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Meta-synthesis of Research on Green Port Performance Evaluation Criteria

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ABSTRACT

The green port concept refers to measures preventing ports' negative effects on the environment. Ports are expected to adopt green measures within the framework of environmental concerns and sustainable development goals. To analyze if a port's processes adopt the green concept, evaluation criteria should be defined. Existing literature handles this topic from regional perspectives or in terms of relations with other concepts. This study, which is the meta-synthesis of related articles ($n=22$), aimed to propose a common list of green port evaluation criteria for the development and operating sequences of a port. As the result of the meta-synthesis, it was revealed that the evaluation of green ports is based on six main criteria: *environmental, energy and resources, management, social, ecological, and economical*. Twenty-two sub-criteria were identified that are linked to the main criteria. By using the critical statements in the reviewed articles, the codes supporting these sub-criteria were determined. This model has revealed that a port adopting the green concept should consider all the dimensions of sustainability (economic, environmental, and social).

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1 Introduction

As concerns about sustainability issues are rising daily, the United Nations (UN) focuses on providing a more livable planet for future generations and drawing attention to climate change and global warming [1]. An ever-increasing trading activity, the maritime industry, has an important share of 2,9% in worldwide GHG emissions [2], the main reason for climate change and global warming. Therefore, the maritime industry and its main components also need to take action to make their processes more environmentally friendly.

The activities of a port, including development stages, have negative side effects on the environment like; air, water, and noise pollution, and habitat destruction [3]. Ports with no satisfactory policies on environmental and ecological issues may be more harmful to the local habitat and people [4]. Besides, increasing global concerns about energy demand and costs, and environmental issues caused a serious competitive environment between ports [5].

With these concerns, the concept of green port entered the maritime sector with the "Environmental Codes of Practice" introduced by the European Sea Ports Organization (ESPO) in 2004 and its importance has gradually increased.

Identifying a port as green could be considered as evaluating the activities in a port in three main aspects; energy conservation, environmental protection, and environmental care [6-8]. In the development stages, a port needs to adopt long-term strategies in line with sustainable and climate-friendly planning of port infrastructure [9]. From this point of view, it could be considered that the green port approach is focusing just on environmental issues. However, environmental strategies, especially those on energy consumption issues, cannot be carried out regardless of economic planning. Thus, some researchers [5, 10] point out that green port development and operating strategies must balance environmental challenges and economic needs. Considering the reflections of this balanced strategy on ports' stakeholders, it is understood that it is necessary to include social issues in the concept.

From this perspective, the green port concept has a structure that touches on all three dimensions of sustainability: environmental, economic, and social.

2 Background

The green concept, which aims to balance environmental and economic benefits in a port [11], for ports has been becoming increasingly important. At this point, it is a major problem that occurs how it can be possible to promote the green concept into action [7]. To overcome this emerging matter, evaluation or performance criteria are used. Measuring or evaluating a port in terms of green concept could be possible by assessing the suitability or availability of that port to such criteria.

There are different ways to organize criteria for green ports [6]. These criteria are mostly related to the matters covering the reduction of environmental impacts of ports without endangering economic development [9]. These matters could be the reduction of emissions, landscape design, energy consumption, waste generation, etc [6, 12]. ESPO [13] sorted the top 10 environmental priorities of the port sector in the way of being green over the years, and the last ranking is as follows: *air quality, climate change, energy efficiency, noise, relationship with the local community, water quality, ship waste, dredging operations, port development (land related), and ship waste*. According to this, ports attach more importance in recent years to air and water pollution, energy efficiency, waste management, and social relations.

Although the research on this area was scant till the beginning of the 21st century [8], the number of research has increased in recent years. The initial study in this field is Frankel (1987), which identifies port activities that have a negative impact on the environment as oil/chemical cargo spills, waste dumping and ballast water damage, air pollution, noise and vibration, and collision and stranding of vessels [3]. Prior studies have classified the green port criteria in various ways. These classifications can be summarized in terms of three dimensions of sustainability.

The green port concept refers mostly to environmental issues, therefore it can be found evidence related to environmental matters in all reviewed studies. *Air pollution* or *air quality* is one of the most said environmental criteria [3, 4, 14, 15]. Some studies [5, 16-18] identified this criterion as *CO₂* or *GHG reduction*. Another significant criterion is *liquid pollution* [3, 4, 14], or in other words *water quality/pollution* [5, 7, 12, 19] or *spill prevention* [16, 20, 21]. *Energy consumption (usage)* [15, 17, 19] or *energy saving* [22, 23], and *waste management* [6, 16, 18] or *waste handling* [7, 15] are the other significant criteria related to environmental issues.

Existing literature indicates that green port efforts refer also to economic activities. These are mostly related to the effectiveness of administration, operation and equipment, effective use of resources, and cost reduction. There-

fore, *port operating efficiency* [10, 17, 24], *cost levels* [14, 17, 18], *economic effectiveness* [14, 24], and *port administrative* or *infrastructure efficiency* [10] can be primary identifiers of a green port in economic perspective.

Some research mentions the relationship of a green port with the social environment. *Community impact* [16, 20, 21], *stakeholder management* [24, 25], and *port staff training* [7, 18] are counted to be significant criteria in social understanding. As the activities of a port would have reflections on local or regional elements, taking the relations with the social environment into account is considered to be vital for the reputation and sustainability of the port enterprise.

3 Motivation and Objectives

In order to evaluate if a port has features reflecting the green concept, or to measure a port's green performance, a well-structured measurement tool is necessary. Therefore, a set of criteria reflecting the requirements to identify a port as green is crucial. The relevant literature shows that indeed there is some research to identify green port evaluation criteria. However, even though some of the criteria that researchers exposed are common, most of the criteria exposed mention different characteristics of the green port concept. While some research on this field handles the issue in a regional or country-based way, some other research preferred to examine the issue from a narrower conceptual perspective. With this, although a few research propose a set of criteria touching on all three dimensions of sustainability, some research limits their framework within the environmental issues. This situation shows that a full set of green performance evaluation criteria is required to identify the needs of a green port from a global and wider perspective. In this context, this study aimed to present a broad and common set of criteria to be used to evaluate the green performance of ports, as a synthesis of criteria proposed by relevant studies.

4 Materials and Methods

As a qualitative research method, meta-synthesis aims to reach a common assumption by revealing the similarities between assumptions [26]. It is a way of summarizing and generalizing the assumptions in terms of explicated metaphors and codes that they include.

In other words, meta-synthesis is the theories, narratives, generalizations, and interpretive translations revealed by comparing and combining qualitative studies [27, 28], simply, the evaluation of evaluations or interpretation of interpretations. In this context, this study was designed as a meta-synthesis presenting an evaluation of research determining key criteria for the green port concept.

Meta-synthesis studies were performed by following a few steps including determining the research problem, re-

vealing the studies suitable for the problem, creating the themes related to the selected studies, synthesizing the findings related to these themes, and reporting [29, 30]. In this study, the below research steps suggested by Noblit and Hare [26] were followed:

Step 1. Deciding the phenomenon of study: This first step is the one that where topic and context of the study are determined. "Green port evaluation criteria" was the starting point of this study.

Step 2. Revealing the relevant studies: This is the literature review stage to find out the studies to be used in research. To do this in this study, a two-step search was conducted on the Web of Science Database. The key terms in the first step were 'green port OR greenport'; and in the second step 'green criteria OR green key factors OR green indicators' were searched in the title and keywords. The search was limited to the articles published in SCI, SSCI, SCI-E, and ESCI-indexed journals. Subsequently after basic search, the abstracts were checked and irrelevant studies were eliminated. The rest of the studies were examined in terms of methodology, and the quantitative ones were removed. At the final stage, the studies were examined with regard to content, context, and relevancy. After reading full texts, the studies that did not intend to propose a set of criteria or proposed criteria that are not directly related to the green port concept were removed. At the end of this process, 22 studies were decided to be involved in meta-synthesis. The search flow diagram is given in Figure 1.

The description of the research that decided to be involved in meta-synthesis is given in Table 1.

Step 3. Careful reading: The step for extracting the metaphors, codes, or themes. All articles were read completely and the green port criteria were revealed.

Step 4. Determining the relation between studies: This step is for revealing similarities and relations of studies. The similar or related criteria revealed in the 3rd stage were gathered under a common title. The categorization of the criteria was made.

Step 5. Re-evaluating the studies altogether: This stage requires a comprehensive and deep review of studies. The statements regarding each criterion of a paper were determined, and compared to the statements covered by other studies. The similarities and contradictions were clarified.

Step 6. Synthesizing: To provide a new conceptual viewpoint, this stage requires a high level of interpretation and evaluation. In this stage, the revealed criteria were redefined as a synthesis of obtained statements. A list of criteria was formed covering the main criteria, sub-criteria, and their codes.

Step 7. Reporting: This is the final step in which the results of the meta-synthesis are documented and reported.

Validity has been taken into account during the process. To ensure the validity of the study, triangulation could be one of the best practices [28]. This contains independent coding and analysis by multiple researchers [35]. All steps of the meta-synthesis were performed with the contributions of all authors. The progress of extracting and interpreting the themes, criteria, and codes contains a separate workout at first, but coordination and consensus after discussion processes followed. After the coding process was done manually, it was re-performed on the MAXQ-DA 2020 software to eliminate possible errors.

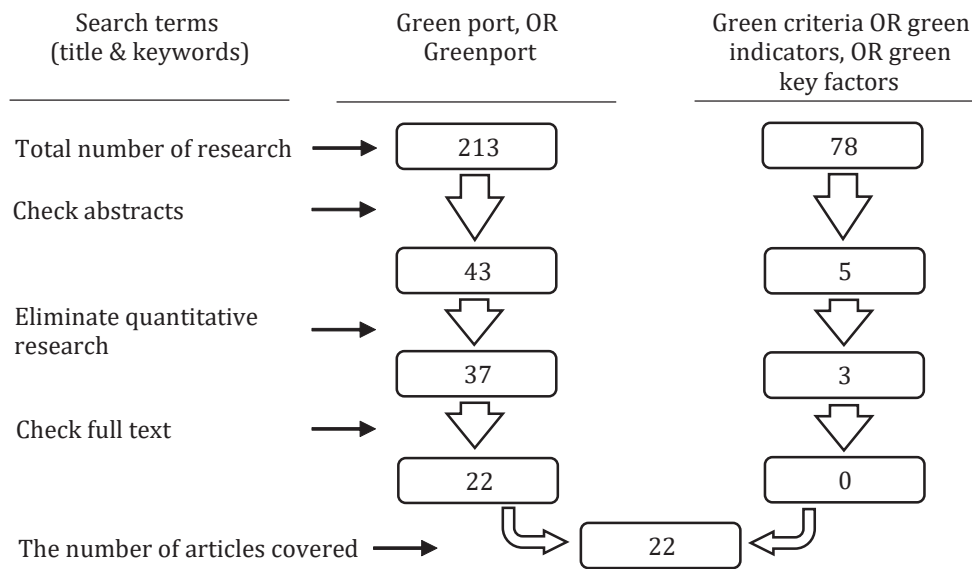


Figure 1 Search flow diagram

Table 1 Description of included studies

Code	Reference	Method	Scope
A1	Lirn, Jim Wu [4]	Mixed	Identifying major green port performance indicators, and measuring the overall green performance of three major ports.
A2	Maritz, Shieh [5]	Mixed	Constructing a hierarchical model based on the green port idea made up of three pillars; environmental construction, environmental quality, and resource management.
A3	Chiu, Lin [7]	Mixed	A Fuzzy hierarchical process to reveal top-priority attributes of green port operation
A4	Roh, Thai [31]	Qualitative	Exploring the main factors affecting sustainable port development to the way of being a green port.
A5	Liao, Ding [10]	Mixed	Constructing a hierarchical model of green port key performance criteria for ports in Taiwan
A6	Chen and Pak [3]	Qualitative	Identifying a set of green port performance evaluation indices for Chinese ports
A7	Badurina, Cukrov [6]	Qualitative	Presenting proposals for transforming the seaports of Croatia to green ports.
A8	Teerawattana and Yang [12]	Mixed	A case study on a Thailand port to figure out the green port assessment criteria and environmental performance indicators.
A9	Chen, Huang [22]	Mixed	Proposing measures and policies in construction of green and smart ports.
A10	Hossain, Adams [16]	Qualitative	Evaluating the sustainability and environmental performance of Canadian ports by using pre-defined green indicators.
A11	Tseng and Pilcher [24]	Mixed	Presenting a holistic view of the factor affecting green port policies.
A12	Stein and Acciaro [32]	Qualitative	Providing a framework of corporate sustainability issues affecting port competitiveness covering also green port criteria.
A13	Zhao, Bao [14]	Mixed	Performance evaluation of a green port within the context of the supply chain via a six-component evaluation model.
A14	Boljat, Vilke [25]	Mixed	Defining and evaluation of energy efficient mobility options for nautical ports in the aspect of green performance management.
A15	Gerlitz and Meyer [17]	Mixed	Providing proposals for small and medium-sized ports in transition to complying with green port standards.
A16	Franchi and Vanelslander [19]	Mixed	Analyzing the best options that a port should follow to pursue the needs of being a green port.
A17	MacNeil, Adams [20]	Qualitative	Proposing a port-specific framework using Global Reporting Initiative data to fill the gap of Canadian ports in complying with Green Marine Environmental Program
A18	MacNeil, Adams [21]	Qualitative	Exposing the gaps of the Green Marine Environmental Program in comparison to the United Nations Sustainable Development Goals.
A19	Jeevan, Salleh [15]	Mixed	Providing a hierarchical framework to expose the critical influential factors required to establish green port hub status.
A20	Garg, Kashav [18]	Mixed	Determining the environmental sustainability factors of green port development.
A21	Jugovic, Sirotic [33]	Mixed	Identifying the main factors in establishing green perspective governance of ports.
A22	DeSombre, Knudsen [34]	Qualitative	Revealing the regulatory ways driving ports to green measures in European Union and United States.

Source: Authors

5 Findings and Discussion

Studies in the sample were analyzed using the meta-synthesis method. The MAXQDA 2020 program was used for the analysis of the identified studies. As a result of the detailed analysis, it has been determined that the factors

that make up the green port will be evaluated under 6 main criteria. The green port evaluation criteria, which consist of Environmental, Energy and Resources, Management, Social, Ecological and Economic factors, are explained in detail below.

Table 2 Green Port evaluation main criteria, sub-criteria, and codes

Main Criteria	Sub-Criteria	Codes
Environmental	Air Pollution Management	<ul style="list-style-type: none"> • Reducing and controlling Greenhouse Gas (CO₂, NO_x, SO₂, VOCs and particles et. al) emissions • Reducing Odor pollution • Reducing dust pollution • Toxic gas control
	Water Pollution Management	<ul style="list-style-type: none"> • Having Fuel Spilling Contingency Plan • Preventing Petroleum Cargo spills • Preventing Petroleum oily residue and oily bilge water spills • Controlling ballast water pollution • Sewage/wastewater treatment
	Waste Management	<ul style="list-style-type: none"> • Having a Waste Management Master Plan • Reducing waste from vessels • To prevent pollution caused by scraping/painting work on board. • Reduce the amount of waste from maintenance and repair work in the port. • Reduce waste from port operations. • Ensure that waste is segregated according to categories. • Improving material selection, taking into account durability, reparability, and recyclability • Identify the waste collection area for recycling. • Establish incineration and sterilization areas for pandemic situations. • Ensure that sites contaminated by waste are cleared.
	Noise Pollution Management	<ul style="list-style-type: none"> • Take measures to reduce underwater noise. • Take measures to prevent noise pollution due to construction and cargo operations. • Avoid the noise caused by truck traffic with effective planning. • Set high standards of noise limits. • Use noise-reducing materials (double insulation windows etc.) in port buildings.
Energy and Resources	Clean Energy	<ul style="list-style-type: none"> • Provide shore power (cold ironing) • Criteria consider the reduction in energy consumption. • Providing energy from clean and renewable energy sources (solar, heat or wind power, etc.)
	Green Equipment Selection	<ul style="list-style-type: none"> • Increasing the Use of Electric machines/equipment • Install air filters on port machines. • Providing in-port transportation with electric vehicles. • Use lower air pollution trucks. • Use noise reduction machines (forklifts, ships, trucks, and other devices vehicles)
	Water Consumption	<ul style="list-style-type: none"> • Establishment of a water management system (sewage and dredging disposal) • Reducing water consumption • Consideration of rainwater collection and use as an option. • Reduce waste of drinking water and irrigation
	Recycling	<ul style="list-style-type: none"> • Establish waste recycling management policies. • Using Recyclable and reusable resources and materials
Management	Environmental Policy	<ul style="list-style-type: none"> • Determination and Regular updating of environmental policies • Improving processes and reducing waiting procedures in in-port operations. • Having environmental accreditations and certificates. • To plan PR studies related to the concept of green ports. • Finding solutions to the obstacles related to the green port concept.
	Eco-friendly Employee	<ul style="list-style-type: none"> • Employ a licensed contractor to handle hazardous waste. • To provide employees with an equal, safe, and well-being working environment. • To employ highly qualified and competent personnel and managers with environmental awareness.
	Technological Progress	<ul style="list-style-type: none"> • Digitization and Monitoring System • Improve efficiency by providing comprehensive E-service. • Use of carbon capture devices • Use energy efficient control system
	Training and Development	<ul style="list-style-type: none"> • Provide training to create environmental awareness for your employees. • Organize emergency and environmental pollution response training and drills. • Organize training for your employees to adapt to new technologies.

Social	Relations with Local Community	<ul style="list-style-type: none"> • Build good relationships with communities and human settlements. • Provide job opportunities to local communities. • Conduct opinion polls on local communities' opinions. • Inform local communities about environmental approaches and port expansions.
	Stakeholders Management	<ul style="list-style-type: none"> • When choosing stakeholders, prefer stakeholders who have adopted environmentalist approaches. • Demand that stakeholders be accredited and certified on environmental issues. • Conduct continuous environmental audits to identify your stakeholders and do business together. • Providing incentives to shipping companies that use clean-burning low-sulfur fuels, environmental-friendly materials, and equipment.
	Urban Texture	<ul style="list-style-type: none"> • Environmentally friendly port architecture • Avoiding the port architecture not causing visual pollution and being designed by the city's architecture. • Ensure that the port and its components do not devalue local residents' real estate. • Planning to reduce the noise caused by ship and port traffic.
	Local Investments	<ul style="list-style-type: none"> • Support the social and cultural activities of local communities. • Allocating budgets for local and regional developments. • Providing support to the needs of local people. • Providing support for the strengthening of the regional economy.
	Collaboration with Local Authorities and Institutions	<ul style="list-style-type: none"> • Establishing good relations with local government authorities. • Establishing the legal framework for the determination and implementation of environmental standards and the establishment of related departments. • Cooperation with urban authorities to evaluate projects such as port expansion, etc. • Establishing cooperation between the port and the scientific community. • To provide scholarships and internship opportunities to students.
Ecological	Wetland and Marine Habitat Preservation	<ul style="list-style-type: none"> • Protecting the coastal and marine ecosystems. • To protect the lake and river ecosystem. • To ensure the migration route and continuity of migratory birds. • Reducing underwater noise.
	Sediment Control	<ul style="list-style-type: none"> • Port Entrance Sediment control • Coastal erosion control
	Afforestation	<ul style="list-style-type: none"> • Tree planting in the port area. • Grow flowers in the port area. • Use biological spectrum lighting. • The use of non-chemical fertilizers in afforestation and flowering processes in the port area
Economical	Port Efficiency	<ul style="list-style-type: none"> • Economic benefit of green port practices. • The cost of modernizing the port. • Modernized port facilities. • Maintenance costs.
	Fees and Surcharges	<ul style="list-style-type: none"> • Incentives and sanctions applied to ship owners. • Incentives and sanctions applied to stakeholders.

Source: Authors

5.1 Environmental Management

The first main criterion is Environmental management. This criterion consists of 4 sub-criteria: air pollution management, water pollution management, waste management, and noise pollution management.

5.1.1 Air Pollution Management

Air pollution management, one of the sub-criteria of environmental management, is an important criterion among green port evaluation. Green ports should take the necessary measures to reduce and control greenhouse gas (CO₂, NO_x, SO₂, VOCs and particles, etc.) emissions [A1-A22], reducing odor pollution [A8, A16, A18, A21], reducing dust pollution [A1, A3, A6, A7, A10, A11, A12, A15, A17, A18, A21] and toxic gas control [A1, A5, A6, A11, A12,

A13, A21]. Factors such as gas emissions from port equipment [A1, A5, A7], gas emissions from fuels used by ships [A1, A5, A6, A10, A16], gas emissions from transportation vehicles [A1, A6, A12] are classified as port-based air pollutants. Dust and odor generated during the incineration of wastes [A18, A21], recycling [A3], handling of bulk and grain cargoes [A1, A7] and construction-maintenance works [A1, A21] are also air pollutants.

Greenhouse gas emissions, odor, dust, and toxic gases have serious negative effects on human health [36]. In addition to the negative effects, they have on the health of people in the immediate vicinity, the damage of these pollutants to the ozone layer and their negative contribution to global warming should not be ignored indirectly [37] Increasing the air quality will also contribute to the comfort of the people living around the port and will also con-

tribute to the port's relationship with the local community. Green port applications include the design and operation of vehicles and equipment used in ports to produce fewer emissions [31]. In addition, the transition to renewable energy sources and energy efficiency measures in ports can also help reduce air pollution [4].

5.1.2 Water Pollution Management

Water pollution management, which is another sub-criteria of environmental management, is one of the green port evaluation criteria. Regarding water pollution management, green ports must have an Oil Spilling Contingency Plan [A1, A3, A6, A10, A12, A13, A15, A17, A18, A19], take precautions against oil spills caused by cargo [A1, A2, A4, A6, A7, A8, A10, A12, A13, A15, A16, A17, A18, A19, A21], oily residue and bilge water [A2, A4, A6, A7, A8, A10, A12, A13, A15, A16, A17, A18, A21, A22], make controls by ballast water management requirements [A1, A2, A3, A4, A5, A6, A7, A10, A11, A12, A13, A15, A17, A18, A19], and do their part in sewage/wastewater treatment [A1, A2, A3, A4, A6, A7, A10, A12, A13, A15, A16, A17, A18, A19]. There should be a holistic [A17] and management-supported response management plan that meets the minimum standards in national and international legislation [A10] regarding oil-based pollution. Precautions should be taken against spills that may occur in port operations [A1, A21], especially during tanker cargo operations (disconnection of cargo pipeline, etc.). Pollution of seawater should be prevented with observations and precautions [A7] regarding the disposal and leakage of oil wastes originating from the machinery of all ships. In addition, technological research is needed to reduce the amount of petroleum-derived pollutants originating from ships [A22]. It should be ensured that some incentives such as priority in port operations to encourage ships to reduce fuel-related wastes, ballast water, and wastewater should be given [A5]. It is necessary to have a structure for the treatment of sewage originating from ships [A3, A10], wastewater originating from ports [A4, A7, A15, A17], product waters [A17] resulting from recycling, etc.

Water pollution in ports causes serious effects on the environment and human health [38]. These impacts pose a direct risk to those living in the vicinity of ports and have long-term effects by polluting water resources. Water pollution in ports is caused by many factors such as maritime traffic, loading and unloading operations, ship waste, and industrial waste from docks. These wastes cause environmental effects by mixing with water resources. Water pollution affects natural life and ecosystems. Polluted waters affect habitats for fish and other sea creatures. It prevents them from breeding, feeding, and migrating. In addition, sea creatures living in waters with high levels of pollution can cause health problems when consumed by humans. Water pollution in ports also causes serious effects on human health. Polluted water causes skin irritation, respiratory diseases, infections, and other health problems in humans [39]. It also raises concerns regarding seafood

and water resources due to water pollution. For these reasons, tackling water pollution in ports is important for green port management. This includes various measures such as wastewater management, regular disposal of waste, monitoring, and regulation of water-polluting activities of industrial plants and ships.

5.1.3 Waste Pollution Management

Waste pollution management, which is another sub-criteria of environmental management, is one of the green port evaluation criteria. It has been determined that the most emphasized issue in green port studies is waste management. Green ports must have a waste management plan [A1, A2, A7, A8, A10, A12, A14, A15, A16, A17, A18, A19, A20]. Regarding waste reduction, it is necessary to take measures to reduce the wastes originating from ships [A1, A2, A3, A4, A6, A7, A8, A9, A11, A13, A17, A18, A21, A22] and to reduce the waste pollution caused by the paint/scraping works carried out on the ship [A1, A4, A7]. Care should be taken to reduce wastes originating from maintenance/repair works [A1] and port operations [A1, A2, A4, A5, A7, A8, A9, A11, A13, A17, A18, A19, A21] in ports. Recyclable and durable materials should be preferred to reduce waste [A1, A2, A3, A8, A11, A17, A18]. Waste should be classified [A3, A17, A18] and collected in a designated area for recycling [A3, A11]. These areas where wastes are collected need to be cleaned and treated [A3]. Recycling is one of the most effective waste reduction methods. In addition, it is necessary to determine and establish facilities and areas where wastes related to pandemic diseases will be sterilized and incinerated [A3].

Waste management includes the proper management of waste generated at ports. These wastes may originate from ships, port equipment [4], and other port activities [6]. Environmentally friendly port practices include waste management and require the use of sustainable methods to properly collect, transport, recycle, and/or dispose of waste [4].

5.1.4 Noise Pollution Management

Noise pollution management has been identified as a sub-criterion of environmental management criteria. Care should be taken to reduce underwater noise pollution [A16, A18], which adversely affects underwater life. In addition, it is necessary to reduce the noise caused by cargo operations and construction [A1, A3, A5, A6, A12, A13, A14, A16, A19], which disturb the environment and local people, and the noise caused by truck traffic in and around the port by effective planning [A5, A7, A14, A15, A16]. It is necessary to set standards for noise levels in green ports and to monitor these rules [A1, A3, A5, A6, A7, A8, A10, A11, A12, A15, A17, A18, A19, A21]. Noise-reducing equipment and materials should be used in the port area and the buildings [A3, A7] so that employees are not adversely affected. Many factors and sources can cause noise pollution in ports. Port operations, ship traffic, and in-port

truck movement are some of the sources that can cause noise [40, 41]. In green ports, sound levels from noise sources in ports can be reduced by using quieter electrical equipment [4, 10] and by using various sound barrier systems [6]. If the amount of noise at the source cannot be prevented, it is necessary to reduce the effects of noise with sound barriers. With the effective planning of the operations in the port, it is possible to reduce the perceptible levels of noise [10].

5.2 Energy and Resources

The second main criterion is energy and resources. This criterion consists of 4 sub-criteria: clean energy, green equipment selection, water consumption, and recycling.

5.2.1 Clean Energy

Clean energy is a sub-criterion of the energy and resources criterion, which is one of the main green port evaluation criteria. While the ships are moored at the quay, they provide the electricity needs of the ship with their means. In this case, greenhouse gases are released into the atmosphere. To prevent greenhouse gas emissions, providing the electricity needed by the ships from the shore (cold ironing) is seen as an important green port factor [A1, A3, A5, A6, A10, A11, A13, A15, A17, A18, A19, A20, A21, A22]. Reducing energy consumption in ports and using more efficient methods in this regard are among the main environmental approaches [A1-A22]. To reduce energy consumption, it is necessary to turn to environmentally harmless, clean, and renewable energy sources [A1, A3, A5, A6, A7, A8, A10, A11, A12, A13, A14, A15, A16, A17, A18, A19, A21, A22]. The concept of green ports emerged with the idea of creating a more sustainable environment. In the evaluation made in this context, it is necessary to use less harmful energy sources for the environment. Energy sources such as wind energy [3, 4], solar energy [3, 4, 7], biomass [18, 31], etc. should be preferred in ports because they are less harmful to the environment and renewable than fossil fuels [10]. In addition, taking the necessary precautions in ports to reduce energy use is seen among the less harmful and more efficient methods for the environment [22].

5.2.2 Green Equipment Selection

Another subject examined under the criteria of energy and resources is green equipment selection. More environmentally friendly electrical equipment/machines should be preferred instead of port equipment/machines that use fossil fuels that are harmful to the environment [A1, A2, A3, A4, A5, A6, A8, A11, A12, A13, A14, A15, A17, A19, A20, A21, A22]. Air filters should be used to reduce the harmful effects of exhaust gas emissions from fossil fuel-using machines [A1, A3, A18, A20]. Electric vehicles [A1, A3, A10, A12, A14, A17, A19, A20] that cause less damage to the environment and trucks that cause less air

pollution should be preferred [A1, A2, A5, A17, A19, A20, A21] for in-port transportation. In addition, it should be ensured that the port vehicles are equipped with equipment that will cause less noise [A1, A3, A6, A19]. The choice of green equipment in ports is very important for the efficient use of energy and resources. Instead of fossil fuel-consuming cranes, systems such as electric cranes e-RTG [10, 12], hybrid system RTG cranes [42], low-emission trucks, forklifts, etc. [4], and energy-efficient lighting systems [3] should be used. A port needs to adopt environmentalist rules with all its components in terms of calling that port a green port.

5.2.3 Water Consumption

An important sub-criterion for the efficient use of resources is water consumption. To reduce water consumption in ports, it is necessary to have a water management system [A1, A3, A6, A7, A8, A11, A14, A15, A18, A19]. Incentives should be provided to reduce the amount of water consumption by various saving methods [A2, A3, A6, A8, A11, A12, A14, A16]. Installing rainwater collection units can be considered an option to save water [A5, A11, A14, A17]. Necessary measures and planning should be made to reduce the waste of drinking water and irrigation water [A2, A3, A18]. Continuous monitoring of water consumption and training of port personnel in this regard are also among the important water consumption-saving methods. In addition, while the ports are being built, they should be equipped with tools that save water consumption.

5.2.4 Recycling

Recycling is an important factor in the efficient use of resources. Recycling is important as a sub-criterion of energy and resource criteria in green port applications. Green ports must have recycling management policies [A3, A7, A8, A14, A17]. Rules such as the reuse of dredged sediments, the recycling of cargo equipment packages, and the classification and storage of recyclable products should be clearly stated in these management policies [A3]. Within the scope of this policy, recyclable and reusable materials should be preferred [A1, A2, A3, A7, A19, A21]. In this way, less waste will be generated and the damage to the environment will be reduced.

Recycling is an important part of the environmental approach. Ports activities produce various wastes back. This amount of waste must be recovered by recycling. In addition, durable and reusable products should be preferred instead of disposable products to reduce the amount of waste. To use resources efficiently and to generate less waste, recycling activities should be carried out in green ports.

5.3 Management and Policy

The third main criterion is management and policy. This criterion consists of 4 sub-criteria: environmental policy, eco-friendly employees, technological progress, and training & development.

5.3.1 Environmental Policy

One of the sub-criteria constituting the main criterion of Management Policy is environmental policy. Every green port management should have environmental policies. These policies should be constantly updated with the developments [A1, A4, A5, A6, A7, A8, A9, A10, A11, A12, A13, A14, A15, A16, A17, A18, A19, A20, A21, A22]. To audit the determined policies and standards, it is necessary to be accredited and certified by applying to the relevant accreditation institutions [A3, A5, A10, A11, A16, A22]. With these determined policies, it should be aimed to ensure the operation regularly. Waiting times that may occur in port operations should be regulated and congestions that may occur should be prevented [A1, A4, A11, A14, A15, A16, A19, A21]. Solution proposals should be found for the obstacles related to the green port concept and initiatives should be created regarding this situation [A7, A22]. In addition, it should be ensured that promotion and public relations activities regarding the green port concept are carried out [A2, A3, A4, A6, A12]. Green ports should set their mission to develop a system of continuous improvement in pollution management [43]. With these policies determined, green ports not only ensure that they gain more market share in the competitive market but also ensure that a port is supported by state institutions within the legal framework [44]. In this context, it will be beneficial to determine green policies for a port to operate in sustainable environmental conditions both in terms of sustainable maritime trade and in terms of the social environment it is in.

5.3.2 Eco-friendly Employee

One of the sub-criteria of the main criteria of management and policy is eco-friendly employees. In this context, it is necessary to employ personnel with high environmental awareness and who are competent and experienced in port operations [A2, A5, A9, A12, A13, A15, A21]. It should be ensured that the necessary policies are established to create safe, equal, and high-standard job opportunities in terms of working conditions for the employees [A2, A4, A15, A17, A18, A19, A20, A21]. Competent and licensed personnel should be employed in terms of specific work to be done [A3]. Employees and managers with high environmental sensitivity are needed in green port businesses. It is necessary to have competent and sincere employees with high environmental sensitivity to identify situations that are contrary to the green port approach in the operation of the port and to offer solutions.

5.3.3 Technological Progress

Another sub-criterion to be examined in this chapter is Technological Progress. Adapting to technology under the green port concept is an important element. It is necessary to constantly monitor environmental impacts, [A3, A5, A6, A8, A9, A10, A11, A13, A14, A15, A16, A18, A19, A20, A21], to expand the use of e-services [A2, A3, A14], to control energy consumption with energy efficiency sys-

tems [A1, A3, A6, A7, A19], and to increase digitalization in transactions within the port. Monitoring systems in green ports are a very important component in monitoring and improving environmental performance. With monitoring, deficiencies can be detected and it helps to take measures for these deficiencies. They are systems that provide important data for the administrative improvement of the system. For this reason, providing all processes with e-services and giving importance to digitalization is important in terms of managerial efficiency.

5.3.4 Training and Development

Another sub-criterion examined under management and policies is training and development. Continuous training should be organized by the management to raise environmental awareness among the employees and managers [A1, A3, A4, A6, A8, A12, A17, A18, A19, A20]. To adapt the employees to the developing technology in the port industry, additional training should be organized [A15, A18, A20, A21]. In addition to this, it is also the responsibility of the management to establish emergency and pollution response teams and to carry out and plan continuous training and drills for the development of these teams [A5, A7, A9].

Green port applications are developing day by day. It is rapidly affected by new management approaches and technological developments, and it is necessary to adapt to new applications quickly. Therefore, green port management should organize training programs to ensure this adaptation. A management and training program that is open to continuous improvement and prepared for emergencies should be implemented.

5.4 Social

The fourth main criterion is social. This criterion consists of 5 sub-criteria: relations with the local community, stakeholders management, urban texture, local investments, and collaboration with local authorities and institutions.

5.4.1 Relation with Local Community

Another important sub-criteria that constitutes the social criterion, which is one of the green port evaluation criteria, is relations with local communities. When the green port concept is examined, it is an important element that it has good relations with the local communities in the region and that it is accepted by the communities [A1, A4, A6, A7, A8, A9, A10, A16, A17, A18, A20, A22]. Providing job opportunities to local communities within the port will increase port and community interaction [A3, A4, A12, A15, A20, A21]. In addition, conducting surveys to get the opinions of local communities [A3, A10, A17] and informing community leaders about the environmental approach of the port [A2, A3, A4, A6, A14, A22] will make the port a part of the community it is in.

Green ports should be in contact with the community they are in, provide interaction for the development of the community [45], implement clear and transparent policies [46], work together, and feel responsible for the development of the community [47].

5.4.2 Stakeholders Management

Another sub-criterion examined under the heading of social is stakeholder management. For a port to be an environmentally friendly port, it is not enough to comply with environmental rules alone. For this reason, when considering green port management, stakeholders with high environmental awareness should be preferred while identifying and selecting stakeholders [A2, A4, A7, A10, A11, A12, A14, A15, A20, A21]. Stakeholders must be accredited and certified for environmental awareness [A4]. In addition, the port management should conduct regular inspections to determine whether the stakeholders comply with the environmental rules [A4]. An important stakeholder of the ports is the ship owner companies. It is an important element to offer some incentives in port tariffs to ships that use low sulfur fuels and have high environmental awareness [A1, A4, A5, A9, A10, A11, A12, A16, A22].

Ports should consider certain criteria when determining their stakeholders to avoid damaging their reputation in environmental issues. As green ports comply with environmental rules in their operations, they should expect the same performance from their stakeholders [48].

5.4.3 Urban Texture

When the concept of the green port is examined, there is a perception that it should not spoil the visual silhouette of the cities it is in. For this reason, another subject examined under the title of social is the urban texture. The port should be designed by the architecture of the urban texture in which it is located [A1, A12, A15]. It is necessary to pay attention to the fact that the materials used in the construction of the port are environmentally friendly products [A2, A3, A5, A12, A16, A17]. Care should be taken not to position the port structures (pipelines, etc.) in a way that would devalue the real estate of the local people [A1]. In addition, effective planning should prevent city and ship traffic from causing negative effects on the lives of local communities [A1, A5, A14, A15, A16, A19, A21].

The integration of green ports with the city they are in is an important criterion. In this context, the combined design of the city, transportation network, environment, and port plans is very important for urban development [49]. While making this design plan, aesthetic and visual elements should not be ignored. The historical and cultural texture of the city should not be damaged.

5.4.4 Local Investments

Another important sub-criterion of the social main criterion is local investments. In this context, it is necessary

to support the social and cultural activities of local communities by the port management [A4, A14], to transfer a budget for regional development [A4, A10, A14, A15, A16, A20], and to make investments for the needs of local communities [A17].

Investments made in the region where green ports are located will lead to the formation of new hinterlands. Regional development and the presence of the port will attract new businesses. The increase in trade in the region will also contribute to regional development and cause economic growth.

5.4.5 Collaboration with Local Authorities and Institutions

Another important sub-criteria to be examined under this heading is cooperation with local authorities/institutions. First of all, each port must establish good relations with the government authorities in its environment [A2, A4, A6, A7, A20, A21]. Establishing a legal framework for environmental approaches and establishing relevant departments [A10, A14, A15, A22] will lead the port to gain an advantage in competitive environmental conditions. Good relations with local communities and government authorities will allow for the expansion and development of the port. In addition, joint studies with local scientific societies will contribute to pioneering and innovative developments. For this reason, the scientific community should be supported with scholarships and internship opportunities [A4].

The green port has to establish good relations with the local authorities of the region in which it is located. Establishing good relations also strengthens the relationship between the port and the local community. Considering the development of regulations by local authorities, providing investment incentives, financing support for projects, and their contribution to the development of the region, communication and coordination between the green port and local governments should be good.

5.5 Ecological

The fifth main criterion is ecological. This criterion consists of 3 sub-criteria: wetland and marine habitat preservation, coastal erosion control, and afforestation.

5.5.1 Wetland and Marine Habitat Preservation

Wetland and habitat preservation is an important sub-criterion within the green port performance evaluation criteria. One of the primary purposes of the green port is to protect the coastal and marine ecosystems in which it is located [A1, A3, A6, A8, A10, A11, A12, A13, A15, A17, A18, A19, A21, A22]. In addition, it should continue its activities in a way that does not harm the freshwater resources, lake, and river ecosystems in its vicinity [A17]. Considering the migration routes of migratory birds, the ports should be positioned, and care should be taken not to de-

teriorate the natural environment at the points on the migration route [A17]. In addition, considering that the underwater noise caused by the operations in the port and the ship maneuvers may have negative effects on the life quality of mammals, necessary precautions should be taken [A18]. The concept of the green port is a set of practices that aim to cause the least damage to the environment and the vitality of that environment [20]. All factors should be evaluated together. Green port practices, it is aimed to reduce the level of being affected by the presence of the port on the vitality of the land and sea [32]. It is necessary to minimize the impact on the lives of endangered creatures, and marine and coastal ecosystems [12].

5.5.2 Sediment Control

Another important sub-criteria examined under the ecological title is sediment control. In green ports, it is necessary to constantly control the sediments that cause damage to the port traffic and structures due to the presence of the port and ensure that they are disposed of in a way that does not disturb the ecological balance [A1, A3, A5, A6, A8, A10, A11, A12, A13, A19, A21]. In addition, coastal erosion control is faced with green ports as an element that needs to be constantly controlled and necessary precautions should be taken in a way that will not harm the ecological balance and the port itself in similar ways [A1, A6, A10, A12, A13, A19]. When the ports are not designed by the coastal structure, it causes coastal erosion by changing the environmental effects (wave effect, etc.) in the region [50]. In addition, it can cause sediment accumulation under water and above water, together with effects such as ship traffic. Considering these situations, it is possible to damage life on the coastline or the seabed. Necessary measures should be taken in this regard.

5.5.3 Afforestation

Considering the environmental sensitivity of green ports, afforestation and flower planting in the port area are important factors. In addition, while this afforestation [A3, A6, A7, A11, A12] and flowering [A3] process is carried out, it is necessary to choose the species suitable for the natural habitat and to choose non-chemical [A3], harmless products during fertilization activities.

5.6 Economic

The sixth and last main criterion is economical. This criterion consists of 2 sub-criteria: port efficiency and fees & sub-charges.

5.6.1 Port Efficiency

When the economic efficiency of green ports is examined, there are long-term benefits. Although there is a cost used to modernize the port [A4, A14, A15, A17, A19, A20, A21], the added value of the port increases [A4, A5, A11, A13, A14, A15, A17, A19, A20, A21] and the maintenance and operating costs [A15, A17] decrease. Although it caus-

es economic losses in addition to its environmental benefits, encouragement should be given to extending the green port practices with the determined incentives.

When green ports are examined from an economic point of view, they offer new benefits with additional costs. The green port saves resources and leads to reductions in recycling and costs [51, 52]. It creates economic benefits as well as environmental benefits with the investment cost in the first place and the efficient use of resources in the long term. Thanks to technology and digitalization, employment causes cost reductions [10]. In addition, the idea of being a pioneer in technological developments and creating innovative products [33], also contributes to additional income items. In addition, it should not be forgotten that it creates an economic input with the advantage of obtaining state support [20] and differentiating in the competitive market [53].

5.6.2 Fees and Sub-charges

Other sub-criteria examined under the economic heading are fees and sub-charges. Under this title, the incentives and sanctions applied to ship-owners [A1, A3, A4, A5, A6, A10, A11, A12, A14, A16, A20, A22] and stakeholders [A3, A4, A11, A14, A15, A20, A21] are mentioned. As stated before, a port should not be evaluated with environmental measures alone, but together with all its stakeholders on whether it complies with green port practices. Therefore, incentives and penalties should appear to encourage its stakeholders. It would be beneficial to provide discounts in port tariffs for ships that comply with environmental sensitivities and to prioritize the operation to be carried out. Likewise, it is seen as an important incentive for ports to choose enterprises with environmental sensitivity when determining their other stakeholders.

6 Conclusion

A total 22 of studies in the green port area were accepted as samples and a meta-synthesis was carried out. Because of this meta-synthesis, a green port evaluation criteria model consisting of 6 main criteria and 22 sub-criteria was revealed. 90 codes constituting each sub-criterion were revealed in the in-depth examination of the studies. It is possible that this model will be useful to use as a guide in the green port development process to determine the weights of the main criteria and sub-criteria of this model in the evaluation process, it should be analyzed using multi-criteria decision-making methods within the scope of future studies.

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