Accepted Manuscript

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PII: S0957-4174(14)00303-0
DOI: http://dx.doi.org/10.1016/j.eswa.2014.05.023
Reference: ESWA 9340

To appear in: *Expert Systems with Applications*

Please cite this article as: Rabbani, A., Zamani, M., Yazdani-Chamzini, A., Zavadskas, E.K., Proposing a new integrated model based on sustainability balanced scorecard (SBSC) and MCDM approaches by using linguistic variables for the performance evaluation of oil producing companies, *Expert Systems with Applications* (2014), doi: http://dx.doi.org/10.1016/j.eswa.2014.05.023

Proposing a new integrated model based on sustainability balanced scorecard (SBSC) and MCDM approaches by using linguistic variables for the performance evaluation of oil producing companies

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Abstract

Using the balanced scorecard approach based on sustainable development parameters is a powerful and useful methodology to evaluate the sustainable performance of organization or company. In this paper, a new approach based on sustainability balanced scorecard (SBSC) and multi criteria decision making (MCDM) approaches is developed for evaluating the performance of oil producing companies in Iran. For reflecting the interdependent relationships among factors influencing the problem under consideration, analytical network process (ANP), a branch of the MCDM techniques, is employed. However, using the ANP method for calculating the preference ratings of alternatives is a time-consuming and bothersome process; therefore, COPRAS (COmplex PRoportional ASsessment) technique is adopted to prioritize the feasible alternatives in terms of linguistic variables. Based on this study, the results demonstrate the effectiveness of the proposed model. The performance evaluation model proposed by using a combination

of the MCDM methods and the SBSC approach helps authorities to make an attempt for achieving a competitive advantage.

Keywords: Performance evaluation, MCDM, COPRAS, Sustainability balanced scorecard, ANP, Fuzzy logic.

1. Introduction

Oil as one of the most important energy resources plays a significant role from economical and political points of view. However, oil provides about 40% of the energy required in the world. Iran is becoming a major supplier of oil to many different centuries and has a profound impact on the global energy equation.

Iran has a high production potential so that it is now producing approximately 4 million barrels per day and is capable of increasing its output by more than 6 million barrels per day. Likewise, the proved oil reserves in Iran rank third largest in the world at approximately 150 billion barrels as of 2007[1]. This product is the heart of the economy of Iran. The responsibility of extraction and production of crude oil is exclusively entrusted to the National Iranian Oil Company (NIOC). According to the survey conducted by Energy Information Administration, in 2006 NIOC generated some $46.9 billion in oil export revenue, comprising 80-90 percent of Iran's total exports and 40-50 percent of the government's budget[2].

According to the key role of oil in the Iran's economy, it is necessary to develop the new approaches with a high potential to evaluate the performance of oil producing companies. This helps authorities to understand the strengths and weaknesses; as a result, the authorities can properly make a solution for developing the forthcoming strategies. Different methods have been developed to comprehensively evaluate the performance of organization. These methods usually offer some future measures and help managers to translate strategies into action.

[1] http://en.wikipedia.org
[2] http://www.eia.doe.gov/emeu/cabs/Iran/Background.html (accessed December 29, 2006)

The balanced scorecard (BSC) approach, introduced by Kaplan & Norton (1996), is well-known as one of the most popular methods in performance evaluation for mapping out strategies. This technique can translate the best strategies into tangible goals and measurements (Chen et al., 2011). In the system of the BSC method, not only financial parameters are considered as input factors, but also non-financial indicators are taken into account. However, this method ignores the important aspects of sustainable development in the process of performance evaluation; so that, some studies have been conducted to develop a new methodology based on BSC for performance evaluation. A two-years research project "Sustainability Balanced Scorecard (SBSC)" (2000–2002), accomplished by University of Lüneburg and St. Gallen methodology, was funded by the German Federal Ministry for Science and Education to operationalize corporate sustainability (Chai, 2009). They developed a new methodology to incorporate strategies and measure the environmental and social performance. Therefore, this method can cover all aspects of a performance assessment problem in order to obtain a more accurate and reliable model.

In this study, the SBSC approach is employed for calculating the performance of oil producing companies. Nevertheless, there are a large number of factors that would affect the performance of oil producing companies. These factors can be grouped into several classes. Then, decision analysis is conducted based on this new list of factors. The merit of using multi-criteria decision making (MCDM) techniques is to formulate a decision making problem where the evaluation criteria are in conflicting with each other.

The COPRAS technique, first developed by Zavadskas & Kaklauskas (1996), is a branch of the MCDM techniques that its effectiveness and value is demonstrated by different researchers (Kaklauskas et al., 2006, 2010; Madhuri et al., 2010; Chatterjee et al., 2011; Podvezko, 2011; Mulliner et al., 2013; Tamosaitiene & Gaudutis 2013; Kanapeckiene et al., 2011, Palevičius et al., 2013; Medineckiene & Bjork 2011; Stanujkic et al. 2013). COPRAS–G method (Complex Proportional Assessment of alternatives with Grey relations) was suggested by Zavadskas et al. (2009) with attributes expressed in interval values, which are suitable for real situations of decision makers and the applications of the grey theory. COPRAS–G method used Tavana et al. (2013), Maity et al. (2012), Nguyen et al. (2014), Aghdaie et al. (2013), Hashemkhani Zolfani et al. (2012), Barysienė et al. (2012), Chatterjee & Chakraborty (2012), Popovic et al. (2012).

COPRAS method is employed in this paper because of its unique advantages, including (1) COPRAS allows simultaneous consideration of the ratio to the ideal solution and the ideal-worst solution, (2) simple and logical computations, and (3) results are obtained in shorter time than other methods such as AHP and ANP (Fouladgar et al., 2012a).

However, the COPRAS technique is not capable of handling the inherent uncertainty involved in the process of modeling a decision making problem. Fuzzy logic is a mathematical tool for taking into account the uncertainty. Therefore, the fuzzy COPRAS method is developed to integrate the advantages of both fuzzy logic and the COPRAS method into a powerful technique for solving a decision making issue (Zavadskas & Antucheviciene, 2007; Yazdani et al., 2011; Fouladgar et al., 2012a; Chatterjee & Bose 2013; Antucheviciene et al., 2012).

On the other hand, the assumption of independence of criteria is not always correct because in real world the criteria are often dependent on each other. Analytical network process (ANP) is an appropriate tool in order to model complex problems with all kinds of relationship, dependency and feedback in the model and draws a systematical figure of the decision making problem (Azimi et al., 2011).

The adaptation of the ANP technique in this paper is to formulate the interdependency relationships between criteria. This model can be known as the universal one because of using the information from both professional experts and clients.

The reasons for using an ANP-based decision analysis approach are: (1) ANP can measure all tangible and intangible criteria in the model (Saaty, 1996), (2) ANP is a relatively simple, intuitive approach that can be accepted by managers and other decision-makers (Presley, Meade 1999), (3) ANP allows for more complex relationship among the decision levels and attributes as it does not require a strict hierarchical structure (Yazgan et al., 2010), and (4) ANP is more adapted with real world problems (Fouladgar et al., 2012b).

The novelty of this paper is pertaining to establishing a new integrated model for evaluating the performance of oil producing companies under sustainable development indicators in the term of linguistic variables. The model is developed based on a combination of two MCDM methods, taking not only financial and non-financial factors into account in the terms of linguistic variables, but also considers environmental and social parameters.

The remainder of this paper is organized as follows. The SBSC methodology is illustrated in next Section. In Section 3, the ANP method is briefly presented. The fuzzy COPRAS technique is described in section 4. In section 5, the proposed model is introduced. The implementation of the proposed model is illustrated in section 6. In the last section, conclusions are described.

2. Sustainability Balanced Scorecard (SBSC)

The Balanced Scorecard (BSC) was first introduced in early of the 1990s by Kaplan and Norton to develop business performance evaluation system. This methodology was introduced because of some weaknesses of the traditional performance evaluation that the current system overemphasizes financial parameters and other perspectives were neglected. The innovation of the BSC technique is to evaluate an organization from four perspectives, including financial, customer, internal process, and learning and growth perspectives. Fig. 1 shows the relationship among various factors of BSC. The BSC is a systemic approach, which helps integrating physical and intangible assets into a comprehensive model and builds a meaningful relationship among different criteria. The concepts of the BSC approach are widely applied to performance measurement. Table 1 lists a number of recent studies conducted with the BSC approach. According to recent survey of more than 1,000 organizations, 80% of the organizations that regularly use the BSC reported improvements in operating performance and 66% of them also reported an increase in profits[3].

However, the BSC technique ignores environmental and social aspects as essential pillars of a sustainable business; so that, new methods were developed for curing the problem. Figge et al. (2002) believed that BSC can help to take all aspects relevant for achieving sustainability into account simultaneously and in a balanced manner. Since the BSC has high potential to integrate environmental and social aspects into the general management system, the BSC has been combined with sustainable parameters, called as the sustainability BSC (SBSC), to provide a meaningful instrument to the sustainability management (Chai, 2009). Fig. 2 shows a typical

[3] www.ameinfo.com

structure of the SBSC method. By integrating all three pillars of sustainable development, economic, social and environmental dimensions, into the business strategy, the corporate sustainability has been promoted (Hahn & Wagner, 2001). Therefore, the SBSC may not only help detect important strategic environmental and/or social objectives of the company but may also enhance the transparency of value-added potentials emerging from social and/or ecological aspects and prepare the implementation process of the strategy (Hsu et al., 2011).

Fig. 1. A simple framework of BSC elements (Niven, 2008)

Table 1. A list of the recent studies

Fig. 2. Structure of SBSC technique

3. ANP technique

Analytic Hierarchy Process (AHP), first introduced by Saaty (1980), is an effective and robust technique to model the sophisticated decision problems. This method solves a complex problem by decomposing it into several simple sub-problems by using the hierarchical levels, in which the goal is situated in the top level, the second and third levels contain of main and sub-criteria, respectively, the feasible alternatives are located in the last level. However, in the system of the AHP method, it is assumed that the elements of decision are independent and the relationships between the levels of decision are linear; so that, it ignores the interrelationships among the elements.

The analytic network process (ANP) method is developed to remedy this problem by considering the interdependent relationships among the elements. The ANP technique is the generalization of the AHP technique (Saaty, 1996).

Fig. 3 illustrates the difference between hierarchy and network structures. As shown in Fig. 3, a hierarchy is a linear top down structure and network is a non-linear structure that spreads out in all directions. An ANP system uses arcs to show the relationships among elements, where the directions of arcs signify directional dependence (Chung et al., 2005). The ANP technique extends the AHP to facilitate the process of formulating the problems with feed-back and dependence (Fouladgar et al., 2012b). This method replaces the hierarchy in the AHP with a network to equip the ANP for modeling the interrelationships among decision elements in order to solve the problems that are nonlinear and more complex. Thus, the ANP produces priorities or relative importance of elements in a complex network model with consideration of inter-dependency among elements.

Fig. 3. The difference between a hierarchy (A) and a network (B) (Azimi et al., 2011)

Like with AHP, pairwise comparison in ANP is performed in the framework of a matrix, and a local priority vector can be derived as an estimate of the relative importance associated with the elements (or clusters) being compared by solving the following equation (Yüksel & Dağdeviren, 2010):

(1)

$$A \times w = \lambda_{\max} \times w$$

where A is the matrix of pairwise comparison, w is the eigenvector, and $\lambda_{\max}$ is the largest eigenvalue of A.

In this paper, the hierarchy and network model proposed for modeling the mutual relationships among the SBSC parameters is comprised of four levels. In the first level, the optimum performance (the goal) is located, the SBSC parameters (main criteria) and the SBSC sub-factors (sub-criteria) are situated in the second and third levels, respectively, and the oil producing companies (alternatives) are located in the last level. The structure of a supermatrix- a matrix of the influences among the elements- for the SBSC network with four levels is can be defined as follows:

(2)

$$W = \begin{array}{c} Goal \\ \text{SBSC } factors \\ \text{SBSC } sub-factors \\ Alternatives \end{array} \begin{pmatrix} 0 & 0 & 0 & 0 \\ W_1 & W_2 & 0 & 0 \\ 0 & W_3 & 0 & 0 \\ 0 & 0 & W_4 & I \end{pmatrix}$$

where W_1 is a matrix that reflects the impact of the overall purpose (selecting the optimal performance) on the main criteria (SBSC factors); W_2 is the matrix that represents the impact of each of the main criteria on each other or inner independence of the SBSC factors; W_3 is the vector that shows the impact of the main criteria (SBSC factors) on each of the sub-criteria (SBSC sub-criteria); W_4 is the matrix that reflects the impact of the sub-criteria (SBSC sub-criteria) on each of the alternatives (oil producing companies); and I is the identity matrix.

In order to perform the ANP methodology for obtaining the importance weights of the SBSC factors, the algorithm employed is as follows:

Step 1: Define the problem and identify the factors having an inner dependency with each other.

Step 2: Without taking into account the dependence among the SBSC factors; calculate the importance weights of the factors with a Saaty's (1–9) scale (Saaty, 1980). This means that the process of this step leads to W_1 be acquired.

Step 3: Calculate the inner dependence matrix of each SBSC factor with respect to the other factors with a 1–9 scale. This means that this step calculates the W_2 matrix.

Step 4: Measure the interdependent priorities of the SBSC factors. Calculating $W_{factors} = W_1 \times W_2$ is performed in this step.

Step 5: Calculate the local importance weights of the SBSC sub-factors with a 1–9 scale. $W_{sub-factors(local)}$ is obtained in this step.

Step 6: Measure the global importance weights of the SBSC sub-factors by multiplying the values of steps 4 and 5 ($W_{sub-factors(global)} = W_{factors} \times W_{sub-factors(local)}$).

4. Fuzzy logic

Fuzzy set theory is developed by Zadeh (1965) to take into account the inherent uncertainty and complexity involved in process of modeling a real world problem. Fuzzy theory enables decision makers to simply formulate a sophisticated problem by using the linguistic terms instead of precise and strict values. Fuzzy sets are defined by membership function, which shows the grade of belongings to the set under consideration. If an element x fully belongs to a set A, $\mu_A(x)=1$, and if an element x does not belong to the set under consideration, $\mu_A(x)=0$ (Yazdani-Chamzini & Yakhchali, 2012). The higher is the membership value, the greater is the belongingness of an element x to the set A.

5. Fuzzy COPRAS technique

The COPRAS (COmplex PRoportional ASsessment) method (Zavadskas & Kaklauskas, 1996) assumes direct and proportional dependence of the significance and utility degree of the investigated versions in a system of criteria adequately describing the alternatives and of values and weights of the criteria (Kaklauskas et al., 2010). This method is widely applied when a decision-maker has to select the optimal alternative among a pool of alternatives by considering a set of evaluation criteria.

In the classical COPRAS method, the weights of the criteria and the ratings of alternatives are known precisely and crisp values are employed in the evaluation process. However, under many conditions crisp data are not capable to model real-life decision problems and it is often difficult for evaluators to determine the precise ratings of alternatives and the exact weights of the evaluation criteria. The merit of using a fuzzy approach is to determine the relative importance of attributes using fuzzy numbers instead of precise numbers (Önüt & Soner, 2008; Sun & Lin, 2009; Sun, 2010; Kara, 2011). Therefore, the fuzzy COPRAS method is developed to deal with the deficiency in the traditional COPRAS. Fuzzy COPRAS assigns the weights of criteria and ratings of alternatives are evaluated by linguistic terms represented by fuzzy numbers. The procedure of the Fuzzy COPRAS method includes the following steps:

Step 1. Define the linguistic terms. Linguistic terms used by decision maker team are presented in Table 2.

Table 2. Linguistic terms for the preference rating of alternatives

Step 2. Construct the fuzzy decision matrix. The preference ratings of alternatives are expressed with linguistic variables in positive TFNs.

Step 3. Determine the weights of criteria. Due to the existence of dependence and feedback relation between the SBSC factors, in this study, ANP is employed to calculate the importance weights of main criteria.

Step 4. Determine the aggregated fuzzy rating $\tilde{x}_{ij}$ of alternative A_i, i= 1,2, . . ., m under criterion C_j, j= 1,2, . . ., n,.

(3)

$$\tilde{D} = \begin{array}{c} \\ A_1 \\ A_2 \\ \vdots \\ A_m \end{array} \begin{array}{c} \begin{array}{cccc} C_1 & C_2 & \cdots & C_n \end{array} \\ \begin{bmatrix} \tilde{x}_{11} & \tilde{x}_{12} & \cdots & \tilde{x}_{1n} \\ \tilde{x}_{21} & \tilde{x}_{22} & \vdots & \tilde{x}_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ \tilde{x}_{m1} & \tilde{x}_{m2} & \cdots & \tilde{x}_{mn} \end{bmatrix} \end{array}, i = 1, 2, \ldots, m; j = 1, 2, \ldots n$$

(4)

$$\tilde{x}_{ij} = (x_{ij1}, x_{ij2}, x_{ij3})$$

$$x_{ij1} = \min_k \{x_{ijk1}\},\ x_{ij2} = \frac{1}{K}\sum_{k=1}^{K} x_{ijk2},\ x_{ij1} = \max_k \{x_{ijk3}\}$$

where $\tilde{x}_{ijk}$ is the rating of alternative A_{i} with respect to criterion C_j evaluated by kth expert (here k=19), $\tilde{x}_{ijk} = (x_{ijk1}, x_{ijk2}, x_{ijk3})$.

Step 5. Defuzzify the aggregated fuzzy decision matrix obtained in previous step and derive their crisp values. This research for transforming the fuzzy weights into the crisp weights applies the center of area method which is a simple and practical method to calculate the best nonfuzzy performance (BNP) value of the fuzzy weights of each dimension. The BNP value of the fuzzy number $\tilde{x}_{ij}$ can be found using Eq. (5):

$$x_{ij} = \frac{[(Ux_{ij} - Lx_{ij}) + (Mx_{ij} - Lx_{ij})]}{3} + Lx_{ij} \qquad (5)$$

Step 6. Normalize the decision matrix (f_{ij}). The normalization of the decision making is calculated by dividing each entry by the largest entry in each column to eliminate anomalies with different measurement units, so that all the criteria are dimensionless.

Step 7. Calculate the weighted normalized decision matrix ($\hat{x}_{ij}$). The fuzzy weighted normalized values are calculated by multiplying the weight of evaluation indicators (w_j) with normalized decision matrices:

$$\hat{x}_{ij} = f_{ij} \cdot w_j \tag{6}$$

Step 8. Sums P_j of attributes values which larger values are more preferable (optimization direction is maximization) calculation for each alternative (line of the decision-making matrix):

$$P_i = \sum_{j=1}^{k} \hat{x}_{ij} \cdot \tag{7}$$

Step 9. Sums R_i of attributes values which smaller values are more preferable (optimization direction is minimization) calculation for each alternative (line of the decision-making matrix):

$$R_i = \sum_{j=k+1}^{m} \hat{x}_{ij}. \tag{8}$$

In formula (8) $(m - k)$ is number of attributes which must to be minimized.

Step 10. Determine the minimal value of R_i:

$$R_{\min} = \min_i R_i; \; i = 1, \ldots, n. \tag{9}$$

Step 11. Calculate the relative weight of each alternative Q_i:

$$Q_i = P_i + \frac{R_{\min} \sum_{i=1}^{n} R_i}{R_i \sum_{i=1}^{n} \frac{R_{\min}}{R_i}}. \tag{10*}$$

Formula (10) can to be written as follows:

$$Q_i = P_i + \frac{\sum_{i=1}^{n} R_i}{R_i \sum_{i=1}^{n} \cdot \frac{1}{R_i}}. \tag{11}$$

Step 12. Determine the optimality criterion K:

$$K = \max_i Q_i; \; i = \overline{1, n}. \tag{12}$$

Strep 13. Assign the priority of the alternatives. The greater weight (relative weight of alternative) Q_i, the higher is the priority (rank) of the alternatives. In the case of $Q_{\max}$, the satisfaction degree is the highest.

Step 14. Calculate the utility degree of each alternative:

$$N_i = \frac{Q_i}{Q_{\max}} 100\%, \tag{13}$$

where Q_i and $Q_{\max}$ are the weight of projects obtained from Eq. (12).

6. The proposed model

In this paper, the ANP and fuzzy COPRAS techniques are employed as an integrated methodology for performance evaluation of oil producing companies. The proposed model includes three steps: (1) determining the weights of evaluation criteria by the ANP technique, (2) evaluating the preference rating of alternatives, and (3) ranking the alternatives and choosing the optimal performance. In the first step, the ANP method is applied for decomposing the structure of decision process into a hierarchical structure in order to determine the importance of each criterion through pairwise comparisons and formulate the interdependent relationships among the main criteria. After constructing hierarchical structure and calculating the weights of the main and sub-criteria, the importance of alternatives are evaluated via the fuzzy COPRAS technique. Finally, according to the results of the fuzzy COPRAS method, alternatives are ranked in descending order and the best performance is selected as the first choice. Schematic diagram of the proposed model for selecting the optimal maintenance strategy is shown in Fig. 4.

Fig. 4. Schematic diagram of the proposed model

7. Problem definition and model construction

7.1. Problem definition

This section comprises a performance evaluation of oil producing companies in Iran. To achieving the aim, the relationships among the performance evaluation indicators are evaluated. In order to obtain a complete list of the key criteria, a number of face to face interviews are conducted. As well as, a questionnaire is filled out by the high and medium level managers of oil producing companies.

Iran is well-known as energy superpower in the region of Middle East and its oil industry plays a significant role in the country. According to the reports published by the National Iranian Oil Company in 2004, Iran produced 3.9 million barrels per day, which includes 5.1 percent of the world's total crude oil. In this year, the revenues derived from sale of oil were more than US$25 billion and was the main source for foreign currency. The importance of oil production to Iran's economy is not only due to its significant role in gross domestic product (GDP), including approximately 18.7 percent (NIOC, 2006), but also this sector has been the engine of economic growth; so that, this industry has a significant impact on development plans, national projects, budgeting, and both imports and exports.

Based on the reports issued by the Organization of Petroleum Exporting Countries (OPEC) in 2012, Iran was the second-largest exporter among the members of the OPEC with about 1.5 million barrels of crude oil a day. Based on statistics published by OPEC in 2013, Iran earns about $50 billion a year in oil exports. This quantity of oil is produced by eight principal entities. These entities are listed and described in Table 3.

Table 3. List of oil producing companies in Iran

7.2. Model construction

The first step in the model implementation is to identify the indicators influencing the process of evaluation. To achieving the aim, a comprehensive review of the literature and a lot of face to face interviews with experts in the field are accomplished. Therefore, twenty indicators influencing the problem of sustainable performance evaluation are determined. Then, these indicators are grouped into five perspectives (based on the structure proposed by Chai (2009)) as shown in Table 4.

Table 4. List of main and sub-criteria

After identifying the evaluation criteria, the structure of decision hierarchy for performance evaluation of oil producing companies is formed. The hierarchy contains of four main levels, in which the overall goal is at the top level, the evaluation criteria are situated in the second level, the sub-criteria are in the third level, and the last level belongs to the possible alternative as shown in Fig. 5.

Based on the expert's knowledge, the aspects of economic, environmental, social, internal process, and learning and growth are mutually interrelated. As seen in Fig. 5, the double-side arrows show the interdependency among SBSC parameters.

7.3. Determining the importance weights of the criteria

Assuming that there is no dependence among the SBSC factors, pairwise comparison judgments of the main and sub-criteria are made with respect to the goal. After forming the decision hierarchy, the evaluators, including nineteen experts with a high experience in field of oil project management, are asked to respond to the relative importance of each criterion by a two-by-two comparison matrix. In order to compare the two elements, a scale of (1-9), where a score of 1 expresses equal importance for the two elements and a score of 9 addresses the overwhelming dominance of the row element over the column element, is utilized. A scale of 1 to 1/9 is employed as the impact of one element is weaker than that of its comparison element, in which 1 indicates indifference and 1/9 indicates overwhelming dominance of the column component over the row component. In the construction of a comparison matrix, group decision making is employed for avoiding decision-maker bias towards particular providers (Hsu et al., 2011). To achieving the aim, the geometric mean technique (Dyer & Forman, 1992) is applied for integrating individual judgments into the final comparison matrix. For instance, economic factor (EC) and environmental factor (EN) are compared by asking ''How important is 'EC' when it is compared with 'EN'?" and the answer "3, 4, 4, 3, 4, 3, 5, 4, 3, 3, 4, 3, 4, 2, 4, 3, 3, 4, 5" by nineteen decision makers is derived and located in the relevant cell against the aggregated weights (3.50). Tables 5-10 show the results of the pairwise comparison matrices.

Fig. 5. Structure of decision hierarchy

The computations of the consistency rate for individual matrices show that this rate is smaller than 0.1; as a result, the questionnaires are valid. In order to valid the final questionnaire, the group consistency ratio (GCR) is computed by using Eq. (14), as listed in the last row of the matrix.

$$GCI = (\lambda_{\max} - n) / n \tag{14}$$

Table 5. Local weights of SBSC factors

Table 6. Local weights of EC sub-factors

Table 7. Local weights of EN sub-factors

Table 8. Local weights of SO sub-factors

Table 9. Local weights of IP sub-factors

Table 10. Local weights of GL sub-factors

Then, the interdependency among the SBSC components is considered in the process of modeling. With this reason, the impact of each factor on every other factor is investigated by using the pairwise comparisons conducted through the evaluator team. Tables 11-15 show the interrelationship among the SBSC factors. These matrices are constructed by asking "What is the relative importance of 'economic parameter' when compared with 'environmental parameter' on controlling 'social parameter'?" and answers were received from nineteen decision makers as "3, 3, 4, 5, 4, 4, 3, 2, 3, 3, 3, 4, 4, 5, 4, 4, 3, 3, 2" (3.37). The resulting relative importance weights are located in the last column of Tables 11-15.

Table 11. Interdependence matrix of the factors with respect to "Economic parameter"

Table 12. Interdependence matrix of the factors with respect to "Environmental parameter"

Table 13. Interdependence matrix of the factors with respect to ''Social parameter"

Table 14. Interdependence matrix of the factors with respect to "Internal process parameter"

Table 15. Interdependence matrix of the factors with respect to "Growth & Learning parameter"

After calculating the relative importance among the main criteria, the interdependency matrix is derived. To calculate the interrelationship weights of the main criteria, the interdependency matrix is multiplied with the local weights of the SBSC parameters resulted from the previous stage as presented below.

$$\begin{bmatrix} EC \\ EN \\ SO \\ IP \\ GL \end{bmatrix} = \begin{bmatrix} 1 & 0.276 & 0.441 & 0.411 & 0.364 \\ 0.176 & 1 & 0.153 & 0.093 & 0.145 \\ 0.281 & 0.333 & 1 & 0.287 & 0.258 \\ 0.312 & 0.230 & 0.240 & 1 & 0.233 \\ 0.232 & 0.161 & 0.165 & 0.208 & 1 \end{bmatrix} \times \begin{bmatrix} 0.417 \\ 0.120 \\ 0.165 \\ 0.130 \\ 0.169 \end{bmatrix} = \begin{bmatrix} 0.319 \\ 0.127 \\ 0.201 \\ 0.183 \\ 0.169 \end{bmatrix}$$

From the final weights of the SBSC parameters, it can be evident that the results significantly differ from the relative weights neglecting the interdependency among the parameters. The final weights change from 0.417, 0.12, 0.165, 0.13, and 0.169 to 0.319, 0.127, 0.201, 0.183, and 0.169 for the priority values of factors EC, EN, SO, IP, and GL, respectively. Fig. 6 graphically indicates the difference between the weights resulted from the two methodologies.

Fig. 6. Difference between outputs when interdependency is or is not considered

In the next step, the overall priority weight for the SBSC parameters is resulted from multiplying the weights derived from the initial weights with assumption of independence among the main-criteria and the interdependency weight of the criteria. The overall weights are calculated for each indicator as presented in Table 16. From the table, it can be obvious that "EC1" and "EN2" with the values of 0.149 and 0.012, respectively, are the most and the least critical indicators influencing the performance of oil producing companies. This means that "EC1" is the major concern for the companies.

Table 16. Overall weights for indicators

7.4. Determining the preference ratings of alternatives

After obtaining the relative weights of the evaluation indicators, the fuzzy preference of the Iranian oil producing companies with respect to the criteria under consideration. In order to limit the number of pairwise comparisons, the fuzzy COPRAS method is employed. To achieving the aim, the expert team is asked to evaluate the alternatives based on the scale given in Table 2. For the benefit type indicators (EC1, EC2, EC3, EN5, SO1, SO2, SO3, SO4, IP1, IP2, IP3, IP4, GL1, GL2, GL3, and GL4), the higher the score, the better the performance of the oil company is. Whereas, for the cost type indicators (EN1, EN2, EN3, and EN4), the higher the score, the worse the performance of the oil company is.

Then, the individual fuzzy decision matrices are aggregated into the final fuzzy decision matrix in order to prioritize the performance of the oil companies as presented in Table 17. After constructing the final decision matrix, the crisp values of the fuzzy outputs are calculated by the process of defuzzification as presented in Table 18.

Table 17. Fuzzy decision matrix

Table 18. Defuzzified decision matrix

To normalize the decision matrix, the preference ratings for the alternatives on a criterion are divided by the top value among all alternatives on the same criterion in order to transfer the values into the closed interval zero and one. Then, the normalized decision matrix is multiplied with the importance weights of the evaluation indicators derived from the previous step to form the weighted decision matrix as shown in Table 19. Based on the proposed model, each alternative has the preferable values for the maximizing and minimizing indices. Then, the relative weight and the optimality criterion are computed as shown in Table 20. According to the value of the optimality criterion, the priority of the alternatives is acquired. Finally, the utility degree of each alternative is measured as presented in Table 20. From the table, it can be seen that the priority of the alternatives on the bases of their preference ratings is ranked in descending order as shown in Fig. 7. Therefore, A1 and A4 are first and last in the list of priorities.

Table 19. Weighted decision matrix

Table 20. Fuzzy COPRAS results

Fig. 7. Ranking of working strategies

8. Conclusions

The problem of sustainable performance evaluation of oil producing companies is a critical because of its unique role in economy, society, and environmental of the country. This industry is faced with increasing market competition. Serve changes in the economical and financial components may lead to an undesirable situation to make a profit. Although the sustainable balanced scorecard approach uses five evaluation perspectives discussed in Section 2 to evaluate the performance of organization, it cannot take into account the relative weight of the factors. It is valuable for the strategic management analyzers to perceive the importance weights of the main and sub-criteria for the purpose of performance evaluation. Therefore, a new model based on multi criteria decision making methods under fuzzy environment is developed. In this study, the importance weights of the evaluation indicators are calculated by employing the ANP technique based on pairwise comparison matrix. This technique is capable of taking into account the interrelationship among the criteria under consideration. Therefore, the overall weights of the evaluation criteria can be correctly obtained. However, using the ANP technique for calculating the relative ratings of alternatives is a time-consuming and bothersome process. To achieving the aim, fuzzy COPRAS is employed for prioritizing the alternatives with respect to the criteria under consideration. According to the results of the ANP model, the top two criteria are key parameters that can sharply enhance the performance of oil producing companies. Likewise, the results show that A1 (National Iranian South Oil Company) has the highest performance. It can assist oil producing companies to enhance their performance with the aid of benchmarking patterns in order to maintain competitiveness. The proposed model provides a framework for analyzing organizations to develop a strategy map as a reference for the future development. The results demonstrate that the proposed model has a high potential to evaluate the oil companies and prioritize the companies in descending order. It is hoped that this model can assist oil producing companies to maintain competitiveness.

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Figures

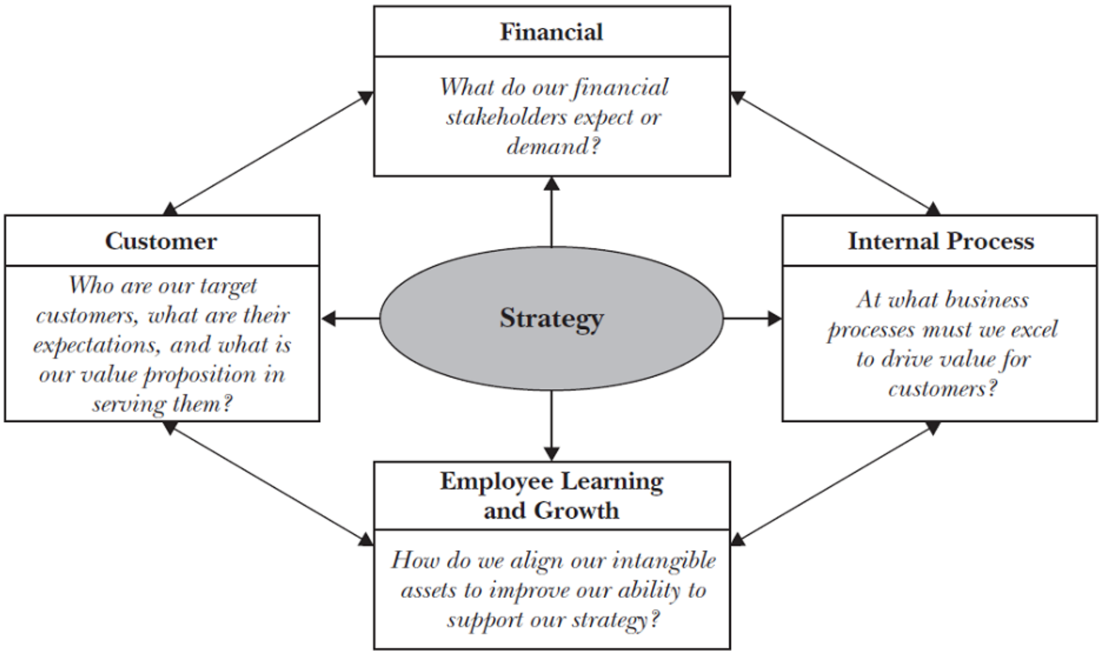

Fig. 1. A simple framework of BSC elements (Niven, 2008)

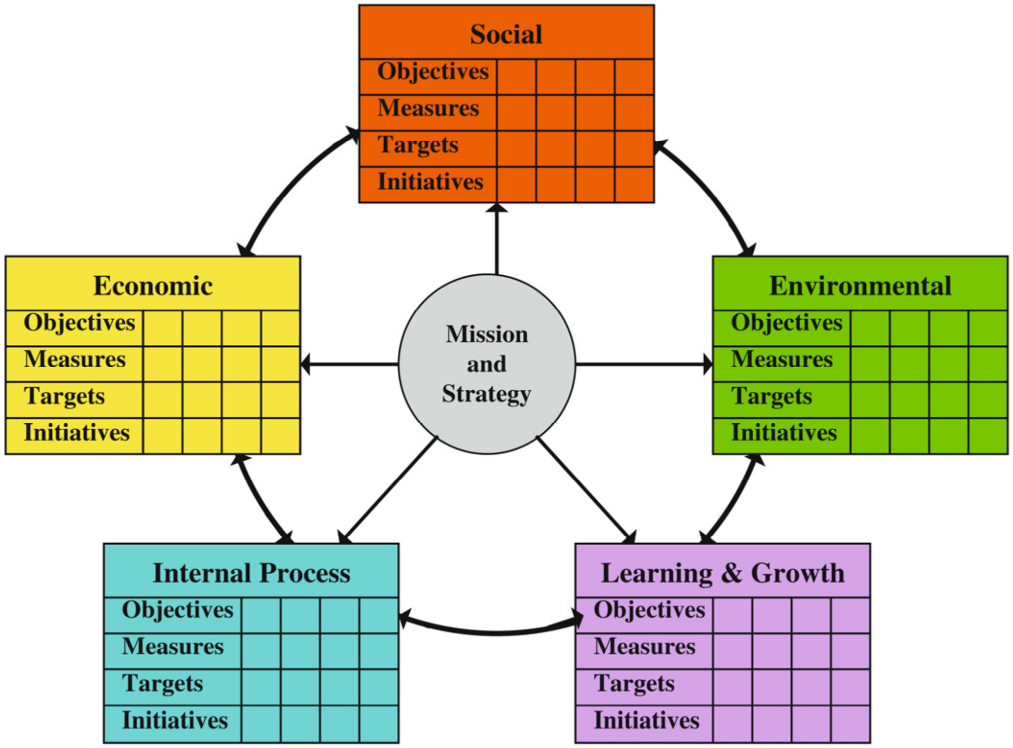

Fig. 2. Structure of SBSC technique

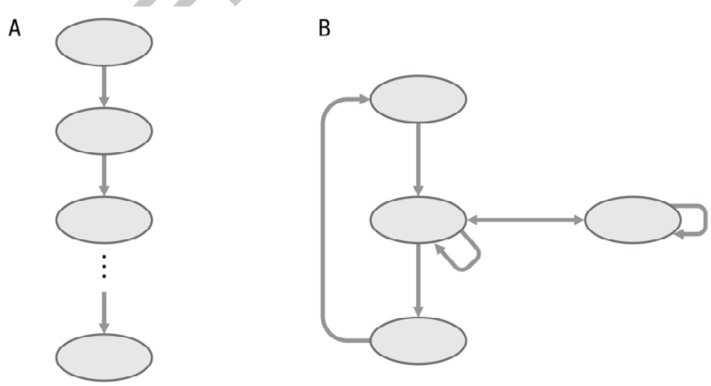

Fig. 3. The difference between a hierarchy (A) and a network (B) (Azimi et al., 2011)

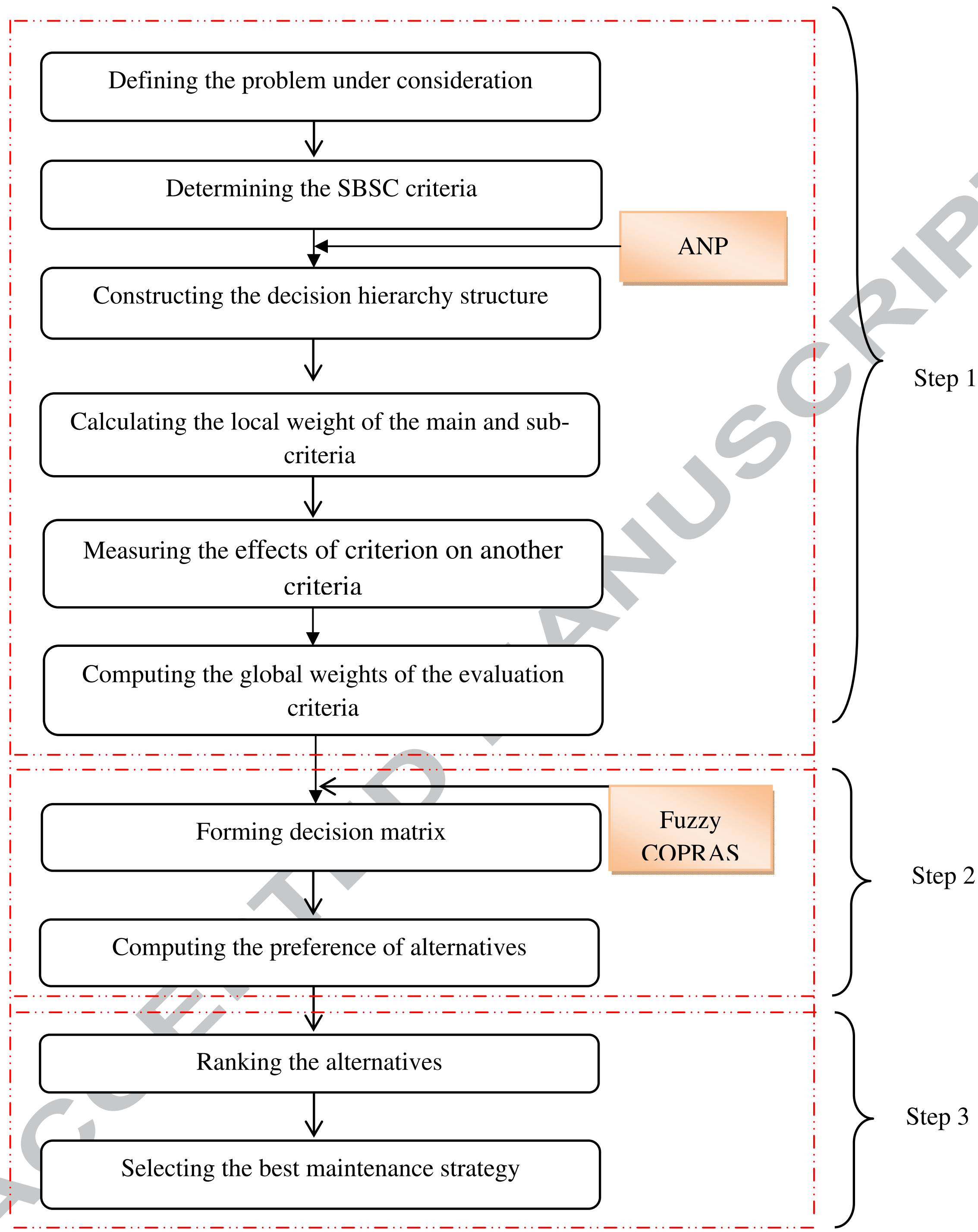

Fig. 4. Schematic diagram of the proposed model

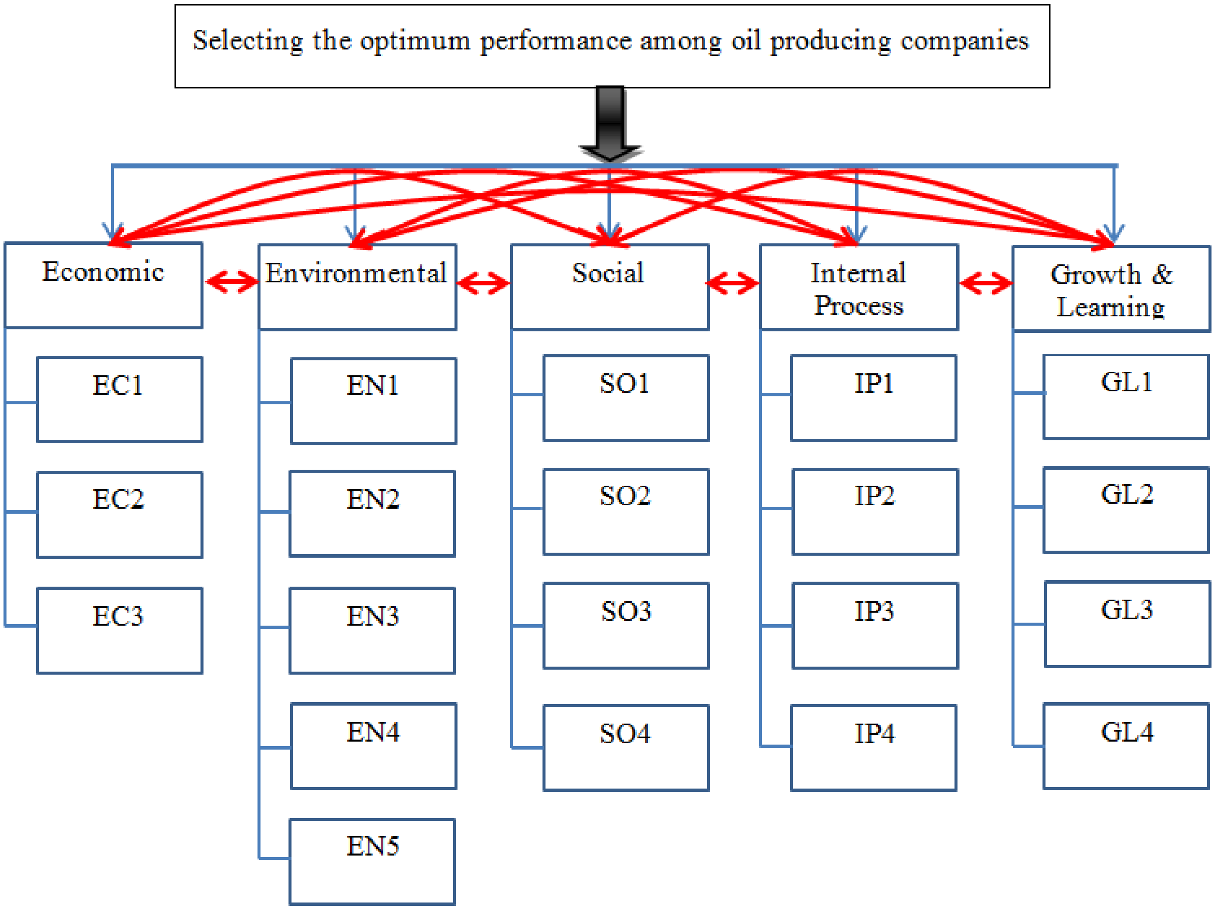

Fig. 5. Structure of decision hierarchy

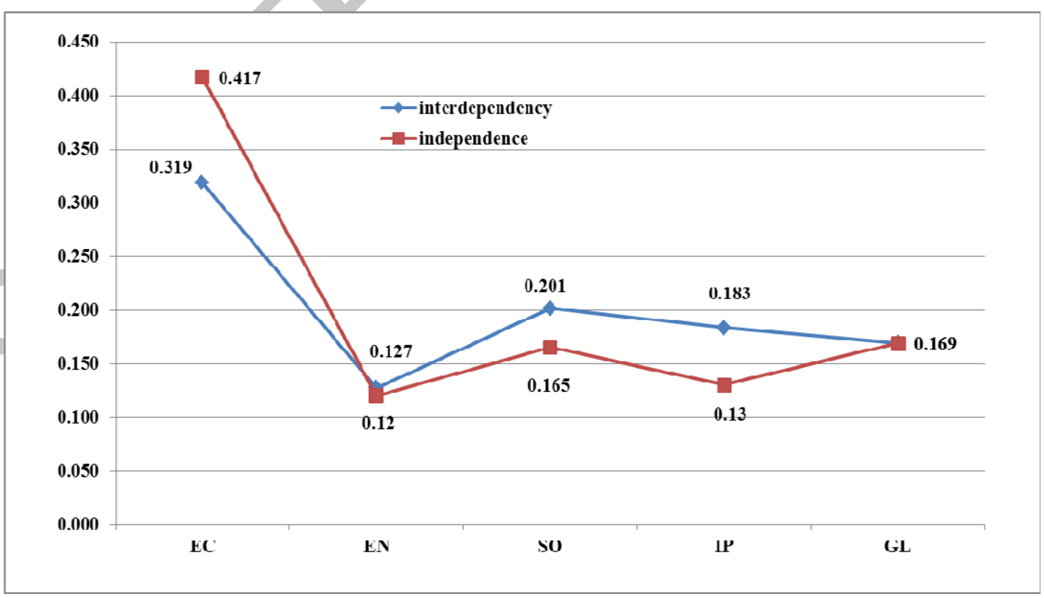

Fig. 6. Difference between outputs when interdependency is or is not considered

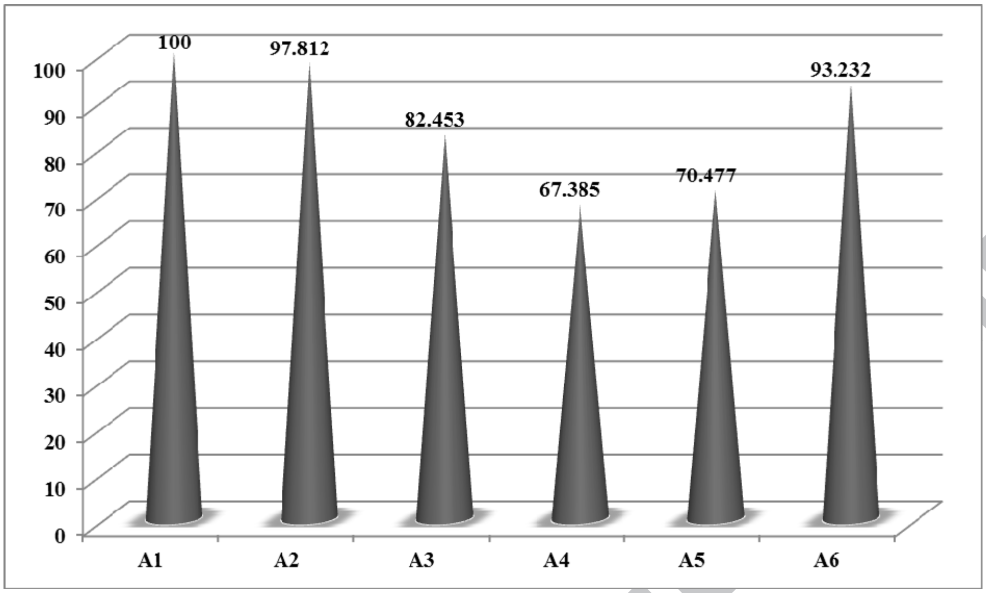

Fig. 7. Ranking of working strategies

Table 1. A list of the recent studies

Proposed by	Application
Asosheh et al (2010)	Information technology project evaluation
Chen et al (2011)	Measuring the sustainable performance of the semiconductor industry
Chytas et al (2011)	Generating a dynamic network of interconnected key performance indicators
Li et al (2011)	determine the aggregated priority ratings of engineering characteristics in the extended product planning house of quality
Hsiao & Wen (2011)	Performance measurement of knowledge management
Fouladgar et al (2011)	Prioritizing strategies of the Iranian mining sector
Grigoroudis et al (2012)	Strategic performance measurement in healthcare organization
Amado et al (2012)	Assessing decision making units
Lin et al (2013)	Evaluating operating room performance in hospitals
Hashemkhani Zolfani & Ghadikolaei (2013)	Performance evaluation of private universities
Dreveton (2013)	Public sector
Costa & Menichini (2013)	Corporate social responsibility assessment
Elbanna (2013)	Public sector
Ehbauer & Gresel (2013)	Luxury stores

Table 2. Linguistic terms for the preference rating of alternatives

Linguistic term	Corresponding triangular fuzzy number
Very poor (VP)	(0,1,3)
Poor (P)	(1,3,5)
Fair (F)	(3,5,7)
Good (G)	(5,7,9)
Very good (VG)	(7,9,10)

Table 3. List of oil producing companies in Iran

Company	**Symbol**	**Description**
National Iranian South Oil Company (NISOC)	A1	This entity is responsible for onshore oilfields in the south of Iran. The entity focuses onshore upstream activities on oilfields in the province of Khuzestan, where the main oil resources of Iran are identified. This entity is one of the most important entities in the NIOC family.
Khazar Oil Exploration and Production Company	A2	This entity has responsibility for both onshore and offshore of Iran's Caspian Sea sector.

Pars Oil and Gas Company (POGC)	A3	This entity has responsibility of the offshore North and South Pars gas fields.
Arvandan Oil & Gas Company (AOGC)	A4	This entity is in charge of developing the Arvandan oil & gas fields. The entity is the main operator in oil and gas production from Yadavaran, Jufeyr, Arvand, Azadegan, Omid, Darquain, , Moshtagh, Khorramshahr, Susangerd, Band-e-Karkheh, and other fields located in west of Karun River.
Iranian Offshore Oil Company (IOOC)	A5	This entity has responsibility for offshore oil fields in the Persian Gulf with the exception of South Pars. The entity focuses mainly on installations, ancillary facilities, and production platforms.
National Iranian Central Oil Company	A6	This entity supervises all upstream activities in the central oil and gas fields of the country, excluding the oil-rich southern Khuzestan province, offshore, and Caspian.

Table 4. List of main and sub-criteria

Main criteria	Sub-criteria
Economic (EC)	Revenue growth rate (EC1)
	Financial risk reduction (EC2)
	Diminishing the overall cost (EC3)
Environmental (EN)	Air pollution (En1)
	Noise (EN2)
	CO2 emissions (EN3)
	Impacts on ecosystems (EN4)
	Animal welfare (EN5)
Social (SO)	Customer relationship management (SO1)
	Equity (SO2)
	Job security for employees (SO3)
	Quality of life (SO4)
Internal Process (IP)	Personnel rights (IP1)
	Ability to respond to emergencies (IP2)
	Improvement of efficiency (IP3)
	Employee productivity (IP4)
Growth & Learning (GL)	Employee education (GL1)
	Research & development (GL2)
	Employee knowledge sharing (GL3)
	Enhancing the labor force skills (GL4)

Table 5. Local weights of SBSC factors

SBSC factors	EC	EN	SO	IP	GL	Local weights
EC	1.00	3.50	2.67	3.21	2.35	0.417
EN	0.29	1.00	0.78	0.96	0.64	0.120
SO	0.37	1.28	1.00	1.37	1.02	0.165
IP	0.31	1.04	0.73	1.00	0.87	0.130
GL	0.43	1.56	0.98	1.15	1.00	0.169
GCI	0.001					

Table 6. Local weights of EC sub-factors

EC sub-factors	EC1	EC2	EC3	Local weights
EC1	1.00	1.68	1.14	0.405
EC2	0.60	1.00	1.72	0.331
EC3	0.88	0.58	1.00	0.264
GCI	0.026			

Table 7. Local weights of EN sub-factors

EN sub-factors	EN1	EN2	EN3	EN4	EN5	Local weights
EN1	1.00	3.46	1.56	2.32	1.78	0.336
EN2	0.29	1.00	0.63	0.89	0.72	0.117
EN3	0.64	1.59	1.00	2.46	3.08	0.278
EN4	0.43	1.12	0.41	1.00	0.91	0.127
EN5	0.56	1.39	0.32	1.10	1.00	0.142
GCI	0.022					

Table 8. Local weights of SO sub-factors

SO sub-factors	SO1	SO2	SO3	SO4	Local weights
SO1	1.00	0.93	0.67	1.21	0.226
SO2	1.08	1.00	1.16	1.72	0.293
SO3	1.49	0.86	1.00	2.26	0.316
SO4	0.83	0.58	0.44	1.00	0.164
GCI	0.009				

Table 9. Local weights of IP sub-factors

IP sub-factors	IP1	IP2	IP3	IP4	Local weights
IP1	1.00	0.67	0.43	0.55	0.153
IP2	1.49	1	0.87	1.08	0.263
IP3	2.33	1.15	1.00	1.23	0.324
IP4	1.82	0.93	0.81	1	0.260
GCI	0.003				

Table 10. Local weights of GL sub-factors

GL sub-factors	GL1	GL2	GL3	GL4	Local weights
GL1	1.00	0.78	1.42	0.94	0.248
GL2	1.28	1	1.78	1.23	0.317
GL3	0.70	0.56	1.00	0.79	0.184
GL4	1.06	0.81	1.27	1	0.251
GCI	0.001				

Table 11. Interdependence matrix of the factors with respect to "Economic parameter"

Economic parameter	EN	SO	IP	GL	Relative importance weights

EN	1.00	0.78	0.54	0.63	0.176
SO	1.28	1.00	0.86	1.56	0.281
IP	1.85	1.16	1.00	1.27	0.312
GL	1.59	0.64	0.79	1.00	0.232
GCI	0.011				

Table 12. Interdependence matrix of the factors with respect to "Environmental parameter"

Environmental parameter	EC	SO	IP	GL	Relative importance weights
EC	1.00	0.91	1.12	1.67	0.276
SO	1.10	1.00	1.48	2.22	0.333
IP	0.89	0.68	1.00	1.37	0.230
GL	0.60	0.45	0.73	1.00	0.161
GCI	0.001				

Table 13. Interdependence matrix of the factors with respect to ''Social parameter"

Social parameter	EC	EN	IP	GL	Relative importance weights
EC	1.00	3.37	1.83	2.34	0.441
EN	0.30	1.00	0.79	0.87	0.153
IP	0.55	1.27	1.00	1.76	0.240
GL	0.43	1.15	0.57	1.00	0.165
GCI	0.009				

Table 14. Interdependence matrix of the factors with respect to "Internal process parameter"

Internal process parameter	EC	EN	SO	GL	Relative importance weights
EC	1.00	5.23	1.12	2.14	0.411
EN	0.19	1.00	0.36	0.48	0.093
SO	0.89	2.78	1.00	1.19	0.287
GL	0.47	2.08	0.84	1.00	0.208
GCI	0.009				

Table 15. Interdependence matrix of the factors with respect to "Growth & Learning parameter"

Growth & Learning parameter	EC	EN	SO	IP	Relative importance weights
EC	1.00	3.21	1.12	1.57	0.364
EN	0.31	1	0.56	0.78	0.145
SO	0.89	1.79	1.00	0.89	0.258
IP	0.64	1.28	1.12	1.00	0.233
GCI	0.015				

Table 16. Overall weights for indicators

SBSC factors	Weight of the main criteria	Evaluation indicators	Local weights	Global weights
EC	0.417	EC1	0.169	0.149

		EC2	0.138	0.122
		EC3	0.110	0.097
EN	0.120	EN1	0.040	0.036
		EN2	0.014	0.012
		EN3	0.033	0.029
		EN4	0.015	0.013
		EN5	0.017	0.015
SO	0.165	SO1	0.090	0.080
		SO2	0.056	0.049
		SO3	0.067	0.059
		SO4	0.083	0.073
IP	0.130	IP1	0.020	0.018
		IP2	0.034	0.030
		IP3	0.042	0.037
		IP4	0.034	0.030
GL	0.169	GL1	0.042	0.037
		GL2	0.054	0.047
		GL3	0.031	0.027
		GL4	0.042	0.037

Table 17. Fuzzy decision matrix

	A1	A2	A3	A4	A5	A6
EC1	(5, 7.52, 10)	(3, 6.78, 10)	(1, 3.25, 7)	(1, 4.21, 9)	(1, 4.34, 9)	(3, 7.21, 10)
EC2	(3, 5.21, 9)	(5, 8.31, 10)	(1, 4.76, 9)	(1, 3.78, 9)	(1, 3.78, 9)	(5, 7.79, 10)
EC3	(1, 4.23, 7)	(1, 5.12, 9)	(0, 3.21, 7)	(0, 3.2, 7)	(1, 5.23, 9)	(3, 6.89, 10)
EN1	(1, 5.16, 9)	(0, 3.56, 7)	(1, 4.57, 9)	(0, 4.12, 7)	(1, 4.87, 9)	(0, 2.87, 7)
EN2	(3, 7.89, 10)	(0, 2.76, 5)	(0, 2.87, 7)	(0, 1.87, 7)	(3, 5.48, 9)	(1, 3.76, 7)
EN3	(5, 8.14, 10)	(0, 3.89, 7)	(0, 3.91, 9)	(0, 2.56, 9)	(1, 4.32, 9)	(1, 5.38, 9)
EN4	(1, 4.31, 7)	(1, 5.12, 9)	(0, 1.64, 7)	(1, 4.31, 9)	(3, 6.12, 10)	(1, 5.09, 9)
EN5	(3, 6.42, 9)	(1, 3.76, 7)	(3, 6.47, 9)	(3, 6.25, 10)	(1, 4.21, 7)	(1, 3.66, 7)
SO1	(3, 7.43, 10)	(3, 6.92, 10)	(1, 4.75, 9)	(1, 5.23, 9)	(3, 5.46, 9)	(5, 7.86, 10)
SO2	(5, 8.13, 10)	(3, 7.21, 10)	(1, 5.32, 10)	(3, 5.56, 10)	(3, 6.43, 10)	(5, 8.09, 10)
SO3	(1, 4.76, 7)	(1, 3.98, 7)	(0, 2.09, 5)	(1, 3.78, 9)	(1, 4.69, 9)	(1, 5.13, 9)
SO4	(3, 6.21, 9)	(1, 4.54, 9)	(1, 5.14, 10)	(1, 4.06, 7)	(0, 3.56, 7)	(3, 6.37, 10)
IP1	(3, 5.42, 9)	(1, 4.23, 9)	(1, 4.23, 9)	(0, 3.24, 7)	(1, 3.77, 9)	(1, 4.56, 9)
IP2	(3, 6.57, 10)	(1, 4.42, 7)	(1, 3.86, 7)	(1, 4.51, 9)	(1, 3.45, 10)	(3, 5.52, 10)
IP3	(1, 5.13, 9)	(3, 6.29, 9)	(1, 3.67, 7)	(1, 3.89, 7)	(1, 4.09, 9)	(1, 5.32, 9)
IP4	(1, 4.35, 7)	(1, 4.41, 7)	(0, 4.16, 9)	(0, 3.07, 7)	(0, 3.12, 7)	(1, 4.13, 9)
GL1	(3, 6.76, 10)	(1, 5.13, 9)	(3, 6.23, 10)	(1, 4.78, 9)	(1, 4.24, 9)	(3, 5.78, 10)
GL2	(5, 8.34, 10)	(5, 7.78, 10)	(3, 7.11, 10)	(1, 3.65, 7)	(1, 5.56, 9)	(3, 6.15, 10)
GL3	(0, 3.21, 7)	(3, 5.87, 9)	(1, 4.78, 9)	(0, 3.12, 7)	(1, 3.56, 7)	(1, 3.78, 9)
GL4	(1, 4.89, 9)	(1, 4.56, 7)	(1, 3.93, 7)	(1, 5.09, 9)	(3, 6.32, 9)	(3, 7.36, 10)

Table 18. Defuzzified decision matrix

	Global weights of indicators	A1	A2	A3	A4	A5	A6
EC1	0.149	7.507	6.593	3.750	4.737	4.780	6.737
EC2	0.122	5.737	7.770	4.920	4.593	4.593	7.597
EC3	0.097	4.077	5.040	3.403	3.400	5.077	6.630
EN1	0.036	5.053	3.520	4.857	3.707	4.957	3.290

EN2	0.012	6.963	2.587	3.290	2.957	5.827	3.920
EN3	0.029	7.713	3.630	4.303	3.853	4.773	5.127
EN4	0.013	4.103	5.040	2.880	4.770	6.373	5.030
EN5	0.015	6.140	3.920	6.157	6.417	4.070	3.887
SO1	0.080	6.810	6.640	4.917	5.077	5.820	7.620
SO2	0.049	7.710	6.737	5.440	6.187	6.477	7.697
SO3	0.059	4.253	3.993	2.363	4.593	4.897	5.043
SO4	0.073	6.070	4.847	5.380	4.020	3.520	6.457
IP1	0.018	5.807	4.743	4.743	3.413	4.590	4.853
IP2	0.030	6.523	4.140	3.953	4.837	4.817	6.173
IP3	0.037	5.043	6.097	3.890	3.963	4.697	5.107
IP4	0.030	4.117	4.137	4.387	3.357	3.373	4.710
GL1	0.037	6.587	5.043	6.410	4.927	4.747	6.260
GL2	0.047	7.780	7.593	6.703	3.883	5.187	6.383
GL3	0.027	3.403	5.957	4.927	3.373	3.853	4.593
GL4	0.037	4.963	4.187	3.977	5.030	6.107	6.787

Table 19. Weighted decision matrix

	A1	A2	A3	A4	A5	A6
EC1	0.149	0.131	0.075	0.094	0.095	0.134
EC2	0.090	0.122	0.077	0.072	0.072	0.119
EC3	0.092	0.113	0.077	0.050	0.074	0.097
EN1	0.036	0.025	0.034	0.026	0.035	0.023
EN2	0.012	0.005	0.006	0.005	0.010	0.007
EN3	0.029	0.014	0.016	0.015	0.018	0.020
EN4	0.009	0.011	0.006	0.010	0.013	0.011
EN5	0.143	0.091	0.143	0.013	0.009	0.008
SO1	0.071	0.069	0.051	0.053	0.061	0.080
SO2	0.049	0.043	0.035	0.040	0.042	0.049
SO3	0.050	0.047	0.028	0.054	0.057	0.059
SO4	0.069	0.055	0.061	0.046	0.040	0.073
IP1	0.018	0.014	0.014	0.010	0.014	0.015
IP2	0.030	0.019	0.018	0.022	0.022	0.029
IP3	0.031	0.037	0.024	0.024	0.029	0.031
IP4	0.026	0.026	0.028	0.021	0.021	0.030
GL1	0.037	0.028	0.036	0.028	0.027	0.035
GL2	0.047	0.046	0.041	0.024	0.032	0.039
GL3	0.016	0.027	0.023	0.016	0.018	0.021
GL4	0.027	0.023	0.022	0.028	0.034	0.037

Table 20. Fuzzy COPRAS results

	A1	A2	A3	A4	A5	A6
P_i	0.945	0.894	0.752	0.595	0.646	0.857
R_i	0.086	0.054	0.063	0.056	0.077	0.060
Q_i	0.994	0.973	0.820	0.670	0.701	0.927
N	100.000	97.812	82.453	67.385	70.477	93.232
Rank	1	2	4	6	5	3

Research highlights

► The balanced scorecard (BSC) approach is a performance evaluation technique. ► The BSC method can be combined with sustainable development factors. ► the ANP technique is capable of formulating the interdependency among criteria. ► COPRAS method is an appropriate tool for evaluation alternatives. ► Combination of the ANP and COPRAS is a new powerful for making a decision.