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Development of a Tool for Environmental Performance Evaluation in Ports: A Case Study based on the Delphi Technique in Port Environment

ALIJAN ALI AKBARI [1], FARZAM BABAEI SAMIROMI [*1], REZA ARJMANDI [1], MASOUMEH SHOJAEI [2]

[*1] *Department of Environmental Management, Islamic Azad University, Science and Research Branch, Tehran, Iran*

[2] *Department of Environmental Engineering, Islamic Azad University, Parand Branch, Tehran, Iran*

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ABSTRACT

Ports as one the most important parts of the maritime transport system play a paramount role in world trade. The set of designed and implemented processes in ports can significantly impact the surrounding environment. Therefore, the environmental consequences associated with a variety of activities and processes in ports can threaten sustainable global development. Thus, this study was designed and conducted with the aim of developing a tool for environmental performance evaluation in ports. Twenty-five experts in the field of environment and marine sciences participated in the present study. The study was conducted in three rounds based on the Delphi technique in the years 2019-2020. The index of coefficient variation (CV) and acceptance criteria for each of the parameters in this study were considered <20% and 4≤, respectively. The validity of this tool was evaluated using the content validity index (CVI) and content validity ratio (CVR). In addition, its reliability was evaluated using Cronbach's alpha coefficient. CV index in the third round of this Delphi was 0.08. Therefore, the green ports performance evaluation questionnaire was developed with six factors and 32 parameters after three Delphi rounds. These six factors of environmental performance included reactive performance (5 parameters), proactive performance (5 parameters), sustainability (5 parameters), socio-cultural (6 parameters), economic (5 parameters), and governance (6 parameters). The results of the validity evaluation showed that the CVR and CVI of this developed questionnaire were 0.875 and 0.906, respectively. In addition, based on Cronbach's alpha coefficient, the reliability of this tool was estimated to be α=0.92. The findings indicated that the developed tool for evaluating the environmental performance in ports had good validity and reliability. Therefore, this tool can be used as an acceptable estimator of the ports' environmental performance in the maritime transport system.

KEYWORDS: *Environmental Performance Evaluation; Green Port; Maritime Transport system; Delphi Technique*

INTRODUCTION

The maritime transport system is one of the most important parts of international trade. Nowadays, almost eighty percent of global trade in volume and more than seventy percent in value is transported through seas and ports around the world [1]. The contribution of maritime transport in world trade exceeds these estimates in developing countries. Therefore, ports were recognized as one of the most important centers of trade facilitation in the global trade literature. Ports also boost countries' economic and trade development by facilitating and creating opportunities through maritime transport. Therefore, countries tend to invest in their ports and maritime transportation with two main objectives. First, maritime transportation is full of great and influential opportunities in subordinate and complementary fields of transportation and industry. On the other hand, it brings high income with sustainable employment and entrepreneurship for countries. Second, ports are the economic and commercial frontiers, which is why most of the world's major cities are built near the seas. So, ports make it possible for nearby cities to produce at a lower cost and accelerate their development by providing the opportunity to export their products [2-3]. Thus, it is of particular importance to monitor ports and ships' performance and possible challenges of these two main parts of the maritime transport system.

Environmental impacts are one of the most important challenges that organizations, industries, countries, and the international community face in various forms. Environmental impacts can disrupt the operations and processes of an organization or industry at lower levels and impose detrimental effects on achieving sustainable development goals at higher levels. In addition, potential environmental impacts arise not only from inland operations but also from maritime activities [4-5]. Accordingly, ships, ports, and maritime transport systems are affected by a variety of environmental challenges depending on the type of processes and activities.

Various studies on maritime transport and the challenge of climate change showed that maritime transport is one of the parameters that can affect climate change [6-8]. Therefore, the type and scope of environmental impacts vary depending on local conditions, transportation systems, plans and policies, and the ability to adapt and minimize costs. These studies showed that direct impacts might possibly be attributed to infrastructure, operations, and maintenance in maritime transport. Additionally, maritime transport can have indirect effects on the environment. These effects can arise from the types of services provided in the maritime transport system due to changes in demand, investment decisions, population affairs, agricultural production, energy exploitation, and other services such as fishing [5-6-8].

Although maritime transport is known as one of the most environment-friendly transportation systems, with the growth of freight traffic, the issue of the long-term sustainability of this growth has become an important part of policy issues in the field of globalization, trade and development, environmental sustainability, energy security, and climate change [9]. Due to abnormal changes in the global environment, communities face serious problems such as global warming, water pollution, waste disposal, air pollution, ozone depletion, space destruction, and rapid energy consumption. On the other hand, the amount and severity of pollution and emissions of greenhouse gases from port activities also cast doubt on the sustainability of this type of transportation. This has become a top priority as the number of global supply chains promote sustainable operations and seek cleaner and greener networks. Furthermore, the structure of global supply chain networks is no longer limited to reducing costs but also to reducing the negative impacts on the environment. In such circumstances, the sustainable development plan has been defended and supported to reduce land degradation [10-11].

Therefore, considering the great importance of maritime transportation as well as the environmental consequences and effects related to processes, operations and activities in ships and ports as the two main parts of the maritime transport system, the present study was designed and conducted with the aim of developing a tool to evaluate the performance of green ports based on the Delphi technique.

Corresponding author: Farzam Babaei Samiromi
E-mail: farzam.babaei@gmail.com

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METHOD

This cross-sectional study was carried out based on the Delphi technique and experts' opinions with the aim of designing and developing a tool for the environmental performance evaluation of ports in the years 2019-2020. The implementation steps of the present study have been presented in Figure 1.

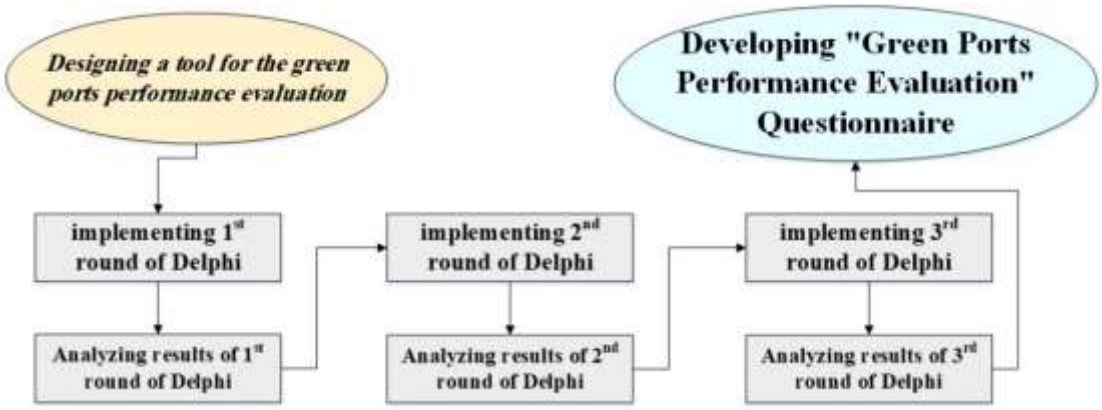

Figure 1. Implementation steps of the present study

Green ports:

Green port is a policy to improve environmental protection programs to reduce the negative effects of port activities. Despite the important role and high share of ports and maritime transportation in world trade, processes and activities in this area have implications with significant environmental effects. Sustainable port operations are those port strategies and activities that meet the current and future needs of the port and its stakeholders, protect natural resources and help to maintain them. In other words, the sustainable port is a port that creates a favorable balance between the economic performance of business units, utilizes existing capacities, limits the use of space, and minimizes negative impacts on the environment. Previous researches on sustainable port operations were the result of increasing environmental laws and regulations [12-13]. But the new role of ports in the context of sustainable supply chain changed the expectations of shippers in relation to customer service and challenging costs and innovations in the field of sustainable logistics [14]. Therefore, studies related to sustainable port operations were more focused on studying the environmental effects of port operations in European and Asian ports as well as the development of indicators or frameworks for sustainable port evaluation. The environmental impacts of port operations have the most important types of environmental impacts on the climate. For example, off the coast of Europe, East Asia, and South Asia, more than 60,000 people die each year from heart failure or lung cancer due to the presence of particulate matter from floating greenhouse gases. Furthermore, asthma and other respiratory and cardiovascular diseases as well as premature death are among the effects of port pollution on human health [15].

As such, the concept of green port deals with the protection of the environment as well as its practical promotion. Examples of these executive policies are placing trees in the port to absorb noise and reduce pollution, use of renewable energy for port operations and activities, and implementing methods such as recycling and reuse of materials [14-16]. Accordingly, ports should follow a number of goals to be recognized as green ports. These goals are

including waste management (waste reduction from port operations is achieved through material reuse, recycling, and compost), sustainable development (while increasing long-term economic benefits, it enhances the environmental performance of ports), sustainable practices in trade (gives equal importance to environmental, economic and social concerns), water quality improvement, energy-saving, and energy efficiency maximizing in port operations, and greenhouse gases and other hazardous gases emission reduction into the air through port operations [16-17].

Designing a tool for the green ports performance evaluation:

In order to design and develop a tool for the performance evaluation of green ports, firstly, we conducted a comprehensive literature review with respect to the study objectives and important areas, including environmental pollution from different types of port and ship operations. The major components and parameters affecting ports' performance in the field of combating these pollutants and organizational performance indicators were based on the environmental parameters and considerations. After that, the first draft of the instrument including six factors and 30 parameters was designed and introduced based on this literature review. These six factors of environmental performance included reactive performance, proactive performance, sustainability, socio-cultural, economic, and governance.

Reactive performance factors:

Included carbon footprint, the amount of generated waste, improving air quality and water resources, the total amount of water consumed, and dust pollution parameters. It is noteworthy that the carbon footprint included the impact of pollution and carbon dioxide emissions from fuel consumption in port.

Proactive performance factors:

Included five parameters such as environmental management program, environmental training, hazardous cargo management, energy/fuel efficiency improvement, and environmental risk assessment.

Sustainability factors:

Included training and upgrading port activities, construction management program, use of renewable energy, use of recyclable resources, reduction of energy consumption, and marketing activities.

Socio-cultural factors:

Included five parameters of employee safety, justice, physical impact, cultural impact, and public safety. The parameter of justice included the fair allocation of resources in society. In other words, the law must achieve an acceptable level of real and formal justice and must ensure the fair distribution of resources and equal access to opportunities. In addition, the parameter of physical impact included the importance of space integrity, dimensions, proportions, flexibility, geometric form, confinement, and spatial continuity.

Economic factors

Included direct employment, indirect employment, financial health, investments in technology development, and training of full-time employees.

Governance factors:

Included the parameters such as government investment in port, the productivity of the public sector port's employees, level of safety, open market of the port, and corporate social responsibility report. It is noteworthy that the open market of the port parameter refers to the port's commercial relationship with other ports in the country and ports in the region.

Development of green ports performance evaluation tool based on the Delphi technique:

The Delphi technique is one of the study methods that is used to reach consensus in group decisions. In Delphi studies, participants have knowledge and awareness about the subject. The Delphi technique is a structured process based on the fact that the opinion of experts is the most correct in any field of science about predicting the future. Therefore, unlike survey research methods, the validity of the Delphi method does not depend on the number of participants in the research but on the scientific validity of the experts participating in that

study. In various studies, the appropriate number for the experts' panel in one study has been mentioned to be 5-20 [18]. At the beginning of this study, 25 experts with master's and Ph.D. degrees in fields related to the study, including management and engineering specialties in two main fields of the environment and marine sciences expressed their willingness to participate in the current study. Accordingly, after the initial design of the green ports performance evaluation questionnaire by the study group, the questionnaire was developed based on the Delphi technique and using the opinions of the panel of experts in three rounds.

The first round of Delphi:

In the first round, the initial design of this tool entitled "green ports performance evaluation questionnaire" was designed and introduced by the research team based on a thorough review of the literature. As presented in the previous section (2.1 section), this tool was provided to the panel of experts including six factors and 30 parameters. In this round, 25 experts in the panel of experts were asked to comment on the desirability and importance of these parameters based on a five-point Likert scale (very low, low, medium, high, and very high). In addition, they were asked to submit a proposal to add a parameter to evaluate the performance of green ports. Then, the results of the first round of the Delphi were analyzed.

Second round of Delphi:

After collecting the experts' opinions and analyzing the results of the first round of Delphi, during the second round, possible changes based on the experts' opinions were made in the designed questionnaire and sent to the panel of experts for comments. In this round, the participating experts were asked to comment again on the desirability and importance of the presented parameters. In addition, they were again asked to submit a proposal to add a parameter to evaluate the performance of green ports. Then, the results of the second round of the Delphi were analyzed.

Third round of Delphi:

During the third round and after analyzing the results of the second round and making possible changes, a green ports performance evaluation questionnaire was sent to the panel of experts to re-comment on determining and evaluating the importance and desirability of these parameters in this tool. After collecting the experts' opinions in the third round and analyzing the data and considering the lack of relative change in the coefficient of variation (CV) compared to the second round (<20%), the study was completed after three rounds. According to the results, the green ports performance evaluation questionnaire was developed based on the Delphi technique. It should be noted that the acceptance criterion for each of the parameters in this Delphi was considered 4≤ [19].

Validity and reliability assessment:

Validity and reliability assessment of green ports performance evaluation questionnaire was performed using two validity indicators including content validity index (CVI) and content validity ratio (CVR) as well as Cronbach's alpha coefficient reliability index. Content validity index (CVI) was used to assess the validity of the questionnaire. The CVI index is provided by Waltz & Bausell. It should be noted that CVI > 0.79 is acceptable. The content validity indicates the extent to which a scale (questionnaire) measures all aspects of the structure. The content validity ratio (CVR) is designed by Lawshe. To calculate this ratio, the experts' opinions in the field of test content were used (Equation 1). The minimum acceptable CVR based on the number of experts ≥20 was 0.42 [20-21].

$$\boldsymbol{CVR = \frac{n_e - N/2}{N/2}} \quad (1)$$

CVR: Content Validity Ratio
N: Total number of experts
n_e*:* The number of experts who have selected the necessary item/parameter

The reliability of a questionnaire was assessed using the Cronbach's alpha test, which results in a coefficient called Cronbach's alpha. Cronbach's alpha was used to measure the one-dimensionality of attitudes, judgments, and other categories that were

not easy to measure (Equation 2). Notably, α ≥0.7 is acceptable and α≥0.9 is excellent [20-21].

$$\alpha = \left(\frac{k}{k-1}\right) \times \left(1 - \frac{\sum_{i=1}^{k} s_i^2}{s_t^2}\right) \quad (2)$$

α: Reliability
k: Number of items / questions
s_i^2: The variance of each item/question
s_t^2: The total variance of the items/questions

RESULTS

The Delphi study for the development of the green port performance evaluation tool started with the participation of 25 experts and ended with 22 experts. Three experts from the panel did not participate in the third round of the study. So the results of this study were based on the participation of 22 experts. The demographic variables results of the experts' panel showed that the mean age and work experience of these experts were 40.42±7.73 and 12.15±4.35 years. 18.18% (4 people) were female and 81.82% (18 people) were male, 77.27% (17 people) were married, and 22.73% (5 people) were single. In addition, 68.18% (15 people) of the experts' panel had a master's degree and 31.82% (7 people) had a Ph.D. degree (see Table 1).

The results of the first round of the Delphi technique showed that all members of the experts' panel provided their answers based on the importance or desirability of the parameters provided in the questionnaire designed for environmental performance evaluation in ports (participation rate=100%). Additionally, some panel members suggested different parameters for six factors in this tool (14 parameters). In this round, the following parameters were proposed for the governance factor: two parameters of noise pollution and water pollution of ships balance for reactive performance factor, two parameters for proactive performance factor including environmental monitoring program and pollution and non-polluting sediment management. Three parameters, including technology development, optimal use of ports' facilities, and implementation of sustainable methods in design and construction for the sustainability factor. Two parameters, including discourse-interaction and comprehensive education and social participation for the socio-cultural factor. Three parameters, including value-added, production and consumption patterns, and tourism development for the economic factor. Two parameters, including independent management and the integration of port stakeholder activities.

After applying changes in the first draft of the tool based on expert opinions in the first round (adding 14 parameters), the second round of this Delphi was performed. The results of this round showed that no parameters were suggested by experts for this tool. The participation rate for this round was 100%.

To assess the reliability of the answers provided by the experts' panel in the second round, once again during the third round of the Delphi study, these individuals were asked to comment on the parameters presented in the green ports performance evaluation questionnaire. The results of this round showed that the CV index was 0.08 compared to the second round, which value was much lower than the standard value considered for this study (<20%). Finally, according to this coefficient of variation (CV), the Delphi study was completed at this round. 22 experts participated in this round (final participation=88.0%).

At the end of the third round of the Delphi study, based on the acceptance criteria considered for each of the parameters in this tool (4≤), twelve parameters were removed. Finally, the green ports performance evaluation questionnaire was developed, including six factors and 32 parameters (Table 2). It is noteworthy that the twelve parameters removed in the third round included the total amount of water consumed and water pollution of ships (reactive performance factor), improving energy/fuel efficiency and pollution and non-polluting sediment management (proactive performance factor), management program construction, marketing activities and optimal use of port facilities (sustainability factor), staff safety (socio-cultural factor), financial health, full-time staff training, tourism development (economic factor) and safety level (governance factor).

The results of the validity assessment of this tool showed that the content validity ratio (CVR) and content validity index (CVI) of this questionnaire were 0.875 and 0.906, respectively. In addition, the total reliability of this questionnaire was calculated using Cronbach's alpha coefficient equaling 0.92. The results of the reliability assessment showed that Cronbach's alpha coefficient of sustainability, socio-

cultural, and governance factors were estimated to be 0.88, 0.87, and 0.89 (acceptable reliability). Furthermore, the reliability of reactive performance, proactive performance, and economic factors were estimated to be excellent (Cronbach's alpha coefficient of these three factors was calculated 0.93, 0.94, and 0.91) (Table 2). It is noteworthy that the green ports performance evaluation questionnaire was developed based on a 5-points Likert scale, including very low, low, medium, high, and very high (Table 2).

Based on this questionnaire, the quality of environmental performance of ports was classified into three levels. Environmental performance levels based on the green port performance evaluation included level 1 or weak (environmental performance index ≤ 2), level 2 or moderate (2< environmental performance index ≤ 3), and level 3 or desirable (environmental performance index > 3).

Table 1. Demographic Characteristics Results of Experts' Panel (n = 22)

Variable		Value
Age (years)		40.7±4.73
Work experience (years)		12.15±4.35
Gender	Female	4 (18.18%)
	Male	18 (81.82%)
Marital Status	Single	5 (22.73%)
	Married	17 (77.27)
Education	Masters	15 (68.18%)
	P.H.D	7 (31.82%)

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Table 2. Reliability of Green Ports Performance Evaluation Questionnaire

Factor	Parameters	Reliability (α)
Reactive performance	Carbon footprint The amount of waste produced Improving air quality & water resources Dust pollution Noise Pollution	0.93
Proactive performance	Environmental management program Environmental training Environmental monitoring program Environmental risk assessment Dangerous cargo management	0.94
Sustainability	Training and upgrading the level of port activities Technology Development Use of renewable energy Use of recyclable resources & reduce energy consumption Implement sustainable practices in design and construction	0.88
Socio-cultural	Justice Physical effects Cultural influences Public security Discourse-interaction and comprehensive education social participation	0.87
Economic	Direct employment Indirect employment Investments in technology development	0.91

Governance	Create added value Production and consumption patterns Government investment in the port Productivity of public sector employees of the port Port open market Corporate Social Responsibility Report Independent management Integration of port stakeholder activities	0.89

DISCUSSION

Ports as one of the two parts of the maritime transport system play an important role in the global economy and trade. The results of previous studies showed that the contribution and value of ports' trade are the highest in value and volume of trade in the world. One of the important pillars in the sustainable development approach is to increase the level of the environmental performance of organizations and industries in order to increase the number of products and services they provide. Therefore, preserving the environment and reducing the harmful effects and consequences on the environment is considered as one of the goals of sustainable development in the industrial and commercial fields in the world. As such, considering the undeniable role of ports in world trade, the findings of various studies showed that the different types of port activities and related activities can have harmful effects and consequences on the environment. In addition, despite the increase in the volume and value of trade in ports, the environmental consequences associated with various operations in ports are not in line with sustainable development goals wherein the long run affect global sustainable development significantly [9-22]. Therefore, paying attention to the environmental performance of ports to protect the environment and reduce the effects associated with operations in ports is one of the important goals of improving the quantity and quality of ports. Accordingly, considering the undeniable role of Iranian ports as a very important commercial hub in the country, the main center of trade with the world, and their increasing role in the national economy, achieving the promotion of ports as a green port is one of the most indispensable steps that must be taken into account.

In the past, port development and operations have often been based on a monitoring-oriented approach. Gradually, several US ports and other international ports adopted optimal management measures, some of which incorporated green port components into their planning, development, and operations. However, rapid growth has raised concerns about the environment, quality of life, declining resource consumption, and rising costs. Given these concerns, a comprehensive and adaptive approach to sustainable development is essential. Such a centralized monitoring approach can be used to build consensus, improve environmental conditions, conserve resources, and achieve significant life-cycle savings. Therefore, the green port approach based on the six principles of wildlife, air, water, soil and sediments, community involvement, and sustainability is very important for maintaining and promoting environmental performance in ports [12-23-24]. The findings of the present study showed that the designed tool as green ports performance evaluation questionnaire is a suitable tool with appropriate validity and reliability for this purpose. In that sense, the content validity ratio and content validity index of

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this tool were estimated to be 0.875 and 0.906. Hence, according to the standard values of CVR (minimum acceptable CVR for the number of experts more than 20 people should be 0.42) and CVI (CVI values greater than 0.79 is acceptable), this questionnaire had acceptable validity. In addition, considering the calculation of Cronbach's alpha coefficient is equal to 0.92 ($\alpha > 0.9$ indicates excellent reliability), this questionnaire had an acceptable level of reliability in evaluating the performance of green ports. The results of evaluating the reliability of the six factors of this tool also showed that the reliability of the three factors was reliable and the reliability coefficient for the other three factors also was excellent (see Table 2). Furthermore, the findings of this study, which was based on the Delphi technique, indicated that the developed tool to evaluate the performance of green ports had six factors or indicators, including environmental performance, including reactive performance, proactive performance, and sustainability, socio-cultural, economic and governance and includes 32 parameters (Table 2).

These results also revealed that the parameters presented in this tool were in accordance with the six principles of the green port approach [23-25]. This finding indicated the appropriate applicability of this tool (in the form of a questionnaire) to evaluate the environmental performance of ports based on the green port approach. For example, paying attention to reactive performance parameters in the field of environments such as carbon footprint index as a measure of the total amount of carbon dioxide and methane emissions from all port activities [16-26]. Similarly, the waste production index including waste from port operations and environmental activities [27] would be an example of attention to the important indicators and factors used in this questionnaire to evaluate the environmental performance of green ports. Furthermore, designing and presenting parameters such as the environmental management plan (including a structural and systematic approach to the carbon management plan by port authorities that reflect port activities in order to continuously improve environmental quality and comply with regulations), environmental training (including various effective and continuous environmental education programs with the aim of encouraging to comply with environmental requirements) and environmental monitoring program (including periodic frequent observations and measurement of selected environmental monitoring parameters) in proactive performance factor can lead to a proper evaluation of environmental performance in ports [16-28].

However, it should be noted that the present study was one of the first studies to design and develop a tool for evaluating environmental performance based on the principles and indicators of the green port. Therefore, the results of the present study may provide a new approach in the field of development, calculation, and evaluation of green port performance. Additionally, the use of this developed tool can be an effective step in the direction of a comprehensive environmental performance management program in ports. As such, the use of this tool can provide an appropriate and acceptable estimator to achieve the green ports' goals. On the basis of the findings, the level of environmental performance can be enhanced against threats caused by various environmental pollutants. It is noteworthy that this study, like other studies, had some limitations. Although different parameters were used to develop a tool for environmental assessment in port environments in this study, it is suggested that factors such as logistics, emergencies and crises, economic development as well as the interaction of environmental consequences and activities be given full attention in the future studies. In addition, due to the limitations in selecting the panel of experts, it is recommended that people with expertise in all areas related to jobs and activities of ports and environmental challenges be present in the panel of experts. Despite conducting a comprehensive literature review in this study, it is suggested that a more comprehensive literature review be conducted and finally, it is recommended that all the mentioned parameters be taken into account.

CONCLUSION

Given the role of ports in the maritime transport system, it is very important to use a tool to evaluate the environmental performance of ports. Therefore, the findings of this study, which was based on the Delphi technique and the opinions of the panel of experts, showed that the designed and developed questionnaire in this study with calculated validity and reliability can be suitable for evaluating the environmental performance of ports. Hence, with high reliability, it can be acknowledged that the use of this

tool, which was based on six groups of factors and indicators and 32-parameters, can lead to a good estimate of the environmental performance of ports.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest in this study.

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