Proceedings of the International Conference on Industrial Engineering and Operations Management
Paris, France, July 26-27, 2018

Employing Multiple Criteria Decision Making to Evaluate HSE Performance of Contractors Case study : Lorestan Province Gas Company

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Abstract

Evaluating the HSE performance of contractors is a major step in the contractor management process. Given the ever-increasing presence of contractors in the gas industry and the key role of HSE performance in continuous improvement, certain methods appear to be necessary for evaluating the

performance of contractors. Therefore, this study aimed to propose an applied model for the HSE performance evaluation of contractors.

Complying with HSE requirements in project management can ensure the health and safety of employees, clients, and contractors, and also a clean environment. Thus, sustainable development and increased productivity can be achieved. Deployment (or Implementation) of HSE frameworks in the workplace will largely reduce accidents, injuries, and environmental impact or their consequences. At the same time, concepts such as customer orientation and premium quantity and quality of industries require contractors to adopt appropriate solutions and equipment resulting in the formation of their performance evaluation index.

Identifying the key indices of HSE performance for management evaluation and analysis can reduce risk, potential environmental factors, and harmful factors in addition to improving safety, which subsequently lead to improvement of relevant operations.

Important evaluation indices of HSE management system performance were determined for analysis of five active contractors based on HSE performance evaluation manual of NIGC[1] contractors and a survey conducted on the HSE experts of the Gas Company ofLorestan Province.The weight of every index was then determined using AHP technique and Expert Choice application. Finally, contractors were ranked using TOPSIS method.

Keywords : performance evaluation , HSE-MS , contractor , AHP , TOPSIS

1. Introduction

In today's world, many companies and organizations, as well as large and small industries such as oil, gas, and petrochemical industries have realized preventing accidents and damageto health, safety, and environment requires establishment of an integrated Health, Safety, and Environment Management Systems (HSE-MS) (Taghdisi & Alizadeh). Moreover, health and safety of employees, customers, contractors and others, as well as a healthy environment, can be provided using this system and employing it in project management with the purpose of achieving sustainable development and increasing productivity (Shahkarami & Msyneh). Therefore, establishing a structure such as HSE-MS in workplaces (including contractor workplace) can reduce the rate of accidents, injuries, and environmental issues and decrease their consequences (Espinosa et al).

On the other hand, certain concepts such as customer orientation, premium quantity and quality, and especially business competition can force industries and companies, including contractors, to adopt appropriate solutions and methods. One of such methods is contractor performance evaluation, which let companies identify service-providing contractors (Mdqalchy, Sbhyeh & Talebi).

A major component of contractor HSE-MS mechanism is the HSE performance evaluation of contractors. It bears special importance in the implementation of a project (Mahmoudi et al) because it results in continuous

[1] National Iranian Gas Company

improvement in the HSE performance of contractors. Such an improvement will have a significant effect on organizational status and projects of employers (Mohamadfam , Kianfar & Taheri). As a result, the rates of work-related accidents and diseases will decrease (Azadeh & Mohammadfam). According to the statistics, outsourcing rate of projects to contractors has been significantly increases in various areas. This increases the risks and responsibilities passed on from employers to contractors. Moreover, mismanagement and improper HSE evaluation of contractors can impose irrecoverable physical and financial losses on employers, industries, and society (Mohammadfam & Zarei).

Therefore, management of contractors in terms of HSE is the responsibility of employers while contractors are responsible for complying with HSE requirements. However, both parties will pledge to protect the health and safety of employees and the environment (Dejban Khan).In addition to establishment of HSE-MS in different oil, gas, and petrochemical companies in recent years, supervision and evaluation of their performance has also been increased significantly and effective measures have been taken to improve safety, health, and environmental performance levels (Rshtchyan , Hashemi & Abdalhamydzadh).

Thus, it appears essential to adopt a method for contractor performance evaluation due to the growing trend in the employment of different contractors in oil, gas, and petrochemical industries and major role of HSE performance in continuous improvement. In the performance evaluation process, an important step is to determine appropriate performance attributes in the operational boundaries of the organization under examination. Therefore, this study used 10 key evaluation attributes to evaluate HSE performance of contractors working at the Gas Company of Lorestan Province, based on HSE Performance Evaluation Manual of NIGC Contractors (Code 106) as well as the opinion of HSE experts of the company.

2. Multiple Criteria Decision Making (MCDM)

Multiple Criteria Decision Making (MCDM) models are divided into Multiple Objective Decision Making (MODM) and Multiple Attribute Decision Making (MADM) models. The MODM model can simultaneously focus on several contradictory objectives and provide the best solution through mathematical planning methods. The MODM model considers relative superiority of objectives and relationships between objectives and attributes.

The MADM model is used to select the best option out of a set of proposed options by considering evaluation attributes of every option. This model is characterized by ease of use. Hybrid procedures (if combined properly) can maintain such an advantage and preserve multiple sources of knowledge and experience. Therefore, AHP and TOPSIS can be combined to make more efficient decisions because disadvantages of one technique can be covered by advantages of the other. In such models, decision-makers try to select the best option with respect to the set target and available attributes. These modelsare widely used in ranking problems and thus, they are also known as ranking models (Hwang).

2.1. AHP

The Analytic Hierarchy Process (AHP) is one of the most famous multipurpose decision-making techniques. It was first introduced by Thomas L. Saaty in 1970. The AHP can be used when there are multiple competing options and criteria for making decisions. These criteria can be quantitative and qualitative. AHP method is based on pairwise comparisons. Decision-makers starts the process by creating a decision hierarchy tree, which indicates compared

factors and evaluated contradictory options for a decision. Then a series of pairwise comparisons should be drawn to determine the weight of each factor for contradictory options. Finally, the AHP logic mixes pairwise comparison matrices to make an optimal decision.

2.2. TOPSIS

In this method, introduced by Hoang and Yun in 1981, *m* options are evaluated by means of*n* attributes. Every problem can be regarded as a geometrical system including *m* points in an *n*-dimensional space. This technique was based on the idea that a selected option should be on the shortest distance from the positive ideal solution (the best possible attribute, A_i^+) and the longest distance from the negative ideal solution (the worst possible attribute, A_i^-). It is assumed that the desirability of every attribute is evenly ascending or descending.

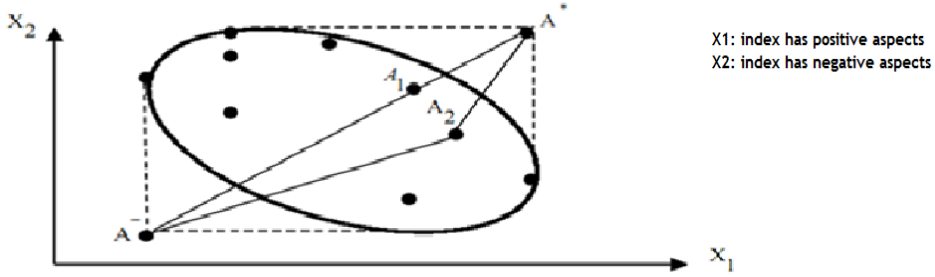

Figure1 : The positive ideal solution and negative ideal solution

TOPSIS can solve a problem in six steps :

1. Use the Euclidean norm to convert the decision matrix D into an unscaled matrix, named N_D.

$$N_{ij} = \frac{r_{ij}}{\left(\sum_{i=1}^{m} r_{ij}^2\right)^{\frac{1}{2}}} \text{ و } (i = 1, \dots, m) \text{ و } (j = 1, \dots, n)$$

2. Obtain the weighted-unscaled matrix, in which v is the weighted-unscaled matrix, and w is a diagonal matrix of weights obtained for attributes.

$$V_{m\times n} = N_{m\times n} \times W_{n\times n}$$

3. Determine the positive and negative ideal solutions (A_i^+, A_i^-), in which V^+_j and V^-_j indicate the positive and negative ideal solutions for the jth attribute, respectively.

$$\text{positive ideal solution} = A^+ = \left\{\left(\max_i v_{ij} | j \in J^+\right), \left(\min_i v_{ij} | j \in J^-\right) | i = 1,2, \dots, m\right\}$$

$$\text{negative ideal solution} = A^- = \left\{\left(\min_i v_{ij} | j \in J^+\right), \left(\max_i v_{ij} | j \in J^-\right) | i = 1,2, \dots, m\right\}$$

$$A_i^+ = (v_1^+, v_2^+, \dots, v_n^+) \quad \text{and} \quad A_i^- = (v_1^-, v_2^-, \dots, v_n^-)$$

$$J^+ = \{j | j = 1,2, \dots, n\} \quad \text{and} \quad J^- = \{j | j = 1,2, \dots, n\}$$

4. Calculate the distances from A_i to the positive and negative ideal solutions by using the Euclidean method.

$$d_i^+ = \left\{\sum_{j=1}^{n} \left(v_{ij} - v_j^+\right)^2\right\}^{\frac{1}{2}}, (i = 1,2, \dots, m)$$

$$d_i^- = \left\{\sum_{j=1}^{n} \left(v_{ij} - v_j^-\right)^2\right\}^{\frac{1}{2}}, (i = 1,2, \dots, m)$$

5. Calculate the relative proximity of A_i to the ideal solution in the following way:

$$CC_i = \frac{d_i^-}{(d_i^- + d_i^+)} \quad , \quad (i = 1,2, \dots, m)$$

(if $A_i = A_i^-$, then $d_i^- = 0$ and $CC_i = 0$) (If $A_i = A_i^+$, then $d_i^+ = 0$ and $CC_i = 1$)

6. Rank options in accordance with the CC_idescending order basedon their importance(Azar & Rajabzadeh).

3. Case Study

In this study, AHP and TOPSIS were employed to select the top solutions for the evaluation of HSE performance of contractors working at the Gas Company of Lorestan Province by selecting five contractor companies operating in the projects implemented by this company. The evaluation attributes of HSE performance of contractors were determined in accordance with the HSE Performance Evaluation Manual of NIGC Contractors and a survey conducted on HSE experts at the Gas Company of Lorestan Province. Table 1 shows the attributes in three areas of health, safety, and environment.

Table 1: Evaluation attributes of HSE performance of contractors

Area	Attributes
Health	H1 Status on housekeeping the workplace H2 Status on monitoring harmful factors of the workplace and presenting results H3 Status on upon-recruitment, periodic, etc. medical examinations of employees
Safety	S1 Status on personal protection equipment (allocation, supply, distribution, and use) S2 Status on safety in operations (welding, hot tap, gas injection, work at height, repair and maintenance, etc.) S3 Status on machinery safety S4 Status on permits to work
Environment	E1 Status on activities for preventing pollution and environmental destruction E2 Status on enforcement of the waste management law and its procedure throughout the agreement E3 Status on proper management of hydrocarbons, used batteries, and decayed rubbers at site

3.1. Rank of contractors using Analytic Hierarchy Process (AHP)

First, the decision hierarchy tree should be drawn to select the best contractor:

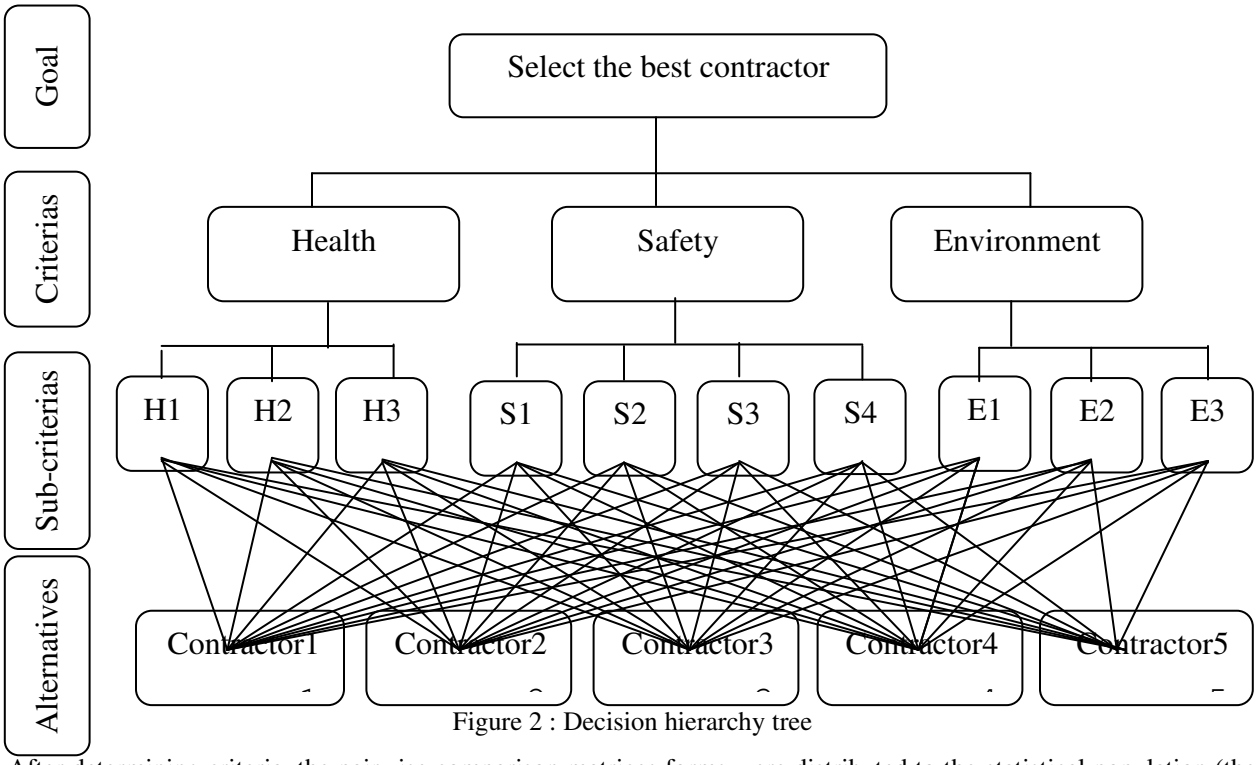

Figure 2 : Decision hierarchy tree

After determining criteria, the pairwise comparison matrices forms were distributed to the statistical population (the HSE experts of the Gas Company of Lorestan Province). A nine-point Saaty's scoring scale was used in the following manner :

Table 2 : Distance scale

Preferable value	i-j comparison status	Explain
1	Equally Preferred	attribute i is as important asj with no superiority
3	Moderately Preferred	attribute i is less important than j
5	Strongly Preferred	i is more important than j
7	Very Strongly Preferred	attribute i is much more preferable than j
9	Extremely Preferred	attribute i is absolutely more important than j
2 , 4 , 6 , 8	Middle	The middle values indicate a score between preferable values. For instance, 8 shows a higher importance than7 and a lower importance than 9 for i

The resultant data were used to draw pairwise comparisons of criteria and calculate the inconsistency rate in Expert Choice.

A very important advantage of AHP method is the consistency measurement and control for every matrix and decision. The acceptable inconsistency range depends on the decision-maker of a system. However, in general, Saaty method suggeststhe decision-makers to revise their judgments if the inconsistency rate of a decision exceeds 0.01.

The weights of major criteria and sub-criteria were determined by completion of pairwise comparisons in Expert Choice, as presented in the following tables.

Table 3 : Weights of major criteria

Criteria	Health	Safty	Environment
Weight	0.243	0.669	0.088

Table 4 : Weights of sub-criteria

Sub-criteria	H1	H2	H3	S1	S2	S3	S4	E1	E2	E3
Weight	0.163	0.540	0.297	0.050	0.398	0.153	0.398	0.230	0.648	0.122

Figures 1-3 show the priorities of contractors with respect to each of the major criteria. Figure 4 indicates the final prioritization of options with respect to the Goal.

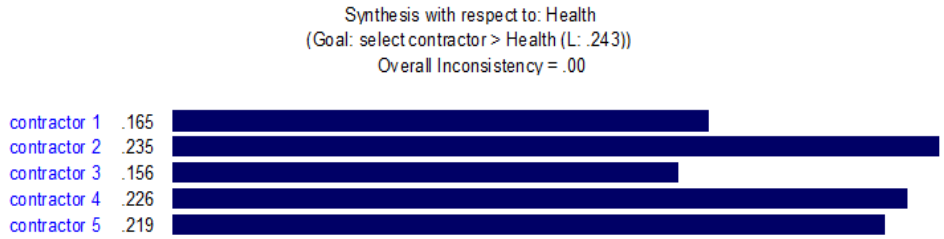

Chart 1 : Prioritize of contractors with respect to Health criteria

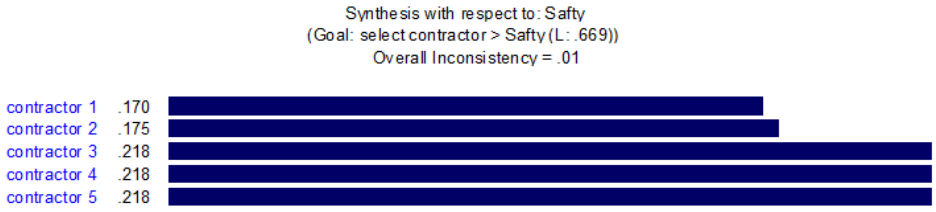

Chart 2 : Prioritize of contractors with respect to Safty criteria

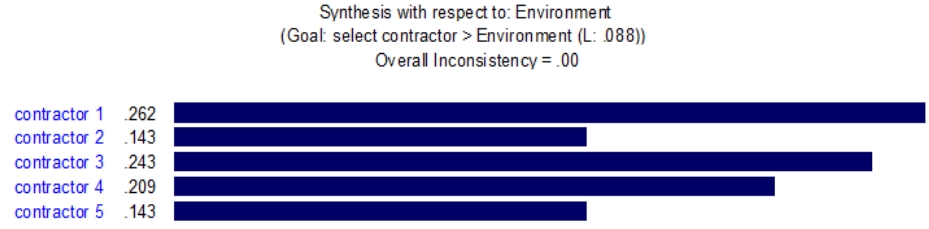

Chart 3 : Prioritize of contractors with respect to Environment criteria

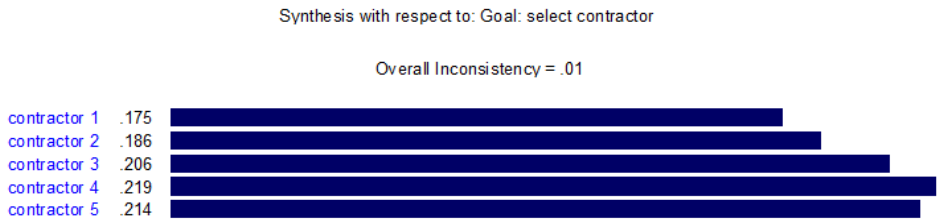

Chart 4 : Prioritize of contractors with respect to Goal

AHP method was employed in Expert Choice to rank contractors by HSE performance based on Figure 4.

Table 5 : Rank of contractors using AHP

contractor	Contractor1	Contractor2	Contractor3	Contractor4	Contractor5
Rank	5	4	3	1	2

3.1.1. Sensitivity analysis

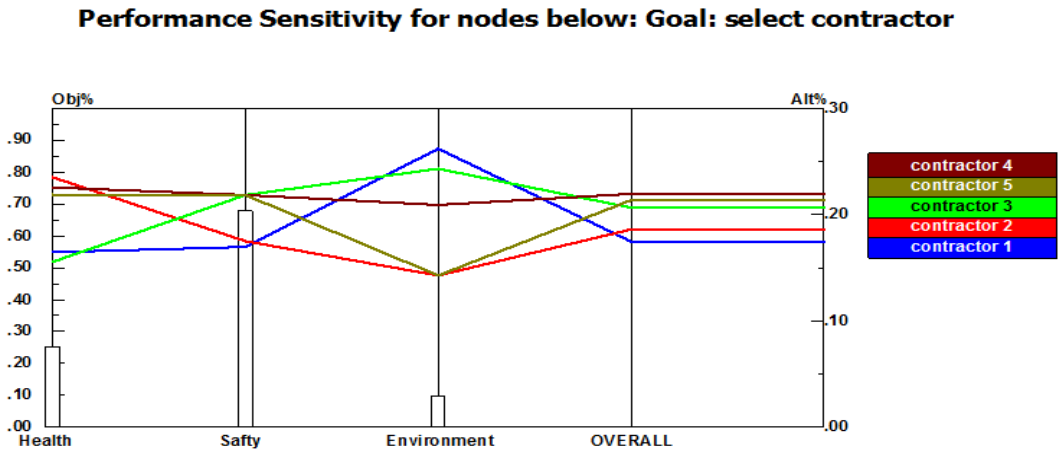

Chart 5 : Sensitivity analysis chart

The sensitivity analysis chart indicates that Contractor no. 4 has the highest level of sensitivity to criteria. In other words, experts gave higher scores to its sub-criteria. Moreover, Contractor no. 1 has the highest level of sensitivity to environmental criteria. In other words, Contractor o. 1 was more efficient in the environment than others were.

3.2. Rank of contractors using TOPSIS

TOPSIS was employed to rank contractors by using the weights of sub-criteria obtained from the AHP.

First, the decision-making matrix was formed for the five contractor companies by using the values of quantitative HSE performance of contractors, scored from 0 to 4 by project supervisors.

Table 6 : Decision-making matrix

	H1	H2	H3	S1	S2	S3	S4	E1	E2	E3
C1	2	3	2	3	3	3	4	3	4	4
C2	3	3	4	4	3	3	4	3	3	3
C3	2	2	4	4	4	3	4	3	4	3
C4	2	3	4	4	4	3	4	4	3	4
C5	4	3	3	4	4	3	4	3	3	3

The contractors were then ranked after using TOPSIS to solve the problem.

Table 7 : Ranked of contractors using TOPSIS

	d_i^+	d_i^-	CC_i	Rank
C1	0.110	0.121	0.524	4
C2	0.107	0.118	0.523	5
C3	0.107	0.124	0.537	3
C4	0.100	0.130	0.564	1
C5	0.099	0.119	0.544	2

Table 7 indicates that AHP and TOPSIS can be combined to rank HSE performance evaluation of contractors more accurately.

4. Discussion & conclusion

Important evaluation indices of HSE management system performance were determined for analysis of five active contractors based onHSE performance evaluation manual of NIGC contractors and a survey conducted on the HSE experts of the Gas Company ofLorestan Province.The weight of every index was then determined using AHP technique and Expert Choice application. Finally, contractors were ranked using TOPSIS method.

Examination of the results revealed a relatively acceptable status of contractors in terms of HSE management. This was consistent with the other findings and the results of citation and observation checklists indicating the commitment of contractors to HSE requirements of employers.

In general, despite the significance of score volatilities in every specialized area (positive in most cases), the HSE-MS structure and relevant culture are still in the transition and establishment stage. However, periodic auditing and constant supervision can significantly facilitate this process. Moreover, employers should pay more attention to necessity of devising an encouragement system, attracting more participants and continuous trainingof employees in relevant areas in order to improve the HSE performance.

The proposed model can be used by the employers of large organizations to evaluate the HSE performance of their contractors. Furthermore, the output of performance evaluation process can be employed to rank contractors by their HSE performance. This ranking can be used as an input to select contractors for the next projects.

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