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Research Paper:
Comparing the Performance Evaluation Models of Gas Refineries Using AHP and TOPSIS

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ABSTRACT

Background: To basically solve the critical environmental problems, macro and infrastructural perspectives of rational development should be designed following environmental protection rules. Creating the proper performance measurement systems in every organization has had a promising interest in university studies, and many researchers are working on it.

Methods: This research intends to compare and rank 4 evaluation performance models used in gas refineries. To achieve the desired model in this study, we employed the grounded theory. The study research consisted of 20 professionals and Health, Safety, and Environmental (HSE) managers of gas refineries who had relevant experience and skills in this area. The normal score was estimated based on the weight obtained from the Analytic Hierarchy Process (AHP) to apply the Technique for Order Preference by Similarity to an Ideal Solution (TOPSIS) process and prioritize the models.

Results: The pairwise comparison matrix of 4 research models of the balanced scoring card, European foundation for quality management business excellence model, Iran national quality award, and environmental performance evaluation depicted that the geometric mean of the evaluation criteria includes the following items: the capability to quantify qualitative data for environmental performance, facilitating, efficient implementing, structuring, and mapping a roadmap of organization maturity to select an environmental performance estimated at 1.22, 0.90, 0.95, and 0.96, respectively. Also, the normal weights of these four criteria are estimated at 0.3039423, 0.2242449, 0.2347026, and 0.2371102, respectively.

Conclusion: The findings resulting from prioritizing the organization's Environmental Performance Evaluation (EPE) models based on TOPSIS depicted that the suggested model with relative proximity to 99% is the first choice of EPE for the gas refinery.

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1. Introduction

Today, the impact of the environment on the economic activities of human societies has raised the term of sustainable development in the world literature [1]. Because of the global trend of using quantitative information to reflect the state of the environment and its improvement, the measurement of sustainable development indices has increased, as well as control and accountability of managerial behaviors [2]. Sustainable development is the proper perception of the engagement to an interconnected system of economic, social, and environmental processes [3]. It is a popular belief that socioeconomic development is not acceptable without observing environmental issues [4]. Indeed, growing pollution, especially in industrial areas and its transfer to other parts, has created concern in the countries around the world and led to raising environmental protection at an international level [5].

Environmental protection refers to any operation done to preserve the environment or prevent its destruction [1]. To realize environmental protection, communities must take effective environmental decisions in this regard [6].

Many environmental problems challenge the control idea, but it is obvious that numerous organizations are looking for ways to recognize, realize, and promote their environmental performance [7]. This target can be obtained through optimally managing activities, products, and services with significant consequences [8]. Many industries are looking for ways to identify, realize, recognize, improve, and present their environmental performance better, and this endower becomes a reality when the factors affecting the environment are well known [9] and under efficient and effective management [10].

Environmental performance assessment is an internal management process and a tool to provide information and determine a reliable and acceptable status for the management to detect how an organization performs according to determined standards and legal requirements [11]. This management process enables the organization to assess its performance using key performance indicators and provide reliable and acceptable information for stakeholders [12].

Salehibarmi et al. [11], using the environmental performance model of Tehran Municipality, showed that the environmental management performance of Tehran Municipality in the field of preserving the urban environment and creating environmental centers in the neighborhoods is at a favorable and acceptable level. However, concerning biodiversity and green space of the city, water and energy management, transportation, quality control, air pollution, and land and building use are not at the desired level. In a study, Najafzadeh and Mamipour [13] measured the environmental performance of regional power companies in Iran (in the context of the contemporaneous and consecutive boundary of the base surplus and directional distance function). The results show that Isfahan, Kerman, and Gilan regional power companies have the highest environmental efficiency, and Sistan-Baluchestan and Kish ones have the lowest. Haghgoo [14], in a study entitled "Evaluation of environmental performance and mechanisms affecting it according to ISO 14031", reported that organizations and industries should identify the factors affecting the environment and provide well-suited management to have a better environmental performance both internally and externally. Furthermore, Guijarro [15] presented a multicriteria model to evaluate environmental performance. In this research, a target programming pattern has been offered to rank countries in accordance with the multi-dimensional nature of environmental performance criteria considering 10 subject categories and 24 performance indicators.

Moreover, del Mar Alonso-Almeida and Fuentes-Frías [16] investigated 39 quality rewards and organizational excellence models worldwide. Then, they introduced 7 dimensions for evaluating and implementing Total Quality Management (TQM) in companies worldwide in cluster analysis. Talwar [17] also investigated 20 models of organizational excellence and the International Quality Award to identify the features and conflicts between these models to make suggestions and develop them.

The gas and petrochemical industries are among the macro and employment-creating industries. They are considered feed industries of other industries and play a main role in the progressive economic movement of countries [18]. Because of the growing trend of the global economy and rising energy demand, the key role of these industries has been increasingly considered and led to their significant expansion and development in recent decades [19]. While these industries face inevitable requirements to meet the environmental protection challenge, proper environmental management, which has become a success factor of these organizations, depends on their environmental performance assessment [20].

According to the growing evolution of business environments, fast-changing markets, and competitiveness promotion [21], the need for models that can assess the

current status of organizations, recognize underlying causes and organizational damage, identify improvable areas, and create the proper basis for strategic planning, is more tangible than ever [9]. Also, because of the expansion of environmental considerations [22], many organizations are looking for new management techniques to realize, recognize, and improve their environmental performance [23]. In addition, the market for application software in this regard has grown a lot [24, 25]. But despite many models and contexts, some conceptual models of researchers have had the greatest impact on the formation of this particular field [26], including four models of the Balanced Scoring Card (BSC), European Foundation for Quality Management (EFQM) business excellence model, Iran National Quality Award (INQA) and Environmental Performance Evaluation (EPE).

Because of no uniform evaluation model for the environmental performance of refinery industries, this study aimed to compare different performance evaluation models and provide the most suitable model to assess the environmental performance of the country's gas refinery.

Introducing Four Performance Evaluation Models

The INQA model had been planned based on the latest edition of the EFQM, enabling organizations to develop processes and resources to promote product quality and create a transparent strategy for their products. It also empowers staff to implement the product strategy [9]. The eight core values and concepts of this model include consequentialism, customer orientation, leadership and consistency in goals, management based on processes and facts, human resource participation and development, learning, innovation, continuous improvement, development of partnerships, and social responsibilities [27] (Figure 1).

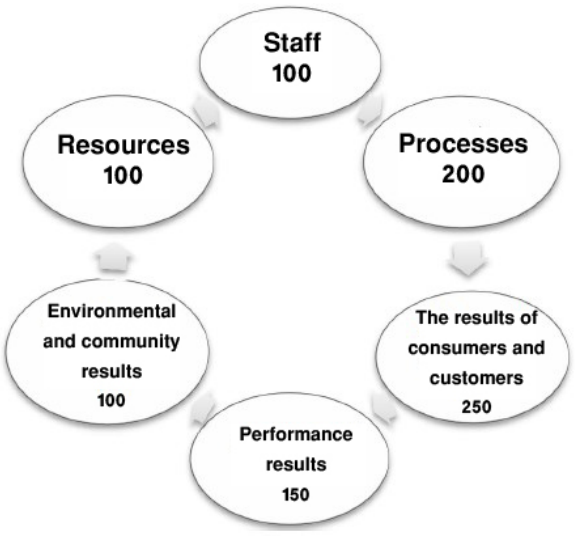

Figure 1. The block diagram of Iran National Quality Award (INQA) [27]

The BSC is one of the most famous and well-known models of the performance evaluation system, created by Kaplan and Norton [28] and then extended and improved [26]. This model suggests that to assess the performance of any organization, a series of balanced indicators should be used so that top managers can have an overall view in terms of four important organizational aspects [29]. These different aspects make it possible to answer the following four basic questions:

1. What are the views on stakeholders? (Financial aspect)

2. What areas should be done well by us? (The internal aspect of the business)

3. How do customers look at us? (Customer aspect)

4. How can we continue to improve and create value? (learning and innovation aspects)

In a traditional performance measurement system, the emphasis was only on financial measurements, such as rate of return on investment or net income, but in the BSC performance measurement system, organizational performance is evaluated in terms of four prospects: financial, customers, internal processes, learning, and growth (Figure 2).

The EFQM was introduced at the beginning of 1992 as a context for evaluating and improving organizations for the European Quality Award and was revised in 1999 [30]. This model is now the most popular performance evaluation system in Europe [31]. The framework of this model includes two separate factors generally divided into "enablers" and "outcomes". The enablers are like levers that managers can use to achieve future results faster [30]. In particular, the main idea of this model is to improve organizational performance through self-assessment and improvable activities based on optimization in the field of nine excellence indicators [32] (Figure 3).

The EPE is an internal management process that uses indicators to compare an organization's environmental performance with its defined performance criteria (Figure 4). Based on ISO 14031 [33] and localized management and operational criteria, EPE reflects the two-dimensional position of the organization and can grow and

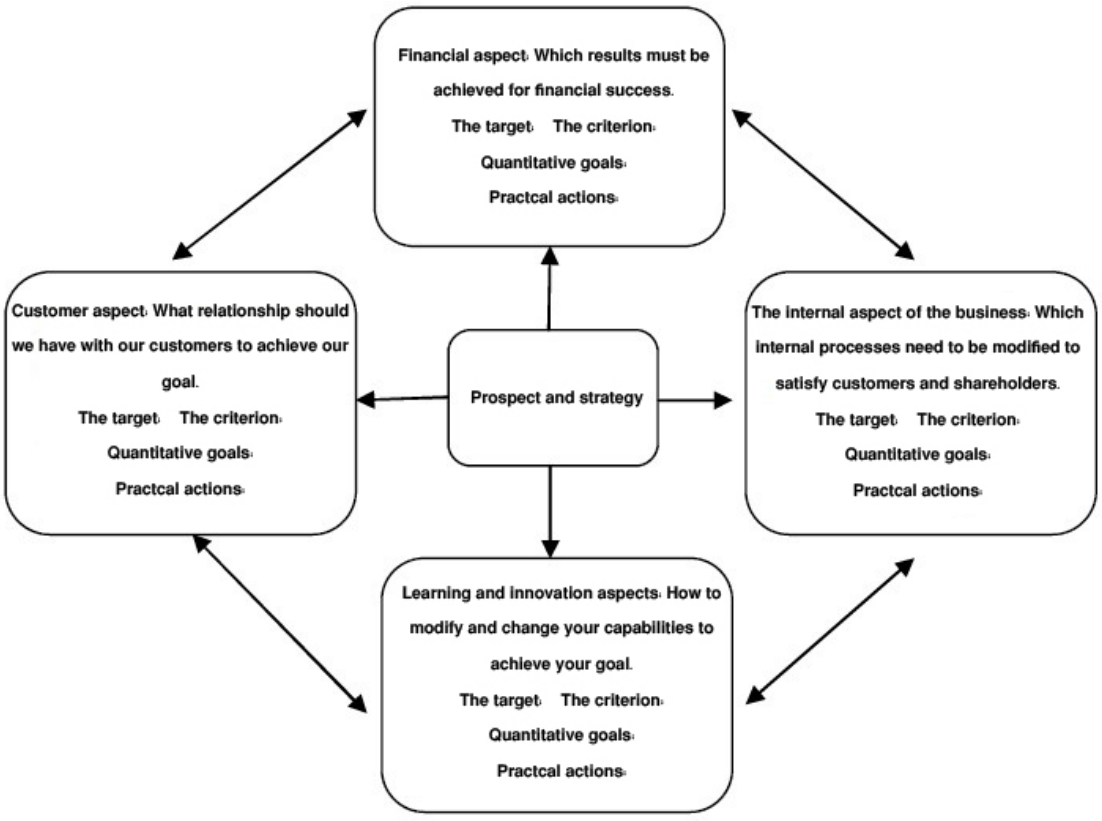

Figure 2. The block diagram of the Balanced Scoring Card (BSC) model [9]

develop it in a balanced way and can be used to compete with similar organizations.

2. Materials and Methods

The study scope

This study aims to present a model to evaluate the environmental performance of gas refineries (a case study is related to the ninth refinery of the South Pars Gas Complex).

South Pars Gas Complex (SPGC) is one of the subsidiaries of the National Iranian Gas Company, established in 2019, responsible for the operation of onshore facilities of multiple phases of the South Pars gas field. It is located in the territorial waters of Iran and Qatar and shared between two countries with an area of 9700 at a depth of 3000 below sea level. It is the largest gas field in the world, 105 from the coast of Asaluyeh Port. Its Iranian part covers an area of 3700 which reserves 14 trillion of gas and 17 billion barrels of gas condensate, equivalent to 8% of the world's gas reserves and 50% of the country's gas reserves. In terms of material resources, this field is considered the most important and valuable economic resource and the great and unique national wealth and treasure. The ninth refinery of the South Pars Gas Complex, known as a leading company in Iranian projects, has been a model for other Iranian companies in recent years and is accountable for large and difficult national projects. This refinery is located in the Tombak region (15 east of Kangan and 65 east of Asaluyeh).

Methodology

The current study was conducted using a mixed exploratory research method.

First of all, according to the review of more than 500 studies in the field of performance evaluation and opinions of experts in this field, four performance evaluation models of BSC, EFQM, INQA, and EPE were selected as the most widely-used performance evaluation model.

In the following, by reviewing the literature on performance management and quality management, several criteria are selected to compare the excellence models. In this regard, experts, supervisors, and advisors were asked about these criteria and instructed to add or reject any criterion to the list. Finally, by gathering the opinions of experts, four main criteria agreed by the experts were extracted to evaluate and rank the models of organizational excellence as follows:

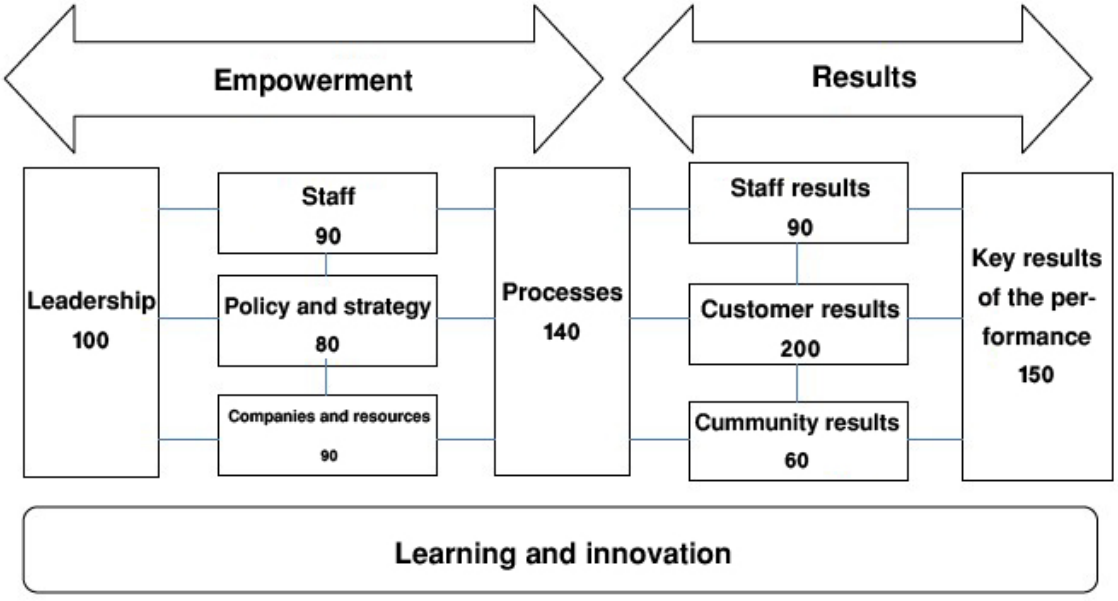

Figure 3. The Block Diagram of European Foundation for Quality Management (EFQM) [32]

Criterion 1: Capability to quantify qualitative data for environmental performance

Criterion 2: Facilitating and efficient implementing

Criterion 3: Structuring

Criterion 4: Mapping a roadmap of organization maturity to select an environmental performance

Finally, using the fuzzy Analytic Hierarchy Process (AHP) and the Technique for Order Preference by Similarity to an Ideal Solution (TOPSIS), pairwise comparisons were identified in the target population after distributing the questionnaire.

The validity of the questionnaire was determined through content validity and its reliability through the Cronbach alpha coefficient (α =0.94).

Figure 5 shows the implementation steps of the research process to determine the best model to evaluate the environmental performance of gas refineries. Figure 6 also presents a research model based on a hierarchical structure to prioritize research models.

The statistical community of research

The study population of this research included managers and experts working in different parts of gas refineries with at least 5 years of relevant work experience in HSE (health, safety, and environmental) and manage-

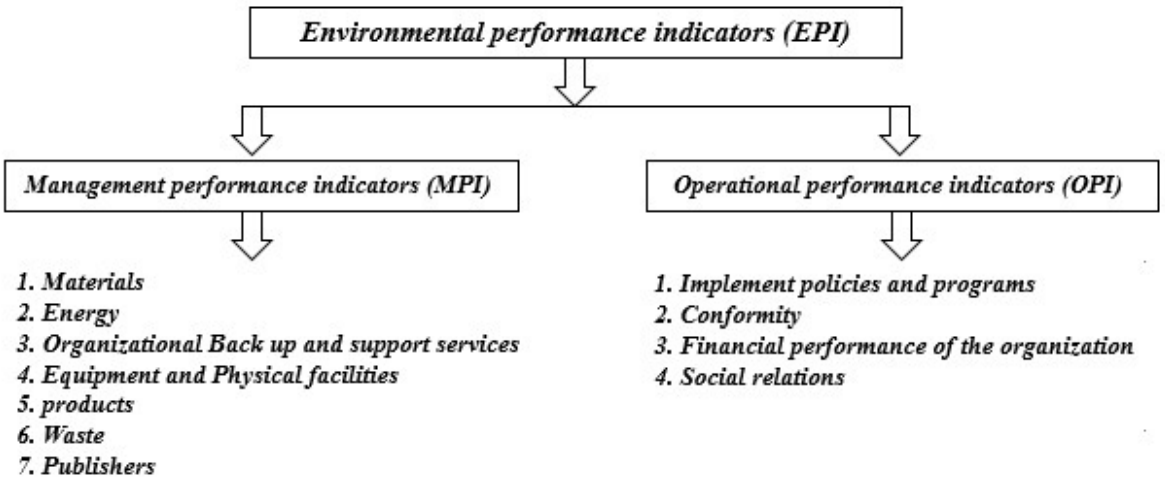

Figure 4. The block diagram of the Environmental Performance Evaluation (EPE) [34]

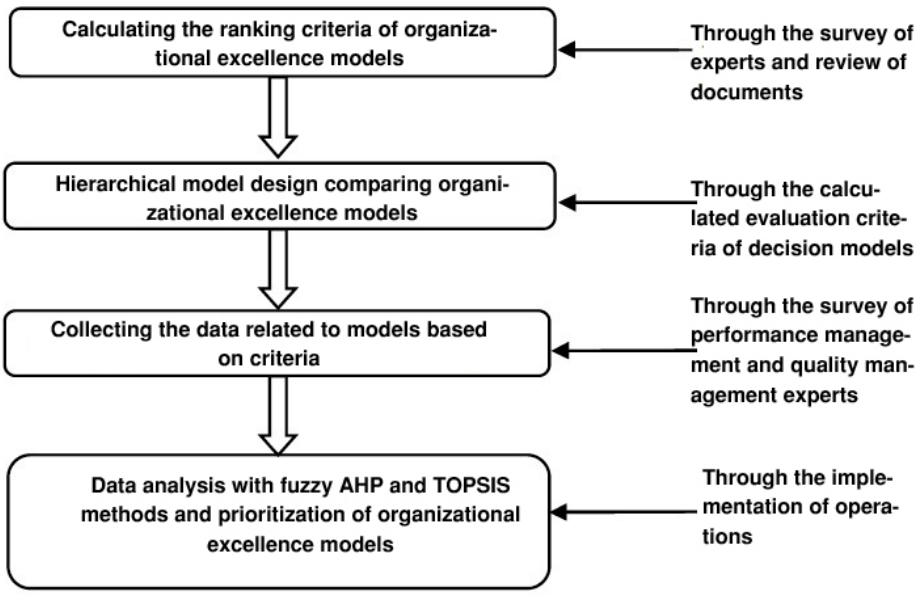

Figure 5. Implementation steps of the research process to determine the best model to evaluate the environmental performance of gas refineries

ment. The maximum sample was randomly determined 20 people based on the Cochran formula for multicriteria decision-making. The research data were collected by questionnaire based on environmental performance evaluation indicators (research options). Considering the existence of 22 professionals and HSE managers and officials in the SPGC who had experience and skills and taking into account the 5% error level, the study sample of 20 people was selected (Table 1). They are chosen by the snowball method.

The experts agreed upon 4 main criteria of the capability to quantify quality data for environmental performance, facilitating, efficient implementing, structuring, and mapping a roadmap of organization maturity to select an environmental performance.

Data analysis method

In this study, the collected data should be analyzed and turned into information that describes the environmental performance of the organization (gas refineries). In other words, they are expressed as an evaluation of environmental performance. To avoid prejudging in achieving the results, all reliable and relevant data already collected were also considered.

The accuracy, adequacy, and completeness of the data are also considered in the data analysis. Finally, fuzzy AHP and TOPSIS were utilized to measure the sub-criteria and extracted indicators.

Fuzzy TOPSIS

The fuzzy TOPSIS technique is a generalization based on the TOPSIS technique in a fuzzy environment. Hwang and Yoon introduced the TOPSIS technique in 1981.

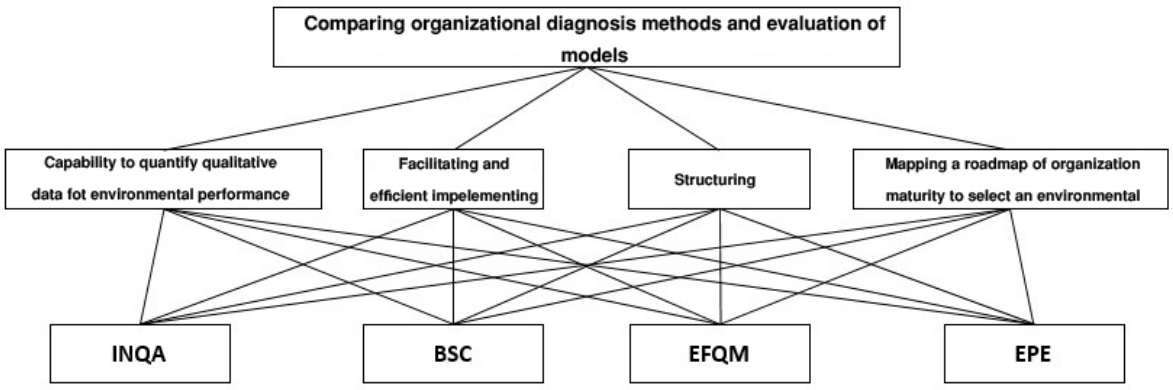

Figure 6. Research model based on hierarchical structure to prioritize research models

Table 1. Characteristics of experts in the research sample

Expertise	Degree of Education	No.	Description
HSE management	Master and higher	4	Inside of the organization (SPGC)
Operations management	Master	2	Inside of the organization (SPGC)
Refining engineering	Master	2	Inside of the organization (SPGC)
Technical inspection	Master	2	Inside of the organization (SPGC)
Repairs	Bachelor and Master	3	Inside of the organization (SPGC)
Financial management	Master	1	Inside of the organization (SPGC)
Real estate and green space	Master	1	Inside of the organization (SPGC)
Operation	Master	2	Inside of the organization (SPGC)
Environmental management	Master and PhD.	3	Outside of the organization (provincial directorate of environment and city directorate of the environment)

SPGC: South Pars Gas Complex; HSE: Health, Safety, and Environmental.

TOPSIS underlying logic is the definition of positive and negative ideal solutions. A positive ideal solution maximizes profit criteria and minimizes cost criteria. The ideal negative solution maximizes cost criteria and minimizes profit criteria. The optimal option is the closest option to the positive ideal solution and the farthest option from the negative ideal solution. In short, the positive ideal solution is a combination of the best achievable values of the criteria, while the negative ideal solution contains the worst achievable values of the criteria.

AHP technique

In decision-making science, in which the selection of a strategy among the existing strategies or the prioritization of strategies is discussed, recently Multicriteria Decision-Making (MCDM) methods have been introduced. In such decisions, several indicators or targets that are sometimes contradictory are considered. If the MCDM refers to the attribute indicator criteria, it is known as a MADM (multi-attribute decision-making). If the MCDM refers to the objective indicator criteria, it is called Multi-Objective Decision-Making (MODM). One of the first decision-making methods with MADM indicators is the AHP method, which has been utilized more than other methods in management science.

3. Results and Discussion

The growing expansion of industries and scientific advances has created new horizons of environmental impacts, and different outcomes of health and safety categories are detected each year [34]. As mentioned before, projects of upstream petrochemical industries in the country showed that in previous programs, natural and environmental values had been overlooked [35]. The result of such measures has been the occurrence of various pollutions and severe destruction of environmental resources [19]. So, large industries such as refineries are increasingly moving towards integrated HSE

Table 2. Pairwise comparison matrix of criteria of four research models

Comparison Criterion	Criterion 1	Criterion 2	Criterion 3	Criterion 4	Geometric Mean	Normal Weight
Criterion 1	1.00	3.00	0.25	3.00	1.22	0.3039423
Criterion 2	0.33	1.00	1.00	2.00	0.90	0.2242449
Criterion 3	4.00	1.00	1.00	0.20	0.95	0.2347026
Criterion 4	0.33	0.50	5.00	1.00	0.96	0.2371102

Criterion 1: The capability to quantify qualitative data for environmental performance; Criterion 2: Facilitating, efficient implementing; Criterion 3: Structuring; and Criterion 4: Mapping a roadmap of organization maturity to select an environmental performance.

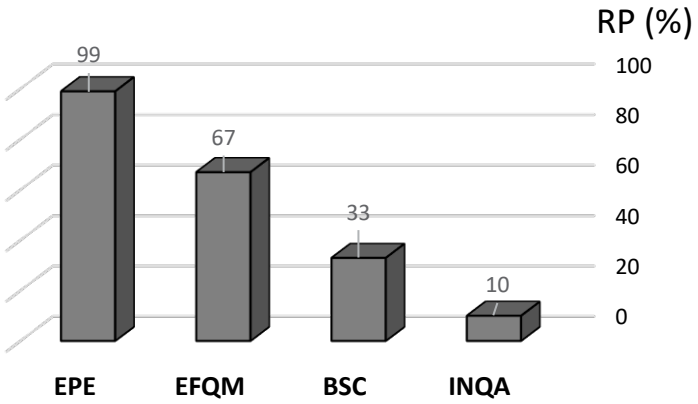

Figure 7. Ranking the EPE models according to the degree of proximity to the positive ideal solution and distance from the negative ideal solution in the TOPSIS method

management systems and trying to achieve the goals of the vision documents of these systems [22]. These organizations always encounter the inevitable requirements to meet the challenge of environmental protection, and proper environmental management has become a factor in the success of these organizations [36].

Proper environmental management of an organization depends on the EPE of the organization to realize and improve the managing elements of the organization's activities, products, and services that interact with the environment [37]. However, ISO 14031 provides instruction for assessing and monitoring the ecological performance of an organization [23]. Unfortunately, measuring these indicators has remained one of the biggest challenges and problems of organizations, especially competent institutions [23]. Several models have been proposed to evaluate environmental performance in Iran [37, 38]. In this research, according to the experts, four models of INQA, BSC, EFQM, and EPE were evaluated. The analyses results were identified by a conceptual model of the research using the fuzzy AHP method

Table 3. The index score of four criteria to evaluate research models

Evaluation Models	Criterion 1	Criterion 2	Criterion 3	Criterion 4
INQA	5	7	7	6
BSC	6	6	8	6
EFQM	7	6	8	8
EPE	8	7	6	8

INQA: Iran national quality award; BSC: Balanced Scoring Card; EFQM: European foundation for quality management; EPE: Environmental performance evaluation.

Table 4. The normal score of criteria for each evaluation model based on the weight obtained from AHP

Evaluation Models	Criteria 1	Criteria 2	Criteria 3	Criteria 4
INQA	0.303942	0.224245	0.234703	0.23711
BSC	1.519712	1.569714	1.642918	1.422661
EFQM	1.823654	1.345469	1.877621	1.422661
EPE	2.127596	1.345469	1.877621	1.896882

INQA: Iran national quality award; BSC: Balanced Scoring Card; EFQM: European foundation for quality management; EPE: Environmental performance evaluation.

Table 5. The prioritization of an organization's EPE models based on TOPSIS

Performance evaluation models		Criteria 1	Criteria 2	Criteria 3	Criteria 4
Calculation of the Score Index	INQA	0.379049	0.536875	0.479632	0.424264
	BSC	0.454859	0.460179	0.548151	0.424264
	EFQM	0.530669	0.460179	0.548151	0.565685
	EPE	0.606478	0.536875	0.411113	0.565685
Index weights using Shannon's entropy	INQA	0.192308	0.269231	0.241379	0.214286
	BSC	0.230769	0.230769	0.275862	0.214286
	EFQM	0.269231	0.230769	0.275862	0.285714
	EPE	0.307692	0.269231	0.206897	0.285714
	E	0.989241	0.997864	0.995176	0.992614
	D	0.010759	0.002136	0.004824	0.007386
	W	0.428551	0.00274	0.006188	0.009474
Balanced non-scale matrix	INQA	0.082414	0.000738	0.001494	0.00203
	BSC	0.098896	0.000632	0.001707	0.00203
	EFQM	0.115379	0.000632	0.001707	0.002707
	EPE	0.131862	0.000738	0.00128	0.002707
	MAX	0.131862	0.000738	0.001707	0.002707
	MIN	0.082414	0.000632	0.00128	0.00203

INQA: Iran national quality award; BSC: Balanced scoring card; EFQM: European foundation for quality management; EPE: Environmental performance evaluation, E: entropy values of each criteria, D: degree of the intrinsic information of each criteria, W: weights of each criteria.

after distributing the pairwise comparison questionnaire to the target population.

The pairwise comparison matrix of the criteria of four research models depicted that the geometric mean of the evaluation criteria of the capability to quantify quality data for environmental performance, facilitating, efficient implementing, structuring, as well as mapping a roadmap of organization maturity to select an environmental performance was estimated as 1.22, 0.90, 0.95, 0.95, and 0.96, respectively. Normal weights of these four criteria are 0.3039423, 0.2242449, 0.2347026, and 0.2371102, respectively (Table 2).

Elite scores for each model were estimated based on the above comparison criteria, from the lowest number 1 to the highest number 9 (Table 3), and the normal score based on the weight obtained from AHP to apply the TOPSIS process, and prioritize the models (Table 4). The current results of prioritizing the organization's EPE models based on TOPSIS (Table 5) showed that the proposed model of the EPE with the relative proximity of 99% is the priority of the EPE for gas refineries (Figure 7).

Abbreviations: INQA, Iran national quality award; BSC, balanced scoring card; EFQM, European foundation for quality management; EPE, environmental performance evaluation.

The results depicted that the proposed model of the EPE with the relative proximity of 99% is the first choice for the gas refinery evaluation.

A comprehensive performance evaluation system is a necessity for public and private organizations. Of course, the intensity of performance evaluation models makes it difficult for organizations to select the optimal model. Many models have been and are helpful to evaluate the performance in different situations [9]. The current study showed that the EPE model is more suitable to assess the performance of gas refineries than other models. In the field of the application of performance evaluation models, there are many studies in which one or at most two models have been utilized independently or in combination in the organization and presented the model implementation results. For instance, because of the growing awareness of intellectual property rights in European research institutes and the sensitivity of this issue, Smandek et al. [39] used the BSC model to overcome the conflict of expectations in this area. Maria del Mar Alonso-Almeida and Fuentes-Frías [16] reported that researchers in many countries believe that the international quality awards and quality excellence models are the appropriate formats for growth and promotion to achieve excellence criteria in the fields of TQM. In contrast, Azar et al. [9] have considered the scoring card model and the organization excellence model as the best models. Williams et al. [40] also reported that most of the businesses are trying to improve the performance of their organization through the use of excellence models, such as the European Foundation's Quality Excellence Model. The authors note that most of these organizations have recently expressed dissatisfaction with using these models.

Although in this investigation, the defaults and philosophy of models are part of the comparative criteria, the main goal is to compare the models and select the optimal model to conduct research, not just deal with one or more models. Indeed, according to the research method, which is a hierarchical analysis process, the models are not measured independently based on the criteria but are confronted with each other. The score of models makes sense with pairwise comparisons of the criteria [41].

4. Conclusion

The studies show that the environmental issues affecting all gas refineries require managers to formulate strategies to conserve natural resources and curb environmental pollution. The EPE provides good ideas to establish the basis for remedial actions in the areas where the performance has not improved significantly or even declined. Unfortunately, in domestic organizations and companies, there is inadequate data on the environmental dimensions of various production, design, development, and after-sales service processes because of inattention to the environment category in recent years. However, in the organization's missions, they must pay attention to environmental values, set long-term goals from an environmental perspective, and implement programs to train staff and managers to protect the environment.

This study is the first effort to extract the weight or importance of evaluation models written in the gas refinery industries. The results showed that the proposed model of the EPE assessment is relatively close to 99% and has priority over other models to assess the environmental performance of the gas refinery.

Ethical Considerations

Compliance with ethical guidelines

The authors certify that all data collected during the study are as stated in the manuscript. This manuscript is the original work of the authors, and no data from the study have been published elsewhere.

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Authors' contributions

All authors were equally contributed in preparing this article.

Conflict of interest

The authors declared no conflict of interests.

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