Environ Monit Assess (2012) 184:2981–2991
DOI 10.1007/s10661-011-2165-9

A strategic management model for evaluation of health, safety and environmental performance

**Majid Abbaspour · Solmaz Toutounchian ·
Emad Roayaei · Parvin Nassiri**

Received: 11 October 2010 / Accepted: 3 June 2011 / Published online: 8 July 2011

Abstract Strategic health, safety, and environmental management system (HSE-MS) involves systematic and cooperative planning in each phase of the lifecycle of a project to ensure that interaction among the industry group, client, contractor, stakeholder, and host community exists with the highest level of health, safety, and environmental standard performances. Therefore, it seems necessary to assess the HSE-MS performance of contractor(s) by a comparative strategic management model with the aim of continuous improvement. The present Strategic Management Model (SMM) has been illustrated by a case study and the results show that the model is a suitable management tool for decision making in a contract environment, especially in oil and gas fields and based on accepted international standards within the framework of management deming cycle. To develop this model, a data bank has been created, which includes the statistical data calculated by converting the HSE performance qualitative data into quantitative values. Based on this fact, the structure of the model has been formed by defining HSE performance indicators according to the HSE-MS model. Therefore, 178 indicators have been selected which have been grouped into four attributes. Model output provides quantitative measures of HSE-MS performance as a percentage of an ideal level with maximum possible score for each attribute. Defining the strengths and weaknesses of the contractor(s) is another capability of this model. On the other hand, this model provides a ranking that could be used as the basis for decision making at the contractors' pre-qualification phase or during the execution of the project.

Keywords Performance · Evaluation · Management · Environment · Safety · Health

M. Abbaspour
School of Mechanical Engineering, Sharif University of Technology, Tehran, Iran

S. Toutounchian (✉)
Graduate Faculty of Environment and Energy, Science and Research Campus, IAU, PO Box 14515–775, Tehran, Iran
e-mail: solmaztoutounchian@yahoo.com

E. Roayaei
Research & Technology, EOR Research Institute, National Iranian Oil Company (NIOC), Tehran, Iran

P. Nassiri
Department of Environmental Health Engineering, School of Public Health, Tehran University of Medical Science, Tehran, Iran

Introduction

Some industrial activities have contractual obligations towards health, safety, environment, and quality (HSEQ) issues. For example, exploration and production of oil and gas are governed by a wide range of regulations related to HSEQ issues and all companies involved in this field follow a specific strategy in order to meet their legal and operational requirements. To this end, world-renowned oil companies, particularly in Europe, have designed the HSEQ management system strategy, which is a part of their comprehensive management system. These companies pursue all the activities related to these four factors simultaneously and under the Integrated Management System (Abbasi 2004). The HSEQ Management System is a managerial tool to control and improve issues related to health, safety, environment, and quality in all development plans and industrial/infrastructural projects (Lindsay 1992). By analyzing these four factors simultaneously, this system provides the appropriate infrastructure for the implementation and execution of the Environmental Management System (ISO 14000), Occupational Health and Safety Assessment Series (OHSAS 18000), and ultimately the Quality Management System (ISO 9000) (UNEP & Exploration and Production Forum 2000).

Records and safety statistics have generally indicated that contractors' employees are involved more frequently in incidents compare to the employees of the mother company. They may be less familiar with site-specific hazards than the mother company's employees. For these reasons, it is particularly important to consider how the HSE-MS of a company (either a principal or a contracting organization) is compatible with that of the contractors and sub-contractors (E & P Forum 1994).

One of the most important strategic contract management decisions to be made by the company is how the contractor, or alliance of contractors, is held responsible for the management of HSE. Two distinctive modes are described below:

Model 1: "The contractor provides human resources and tools for the execution of work under the supervision, instructions and HSE-MS of the company. The contractor has a management system to provide assurance that the personnel for whom he is responsible are qualified and in good health for the job and that the tools and the provided machinery are properly maintained and suitable for the job."

Model 2: "The contractor executes all aspects of the job under its own HSE Management System, provides the necessary instructions and supervision and verifies the proper functioning of its HSE Management System. The company is responsible for verifying the overall effectiveness of the HSE management, controlling put in place by the contractor, and assuring that both the company's and the contractor's HSE-MS are appropriately compatible." (OGP, IMCA & IAGC 1999)

Success of almost any business relies upon selecting and implementing the most suitable project(s) and cooperating between the projects contractor(s)/sub-contractor(s), which bring maximum benefit to the organization in both short and long terms. The added value by the project could take many forms and shapes. It could be monetary or non-monetary; qualitative or quantitative, and tangible or intangible (Sherif and McCowan 2001). It has been correctly argued that fulfilling the needs of an organization through selection and implementation of suitable projects and selecting qualified contractor(s)/sub-contractor(s) are quite a challenge (Melone and Wharton 1984), which if conducted properly, could lead to strategic optimal allocation of resources (Doss Santos 1989). Many different tools and techniques have been developed to assist in projects and their contractor(s)/sub-contractor(s) selection. The models include a wide range of quantitative and qualitative approaches including: scoring (Meredith and Mantel 2001), ranking (Meredith and Mantel 2001; Buss 1983), decision trees (Hess 1993), polar plot (Badiru 1995), Delphi technique (Lygun 1993; Riggs et al. 1992), Analytic Hierarchy Process (Schniederjans and Wilson 1991), and many other mathematical programming-based approaches using linear, nonlinear, integer, and even quadratic programming, cited in (Badri and Davis 2001).

So the comparative quantitative strategic management model, which is based on Deming management cycle, has been developed to screening the contractors according to their HSE performance that could be used as a basis for decision making at the contractors' pre-qualification phase or during the execution of the project. Finally, the model has been illustrated by a case study in oil and gas field.

Materials and methods

Methodologies for conducting and documenting the HSE-MS evaluation may involve the use of questionnaires, checklists, interviews, measurements, and direct observations, depending on the nature of the function being audited (OGP, IMCA & IAGC 1999).

The required data are usually achieved by issuing a standard format document for the contractor to complete, supported where necessary by additional performance records. As a means to streamline the process, the adequate questionnaire can be used. By implementing this standard format, both the company and contractors can devote their resources to improve HSE performance rather than to reformat existing information into a variety of formats.

A point system method, which minimizes subjective judgment, may be used to evaluate contractors' submissions. Contractors that achieve a predefined acceptable score will then be judged on the HSE pre-contract requirements.

The model provides a tool for comparing alternative contractor(s)/sub-contractor(s) in a contract environment analytically. The basis of the decision is an integrative approach rather than a single measure of comparison. The motive behind the development of this model is to integrate these individual approaches, attributes or measures of HSE performance on the basis of quality management system approaches. Having done the analysis, the results (using a variety of QMS models) could be integrated. The model is based on measuring, assessing, deciding, and calculating four attributes (Plan, Do, Check, and Act) and contributing factors or measures of HSE-MS performance at a time for each contractor/sub-contractor. The attributes are used in a six-step process. The steps of decision making process and recommendation or selection on the best contractor/sub-contractor are as follows:

1. Measure, calculate, assess or decide on the HSE value of the QUALITY attributes for each contractor(s)/sub-contractor(s).
2. Normalize the HSE values of the QUALITY attributes using a scale of 0–10.
3. Use two perpendicular axes to show the four QUALITY attributes.
4. Mark the HSE value of 10 on each attribute axis and form the ideal contractor(s)/sub-contractor(s) square by joining the points sequentially. The ideal contractor(s)/sub-contractor(s) are the ones with a value of 10 (or closest to 10) for all the attributes.
5. Mark the HSE values of each QUALITY attribute on the corresponding attribute axis and form the tetragonal associated with each alternative (contractor(s)/sub-contractor(s)) by joining the points corresponding to each project on the four axes.
6. Calculate the area of each tetragonal by adding the area of the four triangles forming the tetragonal and finding the ranking of each alternative by dividing the area of the tetragonal to the area of the ideal contractor/sub-contractor square.

However, for the developed model below, only four factors/attributes could be integrated into the model. Assuming there are four alternatives or projects to choose from and that a_{ij} shows the value of the quality attribute j for contractor(s)/sub-contractor(s) i (a_{max} and a_{min} are the maximum and minimum possible values for a given quality attribute). The set of information required to deal with project selection is shown in Table 1:

According to the six-step process, the values in the table need to be standardized or normalized.

Table 1 Matrix of QUALITY attributes associated with the project alternative

Attributes → ↓ Contractor	$a_{1=Attribute(P)}$	$a_{2=Attribute(D)}$	$a_{3=Attribute(C)}$	$a_{4=Attribute(A)}$
C_1	a_{11}	a_{12}	a_{13}	a_{14}
C_2	a_{21}	a_{22}	a_{23}	a_{24}
C_3	a_{31}	a_{32}	a_{33}	a_{34}
C_4	a_{41}	a_{42}	a_{43}	a_{44}

This means transforming the values for each attribute to a scale of 0 to 10 using Eq. 1:

$$e_{ij} = 10 \times \left[a_{ij} - a_{\min}\right] / \left[a_{\max} - a_{\min}\right] \tag{1}$$

The ideal contractor/sub-contractor is defined as a contractor/sub-contractor that has the maximum values; in this model, the rescaled values are at most equal to 10. The performance of this ideal contractor/sub-contractor is measured by calculating the area of a tetragonal formed when two perpendicular axes are used to show the attributes and the value of each attribute is marked on four directions of these two axes. The tetragonal formed for the ideal project would be a square. To form the square, the marked points on each axis are connected.

Using the same procedure, the normalized values for each alternative contractor/sub-contractor are marked on the relevant attribute axis. These points are connected and as a result a tetragonal is formed for each contractor/sub-contractor alternative. For example, e11 e12 e13 e14 shows the area for contractor 1, e21 e22 e23 e24 shows the area for contractor/sub-contractor 2, and so on. The tetragonal associated with each alternative is shown in (Fig. 1).

The area of the tetragonal associated with each alternative is found by adding the areas of the four triangles forming the tetragonal:

$$A_{c1} = \sum_{i=1}^{4} S_i = S_1 + S_2 + S_3 + S_4$$
$$A_{C1} = \text{the area associated with Contractor one} \tag{2}$$

$$S_1 = {}^1\!/_2\,(e_{11}\ e_{12})$$
$$S_2 = {}^1\!/_2\,(e_{12}\ e_{13})$$
$$S_3 = {}^1\!/_2\,(e_{13}\ e_{14})$$
$$S4 = {}^1\!/_2\,(e_{14}\ e_{11}) \tag{3}$$

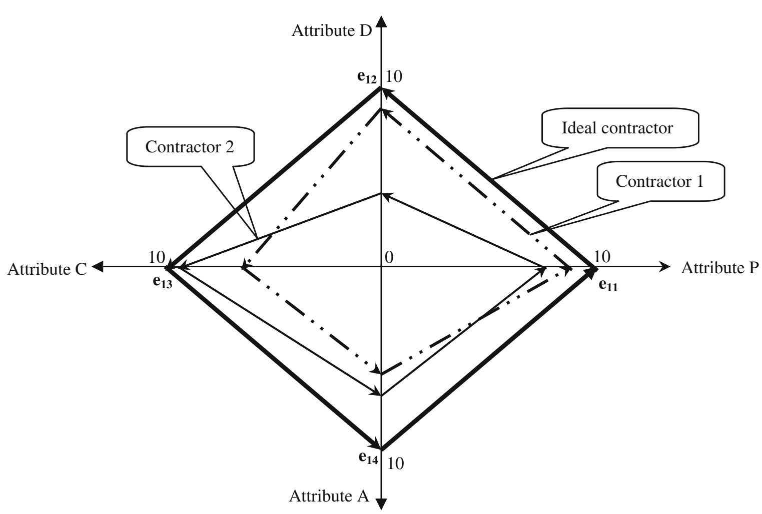

Fig. 1 The tetragonal for three fictitious alternative contractor/subcontractor performances

$$A_{c1} = \sum_{i=1}^{4} S_i$$
$$= {}^1\!/_2 \left(e_{11}\, e_{12} + e_{12}\, e_{13} + e_{13}\, e_{14} + e_{14}\, e_{11}\right)$$
$$A_{c1} = \sum_{i=1}^{4} S_i$$
$$= {}^1\!/_2 \left[e_{12}\left(e_{11} + e_{13}\right) + e_{14}\left(e_{13} + e_{11}\right)\right]$$
$$A_{c1} = \sum_{i=1}^{4} S_i = {}^1\!/_2 \left[\left(e_{11} + e_{13}\right)\left(e_{12} + e_{14}\right)\right] \quad (4)$$

The ranking for each contractor/sub-contractor is calculated by dividing the area of the corresponding tetragonal by the area of the ideal contractor/sub-contractor:

$$R\left(C_i\right) = \left[A_{\text{Contractor } i} / A_{\text{Ideal}}\right] \quad (5)$$

Where R (C_i) shows the ranking for contractor/subcontractor i:

$$R\left(C_i\right) = \left\{\left[1/2\right]\left[\left(e_{i1} + e_{i3}\right)\left(e_{i2} + e_{i4}\right)\right]/200\right\} \times 100$$
$$R\left(C_i\right) = \left\{\left[1/4\right]\left[\left(e_{i1} + e_{i3}\right)\left(e_{i2} + e_{i4}\right)\right]\right.$$

In other words:

$$R\left(C_i\right) = \left[\left(e_{i1} + e_{i3}\right)/2\right] \times \left[\left(e_{i2} + e_{i4}\right)/2\right] \quad (6)$$

Formula (6) could simply be stated as:

The HSE performance (ranking) of each contractor/sub-contractor in percentage is equal to the product of the average value of alternative QUALITY attributes, i.e. average of the first and the third attribute times the average of second and the fourth attributes. The result is presented as a percentage of the ideal contractor/sub-contractor in issued HSE performance.

Evaluation indicators

The proposed model could be used to integrate the leading and lagging indicators (the managerial and practical infrastructure) which are the two dimensions of the HSE management system structure. A better method of evaluating HSE performance would be to include a balance of leading and lagging indicators as well as an investigation of the policies and programs that lead to the overall performance of the contractor. With more comprehensive evaluation, there will be a better understanding of relative performance of the contractors including their weaknesses and strengths. A more comprehensive evaluation will also place less stress on the lagging indicator measurement system (Knode and Cook 2004).

During the incipient phases of active management, the HSE performance within contractor(s) typically oversaw creation of the evaluation methods. These evaluations could, and in some cases did, become more sophisticated. Contractor performance, in these situations, was measured against a standard, and when the lagging indicators were above predetermined limits, the contractor had to implement improvement measures to become eligible for work.

As the incident rate and overall HSE performance and programs are becoming screening criteria in any contractor evaluation program, a certain amount of redundancy is being created. This occurs when contractors are evaluated for master service agreements, projects, and routine vendor assessments. The results of the redundancy is that several different layers within both the operators and the contractor organizations may go through the same process, which is lengthy for the contractors to get approval. This inefficiency ties up resources for both groups with overlapping goals and methods and it provides no substantive benefit (Knode and Cook 2004). An example of this is the request for policies, information on management systems, incident reporting and investigation procedures, training, and personal protective equipment) requirements to name a few. For the most part, these items will remain with fairly constant probability deviations. So, the developed model depends less heavily on lagging indicators such as injury rates and focuses more on systems. The model would also minimize or eliminate redundant efforts from different selecting tools and techniques.

To develop this model, a data bank has been created which includes the statistical data calculated by converting the HSE performance qualitative data to quantitative values as importing data.

Table 2 Scoring system of indicators

A	B	C	D
HSE Plan Documentation Indicators			
0	3	6	10
Performance and Experience Factors (HSE incidents) Indicators			
0	7	14	20

Based on this fact, the structure of the model has been formed by defining HSE performance indicators according to HSE-MS model (E & P Forum 1994). The key elements of HSE management system are as follows:

- Leadership and commitment (5 indicators)
- Policy and Strategic objectives (3 indicators)
- Organization, resources and documentation (57 indicators)
- Evaluation and risk management (30 indicators)
- Planning (35 indicators)
- Implementation and monitoring (30 indicators)
- Auditing and reviewing (8 indicators)
- Qualification and certificate (10 indicators)

Therefore, 178 indicators have been selected to evaluate the HSE performance of contractor(s)/sub-contractor(s).

In another stage, these indicators have been grouped into four attributes: Plan, Do, Check, and Act.

Evaluation method

In order to gather required information about HSE Management System, appropriate questionnaire has been used. Emphasis has been placed on the need for complete answers substantiated by supporting documentation as far as it is practicable. Submissions have been assessed by a scoring mechanism that can be used in the evaluation process.

So the contractor(s)/sub-contractor(s) can be evaluated by attaching a score to the selected response for each category. The scoring system is chosen in accordance with OGP (Oil and Gas Producer Association) is widely being used by all OGP members (OGP, IMCA & IAGC 1999). As a result the scoring system is presented in Table 2.

Rating of contractor(s)/sub-contractor(s) HSE performance indicators have been done by a scoring system. The scoring scale for HSE plan is 0 up to 10, whereas the scale for performance and experience factors is 0 up to 20; this is due to the fact that they have given a higher weight for performance compare to planning phase which is considered as a weak point in all stages of HSE management system.

In this system, each of the four categories has been described to illustrate the situation of getting the assigned point from the worst (category A) to the best (category D).

By adding the points of sub-indicators the score of each key performance indicator will be gained.

Results and discussion

To illustrate the developed model, Shahid Tondgouyan Petrochemical Complex has been selected as a case study to show how the contractor(s)/sub-contractor(s) selecting decision is made using the model. This petrochemical complex which has been located in Mahshahr Petrochemical Zone and Khozestan Province in NW of Persian Golf has two main products: pure terfetalic acid (PTA) and polyethylene terfetalate (PET). The main parts of the Shahid Tondgouyan Petrochemical Complex which have been evaluated and ranked based on HSE performance model, are PTA-1, PET-1, waste water treatment plan (WWTP), and common facilities (CF) in the first phase of de-

Table 3 The HSE values of the QUALITY attributes

Attributes Contractor	Plan	Do	Check	Act	Total score
C1=PET1	855	819	80	30	1784
C2=PTA1	845	800	69	30	1744
C3=PET2	852	800	69	30	1751
C4=PTA2	845	812	69	30	1756
C4=CF&WWTP	848	819	80	30	1777

Table 4 The range of the attributes

	Min	Max
Plan	0	1080
Do	0	980
Check	0	80
Act	0	30

veloping program of refinery and PTA-2, PET-2 in the second phase. Each part has its own organizational chart, which is under the supervision and management of the Managing Director. In fact, they differ in their contractor(s), final products, and production capacity. Planning the HSE management system is the same in all of the divisions. But implementation and performance of this system are different.

By evaluating the values of HSE key performance, indicators of each complex units the total scores of each attribute has been significant, as shown in the Table 3.

In the next step, all attributes are normalized. Table 4 shows the minimum and maximum ranges of the attributes.

By using the normalizing equations, each value should be transformed into a scale of 0 to 10. The results of normalizing attributes are shown in Table 5.

Figures 2, 3, 4, 5, and 6 show the comparison of each HSE performance indicator with ideal performance and based on (P, D, C, A) Deming management model.

Analyzing (Figs. 2, 3, 4, 5, and 6) shows that PET-1 and CF, WWTP have the best performance in Check attribute. Also all units have been weak in Plan and Do attributes while good performance in Act attribute is the strongest point of all of them.

Then, by using number (7) mathematical algorithm the performance evaluation of contractors of each division based on designed model was done.

$$AC_i = \sum_{i=1}^{4} S_i = S_P + S_D + S_C + S_A \tag{7}$$

Finally, to find the ranking of each contractor the correspondent area of each part is calculated based on equation No. 8:

$$A_{\text{IdealContractor}} = 4 \times 10 \times {}^{10}/_{2} = 200$$

$$R\left(C_i\right) = \left[\mathrm{AC}_i / A_{\text{Ideal}}\right] \tag{8}$$

The purpose of this study is to evaluate the HSE performance of contractor(s)/sub-contractor(s)

Table 5 The value of normalized attributes

	Plan	Do	Check	Act
PET1	7.92	8.36	10.00	10.00
PTA1	7.82	8.16	8.63	10.00
PET2	7.89	8.16	8.63	10.00
PTA2	7.82	8.29	8.63	10.00
CF&WWTP	7.85	8.36	10.00	10.00

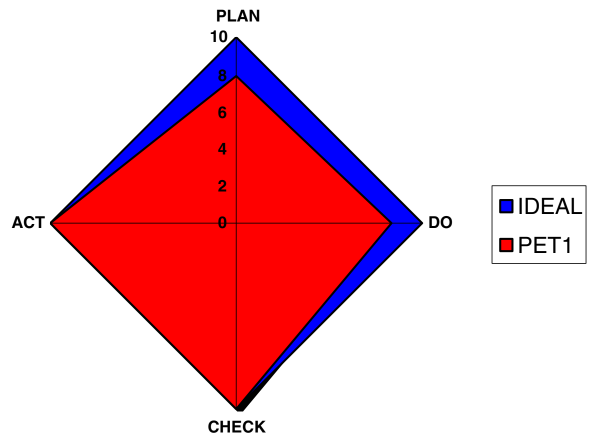

Fig. 2 Comparison of performance of PET-1 and Ideal performance

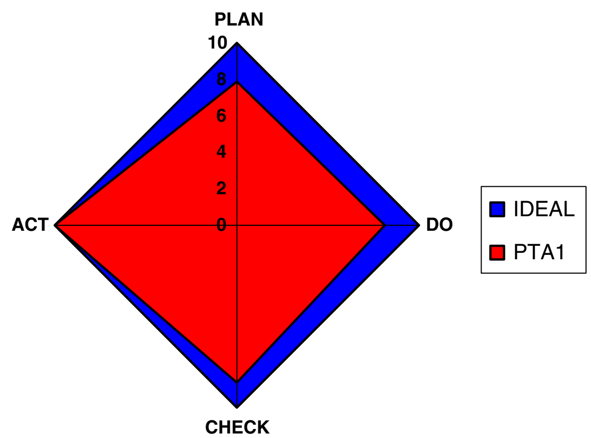

Fig. 3 Comparison of performance of PTA-1 and Ideal performance

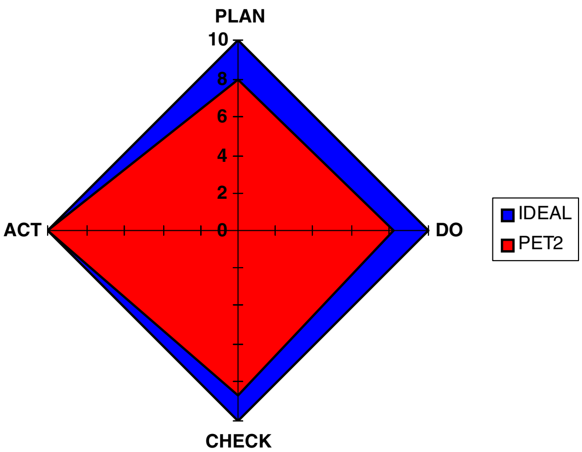

Fig. 4 Comparison of performance of PET-2 and Ideal performance

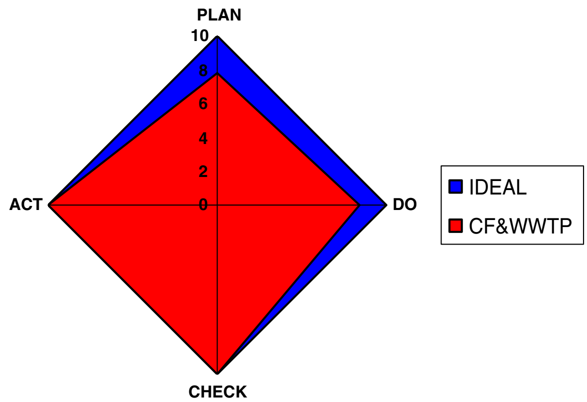

Fig. 6 Comparison of performance of CF&WWTP and Ideal performance

and ultimately compare their performance. One hundred seventy-four indicators of four variables have been evaluated. Table 6 indicates the ranking of the different units of Shahid Tondgouyan petrochemical Complex.

The above analysis shows that (PET-1) has the best HSE Performance, and it provides a ranking for all the contractors which could be used as the basis for decision making. And PTA-1 with the lowest score has the worst HSE performance.

Obtaining the strengths and weaknesses of contractors is another capability of this model. As it has been shown in (Figs. 7, 8, 9, and 10), the performance of each contractor based on each of the fourth attributes can be easily evaluated.

Analyzing the results of indicators in planning phase (Fig. 7) shows that PET-1 by having less deviation (20.5%) compared to ideal performance has the best performance in the planning phase of the HSE management system, and PET-2 by having the most deviation (23.3%) has the worst performance in this phase.

Referring to the indicators and deeper analysis, the weak point of this contractor can be identified by comparing it to the ideal performance in this attribute.

Figure 8 indicates that PET-1 and CF&WWTP have the best performance in conducting HSE programs. They both have almost the same final score, but at the same time they still have a 16.4% gap to the ideal point.

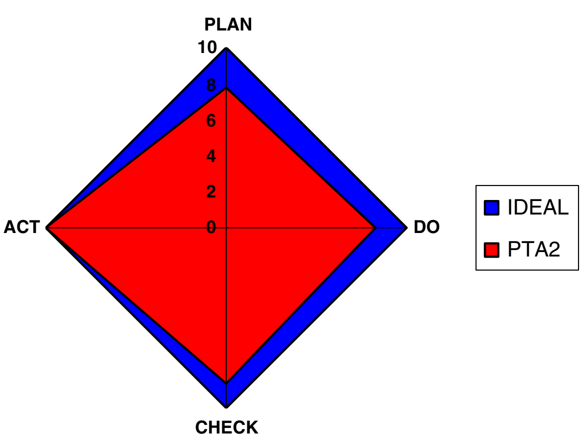

Fig. 5 Comparison of performance of PTA-2 and Ideal performance

Table 6 Ranking of the units according to their performance

	Area	Ideal area	Ranking	Performance
PET1	164.45	200.00	82.22%	The best
CF&WWTP	163.85	200.00	81.93%	–
PTA2	150.39	200.00	75.20%	–
PET2	149.97	200.00	74.99%	–
PTA1	149.38	200.00	74.69%	The worst

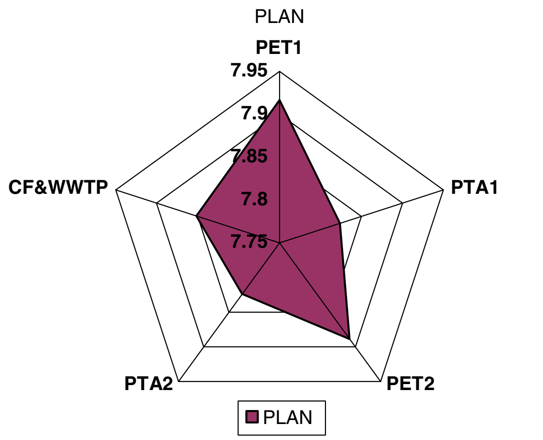

Fig. 7 Comparing performance of contractors in the Planning phase

Figure 9 shows the strength of PET-1 and weaknesses of the other units in performing Check attribute.

Figure 10 shows that all units have good performance in Act attribute.

The model was verified with OGP contractor pre-qualification guideline (OGP, IMCA & IAGC 1999), and the results have been illustrated in Table 7.

This shows that the designed model is more suitable and useful because of the number and variety of defined quantitative indicators. In fact,

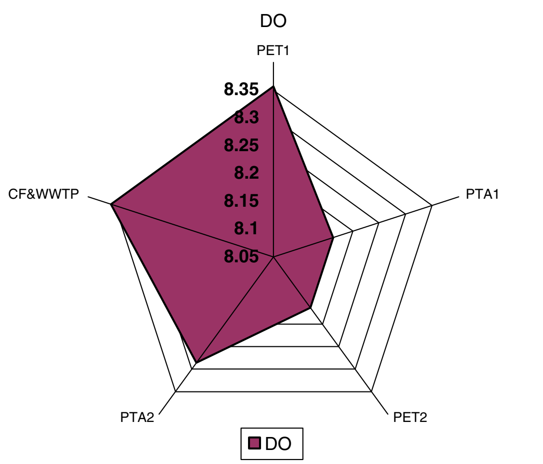

Fig. 8 Comparing performance of contractors in the Do phase

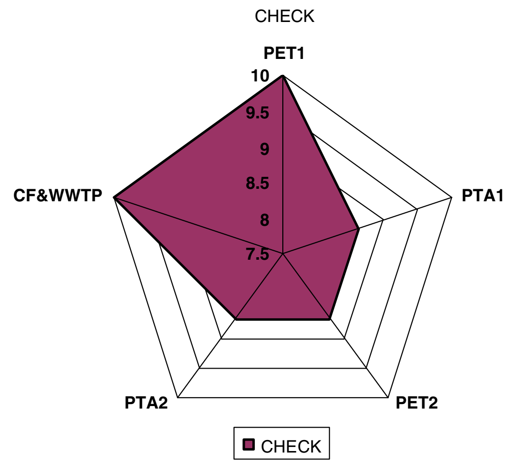

Fig. 9 Comparing performance of contractors in the Check phase

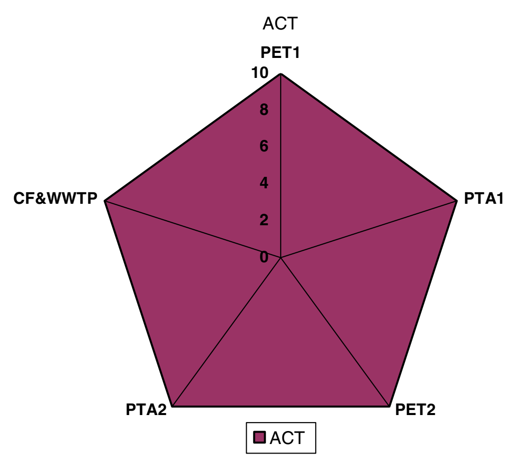

Fig. 10 Comparing performance of contractors in the Act phase

Table 7 Comparing the results between proposed model with OGP method

	OGP method	Proposed model
PET1	214	1788
PTA1	214	1751
PET2	214	1738
PTA2	214	1766
CF&WWTP	214	1777

the OGP contractor pre-qualification method uses limited HSE-MS indicators to assess the implementation of HSE management system; therefore, similar results would be achieved for different units. Therefore, it would not be a perfect decision making method.

Conclusions

The proposed comparative quantitative strategic management model has been developed to screening the contractors according to their HSE performance that could be used as a basis for decision making at the contractors' pre-qualification phase or during the execution of the project.

To develop this model, a data bank has been created, which includes the statistical data calculated by converting the HSE performance qualitative data into quantitative values. Based on this fact, the structure of the model has been formed by defining HSE performance indicators according to the HSE-MS model. Therefore, 178 indicators have been selected which have been grouped into four attributes.

Model output provides quantitative measures of HSE-MS performance as a percentage of an ideal level with maximum possible score for each attribute.

To sum up, the proposed model is well defined since:

1. It offers a scalar and logical algorithm that can easily be interpreted to compare the performance of different groups and to distinguish the superior performance.
2. It is capable of comparing different groups with variety of activities, and it is independent from processes,
3. It is capable of scoring the indicators with regards to different substantial and operational status of each indicator.
4. The proposed model is capable of comparing group performances at the same time period or different time periods.
5. It would also be possible to weigh indicators based on their classified definitions, not based on the scorers' point of view. By this, weighing constraints would not be changed by changing the scorer.
6. The proposed management model is not dependent on specified operational processes and is not influenced by similarities or varieties and nature of operational processes in an industrial complex or its internal units.

So this model is very versatile and can be used in variety of organizations and processes. Finally, in future, it would be possible to apply the proposed model to develop appropriate models capable of comparing quality management system performance as an integrated system to the health, safety, and environmental management system.

Acknowledgements The author wishes to thank Dr. T. Dana from Iranian Offshore Oil Company for his supportive consultation and Professor H. Khamooshi from the Management Department of George Washington University.

References

Abbasi, L. H. (2004). Health, safety and environmental management system (HSE-MS). *Journal of Exploration and Production, NIOC, 11*, 31–33.

Badiru, A. B. (1995). *Project management in manufacturing and high technology operations* (2nd edn.). Chichester: Wiley.

Badri, A., & Davis, D. (2001). A comprehensive 0–1 goal programming model for project selection. *IJPM, 19*, 243–252.

Buss, M. (1983). How to rank computer projects. *Harward Business Review, 16*, 118–125.

Doss Santos, B. (1989). Information systems similarities and differences across organisations. *OMEGA, 1s7*, 9–20

E & P Forum (1994). *Guidelines for the development and application of health, safety and environmental management system*. Report No.6.36/210.

Hess, S. (1993). Swinging on a branch of a tree: project selection applications. *Interface, 25*, 5–12

Knode, T., & Cook, P. (2004). Evaluation of contractor HSE performance based on lagging indicators: is there a better way. Report No. 86655. In 7th SPE International Conference on Health, Safety and Environment in Oil and Gas Exploration and Production. Calgary, Alberta, Canada 29–31 March.

Lindsay, F. D. (1992). Successful health and safety management- the contribution of management audit. *Journal of Safety Science, 15*, 387–402.

Lygun, M. (1993). A decision support system for R & D project selection and resource allocation under uncertainty. *Project Management Journal, 24*, 5–13.

Melone, N., & Wharton, T. (1984). Strategies for MIS project selection. *Journal of System Management, 16*, 26–33.

Meredith, J., & Mantel, S. (2001). *Project management a managerial approach*. Chichester: Wiley.

OGP, IMCA & IAGC (1999). *HSE management guidelines for working together in a contract environment*. Report No. 6.64/291.

Riggs, J., Goodman, M., Finley, R., & Miller, T. (1992). A decision support system for predicting project success. *Project Management Journal, 23*, 27–43.

Schniederjans, M., & Wilson, R. (1991). Using AHP and goal programming for project selection. *Information and Management*, 333–342.

Sherif, M., & McCowan (2001). Modelling project investment decision under uncertainty using possibility theory. *IJPM, 19*, 231–241.

UNEP & Exploration and Production Forum (2000). Environmental Managements in Oil and Gas Exploration and Production—an Overview of Issues and Management Approaches. Joint E&P Forum and UNEP Technical Publication.