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Implementing Fuzzy Logic and AHP into the EFQM model for performance improvement: A case study

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ABSTRACT

In the current volatile and demanding business environment, managers are so eager to demonstrate that their organizations are excellent which can mainly be achieved through continuous performance improvement. The most applicable and suitable tools that by the assessment of organizations shows how successful they are in the organizational excellence path is European Foundation for Quality Management (EFQM) Excellence Model. This study aims at presenting a new integrated approach based on EFQM model using Fuzzy Logic, Analytical Hierarchy Process (AHP) technique and Operations Research (OR) model to improve the organizations' excellence level by increasing the quality of business performance evaluation and determining of improvement projects with high priority. A case study in Yazd Regional Electricity Co. in Iran is presented to demonstrate the applicability of the proposed approach. In a way that, primarily, performance assessment by crisp method and the proposed method, Fuzzy method, is carried out. Then, strength points and the areas for improvement are identified by defining the scores for sub-criteria. Next, sub-criteria are prioritized to define the improvement projects by using AHP technique and Operations Research model. Finally, improvement projects with high priority are determined and some action plans for improvement projects are defined.

1. Introduction

Each organization, regardless of its activity, size, structure, experience or success to meet its own organizational goals, requires measuring its success to achieve its ideal goals and business strategies. In different organizations, there are various models such as EFQM for evaluating performance. EFQM model was developed in Europe in 1998. At present, it is applied as an executive tool to help organizations to measure how much they are in the path of organizational excellence and evaluate their balanced growth. This model helps organizations to identify discrepancies by comparing their current and ideal positions, define some solutions to optimize their current position, implement them according to these discrepancies, and examine their causes. The aim of self-assessment is to analyze the strength points and the areas for improvement. Therefore, to achieve this goal, EFQM model most applied in the process of self-assessment by organizations, considering a cause and effect relationship between enablers and results criteria. Since the nature of assessment is qualitative, the framework definition by itself cannot solve all assessment problems.

Nowadays, decisions are made in increasingly complex environments, as multi-criteria decision-making problems and stakeholders dealt with many issues. For instance, on the one hand, there is not enough precise information about the preferences of decision-makers. On the other hand, the decision-makers are usually unable to explicit about their preferences due to the Fuzzy nature of the decision process; they give point judgments instead of interval ones. Meanwhile, in more and more cases today the use of experts in various fields is necessary, such as self-assessment. As the self-assessment results are partly varied depending on various opinions, thus the scores of various assessors will be different. It sounds that Fuzzy Logic can be an appropriate tool to solve the above problems by providing the flexibility and robustness needed for the decision makers.

Leading organizations to stay ahead in today's dynamic competitive business market and in order to continue on the path of excellence require continuous implementation of performance improvement projects. The matter in the first instance through a detailed performance evaluation and then determining and implementation of improvement projects with high priority is possible.

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In contrast, as mentioned earlier, self-assessment using EFQM model has some shortcomings. According to the literature, it seems that applying Fuzzy Logic in some performance assessment models such as EFQM excellence model has not yet been considered in the literature and particularly, there is no study aimed at evaluating the performance by EFQM excellence model and obtaining the prioritization using Fuzzy Logic, AHP technique and OR model in the related literature. The main purpose of this study is to provide practitioners and academics with a methodology in which Fuzzy Logic used, in the performance evaluation using the EFQM model for dealing with imprecision and applying AHP and OR in the priority setting of improvement projects in order to accelerate achieving the goal. The use of Fuzzy Logic for EFQM excellence model simplifies the process of assessment. Additionally, the results of assessment do not depend on various opinions. Therefore, it can be a definite and comprehensive alternative for evaluating all organizations. Based on Fuzzy Logic, the tasks of assessors for defining the scores for the enablers comprising of the elements of approach, deployment, and assessment & refinement and for the results consisting of the elements of performance, relevance, and usability are facilitated; regarding assessments scores, there are decreased discrepancies among various assessors. Moreover, using AHP technique and OR model leads to considerable savings in the resources of organization caused by improvements in the areas for improvement with low priority. In summary, the proposed method has not only the advantage of mathematically represent uncertainty, and provide a formalized tools for dealing with the imprecision intrinsic to performance assessment process and in the priority setting of improvement projects, but also it can provide the simple, flexible, and adaptable solution for better organizational excellence management. These merits of the approach developed would facilitate its use for making efficient performance improvement projects. The contribution provides originality to this study is not only employing Fuzzy Logic as well as using AHP technique and OR model to improve the excellence level of organizations by EFQM excellence model for the first time, but also releasing a comprehensive literature review of applying EFQM model and its combination with other models, techniques and methodologies, development and using of Fuzzy Logic, studies conducted by using combined Fuzzy Logic and AHP, development of Fuzzy AHP technique and examples of its applications, and using of expert system and its combination with Fuzzy Logic and Fuzzy AHP methods. In addition, by stating the steps of implementing Fuzzy Logic, AHP technique and OR model into the EFQM model clearly and numerically, this study can be a comprehensive guide of the practical methodology to be implemented to other performance improvement projects in any field of study.

The rest of this paper is organized as follows: Section 2 illustrates literature review. Section 3 presents EFQM excellence model, Fuzzy Logic and Analytical Hierarchy Process. Section 4 describes the proposed method in a way that, primarily, performance assessment is conducted by a Fuzzy method. Next, the order for implementing improvement projects is defined by using AHP technique and OR model. Then, the results for applying this method are provided. Finally, the conclusions and future work directions are discussed in Section 5.

2. Literature review

In line with the already discussed critical issues and challenges, for articulation of research problem, research literature will be studied in a way that, primarily, the implementation of EFQM model and its combination with other models, techniques and methodologies, then, Fuzzy Logic, a combination of Fuzzy Logic and AHP technique, Fuzzy AHP technique and finally, applying expert system will be discussed in more detail.

Various articles introduced on applying EFQM model in organizations in the literature, can be categorized in the following two general groups:

1) There are some articles which have presented a discussion only about the implementation of EFQM model and have led to applying and analyzing EFQM model and moving towards the excellence as follows: Mariscal et al. [1] have aimed at finding evidence of the safety culture that was in place at the Sta María de Garona nuclear power plant in Spain, and at identifying both the strengths of that culture and any areas in which it could be improved. For this aim, the identification of perceptions and evidence, the agreement on the strong points and the areas for improvement and the quantification of the safety culture performed by groups comprising volunteers who worked at the plant. The score obtained from an analysis of those strengths and areas for improvement made it possible to prioritize the actions to be taken. Research of Bayo-Moriones et al. [2] which is conducted in the region of Navarre in Spain, tries to analyze the differences between the two most frequently used quality management approaches implemented by firms, ISO 9000 and EFQM, in terms of their impact on the adoption of innovative work organization practices. In order to accomplish this objective, they selected a sample of 665 establishments with at least 20 employees, from the manufacturing, building and service sectors. Results indicated that, as expected, EFQM involves an advance over ISO 9000 regarding the use of innovative work practices. Sozuer [3] has surveyed four-star city hotels in Istanbul and has found areas for improvement. The survey tool was the EFQM excellence model and applied to eight hotels as a multiple-case studies design. Findings demonstrated that, while hotels are managing customer related processes properly, there appears a big gap between the current approaches and the model's leadership, strategy, and people criteria. Research of Nazemi [4] which is conducted in Iranian companies from different business sectors from manufacturing to service but almost in automotive supply chain, tries to analyze EFQM model integrity and its appropriateness for improvement plans. Results showed that the model does not have a structured approach about how to exploit strengths, classify and prioritize areas of improvement. Research of Michalska [5] which is carried out in a selected company of the machine industry in Poland aimed at showing the EFQM excellence model approach. Therefore, the EFQM excellence model is applied not only in the whole organization but also in the selected processes in the company. The best result was obtained in customer results, and the worst was society results. Through this approach, the organization is better able to balance its priorities, allocate resources and generate realistic business plans. Research of Shafaei and Dabiri [6] which is conducted in a selected Iranian company which manufactures industrial components, tries to propose an EFQM based model to assess the readiness of an enterprise for effective and successful Enterprise Resource Planning (ERP) implementation. The proposed model is applied to assess the readiness of the company intending to implement an ERP system. Finally, the results of the assessment are discussed and concluding remarks are presented.
2) The articles which have provided a combination of EFQM model with other models, techniques and methodologies, such as Data Envelopment Analysis (DEA) [7], intellectual capital management [8], DEMATEL technique [9], and Systems Dynamics [10–12], improve the effectiveness of EFQM model.

In the coming part, at first, the literature will be reviewed with regard to the development and application of Fuzzy Logic; and the research conducted using combined Fuzzy Logic and AHP techniques. After that the research done on the development of Fuzzy AHP technique and examples of its applications are discussed. Then, the research conducted into the applying expert system and its combination with Fuzzy Logic and Fuzzy AHP methods is presented.

Some studies in the literature have been conducted towards the advances in Fuzzy Logic. Godoy Simoes and Friedhofer [13] developed an improved Fuzzy decision support algorithm based on a diffusion–intensification operator. Sałabun [14] presented how to identify nonlinear multi-criteria decision-making models using new Fuzzy method called the Characteristic Objects Method (COMET).

In the area of using Fuzzy Logic, many researches have been performed to consider the Fuzzy Logic in diverse applications as an effective tool on the development of various fields. Lin et al. [15] proposed a Fuzzy multi-criteria decision-making procedure to facilitate data warehouse system selection considering both technical and managerial criteria. Dattathrey et al. [16] brought forward a novel Fuzzy deterministic non-controller type (FDNCT) system and an FDNCT Inference Algorithm (FIA) to detect and to eliminate potential fires in the engine and battery compartments of a hybrid electric vehicle. Kaleem et al. [17] presented the design and implementation of a Fuzzy multi-criteria based Vertical Hand Off Necessity Estimation (VHONE) scheme that determines the proper time for VHO, while considering the continuity and quality of the currently utilized service, and the end-users' satisfaction. Dixit and Singh [18] developed a Fuzzy inference system for Crack Detection and Impact Source Identification (CDISI) with Field-Programmable Gate Array (FPGA) implementation. Ekel et al. [19] presented the use of Fuzzy set based models and methods of decision making for solving Power Engineering Problems. Vahidi et al. [20] proposed a model for selecting a suitable ERP system with triangular Fuzzy numbers and Mamdani inference.

Although there are many applications of Fuzzy Logic and AHP techniques in various fields but little research has addressed a problem using the hybrid techniques. Salehi et al. [21] used Fuzzy Logic and AHP techniques to evaluate soil fertility using soil organic carbon, potassium, phosphorus and salinity factors for rice cultivation in the Jooybar city of Mazandaran province in Iran.

More studies have been done on development of Fuzzy AHP over the past three decades. So, several procedures to improve the uncertainty and to attain the priorities in Fuzzy AHP method have been developed. The earliest work, in this regard, appeared in Van Laarhoven and Pedrycz [22], which applied Lootsma's Logarithmic least Square Method (LLSM) to derive Fuzzy weights with triangular Fuzzy numbers. Afterwards, Buckley [23] utilized a new method called the geometric mean method to derive Fuzzy weights with trapezoidal membership functions. Boender et al. [24] proposed a more robust approach for the normalization of the local priorities with the modification of Van Laarhoven and Pedrycz's method, a method based on the Fuzzy modification of the LLSM. Chang [25] introduced a new approach for handling pair-wise comparison scale based on triangular Fuzzy numbers. Also, Chang [26] presented a new approach for handling Fuzzy AHP with the use of triangular Fuzzy numbers for pairwise comparison scale of Fuzzy AHP, and the use of the extent analysis method for the synthetic extent value of the pairwise comparison. Xu [27] posited a Fuzzy least square priority method in the analytic hierarchy process. Csutora and Buckley [28] put forward a new method of finding the Fuzzy weights in Fuzzy hierarchical analysis, which is the direct fuzzification of the Lambda-Max method, used by Saaty in the analytical hierarchical process. Mikhailov [29] propound a new approach for deriving priorities from Fuzzy pairwise comparison judgments. Wang et al. [30] brought forward a two-stage logarithmic goal programming method for generating weights from interval comparison matrices. Wang and Chen [31] applied Fuzzy linguistic preference relations (Fuzzy LinPreRa) to construct a pairwise comparison matrix with additive reciprocal property and consistency to the improvement of consistency of Fuzzy AHP. More recently, Nieto-Morote and Ruz-Vila [32] presented a Fuzzy AHP methodology in which its most significant difference with the above methods is the use of an algorithm to handle the inconsistencies in the Fuzzy preference relation when pair-wise comparison judgments are necessary.

Turning attention to the applied aspect of Fuzzy AHP technique in the literature, it has been applied by many researchers for making decision in different fields. Some recent examples of Fuzzy AHP applications can be considered next. Zeng et al. [33] developed a modified Fuzzy AHP for the project risk assessment. Bozbura and Beskese [34] applied a methodology based on the extent Fuzzy analytic hierarchy process (AHP) to improve the quality of prioritization of organizational capital measurement indicators under uncertain conditions. Celik et al. [35] applied Fuzzy extended AHP methodology on shipping registry selection in the Turkish maritime industry. Chatterjee and Mukherjee [36] developed a Fuzzy AHP model to search the criteria for the evaluation of best technical institutions in India, which can tolerate vagueness and uncertainty of stakeholders. Talinli et al. [37] considered a holistic approach using the FAHP to find priority sequence of alternatives and obtain the key success factors for the selection of appropriate sites of wind farms. Tang and Lin [38] utilized the Fuzzy analytic hierarchy process to the lead-free equipment selection decision in an electronics company in Taiwan. Büyükozkan et al. [39] performed strategic analysis of healthcare service quality in Turkey using Fuzzy AHP methodology. Badizadeh and Khanmohammadi [40] developed a Fuzzy multi-criteria decision making model for assessment and selection of the best idea of new product development based on the criteria in a company associated with the automobile manufacturing industry in Iran. Kabir and Hasin [41] used a Fuzzy analytic hierarchy process for multiple criteria ABC inventory classification in a large power engineering company of Bangladesh. Javanbarg et al. [42] presented a Fuzzy optimization model to solve Multi-Criteria Decision Making (MCDM) systems based on Fuzzy AHP using an improved Particle Swarm Optimization (PSO). Rezaei et al. [43] proposed a Fuzzy AHP based approach to select the optimal alternative for construction of an underground dam in Iran's Kerman province. Batuhan Ayhan [44] applied a Fuzzy AHP approach for supplier selection in a gear motor company in Turkey. Mahendran et al. [45] used a Fuzzy AHP approach for choosing of measuring instrument for engineering college selection in India. Anvary Rostamy et al. [46] applied a Fuzzy Hierarchal Analysis Process (FAHP) for evaluation of the effects of Information Technology (IT) capabilities on the quality of customer service process in Iranian insurance companies. Mohaghar et al. [47] proposed a new integrated approach based on Fuzzy AHP and TOPSIS methods for selecting the best solution of knowledge management adoption in supply chain of a textile manufacturer.

Also, reviewing the resources associated with applying expert system shows that some researchers have focused on various fields using expert system such as identifying machine defects [48,49], improving compilers [50], the diagnosis of human diseases [51], detecting the defects of rolling ball bearing [52], predicting of forging load and axial stress [53], prediction of carbon monoxide concentration in mega-cities [54], linking multiple-receiver data for simulating the performance of land vehicle [55], solving lost circulation problem [56], and design of a pipeline leakage detection [57]. Some of researchers have also provided a combination of expert system with Fuzzy Logic and Fuzzy AHP methods, such as Cebeci [58] who proposed a Fuzzy AHP-based decision support system for selecting ERP systems in textile industry by using balanced scorecard. Fazel Zarandi et al. [59] developed a Fuzzy rule-based expert system for evaluating intellectual capital. Pal and Bhattacharya [60] presented a model to investigate the effect of road traffic noise pollution on human work efficiency in government offices, private organizations, and commercial business centres in Agartala city using Fuzzy expert system.

3. Preliminaries

3.1. EFQM excellence model

European Foundation for Quality Management (EFQM) consists of nine criteria. Five criteria are known as enablers and four others are called results. "Enablers" cover what an organization performs and "results" include what an organization obtains. "Results" are obtained by implementing "enablers" and "enablers" are improved by getting a feedback from "results". Enablers include leadership, strategy, people, partnerships & resources, and processes, products & services. Results are for customer, people, society, and key performance. All enablers, except strategy, include 5 sub-criteria. Strategy criterion includes 4 sub-criteria. Each of results also includes two sub-criteria. Thus, 24 sub-criteria and 8 sub-criteria respectively have been defined for enablers and results [61,62].

3.2. Fuzzy Logic

The theory of Fuzzy Logic is based on the notion of relative graded membership, as inspired by the processes of human perception and cognition. Fuzzy set theory was introduced by an Iranian scientist named Lotfi A. Zadeh in 1965. Fuzzy logic can deal with information arising from computational perception and cognition, that is, uncertain, imprecise, vague, partially true, or without sharp boundaries. Fuzzy Logic allows for the inclusion of vague human assessments in computing problems. Also, it provides an effective means for conflict resolution of multiple criteria and better assessment of options [63]. A fuzzy set is a class of objects, with a continuum of membership grades, where the membership grade can be taken as an intermediate value between 0 and 1. A fuzzy subset A of a universal set X is defined by a membership function $f(x)$ which maps each element x in X to a real number [0,1]. When the grade of membership for an element is 1, it means that the element is absolutely in that set. When the grade of membership is 0, it means that the element is absolutely not in that set. Ambiguous cases are assigned values between 0 and 1. The theory also allows mathematical operators such as addition, subtraction, multiplication and division, to be applied to the fuzzy sets [15].

3.3. Analytical Hierarchy Process (AHP)

Analytical Hierarchy Process (AHP), one of the most efficient decision making techniques, was originally introduced by Thomas L. Saaty in 1980 [64]. AHP is a multi-objective, multi-criteria decision-making approach, which enables the decision maker to arrive at a scale of preference drawn from a set of alternatives. It helps decision makers find out the best suits their goal and their understanding of a complex problem with multiple conflicting and subjective criteria. With this method, a complicated system is converted to a hierarchical system of elements. In each hierarchical level, pair-wise comparisons of the elements are made by using a nominal scale. These comparisons constitute a comparison matrix. To find the weight of each element, or the score of each alternative, the eigenvector of this matrix is calculated. At the end, the consistency of the pair-wise comparisons is calculated by using a consistency ratio. If it is below a predefined level, the comparisons are either revised by the decision-maker or excluded from the calculations [34].

Table 1
Triangular fuzzy numbers.

Option	Qualitative number	Triangular fuzzy number (m, α, β)
1	(Very low) a small segment of regions	(0, 0, 15)
2	(Low) almost one fourth of regions	(25, 15, 15)
3	(Normal) almost a half of regions	(50, 15, 15)
4	(High) almost three fourth of regions	(75, 15, 15)
5	(Very high) almost all regions	(100, 15, 0)

4. Evaluating, defining and prioritizing improvement projects based on EFQM excellence model

4.1. Performance assessment

4.1.1. Performance assessment by Crisp method

A self-assessment was carried out for Yazd Regional Electricity Company using award simulation approach. Yazd is one of the oldest cities of Iran located in central part which is famous for having wind catchers and Qanats [65]. At first, a self-assessment report was compiled. Then, the scores for each sub-criterion as well as total score for the organization were specified using scoring matrix for enablers and results. Company assessment log is shown in Fig. 1.

4.1.2. Performance assessment by Fuzzy method

In Crisp method, since a score from 0% to 100% (with a distance of 5%) is assigned to each element of sub-criterion, this range is spread (20 selectable options) and, so, all assessors may not give same scores to it. Thus, the scores from 0% to 100% can be divided into a limited range. It limits the numbers of selectable options (5 Fuzzy selectable options) for assessors. Hence, hesitancy for selecting proper score is decreased .Also, given all assessors mention that their scores are not definite; the scores of various assessors will mainly be similar. Thus, the scores will be more realistic.

Among the various shapes of Fuzzy number, triangular Fuzzy number is the most popular. Triangular Fuzzy number is a Fuzzy number represented with three points as following Eq. (1).

$$A = (m, \alpha, \beta) \quad (1)$$

In this regard, in the proposed method (Fig. 2), some scores are provided as triangular Fuzzy numbers; assessors define some scores for the features of sub-criterion elements by selecting one of 5 mentioned options are shown in Table 1:

1. 0%: (very low) no available reason and evidence (a small segment of the regions).
2. 25%: (low) limited evidence (almost one fourth of the regions).
3. 50%: (normal) remarkable evidence (almost half of the regions).
4. 75%: (high) precise and high evidence (almost three fourth of the regions).
5. 100%: (very high) widespread and complete evidence (almost all the regions).

There are several rank methods in Fuzzy Logic explained in the relevant literature. In this paper, the authors prefer Minkovoski formula by Rabbani et al. [66], since the steps of this approach are relatively more useful and easier than the other approaches. After obtaining the overall organization score, using Fuzzy Logic concepts and the formula for converting Fuzzy numbers to a definite number (Minkovoski formula) is shown as following Eq. (2), the overall

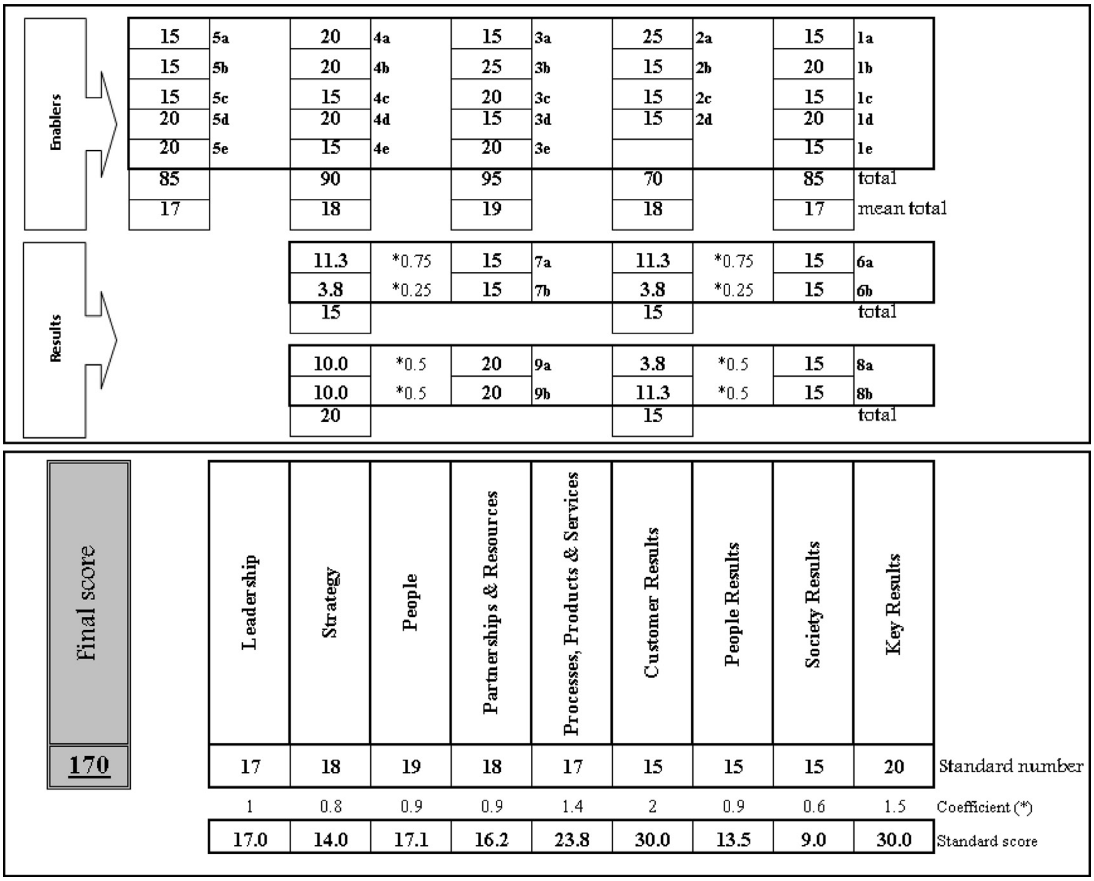

Fig. 1. Assessment log for Yazd Regional Electricity Company.

organization score was obtained as a Fuzzy number which is equal to a definite number.

$$X = m + \frac{(\alpha - \beta)}{4} \text{(Minkovoski formula)} \quad (2)$$

In the tables for scoring enablers, scores are assigned to each feature of approach, deployment, assessment and refinement elements as Fuzzy numbers. Then, the scores of sub-criterion, criterion and total scores are obtained by adding two Fuzzy numbers and scalar multiplication for averaging. Finally, Fuzzy scores for sub-criterion, criterion and total scores are converted to definite numbers, using Fuzzy Logic concepts and the formula for converting Fuzzy numbers to definite numbers (Minkovoski formula).

Similar steps are performed for results scoring tables. In the proposed method, scoring of enablers, results, calculation of EFQM sub-criteria scores, and assessment log for Yazd Regional Electricity Company are illustrated in Tables 2 and 3 and Figs. 3 and 4.

Table 2 depicts the proposed scoring of enablers, the method which changes the meaning of and the method of allocating scores. By using Table 2, each of the enablers sub-criterion elements is evaluated according to the approach, deployment, and assessment & refinement elements based on the amount of evidence identified by selecting one of 5 options, including very low, low, normal, high, and very high.

Table 3 depicts the proposed scoring of results. Each of the results sub-criterion elements is evaluated according to the

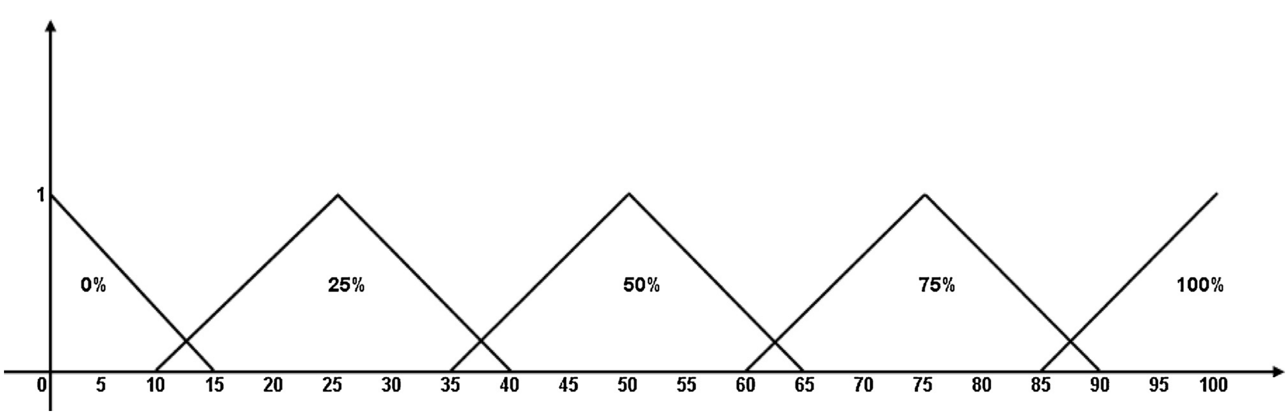

Fig. 2. Display for triangular fuzzy numbers for quintet options.

Table 2
Proposed scoring of enablers.

Elements	Attributes	Very low	Low	Normal	High	Very high
Approach	Sound	No evidence or anecdotal	Some evidence	Remarkable evidence	Precise and clear evidence	Complete and comprehensive evidence
	Integrated	No evidence or anecdotal	Some evidence	Remarkable evidence	Precise and clear evidence	Complete and comprehensive evidence
	Mean					
Deployment	Implemented	No evidence or anecdotal	Implemented in ¼ of relevant areas	Implemented in ½ of relevant areas	Implemented in ¾ of relevant areas	Implemented in all relevant areas
	Systematic	No evidence or anecdotal	Some evidence	Remarkable evidence	Precise and clear evidence	Complete and comprehensive evidence
	Mean					
Assessment and Refinement	Measurement	No evidence or anecdotal	Some evidence	Remarkable evidence	Precise and clear evidence	Complete and comprehensive evidence
	Learning and Creativity	No evidence or anecdotal	Some evidence	Remarkable evidence	Precise and clear evidence	Complete and comprehensive evidence
	Improvement and Innovation	No evidence or anecdotal	Some evidence	Remarkable evidence	Precise and clear evidence	Complete and comprehensive evidence
	Mean					
Total Mean						

Table 3
Proposed scoring of results.

Elements	Attributes	Very low	Low	Normal	High	Very high
Performance	Trends	No results or verbal information	Positive trend and/or sustained good performance for about ¼ results over at least 3 years	Positive trend and/or sustained good performance for about ½ results over at least 3 years	Positive trend and/or sustained good performance for about ¾ results over at least 3 years	Positive trend and/or sustained good performance for all results over at least 3 years
	Targets	No results or verbal information	Set appropriate and achieved for about ¼ key results	Set appropriate and achieved for about ½ key results	Set appropriate and achieved for about ¾ key results	Set appropriate and achieved for all key results
	Comparison	No results or verbal information	Established favourable and appropriate comparisons for about ¼ key results	Established favourable and appropriate comparisons for about ½ key results	Established favourable and appropriate comparisons for about ¾ key results	Established favourable and appropriate comparisons for all results
	Causes	No results or verbal information	Enabling effect visible for about ¼ results and some evidence that performance will be sustained	Enabling effect visible for about ½ results and Remarkable evidence that performance will be sustained	Enabling effect visible for about ¾ results and Precise & clear evidence that performance will be sustained	Enabling effect visible for all results and Complete & comprehensive evidence that performance will be sustained
	Mean					
Relevance and usability	Scope	No result or verbal information	Result presented and relevance established for about ¼ areas involved	Result presented and relevance established for about ½ areas involved	Result presented and relevance established for about ¾ areas involved	Result presented and relevance established for all of the areas involved
Total Mean						

Performance and Relevance & Usability elements based on the amount of results presented by selecting one of 5 options, including very low, low, normal, high, and very high.

Fig. 3 displays the calculation of EFQM sub-criteria scores by the proposed method. As can be seen, the top two rows in Fig. 3 display the scores of sub-criteria for enablers and result domains of the EFQM as fuzzy numbers. The next row displays the scores of the nine criteria as fuzzy numbers.

Fig. 4 displays the assessment log for Yazd Regional Electricity Company by the proposed method. As can be seen, using Fuzzy Logic concepts and the Minkovoski formula, the top two rows in Fig. 4 display the scores of sub-criteria for enablers and result domains of the EFQM as definite numbers, and the next row displays the scores of the nine criteria and total score as definite numbers. Fig. 4 also reports the value of the total score as definite number was specified by Fuzzy method is near to the value of the total score for the organization performance was specified by Crisp method. The total score obtained by applying the proposed method indicates a higher degree of closeness to the real score for the organization performance.

4.2. Strength points and areas for improvement

Strength points and the areas for improvement were identified by defining the scores for sub-criteria. Also, to verify extracted strength points and the areas for improvement, some forms were distributed to get company experts' opinions. Finally, some

Enablers	(8.3,5,15)	5a	(25,15,15)	4a	(8.3,5,15)	3a	(25,15,15)	2a	(17.5,7.5,15)	1a
	(8.3,5,15)	5b	(20.8,12.5,15)	4b	(25,15,15)	3b	(16.6,10,15)	2b	(25,15,15)	1b
	(8.3,5,15)	5c	(8.3,5,15)	4c	(25,15,15)	3c	(8.3,5,15)	2c	(20.8,12.5,15)	1c
	(25,15,15)	5d	(25,15,15)	4d	(8.3,5,15)	3d	(16.6,10,15)	2d	(25,15,15)	1d
	(25,15,15)	5e	(8.3,5,15)	4e	(16.6,10,15)	3e			(21.6,10,15)	1e
	(74.9,45,75)		(87.4,10.5,75)		(83.2,50,75)		(65,40,60)		(108.5,60,75)	total
	(14.9,9,15)		(17.4,2.1,15)		(16.6,10,15)		(16.2,10,15)		(22,12,15)	mean total
Results			(14.0,4.2,11.2)	*0.75	(18.7,11.2,15)	7a	(6.9,4.2,11.2)	*0.75	(9.3,5.6,15)	6a
			(3.7,2.3,3.7)	*0.25	(15.6,9.3,15)	7b	(2.3,1.4,3.7)	*0.25	(9.3,5.6,15)	6b
			(17.7,6.5,15)				(9.3,5.6,15)			total
			(9.35,5.6,7.5)	*0.5	(18.7,11.2,15)	9a	(1.55,0.9,7.5)	*0.5	(3.1,1.8,15)	8a
			(9.35,5.6,7.5)	*0.5	(18.7,11.2,15)	9b	(9.4,6.55,7.5)	*0.5	(21.8,13.1,15)	8b
			(18.7,11.2,15)				(10.95,7.45,15)			total

	Leadership	Strategy	People	Partnerships & Resources	Processes, Products & Services	Customer Results	People Results	Society Results	Key Results
Standard number	(22,12,15)	(16.2,10,15)	(16.6,10,15)	(17.4,2.1,15)	(14.9,9,15)	(9.3,5.6,15)	(17.7,6.5,15)	(10.95,7.45,15)	(18.7,11.2,15)
Coefficient (*)	1	1	1	1	1	1.5	1	1	1.5
Standard score	(22,12,15)	(16.2,10,15)	(16.6,10,15)	(17.4,2.1,15)	(14.9,9,15)	(13.95,8.4,22.5)	(17.7,6.5,15)	(10.95,7.45,15)	(28.0,16.8,22.5)

Fig. 3. Calculation of EFQM sub-criteria scores by the proposed method.

Enablers	10.8	5a	25	4a	10.8	3a	25	2a	19.375	1a
	10.8	5b	21.425	4b	25	3b	17.85	2b	25	1b
	10.8	5c	10.8	4c	25	3c	10.8	2c	21.425	1c
	25	5d	25	4d	10.8	3d	17.85	2d	25	1d
	25	5e	10.8	4e	17.85	3e			22.85	1e
	82.4		103.525		89.45		70		112.25	total
	16.5		20.7		17.9		17.5		22.8	mean total
Results			14.8	*0.75	19.7	7a	8.7	*0.75	11.65	6a
			4.3	*0.25	17.0	7b	2.9	*0.25	11.65	6b
			19.0				11.7			total
			9.8	*0.5	19.7	9a	1.6	*0.5	6.4	8a
			9.8	*0.5	19.7	9b	16.7	*0.5	22.3	8b
			19.7				18.3			total

Final score	Leadership	Strategy	People	Partnerships & Resources	Processes, Products & Services	Customer Results	People Results	Society Results	Key Results	
180	22.8	17.5	17.9	20.7	16.5	11.7	19.0	18.3	19.7	Standard number
	1	1	1	1	1	1.5	1	1	1.5	Coefficient (*)
	22.8	17.5	17.9	20.7	16.5	17.5	19.0	18.3	29.5	Standard score

Fig. 4. Assessment log for Yazd Regional Electricity Company by the proposed method.

Table 4
The range of current and target scores of organization in enablers domain.

Row (constraint)	Sub-criterion current score	Sub-criterion target score
1	24.2	50
2	20	50
3	15	50
4	20	50
5	15	50
6	13.3	50
7	14.2	50
8	13.3	50
9	15	50
10	12.5	50
11	25	50
12	18.3	50
13	13.3	50
14	16.7	50
15	20.8	50
16	19.2	50
17	13.3	50
18	20	50
19	11.7	50
20	15	50
21	12.5	50
22	13.3	50
23	20	50
24	18.3	50
Row (constraint)	Organization current score in enablers domain	Organization target score in enablers domain
25	84	250

meetings were held and final strength points and the areas for improvement were defined based on both above methods.

4.3. Prioritizing sub-criteria to define the projects for improvement by AHP technique and Operations Research model

4.3.1. AHP technique application

Setting the priority of sub-criteria has absolutely crucial role over the course of the organizational performance improvement process. Because, on the one side, almost all the organizations due to the lack of resources such as time and budget cannot implement all the areas for improvement, thus they must effectively prioritize the areas for improvement for the proper allocation and use of resources. On the other side, the efficient performance improvement projects depend critically on the determining of the areas for improvement with high priority. In this respect, in this study, eight experts, having complete and comprehensive information about the company, were selected and the case was explained for each of them separately. Then, some questionnaires were distributed among them to get their opinions. These questionnaires were developed for comparison between criteria and sub-criteria. As to the comparison among criteria, answers were categorized at 7 levels: very low, low, partly low, medium, partly high, high and very high. Scores of 1/4, 1/3, 1/2, 1, 2, 3 and 4 were assigned to each of them, respectively. For other tables, sub-criteria were compared; answers were categorized at 5 levels: very low, low, medium, high and very high; scores of 1/3, 1/2, 1, 2 and 3 were assigned to each of them, respectively. Next, sub-criteria were weighted collectively using filled questionnaires. Also, geometric mean method was selected to specify a relative weight for each criterion and sub-criterion (Fig. 5). It should be mentioned that according to the experts opinions, the weights for results criteria were considered zero because the company was not willing to define improvement projects for them.

4.3.2. Operations Research model application

In the following, OR technique is applied to find the best score with respect to organizational performance assessment achievable by the company. Target function (Z) is defined as the sum of weights multiplications which were given by the organizational experts for sub-criteria ($W'i$) and sub-criterion variable (SCi) as following Eq. (3). Constraints are defined separately based on each sub-criterion variable and the sum of sub-criterion weights (Wi) and SCi multiplications. For constraints, low limits and high limits are defined as current values and target values, respectively (target values are defined according to organizational scores, goals, plans, and policies). OR model is provided as follows (It should be mentioned that as the scores of sub-criteria for result domain are zero, variables include only the sub-criteria of enablers domain. The number of sub-criteria of enablers domain in EFQM model is 24):

Wi : weight for sub-criterion
$W'i$: weight given by organizational experts

$$Z = \sum_{i=1}^{24} (W'i) \times SCi \tag{3}$$

St :
Sub-criterion current score $\leq Sc1 \leq$ sub-criterion target score
⋮
Sub-criterion current score $\leq Sc24 \leq$ sub-criterion target score
Organization current score in enablers domain $\leq \sum_{i=1}^{24} (Wi) \times SCi$ $\leq$ organization target score in enablers domain

In the above model, 25 constraints were defined, of which 24 are associated with the range specified for sub-criteria, high limit of which was set to a target at a value related to capabilities, strategic and action plans of an organization (Table 4); low limit of which was set to the current score of sub-criterion (Table 4). The last constraint is related to the range of organization's current (Table 4) and target score (Table 4) in enablers domain.

4.3.3. Sub-criteria prioritization

The following section demonstrates the computational procedure of the prioritization of sub-criteria. First, by applying sub-criterion weight in the model (*W.M.*) and weight given by organizational experts (*W.E.*), sub-criterion final weight (*F.W.*) is computed as following Eq. (4). Then, to calculate index number for sub-criterion (*Index*), the distance between sub-criterion current score and sub-criterion score obtained from OR model (*D.OR*), and sub-criterion final weight are employed as following Eq. (5). Finally, based on the index number for sub-criterion (*Index*) obtained for each criterion, the improvement projects are prioritized according to sub-criteria prioritization.

Index: index number for sub-criterion
D.OR: distance between the sub-criterion current score and sub-criterion score obtained from OR model
F.W.: sub-criterion final weight
W.M.: sub-criterion weight in the model
W.E.: weight given by organizational experts

$$F.W. = (W.M \times W.E.) \tag{4}$$

$$Index = (D.OR \times F.W.) \tag{5}$$

An ascending–descending ordering was performed (larger index number, higher priority in defining the improvement project). Then, it was observed that sub-criteria of 2a, 2b and 2d obtained the highest index numbers. Thus, they were selected as sub-criteria having the areas for improvement with high priority (Table 5).

For example, the calculation of index number for sub-criterion 2a is given below:

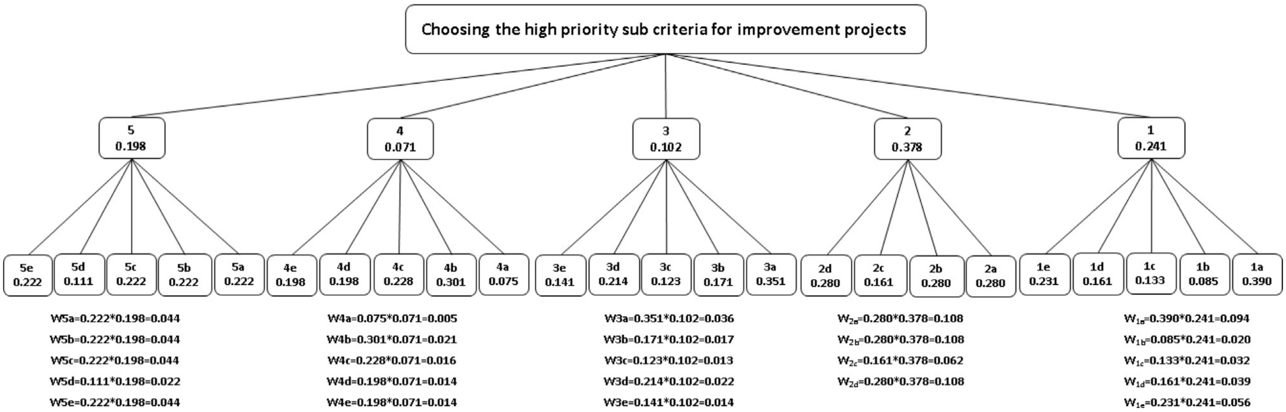

Fig. 5. AHP diagram.

Table 5
Sub-criteria prioritization.

Sub-criterion current score	Index number
2a	793
2b	773
2d	896
1a	0
1b	0
1c	0
1d	0
1e	0
2c	0
3a	0
3b	0
3c	0
3d	0
3e	0
4a	0
4b	0
4c	0
4d	0
4e	0
5a	0
5b	0
5c	0
5d	0
5e	0

Distance between the current value and value obtained from OR model is 36.7. In the model, sub-criterion weight is 2 (%). Sub-criterion weight based on the experts' opinions (using AHP technique) is 10.8 (%). Thus, the index number for this sub-criterion is equal to:

$36.7 \times (10.8 \times 2) = 793$

4.4. Improvement projects definition

With regards to the sub-criteria of 2a, 2b, 2d, the areas for improvement for each of these sub-criteria were considered to define the improvement projects; 8 titles were defined for improvement projects according to (Table 6) organizational conditions.

4.5. Defining some action plans for improvement projects

To implement each of the defined projects, an action plan, including the average time required for performing the project, the implementation phases of the project and an implementation method for each of these phases, was defined separately for each project. In the following, an example of action plan is provided:

- An action plan was defined for project No. 1 (Fig. 6), with the aim of identifying, understanding and forecasting the market developments during 4 phases (1 – project team formation, 2 – recognition, 3 – analysis, 4 – developing a final report and conclusion). Its average implementation period was determined 5 months. Clearly, the project team must be formed at the beginning. The implementing phases for this project are as follows: in the recognition phase, the factors related to the market are specified; then, the market is categorized according to these factors. In the following step, information requirements for the supply and demand sections are identified. Next, the market information is gathered for past 10 years based on the identified requirements. In the analysis phase, the information for the supply and demand sections is analyzed. At last, a final report is developed.

4.6. Survey for reprioritizing sub-criteria

After defining the action plans, sub-criteria are reweighted. This is done by resurveying the experts of the company periodically throughout the project phases, using the questionnaires provided in Section 4.3.1. In fact, this is an assessment and reviewing phase performed during the implementation process. If it is necessary to delay or cancel a project during its implementation, it helps the company consider this factor by reprioritizing sub-criteria.

5. Conclusions and future work

Organizations need to dramatically boost profits and stakeholders value by ramping up efficiencies and improving performance. The EFQM Excellence Model is a proper practical tool that can be used for carrying out self-assessment as a gate to performance improvement and identifying the areas for improvement. In this respect, in this research a new integrated approach was proposed by implementing Fuzzy Logic, AHP technique and OR model into the EFQM model for performance improvement of Yazd Regional Electricity Co. In the study, first, in the theoretical section of this paper, EFQM excellence model was explained, the concept of Fuzzy Logic was discussed; and the concept of Analytical Hierarchy Process (AHP) was introduced. Then, criteria and sub-criteria were prioritized for the enablers domain to find the areas for improvement with high priority to define the projects for improvement. Thus, criterion 2 and sub-criteria, 2a, 2b, 2d, were selected as the criterion and sub-criteria having the areas for improvement with higher priority than other criteria and sub-criteria. Next, an improvement project was determined for each of the areas for improvement of the sub-criteria 2a, 2b and 2d. Finally, some action plans for improvement projects were defined.

Table 6
Projects for improvement.

Sub-criterion	Areas for improvement for policy and strategy	Defined improvement projects
2-a	1 – Not to identify, understand and forecast market changes	1 – Project for analyzing electricity market state and Yazd Regional Electricity Company position
	2 – Not to identify, understand and forecast stakeholders' (including partners and shareholders) requirements and demands	2 – Project for studying the requirements and demands of Yazd Regional Electricity Company's stakeholders
2-b	1 – Not to create policy based on internal performance measurement and related external activities	1 – Project for reviewing the policy and strategy of Yazd Regional Electricity Company based on organizational performance assessment
	2 – Not to analyze the competitors performance and the best similar organizations	2 – Project for modelling similar internal and external companies
	3 – Not to analyze data for determining the impact of new technologies and business patterns on the organization performance	3 – Project for studying technological changes and its impact on the organization future
2-d	1 – Not to inform all stakeholders about the policy and strategy and evaluate their awareness	1 – Project for evaluating the stakeholders' point of views about the policy and strategy
	2 – No evidence for aligning and prioritizing the plans as well as following up their results	2 – Project for designing a system to define plans priorities and monitor their implementation
	3 – No process for realizing the policy and strategy in the organization	3 – Project for designing the structure and mechanism to implement the policy and strategy

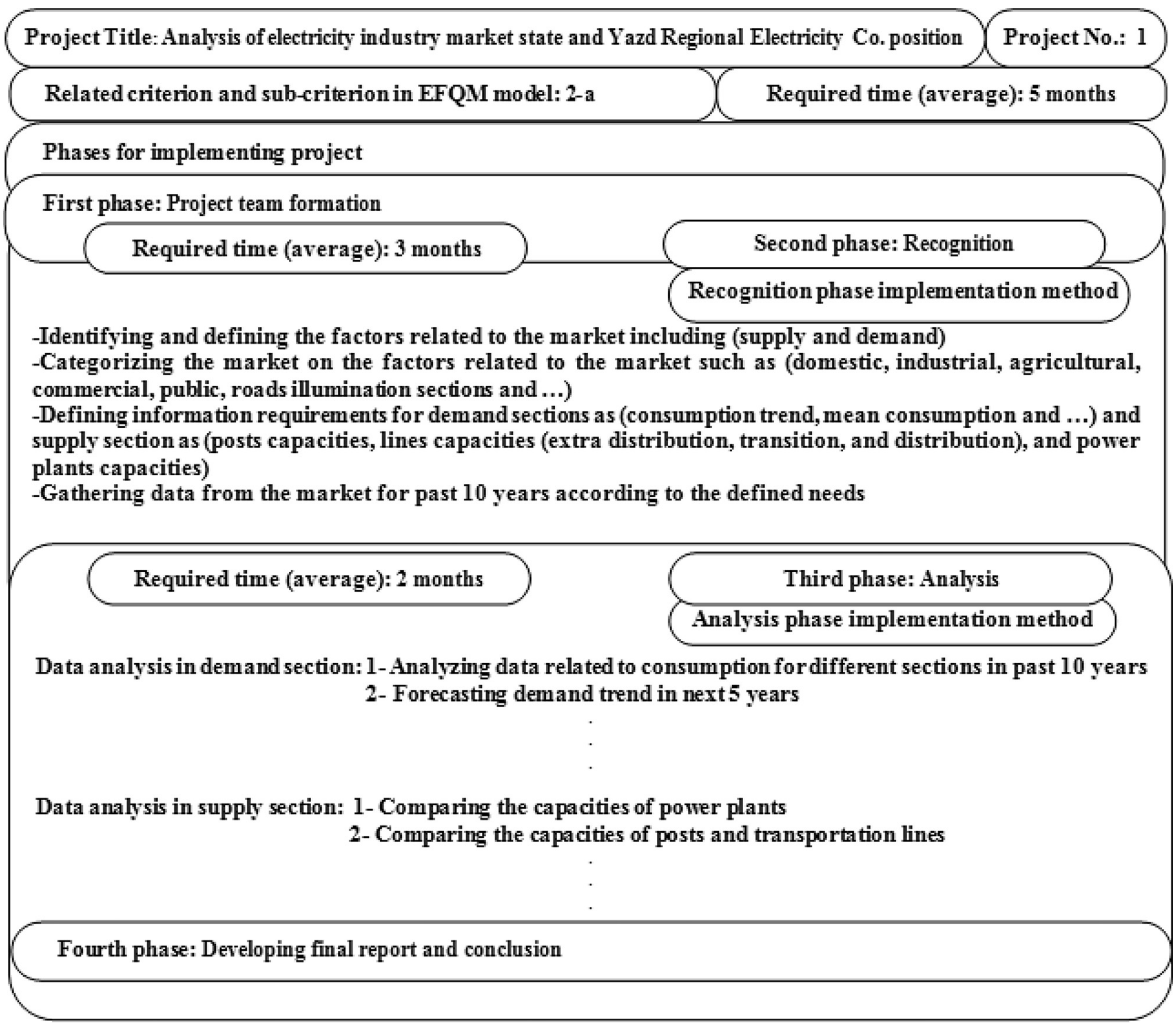

Fig. 6. An action plan for project No. 1.

The proposed integrated approach does have interesting and potentially substantive implications for business excellence practice. First, the proposed integrated approach not only mathematically represent uncertainty but also provide a formalized tools for dealing with the imprecision intrinsic to performance assessment process and in the prioritization of improvement projects. Second, the use of Fuzzy Logic for EFQM excellence model not only make easier the procedure of performance assessment;

the results of assessment do not depend on various opinions but also the total score for the organization performance obtained will be closer to the real score. The numbers of selectable options (5 Fuzzy selectable options) for assessors is limited by using Fuzzy Logic. Hence, the assessors easily calculate the scores of enablers and results, as hesitancy for selecting proper score is decreased. Moreover, the scores of various assessors will mainly be similar. Therefore, the scores of assessors will be more realistic; the total score for the organization performance, suggesting a higher degree of closeness to the real score, will be achieved. Third, after identifying the strength points and the areas for improvement by defining the scores for sub-criteria, using AHP technique and OR model helps organizational excellence mangers for determining and implementation of performance improvement projects with high priority. Performance improvement of organizations is critically dependent on the implementing of the efficient performance improvement projects. In this regard, by applying AHP technique and OR model, improvement projects are prioritized according to sub-criteria prioritization. Consequently, the optimum order for implementing of the improvement projects is defined. Furthermore, according to the limitations of organizations recourses, organizations mangers would be able to make substantial savings in the resources of organizations caused by improvements in areas for improvement with low priority by determining and implementation of improvement projects with high priority. Fourth, for most of the projects, when assessment and prioritization processes are performed and projects for improvement are defined, there are many problems in the implementation phase, because the organization does not cooperate and rely on the model results (as people are not enough satisfied and assured) and the project stops practically. Hence, to ensure cooperation, the organizational experts' opinions have also been gained; it is a great help for realizing the project goals. In the innovative method proposed, to integrate the results obtained for the model and people's opinions, a combined weight is generated; a score is given to each sub-criterion. Lastly, a proper prioritization is made according to them. Fifth, the proposed integrated approach has a special flexibility so that some improvements can be made for it. For example, some coefficients can be assigned to the weights of model or organization by considering the organizational conditions and people awareness. These coefficients decrease or increase the importance of each of them. Finally, it contributes to the managers towards the better management in the organizational excellence path by providing the simple, flexible, and adaptable solution, as it is not limited to the applying in a specific enterprise; rather it can be used in all organizations and companies.

Some recommendations were provided for Yazd Regional Electricity Company to define more precise and cohesive action plans as follows (with regards to the existing conditions and temporal limitation, it was not possible to define more precise action plans):

- To examine which better methods can be used for cooperation with the organization to implement the projects.
- To create a pattern for monitoring the improvement for projects.
- To identify the expectation limits and levels of the projects.
- To identify success indices.
- To define the schedules and resources of the projects (including financial, educational, equipment, human force, etc.) more precisely.
- To design and define a clear and systematic mechanism to control and monitor the financial affairs and efficiency during all of project phases and ensure their implementation.
- To ensure projects activities to be integrated and cohesive with the planning cycle of the company.

Considering the mentioned points, Yazd Regional Electricity Company could try to become an excellent organization by developing an organizational culture through involving all people in corrective actions, so that everyone treats the organization as his/her own property and has a positive view to the defined goals; establishing a proper culture for self-assessment, considering self-assessment results, supporting the strength points and improving them continuously, comparing annual performance with the past performance, and studying the performance of similar Regional Electricity Companies.

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