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ORIGINAL ARTICLE

Evaluating Ports Environmental Performance based on the Fuzzy Analytic Hierarchy Process (FAHP)

ALIJAN ALI AKBARI[1], FARZAM BABAEI SAMIROMI[*2], REZA ARJMANDI[2], MASOUMEH SHOJAEI[3]

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

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ABSTRACT

Appropriate environmental performance is considered one of the most important indicators in the sustainable development of organizations and industries. Evaluating the environmental performance in ports as one of the two main parts of the maritime transport system is of particular importance. Therefore, the current study was designed and conducted to develop a method for evaluating the environmental performance of ports based on the fuzzy analytic hierarchy process (FAHP). In the present study, 22 experts in the field of environment and marine sciences were selected in 2020. Firstly, various studies on the factors affecting the environmental performance of ports were reviewed. Secondly, a questionnaire was designed to assess ports' environmental performance. Thirdly, this questionnaire was developed using the Delphi technique. Finally, by determining the weight of each parameter, the method of environmental performance assessment in ports was developed based on the FAHP. The final normalized weights for six environmental performance factors including reactive and proactive performance, sustainability, socio-cultural, economic, and governance were estimated 0.202, 0.241, 0.226, 0.070, 0.080, and 0.182. Additionally, it was found that each of the parameters had a different weight and impact on these factors. The highest and lowest impact on the environmental performance index belonged to environmental risk assessment (weight=0.217), cultural effects, and justice (weight=0.107). In the current study, a new method was developed for evaluating the environmental performance of ports based on six factors, 32 parameters, and FAHP. Therefore, this method may provide an effective step in reducing environmental impacts and improving the level of environmental performance in ports to achieve the goal of green port.

KEYWORDS: *Environmental Performance; Environmental Impacts, Green Port; Analytic Hierarchy Process (AHP); Fuzzy Logic.*

INTRODUCTION

Maritime transportation plays an important role in international trade. About four-fifths of world trade is done by sea and ports. The share of developing countries in maritime transport in world trade is even higher [1-2]. Where ships and ports are the two main parts of the maritime transport system. Despite the environmentally friendly nature of maritime transportation, in maritime transportation growth literature, the adverse effects of transport development, maintaining, and long-term sustainability have been considered as one of the major policy challenges in trade and development, environmental sustainability, energy security, and climate change [3].

According to the previous studies, there is a direct relationship between industrial growth and the increase in environmental pollutants. These environmental impacts can be classified into air pollution and reduction of environmental quality. These challenges can be addressed by greenhouse gas emissions that the highest emission rates of these gases are related to industries, transportation, domestic, commercial, and public sectors. Some of the most important causes of air pollution are the activities of industries, non-compliance with environmental regulations pertaining to the control of emission limits, failure to install pollution reduction equipment, and especially failure to evaluate environmental performance or incorrect assessment of environmental impacts [4-6]. Accordingly, the evaluation of appropriate environmental performance is considered as one of the important indicators in the sustainable development and productivity of organizations and industries.

The industrial revolution with its significant development of industries and the efforts of countries to achieve economic development, and low environmental literacy of communities coupled with inefficiency or lack of control over pollutants, on the other hand, have caused problems pertaining to environmental pollution. This issue has, in turn, become the center of attention of researchers and policymakers. In many developing countries, the growing tendency for industrialization has paved the way for economic growth and income. Based on statistics, the economic growth in developed countries is more remarkable than that in other countries. The economic growth, alongside the industrial growth, will naturally lead to an increase in the consumption of energy resources. Increasing energy consumption has a significant impact on increasing industrial pollutants [7].

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

Environmental impacts arise not only from inland operations but also from maritime activities and transportation [8]. Accordingly, depending on the type of processes and activities, ships and ports, the maritime transport system is affected by a number of environmental challenges. Studies show that maritime transport is one of the parameters that can affect climate change [4-9-10]. 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. The severity of pollution and greenhouse gas emissions from port activities also casts doubt on the sustainability of this type of transport. In addition, the structure of global supply chain networks is limited to reducing not only the costs but also the negative impact on the environment [11-12].

Although, maritime transport is one of the most environmentally 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 [3]. Evaluation of environmental performance in large and complex organizations such as ports as one of the two main parts of the maritime transport system is very important. Therefore, in the current study, considering the role of maritime transport in world trade, the importance of ports as one of the two main parts of the maritime transport system, as well as the environmental impacts associated with various

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operations, business processes, and various activities in ports, we designed and developed a model to evaluate the environmental performance of ports based on the fuzzy analytic hierarchy process (FAHP).

METHODS

This study was implemented based on the FAHP and with the participation of a panel of experts consisting of 22 experts in the field of environment and marine sciences in 2020.

2.1. Implementation steps:

The study process consisted of four steps:

1: Comprehensive literature review:

In this step, various studies were reviewed based on the factors affecting the environmental performance of ports, including parameters, indicators affecting the environmental performance, and various environmental effects in ports.

2: Designing a questionnaire to evaluate environmental performance in ports:

In the second step, six factors of environmental performance based on the green *ports* were included reactive performance **(**carbon footprint, the amount of generated waste, improving air quality and water resources, the total amount of water consumed, and dust pollution parameters/sub-factors), proactive performance (environmental management program, environmental training, hazardous cargo management, energy/fuel efficiency improvement, and environmental risk assessment), sustainability (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 **(**employee safety, justice, physical impact, cultural impact, and public safety), economic (direct employment, indirect employment, financial health, investments in technology development, and training of full-time employees), and governance factors **(**government investment in the port, the productivity of the employees of the port's public sector, the level of safety, the open market of the port, and the corporate social responsibility report) [8-11-13-17].

3: Delphi study:

In this step, an environmental performance evaluation questionnaire was developed using the Delphi technique in three-round by a panel of experts consisting of 22 experts in the field of environment and marine sciences.

4: Fuzzy analytic hierarchy process (FAHP):

In the final step, based on the FAHP and with the participation of 22 experts, the weight of each of the six factors, as well as the related parameters in the questionnaire developed in the third step, was determined. Accordingly, by determining the weight of each parameter, a method for evaluating environmental performance in ports was developed.

2.2. Delphi technique:

Group decision-making is a good approach to solve complex problems. In group decision-making, with the unanimity of experts in a field, an appropriate decision can be made on the subject. Delphi technique is a qualitative research method that depends on the participants' knowledge about the subject to reach a consensus in group decisions. This method is appropriate for systematically combining the opinions of panel of experts in a field to make a final judgment on an issue [18-19]. In the third step of this study, an environmental performance evaluation questionnaire was used based on the Delphi technique has been developed in three rounds.

2.3. Fuzzy Analytic Hierarchy Process (FAHP):

The analytic hierarchy process (AHP) determines the best option among different options with respect to the calculated total weight of the criteria [20]. The next step is to determine the relative weight of the selected criteria and sub-criteria by pairwise comparisons. At this point, a panel of experts using criteria comparisons determines their relative score [12-21]. In this study, a matrix for pairwise comparison of factors affecting environmental performance in ports and six matrices for pairwise comparison of the parameters set for each of the six factors were formed.

Fuzzy logic is a form of a multi-valued region in which the correct values of the variables may be any real number between zero and one. This logic uses the concept of partial correctness so that its values can be between completely true and completely false [22-23].

In AHP, individual experts' verbal expressions are utilized to estimate the relative importance of factors through pair-wise comparisons. Since verbal expressions are inaccurate, indefinite, and ambiguous in the evaluation of more than one subject.

It is difficult to analyze and summarize the results. However, the fuzzy region provides a very useful tool for measuring ambiguous concepts related to individuals' mental judgments. As a result, it is a powerful tool suitable for overcoming the mentioned problems to obtain more accurate information in the form of verbal expressions [21-22].

A combination of the AHP method with fuzzy logic has been widely used to rank the criteria, sub-criteria, and different methods for performing FAHP. This study was based on the method proposed by Chang because it was easier to implement than other methods and at the same time provides accurate results [24]. The triangular fuzzy numbers are known as one of the commonly used types of fuzzy numbers. A triangular fuzzy number is represented as A = (l, m, u) in which l, m and u denote a fuzzy set. The upper limit, denoted by u is the maximum value that a fuzzy number A can take. The lower limit denoted by l is the minimum value that the fuzzy number A can take. The value of m is the most probable value of a fuzzy number [22]. The membership function of a triangular fuzzy number is as follows:

$$\mu_{\tilde{A}} = \begin{cases} 0, & x < l \\ (x-l)/(m-l), & l \le x \le m \\ (u-x)/(u-m), & m \le x \le u \\ 0 & x \ge u \end{cases}$$

It should be noted that any errors and inconsistencies in comparing the importance between options and indicators distort the final result of the calculations. So, it is necessary to confirm the validity of the answers and data received from experts. In this method, the validity of expert responses and data was determined based on the inconsistency rate.

If the consistency rate is 0.1 or less, it indicates consistency in the comparisons and the validity of the respondents is confirmed [22-24]. Therefore, inconsistency rates were calculated for all matrices of pairwise comparisons and invalid responses were excluded from the study.

RESULTS

3.1. Delphi Findings:

The results of experts' panel demographic data showed that the means of age and work experience of these specialists were 40.42±7.73 and 12.4±15.35 years. In addition, 68.18% (15 people) of the panel of experts had a master's degree and 31.82% (7 people) had Ph.D. A questionnaire for evaluating environmental performance in ports with coefficient of variation (CV) of 0.08 and an acceptance criterion of 4≤ was developed for each of the parameters after three rounds of study based on the Delphi technique.

The questionnaire was made of six factors of environmental performance including reactive performance, proactive performance, sustainability, socio-cultural, economic, and governance. 32 parameters related to environmental performance in ports including carbon footprint, amount of generated waste, improving air quality and water resources, dust pollution and noise pollution (reactive performance factor), environmental management program, environmental education, environmental monitoring program, environmental risk assessment and management of hazardous cargo (proactive performance factor), training and upgrading of port activities, technology development, use of renewable energy, use of recyclable resources, reduction of energy consumption, implementation of sustainable design, construction methods (sustainability factor), physical impacts, cultural effects, public safety, discourse-interaction, comprehensive education, social participation (socio-cultural factor), direct employment, indirect employment, investments in technology development, value creation, production and consumption patterns (economic factor), government investment in the port, productivity of port public sector, port open market, social responsibility report, independent management, and stakeholders' integrity (governance factor).

It should be noted that the evaluation of these parameters should be done based on the five- Likert scale (very low, low, medium, high, and very high).

3.2. FAHP Findings:

The port environmental performance evaluation questionnaire was approved by the Delphi panel of experts. Then, each one of the parameters and factors' weight was estimated using FAHP. In this step, the panel of experts answered the AHP questions. Then, these questionnaires were collected and the validity of each questionnaire and paired comparison matrices were evaluated by calculating the inconsistency rate and invalid questionnaires were removed.

Table 1 and Equation 1 show the fuzzy mean matrix and the final normalized weights of the six factors affecting the environmental performance of the ports. The normalized final weight for the six factors of reactive performance (RP), proactive performance (PP), sustainability (S), socio-cultural (SC), economic (E), and governance (G) for evaluating the environmental performance of ports were obtained 0.202, 0.241, 0.226, 0.070, 0.080, and 0.182. Furthermore, the incompatibility rate of this matrix was CRg=0.017 and CRm=0.007.

The port environmental performance indicator (PEPI) was calculated based on Equation 1:

$$PEPI=0.20RP + 0.241PP + 0.226S + 0.070SC + 0.080E + 0.82G \quad (1)$$

Table 1. Fuzzy mean matrix and final normalized weights of six factors affecting the environmental performance of ports

	Reactive Performance	**Sustainability**	**Proactive Performance**	**Governance**	**Economic**	**Socio-Cultural**	**Normalized weight**
Reactive Performance	1.00, 1.00, 1.00	0.47, 0.71, 1.22	0.61, 0.83, 1.22	0.90, 0.97, 1.05	1.25, 2.20, 3.13	1.33, 2.29, 3.21	**0.202**
Sustainability	0.82, 1.41, 2.11	1.00, 1.00, 1.00	0.70, 1.03, 1.49	0.74, 1.03, 1.42	1.37, 2.26, 3.09	1.46, 2.42, 3.34	**0.226**
Proactive Performance	0.82, 1.21, 1.65	0.67, 0.97, 1.42	1.00, 1.00, 1.00	1.29, 1.98, 2.59	1.41, 2.37, 3.30	1.54, 2.51, 3.44	**0.241**
Governance	0.95, 1.03, 1.11	0.70, 0.97, 1.35	0.39, 0.51, 0.78	1.00, 1.00, 1.00	1.22, 1.88, 2.46	1.10, 1.92, 2.69	**0.182**
Economic	0.32, 0.45, 0.80	0.32, 0.44, 0.73	0.30, 0.42, 0.71	0.42, 0.54, 0.83	1.00, 1.00, 1.00	0.74, 1.10, 1.57	**0.080**
Socio-Cultural	0.31, 0.44, 0.75	0.30, 0.41, 0.69	0.29, 0.40, 0.65	0.37, 0.52, 0.91	0.64, 0.91, 1.35	1.00, 1.00, 1.00	**0.070**

The fuzzy mean matrix and the normalized weights of five parameters of the reactive performance factor have been presented in Table 2. The normalized final weights for parameters of this factor including dust pollution, improved air quality and water resources, noise pollution, amount of waste, and carbon footprint was obtained to be 0.55, 0.206, 0.182, 0.211, and 0.245. Furthermore, the incompatibility rate of this matrix was CRg=0.027 and CRm=0.012.

Table 2. Fuzzy mean matrix and final normalized weights of parameters affecting the reactive performance factor

	Dust pollution	Improved air quality and water resources	Noise pollution	Amount of waste	Carbon footprint	Normalized weight
Dust pollution	1.00, 1.00, 1.00	0.43, 0.62, 1.02	0.57, 0.78, 1.10	0.68, 0.95, 1.29	0.44, 0.68, 1.21	0.155
Improved air quality and water resources	0.98, 1.62, 2.34	1.00, 1.00, 1.00	0.62, 1.03, 1.63	0.54, 0.78, 1.15	0.68, 0.86, 1.11	0.206
Noise pollution	0.91, 1.28, 1.76	0.61, 0.97, 1.61	1.00, 1.00, 1.00	0.54, 0.70, 1.04	0.50, 0.69, 1.06	0.182
Amount of waste	0.77, 1.06, 1.48	0.87, 1.28, 1.85	0.96, 1.42, 1.87	1.00, 1.00, 1.00	0.49, 0.69, 1.13	0.211
Carbon footprint	0.83, 1.47, 2.28	0.90, 1.16, 1.48	0.95, 1.45, 1.99	0.89, 1.44, 2.04	1.00, 1.00, 1.00	0.245

The fuzzy mean matrix and the normalized weights of parameters of proactive performance factor have been presented in Table 3. The finalized weight for five parameters of environmental monitoring program, hazardous cargo management, environmental education, environmental risk assessment, and environmental management program were estimated to be 0.166, 0.216, 0.185, 0.217, and 0.216. Furthermore, the incompatibility rate of this matrix was CRg=0.017 and CRm=0.007.

Table 3. Fuzzy mean matrix and final normalized weights of parameters affecting the proactive performance factor

	Environmental monitoring program	Hazardous cargo management	Environmental education	Environmental risk assessment	Environmental management program	Normalized weight
Environmental monitoring program	1.00, 1.00, 1.00	0.46, 0.66, 1.01	0.74, 1.04, 1.37	0.68, 0.89, 1.16	0.47, 0.67, 1.04	**0.166**
Hazardous cargo management	0.99, 1.51, 2.16	1.00, 1.00, 1.00	0.70, 1.11, 1.67	0.57, 0.80, 1.10	0.75, 1.08, 1.48	**0.216**
Environmental education	0.73, 0.96, 1.35	0.60, 0.90, 1.43	1.00, 1.00, 1.00	0.66, 0.87, 1.15	0.67, 0.95, 1.30	**0.185**
Environmental risk assessment	0.86, 1.13, 1.47	0.91, 1.25, 1.74	0.87, 1.15, 1.51	1.00, 1.00, 1.00	0.69, 0.99, 1.39	**0.217**
Environmental management program	0.96, 1.48, 2.13	0.67, 0.93, 1.33	0.77, 1.06, 1.49	0.72, 1.01, 1.45	1.00, 1.00, 1.00	**0.216**

The fuzzy mean matrix and the normalized weights of parameters of the sustainability factor have been presented in Table 4. Normalized final weight for these parameters including training and upgrading of port activities, use of renewable energy, technology development, implementation of sustainable methods in design and construction, use of recyclable resources, and reduction of energy consumption were obtained 0.178, 0.20, 0.188, 0.214, and 0.200. Furthermore, the incompatibility rate of this matrix was CRg=0.013 and CRm=0.006.

Table 4. Fuzzy mean matrix and final normalized weights of parameters affecting the sustainability factor

	Training and upgrading	Use of renewable energy	Technology development	Sustainable methods in design & construction	Use of recyclable resources	Normalized weight
Training and upgrading	1.00, 1.00, 1.00	0.49, 0.71, 1.15	0.77, 1.10, 1.51	0.69, 0.90, 1.20	0.51, 0.75, 1.25	0.178
Use of renewable energy	0.87, 1.40, 2.05	1.00, 1.00, 1.00	0.71, 1.13, 1.72	0.60, 0.85, 1.21	0.85, 1.27, 1.75	0.220
Technology development	0.66, 0.91, 1.30	0.58, 0.88, 1.41	1.00, 1.00, 1.00	0.68, 0.90, 1.22	0.71, 1.02, 1.48	0.188
Sustainable methods in design & construction	0.83, 1.11, 1.45	0.83, 1.18, 1.67	0.82, 1.11, 1.48	1.00, 1.00, 1.00	0.73, 1.07, 1.58	0.214
Use of recyclable resources	0.80, 1.33, 1.96	0.57, 0.79, 1.18	0.68, 0.98, 1.41	0.63, 0.93, 1.37	1.00, 1.00, 1.00	0.200

The fuzzy mean matrix and the normalized weights of the economic parameters have been presented in Table 5. The normalized final weights of value creation, direct employment, production and consumption patterns, investment in technology development, and indirect employment were estimated to be 0.146, 0.285, 0.40, 0.157 and 0.272. Furthermore, the incompatibility rate of this matrix was CRg=0.004 and CRm=0.002.

Table 5. Fuzzy mean matrix and final normalized weights of parameters affecting the economic factor

	Value added creation	Direct employment	Production & consumption patterns	Investment in technology development	Indirect employment	Normalized weight
Value added creation	1.00, 1.00, 1.00	0.39, 0.54, 0.93	0.82, 1.00, 1.22	0.82, 1.07, 1.35	0.36, 0.53, 0.94	0.146
Direct employment	1.08, 1.84, 2.59	1.00, 1.00, 1.00	1.11, 2.00, 2.90	1.03, 1.62, 2.23	0.82, 1.10, 1.42	0.285
Production and consumption patterns	0.82, 1.00, 1.22	0.35, 0.50, 0.90	1.00, 1.00, 1.00	0.64, 0.88, 1.28	0.45, 0.60, 0.93	0.140
Investment in technology development	0.74, 0.94, 1.22	0.45, 0.62, 0.97	0.78, 1.13, 1.57,	1.00, 1.00, 1.00	0.44, 0.60, 0.99	0.157
Indirect employment	1.06, 1.87, 2.76	0.70, 0.91, 1.22	1.08, 1.67, 2.23	1.01, 1.66, 2.28	1.00, 1.00, 1.00	0.272

The fuzzy mean matrix and normalized weights of socio-cultural parameters have been presented in Table 6. Normalized final weight for socio-cultural parameters including physical impacts, social participation, public safety, discourse-interaction and comprehensive education, cultural influences, and justice were obtained 0.198, 0.204, 0.213, 0.171, 0.107, and 0.107. Furthermore, the incompatibility rate of this matrix was CRg=0.034 and CRm=0.014.

Table 6. Fuzzy mean matrix and final normalized weights parameters affecting the Socio-Cultural factor

	Physical impacts	Social participation	Public safety	Comprehensive education	Cultural influences	Justice	Normalized weight
Physical impacts	1.00, 1.00, 1.00	0.58, 0.80, 1.22	0.64, 0.94, 1.42	0.82, 0.97, 1.16	1.25, 1.94, 2.56	1.29, 1.92, 2.47	0.198
Social participation	0.82, 1.25, 1.73	1.00, 1.00, 1.00	0.73, 1.08, 1.59	0.74, 1.03, 1.42	1.03, 1.47, 2.05	1.29, 1.98, 2.59	0.204
Public safety	0.70, 1.07, 1.57	0.63, 0.92, 1.37	1.00, 1.00, 1.00	1.33, 1.95, 2.50	0.91, 1.41, 2.04	1.27, 1.91, 2.58	0.213
Comprehensive education	0.86, 1.03, 1.22	0.70, 0.97, 1.35	0.40, 0.51, 0.75	1.00, 1.00, 1.00	1.20, 1.75, 2.22	0.87, 1.29, 1.78	0.171
Cultural influences	0.39, 0.51, 0.80	0.49, 0.68, 0.97	0.49, 0.71, 1.10	0.46, 0.58, 0.84	1.00, 1.00, 1.00	0.61, 0.92, 1.42	0.107
Justice	0.41, 0.52, 0.78	0.39, 0.51, 0.78	0.39, 0.52, 0.79	0.56, 0.77, 1.15	0.70, 1.08, 1.64	1.00, 1.00, 1.00	0.107

The fuzzy mean matrix and the normalized weights of the governance parameters have been presented in Table 7. Normalized final weights for these parameters including productivity of port public sector, social responsibility report, government investment, port open market, stakeholder integrity, and independent management were calculated 0.208, 0.205, 0.213, 0.162, 0.105, and 0.108. Furthermore, the incompatibility rate of this matrix was CRg=0.026 and CRm=0.011.

Table 7. Fuzzy mean matrix and final normalized weights parameters affecting the governance factor

	Productivity of port public sector	Social responsibility report	Government investment	Port open market	Stakeholder integrity	Independent management	Normalized weight
Productivity of port public sector	1.00, 1.00, 1.00	0.69, 0.87, 1.18	0.70, 1.07, 1.57	0.78, 1.03, 1.35	1.19, 2.01, 2.83	1.22, 2.04, 2.87	0.208
Social responsibility report	0.85, 1.15, 1.44	1.00, 1.00, 1.00	0.76, 1.19, 1.75	0.78, 1.13, 1.57	1.09, 1.62, 2.26	1.22, 1.80, 2.35	0.205
Government investment	0.64, 0.94, 1.42	0.57, 0.84, 1.31	1.00, 1.00, 1.00	1.20, 1.78, 2.38	0.96, 1.50, 2.15	1.33, 2.23, 3.15	0.213
Port open market	0.74, 0.97, 1.28	0.64, 0.88, 1.28	0.42, 0.56, 0.83	1.00, 1.00, 1.00	1.15, 1.60, 2.01	0.92, 1.21, 1.53	0.162
Stakeholder integrity	0.35, 0.50, 0.84	0.44, 0.62, 0.92	0.47, 0.67, 1.04	0.51, 0.64, 0.88	1.00, 1.00, 1.00	0.64, 0.89, 1.28	0.105
Independent management	0.35, 0.49, 0.82	0.43, 0.56, 0.82	0.32, 0.45, 0.75	0.65, 0.82, 1.09	0.78, 1.12, 1.56	1.00, 1.00, 1.00	0.108

DISCUSSION

Environmental protection is one of the main pillars of management in any organization and industry. Therefore, a lack of organizational development planning will lead to an unstable and one-dimensional development. New approaches in management systems and environmental standards improved environmental performance appraisal and a decreasing trend in harmful environmental impacts. Accordingly, designing and applying a reliable method or technique to evaluate environmental performance in organizations and industries is of particular importance [25]. Therefore, the current study was designed to develop a method for evaluating the environmental performance of ports based on the FAHP.

The findings of this study indicated that the developed method for evaluating the environmental performance of ports had six environmental performance factors including reactive and proactive performance, sustainability, socio-cultural, economic, and governance with 32 parameters. The development of the environmental performance evaluation method was based on the six principles of the green port approach [26-27]. Additionally, the results of this study revealed that the six environmental performance factors had different weights and effects on the ports'environmental performance. Based on these findings, the proactive performance factors, stability, and reactive performance had the most impact on the ports' environmental performance, 0.241, 0.226, and 0.202. As well as, governance, economic, and socio-cultural factors had the least effect on the environmental performance index in ports, 0.070, 080, 0.080, and 0.182.

Based on the structure of modern organizational and management systems, the first and perhaps the most important step in establishing an optimal environment is to analyze and evaluate the risks and opportunities of an organization. This step identifies and evaluates the potential and actual conditions of the risks as a basis for any new design, extensive and minor changes, adopt a variety of control methods, improve the level of environmental performance, and increase the level of stakeholder satisfaction. Therefore, paying attention to the proactive factor, including identifying, evaluating and managing environmental risks, and learning from past experiences is one of the most important factors that can evaluate the environmental performance in an organization [28].

The findings of the current study showed that the majority of the parameters in each of the factors affecting environmental performance in ports had different weights and effects compared to one other. The results in Tables 2, 3, 4, 5, 6, and 7 showed that weights were in line with the results of previous studies in this field. For example, the parameters of carbon footprint and the amount of waste generated were identified as the main parameters in the reactive performance factor. Carbon footprint as a measure of the total amount of carbon dioxide and methane emissions from all port activities [4-10] as well as the amount of generated waste such as waste from port operations and activities [29] can be considered as important parameters in evaluating the environmental performance of ports, which can lead the system to higher environmental goals, including the attainment of a green port [9].

In addition, the parameters of environmental risk assessment and environmental management program were two main parameters in the proactive performance factor identification (weight = 0.217 and 0.216). Environmental risk assessment as a systematic process of assessing the potential adverse effects of activities, pollutions on assets, and ecosystems and environmental management programs as a systematic method for carbon management were used to continually improve environmental quality. Furthermore, compliance with laws was one of the main elements of optimal environmental performance and in line with the goals of sustainable development [30].

The FAHP results of the parameters affecting the sustainability factor showed that the parameters including use of renewable energy and implementation of sustainable methods in design and construction were estimated as two parameters with the greatest impact on this factor (weight=0.220 and 0.214). Various studies showed that these parameters had high capabilities to increase the level of environmental performance and can help as parameters affecting other parameters and factors related to reducing the environmental impact of increments and operations in an organization or industry [31-32].

It should be mentioned that the present study was one of the few studies carried out in order to design and develop an instrument to evaluate the environmental performance of ports based on the principles and indicators of the green port, as well as the analytic hierarchy process and fuzzy logic. As such, the findings of the present study can be regarded as an effective step towards a comprehensive environmental performance management program in ports. In addition, it can improve the level of performance of these ports in order to achieve the green port approach.

Ports play an important role in the maritime transport system and world trade. With regard to the great importance of ports in the development of Iran and trade with other countries, the use of an approach that can be in line with the goals of sustainable development is very indispensable for the ports. Therefore, it is very important to use an acceptable and appropriate method to evaluate the environmental performance in ports. The findings of this study, which are based on analytical hierarchy process and fuzzy logic, indicated that the developed method in this study can be used as a highly reliable tool to evaluate environmental performance in ports.

CONCLUSION

The findings indicated that the use of green port principles and requirements in development of a method for the environmental performance evaluation of ports could lead to accurate results of ports environmental performance. Additionally, the use of analytical hierarchy process (AHP) and fuzzy logic in this study helped to estimate the weight and effect of each factor and sub-factor in measurement and evaluation of environmental performance in ports. Therefore, the use of this approach to evaluate the environmental performance of ports based on the principles of green port as well as the fuzzy analytic hierarchy process (FAHP) can be an effective step towards reducing environmental consequences and upgrading environmental performance in ports.

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CONFLICT OF INTEREST

The authors declare that they had no conflict of interest in this study.

REFERENCES

1. Lam JSL, Cullinane KPB, Lee PT-W. The 21st-century Maritime Silk Road: challenges and opportunities for transport management and practice. *Trans Reviews.* 2018; 34(4): 413-415.
2. Shi W, Li KX. Themes and tools of maritime transport research during 2000-2014. *Maritime Policy & Management*. 2017;44(2):151-169.
3. Woo J-K, Moon DS, Lam JSL. The impact of environmental policy on ports and the associated economic opportunities. *Trans Res Part A: Policy and Practice*. 2018;110:234-242.
4. Yang Y-C. Operating strategies of CO2 reduction for a container terminal based on carbon footprint perspective. *J Cleaner Prod*. 2017;141:472-480.
5. Rao C, Yan B. Study on the interactive influence between economic growth and environmental pollution. *Environ Sci and Pollution Res*. 2020;27(31):39442-39465.
6. Tanha F, Rangkooy H, Marzban M, Kazemi E, Rasoolykalamaki F, Debiehkhosravi A. An Approach to the Control Management of Gaseous Pollutants Emissions from Power Plants Using Analytic Hierarchy Process (AHP). *Intl Journal Occup Hygiene.* 2015;7(1):27-31.
7. Li Y, Zhou S, Jia Z, Ge L, Mei L, Sui X, Wang X, Li B, Wang J, Wu S. Influence of industrialization and environmental protection on environmental pollution: a case study of Taihu Lake, China. *Intl J Environ Res and Public Health*. 2018;15(12):2628.
8. Lee PT-W, Kwon OK, Ruan X. Sustainability challenges in maritime transport and logistics industry and its way ahead. *Multidisciplinary Digital Publishing Insti*; 2019.
9. Venkatesh S, Sriraman V. A Notional research on implementing green port strategy at the new Manglore port trust. *Intl J Management*. 2020;11(10).
10. Teerawattana R, Yang Y-C. Environmental performance indicators for green port policy evaluation: case study of Laem Chabang port. *The Asian J Shipping and Logistics*. 2019;35(1):63-9.
11. Jägerbrand AK, Brutemark A, Sveden JB, Gren M. A review on the environmental impacts of shipping on aquatic and nearshore ecosystems. *Sci of the Total Environ*. 2019;695:133637.
12. Shahbod N, Mansouri N, Bayat M, Nouri J, Ghoddousi J. A fuzzy analytic hierarchy process approach to identify and prioritize environmental performance indicators in hospitals. *Intl J Occup Hygiene*. 2017; 9(2):66-77.
13. Poulsen RT, Ponte S, Sornn-Friese H. Environmental upgrading in global value chains: The potential and limitations of ports in the greening of maritime transport. *Geoforum*. 2018;89:83-95.
14. Asariotis R, Benamara H. *Maritime transport and the climate change challenge*. Geneva, New York , UN, Earthscan, 2012.
15. Monios J, Wilmsmeier G. Deep adaptation to climate change in the maritime transport sector–a new paradigm for maritime economics?. *Mari Poli & Management*. 2020:1-20.
16. Shi W, Xiao Y, Chen Z, McLaughlin H, Li KX. Evolution of green shipping research: themes and methods. *Mari Policy & Management.* 2018;45(7):863-876.
17. Derakhshani E, Naghizadeh A, Shahabi H, Nazinejad M. Evaluation of Environmental and Respirable Dust in Air of Tile Industry in South Khorasan. *Arch of Hygiene Sci.* 2014;3(3):85-90.
18. Flostrand A, Pitt L, Bridson S. The Delphi technique in forecasting–A 42-year bibliographic analysis (1975–2017). *Tech Forecasting and Social Change*. 2020;150:119773.
19. Mohammadfam I, Mansouri N, Nikoomaram H, Ghasemi F. Comparison of commonly used accident analysis techniques for manufacturing industries. *Intl J Occup Hygiene.* 2015;7(1):32-37.
20. Venkata-Siva-Raja-Prasad S, Prasada-Rao Y, Venkata-Chalapathi P. Prioritizing the Elements of OHSAS-18001 in Construction Segments in India–AHP Approach. *Intl J Occup Hygiene*. 2013;5(4):159-165.
21. Hurley JS. Quantifying decision making in the critical infrastructure via the Analytic Hierarchy Process (AHP). *Intl J Cyber Warfare and Terrorism- United States.* 2020: 465-477.
22. Mohammadfam I, Aliabadi MM, Soltanian AR, Tabibzadeh M, Mahdinia M. Investigating interactions among vital variables affecting situation awareness based on Fuzzy DEMATEL method. *Intl J Indus Ergon*. 2019;74:176-195.
23. Shamaii A, Omidvari M, Hosseinzadeh Lotfi F. Performance assessment of HSE management

systems: A fuzzy approach in a Steel Manufacturing Company. *IJOH*. 2016;8(2):100-109.

24. Lyu H-M, Sun W-J, Shen S-L, Zhou A-N. Risk assessment using a new consulting process in fuzzy AHP. *J Const Engin and Management*. 2020;146(3):04019112.
25. Nikpishe Kohjhari F, Morovati M, Sadeghinia M, Amanat Yazdi L. Assessment and Management of Environmental Risks of Steel Industries by EFMEA Method (Case Study: Ardakan Steel and Melting factory). *J Environ Health Engin*. 2020:76-88.
26. Wan C, Zhang D, Yan X, Yang Z. A novel model for the quantitative evaluation of green port development–A case study of major ports in China. *Transp Res Part D: Trans and Environ*. 2018;61:431-43.
27. Hua C, Chen J, Wan Z, Xu L, Bai Y, Zheng T, Fei Y. Evaluation and governance of green development practice of port: A sea port case of China. *J Cleaner Prod*. 2020;249:119434.
28. Xing X, Wang J, Tou L. The relationship between green organization identity and corporate environmental performance: The mediating role of sustainability exploration and exploitation innovation. *Intl J Environ Res and Public Health*. 2019;16(6):921.
29. Svaetichin I, Inkinen T. Port waste management in the Baltic Sea area: A four port study on the legal requirements, processes and collaboration. *Sustainability*. 2017;9(5):699.
30. Haque F, Ntim CG. Environmental policy, sustainable development, governance mechanisms and environmental performance. *Busi Strategy and the Environ*. 2018;27(3):415-435.
31. Hou Y, Iqbal W, Muhammad Shaikh G, Iqbal N, Ahmad Solangi Y, Fatima A. Measuring energy efficiency and environmental performance: a case of South Asia. *Processes*. 2019;7(6):325.
32. Sarkheil H, Rahbari S. HSE Key Performance indicators in HSE-MS establishment and sustainability: a case of south pars gas complex, Iran. *Intl J Occup Hygiene*. 2016;8(1):45-53.