic et al. (2014); Chen and Pak (2017); ANTAQ (2020b)
	3. Design and upgrade buildings to reduce energy consumption	Design the construction of the building with techniques aimed at reducing energy.	Abood (2007); Puig et al. (2015); Seguí et al. (2016); Antão et al. (2016); Ha and Yang (2017); Roos and Kliemann (2017); Chen and Pak (2017); Shan and Hwang (2018); ANTAQ (2020b)
	4. Use of alternative and renewable energy sources	Prioritise alternative and renewable energy sources, such as solar, wind, or other.	Abood (2007); Chen and Pak (2017); Shan and Hwang (2018)
	5. Environmental energy audit	Conduct audits that monitor how the energies used in the ports impact the environment.	Valois (2009); Pavlic et al. (2014)
Water Management		Technologies and efficient management for the optimisation of water resources by reducing consumption, capturing rainwater, and treating and reusing gray water.	Abood (2007); Lee and Burnett (2008); Ali and Nsairat (2009); Alyami et al. (2013); Chiu et al. (2014); Le et al. (2014); Puig et al. (2015); Seguí et al. (2016); Antão et al. (2016); Ha and Yang (2017); Chen and Pak (2017); Roos and Kliemann (2017); Shan and Hwang (2018); ANTAQ (2020b); Tai and Chang (2022); Xie et al. (2022)

Indicator		Description	Authors
Sub-indicators	1. Installations for draining, collecting, and storing polluted surface water.	An infrastructure that allows for the drainage, storage, and treatment of surface water.	Abood (2007); Puig et al. (2014); Cerceau et al. (2014); Carić et al. (2016); Le et al. (2014); Puig et al. (2015); Seguí et al. (2016); Roos and Kliemann (2017); Antão et al. (2016); Ha and Yang (2017); Shan and Hwang (2018); ANTAQ (2020b)
	2. Amount of oil and lubricants discarded by handling equipment	Monitoring and management focused on controlling and preventing the disposal of oils and other liquid materials.	Abood (2007); ANTAQ (2020b)
	3. Spill/leak of chemicals		Abood (2007); Chen and Pak (2017); ANTAQ (2020b)
	4. Solid waste management	Actions aimed at monitoring and reducing waste generation.	Chiu et al. (2014); Chen and Pak (2017); ANTAQ (2020b)
	5. Gray water generation	Monitoring for recycling and disposal of gray water	Chen and Pak (2017); ANTAQ (2020b)
	6. Sewage generation	Sewage treatment management.	
	7. Control and prevention of cargo spills	Monitoring to prevent accidents involving cargo spills.	Abood (2007); Chiu et al. (2014); Chen and Pak (2017)
	8. Ballast water management	Management of water originated in the latrines through reuse or disposal in the correct way.	
Noise Pollution		Excessive noise to the point of impairing human physical and mental health.	Chiu et al. (2014); Chen and Pak (2017); ANTAQ (2020b); Housni et al. (2022)
Sub-indicators	1. Total noise intensity inside the port or terminal	Monitoring of noise inside ports and terminals.	Chiu et al. (2014); Chen and Pak (2017); ANTAQ (2020b); Housni et al. (2022)
	2. Intensity of noise emitted by handling equipment inside the port (or terminal)	Monitoring of noise derived from the operation of equipment.	Chen and Pak (2017); ANTAQ (2020b)
	3. Total intensity of noise emitted by ships inside the port.	Monitoring of noise emitted by ships in ports.	
Cost and Economy		Application of administrative management principles that positively impact the three dimensions of sustainability.	Ali and Nsairat (2009); Alyami et al. (2013); Nilashi et al. (2015); Chen and Pak (2017); Shan and Hwang (2018); Liu et al. (2021); Kong e Lui (2021); D'Amico et al. (2021); Xie et al. (2022); Tai and Chang (2022); Salsas et al. (2022)
Sub-indicators	1. Management skills: planning, leadership, organisation	Management with a qualified team to plan, lead, and organise.	Darby and Jenkins (2006); Chen and Pak (2017)
	2. Management information system	Use of systems that provide key information for executive decisions and efficient management.	Chen and Pak (2017)
Quality of the indoor environment		Assess the quality of the internal environment for the development of human activities.	Lee and Burnett (2008); Ali and Nsairat (2009); Alyami et al. (2013); Seinre et al. (2014); Nilashi et al. (2015); Suzer (2015); Shan and Hwang (2018); D'Amico et al. (2021); Liu et al. (2021)

Indicator		Description	Authors
Sub-indicators	1. Thermal comfort	Ensure thermal comfort for people, using sustainable technologies.	Seinre et al. (2014)
	2. Indoor lighting	The internal lighting must meet, at a minimum, the requirements and standards of comfort and safety of operation.	
	3. Noise level	The noise levels must have systematic analysis policies (internal and external environments), and prior social and environmental impacts to register where the port is installed.	Seinre et al. (2014); Le et al. (2014); Shiau and Chuang (2015); Puig et al. (2015); Carić et al. (2016); Antão et al. (2016); Seguí et al. (2016); Pilouk and Koottatep, (2017)
Materials, inputs and resources		Ensure continuous reduction of the materials; choose environmentally correct origin; recycling; correct handling and disposal of materials, inputs and resources used in the port facilities.	Lee and Burnett (2008); Ali and Nsairat (2009); Alyami et al. (2013); Seinre et al. (2014); Puig et al. (2014); Cerceau et al. (2014); Le et al. (2014); Chiu et al. (2014); Nilashi et al. (2015); Puig et al. (2015); Seguí et al. (2016); Carić et al. (2016); Antão et al. (2016); Roos and Kliemann (2017); Ha and Yang (2017); Shan and Hwang (2018); ANTAQ (2020b); Housni et al. (2022); Salsas et al. (2022); Xie et al. (2022)
Sub-indicators	1. Low emission of materials	Have a policy and control of emissions from materials with a view to continuous reduction.	Seinre et al. (2014); Puig et al. (2014); Hou and Geerlings (2016); Mat et al. (2017); ANTAQ (2020b)
	2. Quantity of discarded spare parts	Management focused on recycling, reuse and efficient disposal of unused parts.	ANTAQ (2020b)
	3. Amount of steel, plastic, wood and/or paper consumed in the operations of the port or terminal or discharged during activities.	Monitoring the number of solid materials used to carry out port activities.	
Construction project management		Management and monitoring of the construction project aiming for socio-environmental sustainability.	Seinre et al. (2014); Suzer (2015); Shan and Hwang (2018); D'Amico et al. (2021); Liu et al. (2021); Tai and Chang (2022); Salsas et al. (2022)
Sub-indicators	1. Sustainable architecture and design	Opt for architecture and design that promotes sustainability.	Shan and Hwang (2018)
	2. Neighbourhood amenities	To aim for the environmental preservation of the neighborhood; control noise in the neighborhood; promote harmony in the neighborhood.	Seinre et al. (2014); Shan and Hwang (2018)
	3. Service quality	Execution of services with quality.	Shan and Hwang (2018)
Social Indicators		Management and policies aimed at monitoring and reducing the impacts derived from port activities on employees and the population around the ports.	Chen and Pak (2017); ANTAQ (2020b); Liu et al. (2021); Kong e Lui (2021); D'Amico et al. (2021); Tai and Chang (2022; Salsas et al. (2022)

Indicator		Description	Authors
Sub-indicators	1. Health and safety of employees at work	Policies aimed at the well-being of employees and the safe performance of their activities.	ANTAQ (2020b); Liu et al. (2021); D'Amico et al. (2021)
	2. Total amount spent on social investments	Investments in social projects.	Ding et al. (2016); Reefke and Sundaram (2017); Tai and Chang (2022)
	3. Customer satisfaction	Monitoring the receptiveness of port customers.	Halme et al. (2006)
	4. Information flow and strategic suppliers	Application of systems that allow the exchange of strategic information.	Dam and Petkova (2014); Chin et al. (2015)
	5. Internal pressures	Explicit or implicit pressures from within organisations may unduly influence the performance of port agents.	Darby and Jenkins (2006); Searcy et al. (2007); Ras and Vermeulen (2009)
Port operations management		Efficient management of the various existing operations in a port	Le et al. (2014); Hou and Geerlings (2016); ANTAQ (2020b); Liu et al. (2021); Kong e Lui (2021); D'Amico et al. (2021); Housni et al. (2022); Salsas et al. (2022); Tai and Chang (2022); Xie et al. (2022)
Sub-indicators	1. Ship waste removal actions	Monitoring the removal of waste from ships.	Chiu et al. (2014); Le et al. (2014); Chen and Pak (2017); ANTAQ (2020b)
	2. Container operations with dangerous products	Monitoring of operations involving dangerous products.	Chiu et al. (2014); Le et al. (2014); ANTAQ (2020b); Kong e Lui (2021)
	3. Environmental Agenda	Disclosure of environmental information about the port	Santos et al. (2016); ANTAQ (2020b); Liu et al. (2021); D'Amico et al. (2021); Housni et al. (2022); Xie et al. (2022)
	4. Online sustainability communication	Online sustainability communication practices and report of these on the port's website	
	5. Environmental Governance	It deals with the organisation's actions, structuring and responsiveness, focused on environmental management, in harmony with its port operations	Hou and Geerlings (2016); Mat et al. (2017); ANTAQ (2020b)
	6. Environmental port licensing and certifications	Adequacy of the port by existing environmental licenses and certificates	ANTAQ (2020b); Housni et al. (2022)
	7. Environmental training and capacity building	Actions aimed at qualifying and training employees related to environmental issues and port impacts.	Puig et al. (2014); Le et al. (2014); Chiu et al. (2014); Chen and Pak (2017); ANTAQ (2020b)
	8. Maintenance and cleaning of the port area	Quantify the cost of the maintenance works, including the economic, environmental, and societal impacts.	Zhang et al. (2017); Salsas et al. (2022)
	9. Environmental dredging management	Monitoring of dredging and control of impacts on the environment.	Valois (2009); Chiuet al. (2014); Chen and Pak (2017)

Initially, Table 2 presents the three sub-indicators located in the literature referring to the emissions reduction and efforts at ensuring air quality indicators. Air quality is directly related to the health of people who work or live near ports (Tai and Chang, 2022). Green policies would significantly improve air quality in the region, as air pollution is understood to be one of the biggest environmental impacts caused by port operations (Zhu et al. 2017).

Then, Table 2 shows the five sub-indicators located in the literature regarding the Energy Management indicator. As for energy management, some initiatives should be pointed out, such as the consumption of energy to dock, the scale of energy consumption on ships, energy capture between ships (cooperation agreements with shipping companies for the use of energy), clean energy sources in port operating machines, ships, and vehicles using electricity, and green lighting on production operations apparatus at the port as well as on posts in the courtyard and harbor streets (Hua et al. 2020).

Table 2 also brings the eight sub-indicators located in the literature for the Water Management indicator. Some definitions are relevant in this indicator and are necessary to explain the concepts. For example, gray water: is water that originates from domestic processes, such as bathwater or dishwater, excluding toilet water. They are waters that do not originate from industrial processes. On the ship, there may be showers and sinks, and this water can be treated and reused. The surface waters are the waters of rivers or streams, in short, waters located on the surface of the earth. These waters are used in different ways, mainly for drinking, but it needs to be treated in rotatable. Another important concept to understand regarding this indicator is the ballast water, used by ships to compensate for the reduction in weight resulting from the loading and unloading of cargo (ANTAQ, 2020b).

Table 2 still brings the three sub-indicators located in the literature regarding the Noise Pollution indicator. A major concern about noise pollution is its negative effects on the mental and physical health of those who work in this type of environment. Also, the communities around the ports are already in a vulnerable condition due to other types of pollution generated by port activities and are also impacted by noise; therefore, these communities need to receive support or some kind of protection from the port managers, who must prioritize their wellbeing when creating a port.

In Table 2 the three sub-indicators found in the literature referring to the Indoor Environment Quality indicator are proposed. For Huo et al. (2017) the design of these buildings must take into account strategies that can guarantee this thermal comfort within them, in addition to ensuring convenient access to public transport and wheelchair-accessible sidewalks, among other important spaces for the safe movement of people inside them.

Table 2 shows the three sub-indicators located in the literature referring to the indicator of materials, inputs and resources. For this indicator, the priority issues are: the collection and treatment of ship-generated waste; unloading of ships (hold, ballast, and sewage); collection and treatment of oil sludge; dust; spills of oil and chemicals (Le et al. 2014).

Table 2 shows the three sub-indicators located in the literature regarding the construction project management indicator. It should be noted that the port must be concerned with the work and execution of activities, but also with the amenities of the neighborhood, that is, local, regional, and global environmental preservation. Also, noise control in the neighborhood, promotes harmony and security in the neighborhood.

In sequence, Table 2 shows the five sub-indicators located in the literature regarding social indicators. The social sphere of sustainability is often overlooked due to the strong focus on environmental and even economic issues. However, when thinking about sustainable practices, care must be taken with people as a whole and the negative effects they suffer due to the actions employed in this type of environment.

Finally, Table 2 demonstrates the nine sub-indicators for the port operations management indicator. The management of operations becomes even more relevant when considering the transport of toxic and flammable substances. The port of Hai Phong prepared an inventory of environmental aspects; the focus of this port inventory was on environmental issues related to safety, management of truck loading, and transportation of chemicals, such as gas and oil (Le et al. 2014).

Validation of the green port model

To validate the model with experts from the port sector, a questionnaire was made available to 64 experts. With these results, a descriptive analysis was performed so that it was possible to assess the relevance of each indicator and sub-indicator. Table 3 presents the descriptive analysis of the sub-indicators.

Table 3

Descriptive analysis of the sub-indicators

	Maximum	Minimum	Median	Mode	Mean	Standard Deviation
Air1	5	1	5	5	4,538	0,776
Air2	5	1	4	5	4,031	1,175
Air3	5	1	5	5	4,446	0,889
Energy1	5	1	5	5	4,354	0,912
Energy2	5	1	5	5	4,508	0,816
Energy3	5	2	5	5	4,385	0,845
Energy4	5	2	5	5	4,585	0,773
Energy5	5	2	4	5	4,292	0,845
Water1	5	2	5	5	4,569	0,753
Water2	5	2	5	5	4,369	0,861
Water3	5	3	5	5	4,708	0,582
Water4	5	1	5	5	4,554	0,795
Water5	5	1	5	5	4,277	0,980
Water6	5	1	5	5	4,615	0,769
Water7	5	1	5	5	4,677	0,714
Water8	5	1	5	5	4,585	0,773
Noise1	5	1	4	4	4,031	0,934
Noise2	5	1	4	4	3,908	0,994

	Maximum	Minimum	Median	Mode	Mean	Standard Deviation
Noise3	5	1	4	5	3,846	1,062
Cost1	5	1	4	5	4,200	1,022
Cost2	5	1	4	4	4,169	0,877
Int.Env1	5	1	4	4	3,969	0,967
Int.Env2	5	1	4	4	3,969	0,950
Int.Env3	5	1	4	5	3,969	1,061
Resource1	5	1	5	5	4,508	0,816
Resource2	5	1	4	5	3,985	1,007
Resource3	5	1	4	5	4,200	0,941
Project1	5	1	4	5	4,123	0,978
Project2	5	1	5	5	4,277	0,913
Project3	5	1	5	5	4,400	0,970
Social1	5	1	5	5	4,708	0,683
Social2	5	1	4	5	4,200	0,974
Social3	5	1	5	5	4,477	0,925
Social4	5	1	5	5	4,308	0,903
Social5	5	1	4	5	4,231	0,934
Port1	5	1	5	5	4,554	0,733
Port2	5	1	5	5	4,523	0,891
Port3	5	1	5	5	4,415	0,868
Port4	5	1	5	5	4,262	0,959
Port5	5	1	5	5	4,508	0,836
Port6	5	1	5	5	4,692	0,687
Port7	5	1	5	5	4,738	0,696
Port8	5	1	5	5	4,631	0,724
Port9	5	1	5	5	4,662	0,672

As can be seen in Table 3, the sub-indicators were considered relevant for the specialists. The decision was made to keep all indicators with an average of 3.5 in the model; therefore, all sub-indicators were kept.

The analysis was also carried out for the indicators, based on the evaluation of the sub-indicators. Table 4 shows the descriptive analysis resulting from the responses of the port specialists to the indicators.

Table 4

Descriptive analysis of the indicators

	Maximum	Minimum	Median	Mode	Mean	Standard Deviation
Air	5	1	5	5	4,328	0,982
Energy	5	1	5	5	4,416	0,841
Water	5	1	5	5	4,531	0,796
Noise	5	1	4	4	3,911	0,996
Cost	5	1	4	5	4,172	0,948
Int.Env.	5	1	4	4	3,953	0,988
Resource	5	1	4	5	4,328	0,982
Project	5	1	5	5	4,255	0,956
Social	5	1	5	5	4,375	0,904
Port	5	1	5	5	4,547	0,799

As for the sub-indicators, it is possible to observe in Table 13 that the indicators were considered relevant for the specialists. Therefore, all the proposed indicators were kept.

4.2 Analysis of ports

From reading sustainability reports, environmental management plans, sustainability plans, and institutional websites, information was collected for the ten green port indicators, as shown in Table 5.

Table 5

Comparison of actions, practices or strategies related to green ports.

Indicator	Port of Shanghai	Port of Rotterdam	Port of Santos
Emission reduction and efforts at ensuring air quality	X	X	X
Energy Management	X	X	X
Water Management	X	X	X
Noise pollution	X	X	
Cost and Economy	X		X
Quality of the interior environment	X	X	X
Materials, supplies and resources	X	X	X
Management of construction products	X		
Social Indicators	X	X	X
Port Operations Management	X	X	X
Global Sustainability Index	100	80	80

Source: Port of Santos (2016); Port of Rotterdam (2017) Port of Shanghai (2016)

The Global Sustainability Index of the ports was measured. The Port of Shanghai, with all indicators, obtained 100 points. The Port of Rotterdam and the Port of Santos partially met the indicators and thus obtained 80 points each, so it can be inferred that these ports have actions aimed at sustainability. For each indicator, information was made available in the port reports, as a way of detailing the actions of each port.

- **Emission reduction and efforts at ensuring air quality:** the greenhouse gas emissions from the Port of Santos (2016) are measured by TEUs handled in the logistics operation and by the kilometers traveled in road transport. The Port of Shanghai (2016) strives to improve energy efficiency and reduce the emission of pollutants gases. The Port of Rotterdam (2017) is examining what options it has to carry out basic infrastructure aimed at collecting and transporting CO2, as well as gas storage.
- **Energy management:** the Port of Santos (2016) informs that it has energy efficiency for the reduction of pollutant gas bases. The Port of Shanghai (2016) created the Office of Energy Conservation and Emission Reduction to conduct energy conservation and monitoring measures. At the port of Rotterdam (2017), several types of energy converge, such as coal, natural gas, biomass, heat, steam, solar, and wind.
- **Water management:** for the Port of Santos (2016), invest in innovation, such as the reuse system, where rainwater is captured, treated, and used to wash the unit's machines. Operations at the Shanghai port terminal (2016) aim for efficiency in the use of water through centralised sewage collection and treatment in the city hall. The port of Rotterdam (2017) is committed to ensuring that the port and its surroundings are safe. They aim to combat climate change, seeking to contribute to Dutch prosperity and employment.
- **Noise pollution:** the port of Shanghai (2016) signed a strategic cooperation agreement to implement the first high-pressure onshore power supply project in Fujian province to help control emissions, reduce noise, and increase efficiency. In the port of Rotterdam (2017), some 'e-noses' (electronic nose) were implemented through the we-nose network system.
- **Cost and economy:** for the port of Santos (2016), ethics and transparency are the pillars that support the business. Therefore, to establish the rules of conduct that guide internal and external relationships, it maintains an updated Code of Ethics and Personnel Regulations. They also have a compliance system that includes a Compliance Policy, a Compliance Committee, and a Confidential Portal for sending complaints and suggestions confidentially. The corporate governance structure of the port of Shanghai (2017), as presented in its report, aims to ensure high standards of corporate conduct in the company.
- **Quality of interior environment:** Port of Santos (2016) states that an example of its security concern was the organisation, by Tecon Santos, of one of the largest fire-fighting simulations ever carried out in the Port of Santos. The initiative was organised in September 2016 involving 250 people, and mobilising another thousand people. The main objective was to assess emergency response times and strengthen integration between all branches to ensure greater security for port customers and, consequently, for local communities. The Port of Rotterdam (2017) states that safety is a priority at the port.

- **Materials, supplies and resources:** the Port of Santos (2016) states that solid waste management has been a topic of debate among managers, aiming to contribute to the dissemination of good waste management practices in the production chain. The Port of Shanghai (2016) emphasises that the waste management policy is based on recycling and the reduction of recycling through the efficient use of materials. The port of Rotterdam (2017) states that it is committed to contributing to the port's prosperity with a view to sustainability.
- **Management of construction products:** the Port of Shanghai (2016) invested in the construction of an intelligent terminal gate to improve terminal operations in the areas of information exchange, standardisation and automation to ensure operational efficiency.
- **Social indicators:** the Port of Santos (2016) it maintains actions aligned with sustainability and private social investment policies, focusing on local and social development, mainly through education. The Shanghai port report (2016) demonstrates the investment made in youth development. The port has been hosting a summer camp for teachers and students for 11 years. At the camp, students can participate in workshops and other activities. The purpose of this action is to provide networking opportunities for students and allow everyone to fully communicate their ideas, in addition to building friendships. The port of Rotterdam (2017) claims to provide teaching material for primary schools, intermediate preparatory vocational education, secondary education, and pre-university education.
- **Port operations management:** the Port of Santos (2016) provides customers with a complete portfolio of solutions and services aimed at adding value to the supply chain. Shanghai supply chain management policies and systems (2016) are formulated based on the characteristics of the business. The port has management manuals, such as "Procurement Management Manual", "Supplier Management Manual", "Centralised Procurement Management Manual", "Tender Procurement Management Stipulations" and "Procurement and Supplier Management of Terminal Operation Equipment Procurement Stipulations". The Port of Rotterdam (2017) mentions the priorities for actions aimed at accessibility and increasing the efficiency of transport supply chains.

CONCLUSIONS

This research aimed to present an evaluation model for a green port, with indicators and sub-indicators mapped in the literature. Methodologically, we used a literature review process. Subsequently, we sought to validate the model through a questionnaire answered by experts in the port sector. Regarding the relevance of the study, ports have a critical role in transport, logistics, and infrastructure development. The actions of this type of enterprise can impact the environment.

As a theoretical contribution, the selected indicators were classified into ten categories, namely: Emission reduction and efforts at ensuring air quality; Energy Management; Water Management; Noise pollution; Cost and Economy; Quality of interior environment; Materials, supplies and resources; Management of construction products; Social Indicators, and Port Operations

Management. Each indicator has a group of sub-indicators that will contribute to the measurement of this indicator and the green port. Consultation with specialists through the questionnaire concluded that all indicators as well as sub-indicators were relevant.

As for the managerial contribution, maritime institutions, as well as terminal and port managers, have been working on the development and application of different strategies to include the dimension of environmental sustainability in their agendas. This study argues that a green port must be economically, socially, and environmentally sustainable. Thus, ports must assess their operations and determine which paths they should take to eliminate or minimise possible environmental impacts. The green port assessment model will allow port managers to carry out a diagnosis and subsequently create proactive actions integrating adaptation and mitigation measures to climate change in their operations and plans.

Regarding the contribution to society, seaports are the main centers of economic activity and also of environmental pollution in coastal areas of urban areas. Transport, including shipping, has an impact on the environment, as well as substantial public investment related to its infrastructure. In this way, the greening of this sector will be a driving force for development in the coming decades, improving transport efficiency and reducing the footprint of greenhouse gases, contributing to the mitigation of climate change. As for the limitations of the research, we suggest that this model of indicators for a green port can be applied to map the social and environmental sustainability practices that are used in ports and, with this, create a green port certification.

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