

## Research Article

# An EFQM-Fuzzy Network Data Envelopment Analysis Model for Efficiency Assessment in Organizations

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One of the new concepts that have found a considerable position in many countries of the world is organizing EFQM organizational excellence models. Different organizations and institutions have been evaluated and compared on its basis, and the move towards improvement and promotion is strengthened in them due to creation of competitive space. The EFQM organizational excellence model cannot remove the managers' and users' need for the levels of quantitative goals' operation solely. Thus, requirement for a tool which considers quantitative goals and present environment was felt, and in this manner, various assessment processes were created to be used in different organizations; one of the most important ones is the technique for Data Envelopment Analysis. Evaluating organization efficiency based on the EFQM model is one of the strategic managerial tools in many organizations. The classic DEA models were designed to work with deterministic data and cannot deal with uncertainties in their inputs. The techniques developed so far for fuzzy performance evaluation are also very limited. Given that the inputs and outputs of a real system are not always definite and accurate and that some data can only be expressed in vague verbal and subjective terms, the use of fuzzy sets in modeling is inevitable (Ali et al., 2019). In this paper, a Network Data Envelopment Analysis Model is proposed in fuzzy conditions for assessing units of an organization based on an organizational excellence model. The suggestive model utilizes the privileges of both Fuzzy Network Data Envelopment Analysis and EFQM organizational excellence models simultaneously in order to assess organization's efficiency. The Fuzzy Network Data Envelopment Analysis model is able to calculate the whole organization's efficiency as well as organization's efficiency separately for various phases of the organizational excellence model. Another privilege of the suggested model is that it utilizes fuzzy theory and concepts for modeling and observance of existing noncertainties in the experts' views while assessing organization's excellence criteria. The EFQM-fuzzy network DEA model is applied for assessing a holding's organizational units within the discipline of "project management."

## 1. Introduction

The necessity and significance for existence of an operation assessment system in each organization is to the extent that lack of assessment system in various dimensions of an organization including assessment of using the sources and facilities, goals, and strategies is regarded as one of the organization's weak point signs. So, each organization has pressing need for the assessment system particularly in the complex and dynamic environments in order to become aware of its activities' efficiency. [1].

In the present world, necessity of having some criteria for determining the situation, planning on the basis of strong

and weak points, seems essential more than ever considering speed and volume of information and also organization's confronting challenges. Creating a competitive atmosphere among organizations and their incessant efforts for improving quality of services and products as well as meeting the clients' expectations and needs have caused the organizations to search for a comprehensive, reliable, and flexible method for their operation assessment in order to obtain precise and exact information concerning their situation, position, and operation in society, and with regard to their past strong and weak points, they prevent from further errors in future; by this means, they guarantee their existence [2].

An assessment which is performed as a process for judging the efficiency of predetermined plans requires using special tools and patterns. Abundant models have been introduced for assessing organizations' operation, and each one has its particular specification. Among them, what is more stressed by European managerial thinkers for assessing organizations' operation is organization's excellence model. Efficiency of this model caused it to be developed in various sections. The Europe organization's excellence model was presented as model and organizational self-assessment and finally received European quality reward. This action in 1992 was introduced as an action for business excellence which became a framework for assessment [3]. This model indicates permanent privileges that an excellent organization shall achieve. This model was considered by European companies rapidly, and it was specified that public sector organizations and small industries are also interested in its application. The organizational excellence model is a voluntarily framework based on 9 criteria; its 5 criteria are empowering and 4 criteria are the conclusions. Empowering criteria envelope what the organization did, and the conclusions criteria envelope what the organization obtains (European Foundation for Quality, 2006).

Allameh and colleagues from EFQM investigated the effect of knowledge sharing on organizational performance in sports organizations [4]. Razavi et al. presented a model of EFQM-AHP to evaluate the quality management status of basic and medal-winning federations in Iran [5].

Gomez-Lopez and colleagues [6] studied the barriers for execution of EFQM excellence model in Spain private companies. In this research, descriptive analysis and factorial analysis have been used for determining the importance of barriers for implementing EFQM. In one of the performed research studies in this field, the EFQM excellence model was used for studying the organization's social effects. In this research, 116 companies in Spain were studied [7]. Dobrovic and colleagues [8] applied the EFQM model as a tool for strategic management with the purpose of increasing business operation in Slovakia tourism domain.

Liu and Ko [9] developed a modified copy of EFQM excellence model based on fuzzy hierarchical analysis process decision-making and used it for self-assessment of hotels.

Daniel and colleagues [10] presented a fuzzy multilayer assessment method for modeling the existing noncertainties in the experts' views regarding EFQM excellence model criteria. The authors' suggested model is based on the fuzzy deduction system which was implemented in an electrical company by a case study.

The EFQM excellence model has been introduced as an initial framework for assessing and improving organizations. Another appropriate and efficient means in the field of organization operation assessment is data envelopment analysis (DEA) [11] that is used as a nonparametrical method to calculate efficiency of decision-making units [12]. At present, using the DEA Technique is developing rapidly and it is used for assessment of various industries and organizations such as banking industry, posts, hospitals, educational centers, power stations, and refineries [13].

Network data envelopment analysis is a powerful tool for assessing system efficiency and also determining subsystems' efficiency. The network data envelopment analysis method has been developed in fuzzy conditions as well, and different strategies have been used for this purpose. For example, Khalili Damghani and Tavana [14] developed a network data envelopment analysis model in fuzzy conditions for assessing the agility of supply chain. The suggested model was used for assessing the operation in dairy materials' supply chain. Ali Ebrahimnejad and colleagues presented a new method for solving dual DEA problems with fuzzy stochastic data [11]. Simsek and Tüysüz [15] presented a network data envelopment analysis model with fuzzy data for assessing the operation in the marine transportation sector. Bagheri and colleagues examined a transport problem (TP) with fuzzy costs in the presence of multiple and conflicting goals. In fact, they proposed a fuzzy data envelopment analysis (DEA) method for solving multi-objective fuzzy TP (FMOTP) [16]. Bagheri and colleagues also proposed a model for solving the short-term multi-objective fuzzy path problem based on the data envelopment analysis approach [17]. Kachouei et al. introduced a common weights approach for the banking industry to evaluate the performance of fuzzy data envelopment analysis with adverse outputs [18]. Edalatpanah, for the first time, established a new model of DEA with triangular neutrosophic numbers (TNN) and obtained some interesting results [19]. Xinna Mao and colleagues developed a neutrosophic-based approach in the analysis of coatings with undesirable outputs [20]. Soltani and colleagues proposed a new two-stage DEA model in fuzzy environments to measure the performance of industrial workshops [21].

Li and colleagues [22] presented a fuzzy network data envelopment analysis model based on epsilon concept for assessing the operation of supply chain in the automotive industry.

As mentioned, the fuzzy network data envelopment analysis method has been used in some fields for assessing the efficiency. However, both the fuzzy network data envelopment analysis method and EFQM organizational excellence model have been used together for assessing the efficiency in the present. In some research studies, only the data envelopment analysis method in definite conditions and EFQM organizational excellence model have been used for assessing the organization efficiency. In the following, these research studies are reviewed and studied. Donnelly [23] presented a system for operation assessment in the public sector using combination of the data envelopment methods and EFQM excellence model.

Shahroudi [24] introduces a new ranking system on the basis of DEA method and EFQM excellence model for assessing the operation in the automotive industry. In this research, 9 main criteria for the EFQM excellence model were considered as operational indicators in the data envelopment analysis method, and then by implementing DEA, the efficiency rate for each one of the decision-making units (DMU) is calculated and ranking is carried out in terms of it. In another research, the EFQM excellence model and data envelopment analysis were combined for assessing

police services operation [25]. Sadegh Amalnick and Zarrin [26] used EFQM excellence model criteria for assessing man power resources in an Iran airline company. In this research, an integrated model has been proposed based on the methods of ANFIS, fuzzy DEA, and statistical tests for assessing the organization efficiency on the basis of EFQM excellence model. Saadat Rezaei and colleagues [27] used EFQM model criteria for assessing food stuff companies' operation based on the data envelopment analysis method.

Table 1 indicates summary of performed research studies in which both the EFQM organizational excellence model and data envelopment analysis have been used for assessing the organization operation. As it shows, only a few research studies have used the combination of EFQM organizational excellence model and data envelopment analysis for assessing the organization operation. Moreover, in these research studies, the common data envelopment analysis has been used as an aiding method for the EFQM excellence model and network data envelopment analysis method has not been used in this field of research to the present. Also, except Sadegh Amalnick and Zarrin [26] research, in none of the research studies, fuzzy concept or other strategies for modeling noncertainties were used for observing the existing noncertainties in EFQM excellence model criteria as well. In this research, a network data envelopment analysis model in fuzzy conditions has not been developed based on the EFQM model for assessing the organization operation. The proposed model is able to model the existing noncertainties in experts' views using fuzzy concepts. Also, the said model is able to calculate the efficiency for various stages of EFQM excellence model in addition to determination of the organization's efficiency rate.

This paper unfolds as follows: in Section 2, some basic knowledge and concepts on network data envelopment

analysis model developed by Kao [28] are explained in detail. Also, in this section, fuzzy copy of network data envelopment analysis model is developed. In Section 3, suggested model by EFQM-Fuzzy Network DEA is presented. In Section 4, the proposed model is illustrated with a case study to ensure its validity and usefulness over the existing models; the suggested model is implemented within the framework of a case study. Section 5 has been dedicated for conclusion.

## 2. Network Data Envelopment Analysis in Fuzzy Environment

*2.1. Network Data Envelopment Analysis.* Consider “ $h$ ” stage system in Figure 1, in which the number of decision-making units is equal to “ $n$ ,” and they are indicated by DMU $j$  ( $j = 1, 2, \dots, n$ ). In this figure, system inputs are indicated by  $X_i$  ( $i = 1, 2, \dots, m$ ) which are also regarded as the first-stage inputs. The number of inputs in the first stage is “ $m$ .” The first stage produces “ $q_1$ ” output using “ $m$ ” inputs. The first-stage outputs are  $Z_p^{(1)}$  ( $p = 1, 2, \dots, q_1$ ). The first-stage outputs have also been considered as the second-stage inputs as well.

Since the variables  $Z_p^{(1)}$  have been considered both as the first-stage output and the second-stage input, they are called “intermediate measures” [11] in the literature. The second stage has also some outputs that their number is equal to “ $q_2$ .” The second-stage outputs are indicated by  $Z_p^{(2)}$  ( $p = 1, 2, \dots, q_2$ ). Similarly,  $z_p^{(t-1)}$  ( $p = 1, 2, \dots, q_{(t-1)}$ ) are input variables for the stage “ $t$ ” and  $z_p^{(t)}$  ( $p = 1, 2, \dots, q_t$ ) are output variables for the stage “ $t$ .” The outputs for this system's last stage are also considered as the whole system output that is indicated by  $Y_r$  ( $r = 1, 2, \dots, s$ ). Total efficiency of this system for the  $k^{\text{th}}$  DMU is calculated using the model as follows [28]:

$$\begin{aligned}
 E_k &= \text{Max} \sum_{r=1}^s u_r Y_{rk}, \\
 \text{S.t.} \quad &\sum_{i=1}^m \vartheta_i X_{ik} = 1, \\
 &\sum_{r=1}^s u_r Y_{rj} - \sum_{i=1}^m \vartheta_i X_{ij} \leq 0, \quad j = 1, 2, \dots, n, \\
 &\sum_{p=1}^{q_1} w_p^{(1)} Z_{pj}^{(1)} - \sum_{i=1}^m \vartheta_i X_{ij} \leq 0, \quad j = 1, 2, \dots, n, \\
 &\sum_{p=1}^{q_t} w_p^{(t)} Z_{pj}^{(t)} - \sum_{p=1}^{q_{(t-1)}} w_p^{(t-1)} Z_{pj}^{(t-1)} \leq 0, \quad t = 2, 3, \dots, h-1, j = 1, 2, \dots, n, \\
 &\sum_{r=1}^s u_r Y_{rj} - \sum_{p=1}^{q_{(h-1)}} w_p^{(h-1)} Z_{pj}^{(h-1)} \leq 0, \quad j = 1, 2, \dots, n, \\
 &u_r, \vartheta_i, w_p^{(t)} \geq 0, \quad \forall r, i, p, t.
 \end{aligned} \tag{1}$$

In the above model, the second restriction is related to the whole system and the third, fourth, and fifth restrictions

are related to the “ $h$ ” stage of the above system. A system is efficient if and only if its whole stages are efficient.

TABLE 1: Summary of the performed research studies concerning combination of EFQM excellence model and data envelopment analysis method.

Reference	Evaluation tool	Helping tool	Description
Donnelly [23]	EFQM	DEA	Implementation of the suggested model in public sector
Shahroudi [24]	EFQM	DEA	Performance evaluation in the automotive industry
Tomažević et al. [25]	EFQM	DEA	Performance evaluation in police services
Sadegh Amalnick and Zarrin [26]	EFQM	ANFIS-fuzzy DEA	Human resources assessment in Iranian airlines
Gómez-lópez et al. [6]	EFQM	—	Excellence evaluation of Spanish companies
Liu and Ko [9]	EFQM	AHP	Self-evaluation rating of hotels
Calvo-Mora et al. [7]	EFQM	—	Evaluation of 116 companies in Spain
Dobrovič et al. [8]	EFQM	—	Evaluating business performance in Slovakia tourism sector
Daniel et al. [10]	EFQM	Fuzzy inference system	Implementation of the suggested model in the electricity company
Suggested model in this research	EFQM	Network DEA	Implementation of the suggested model in Hadaf Modiriart project holding

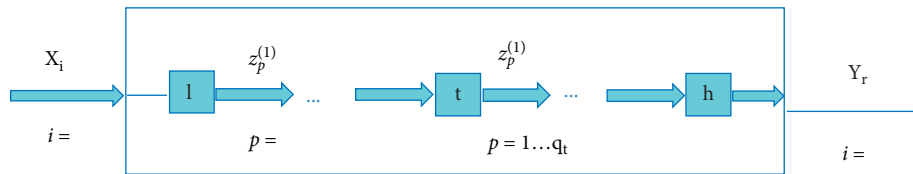


FIGURE 1: Network structure for network data envelopment analysis.

Suppose that, after solving the above model for the  $k^{\text{th}}$  DMU, the optimum amount of decision variables to be in form of  $u_r^*, \vartheta_i^*, w_p^{(t)*}$ . Then, efficiency in each stage of the system for the  $k^{\text{th}}$  DMU is indicated by  $E_k^{(t)}$ ,  $t = 1, 2, \dots, h$ , and it is calculable by the following relations.

The objective function of model (1) maximizes the total weight of the outputs, while in the first constraint of model (1), the total weight of the inputs is considered to be a fixed number (for example, one). The second limitation of model (1) shows that, in the first phase of the network, the total weight of the outputs minus the total weight of the inputs is less than one. In other words, this limitation indicates that the efficiency of the first stage can be less than or equal to one. Subsequent model limitations also address this issue. In other words, the sum of the fourth constraints in model (1) shows that the difference in the total weight of the inputs in step  $t$  can be equal to one. The last constraint of the model also shows that the difference in the total weight of the inputs in the last step can be equal to one. At the end of the model, the model decision variables are defined which can obtain real numbers greater than one.

$$\begin{aligned}
 E_k^{(1)} &= \frac{\sum_{p=1}^{q_1} w_p^{(1)*} Z_{pk}^{(1)}}{\sum_{i=1}^m \vartheta_i^* X_{ik}}, \\
 E_k^{(t)} &= \frac{\sum_{p=1}^{q_t} w_p^{(t)*} Z_{pk}^{(t)}}{\sum_{p=1}^{q_{(t-1)}} w_p^{(t-1)*} Z_{pk}^{(t-1)}}, \quad t = 2, 3, \dots, h-1, \\
 E_k^{(h)} &= \frac{\sum_{r=1}^s u_r^* Y_{rk}}{\sum_{p=1}^{q_{(h-1)}} w_p^{(h-1)*} Z_{pk}^{(h-1)}}.
 \end{aligned} \quad (2)$$

**2.2. Fuzzy Network Data Envelopment Analysis.** Fuzzy set in modern mathematics is said to be the set in which the membership of some members or the whole members is not completely clear, and its elements partially belong to that set. A fuzzy set is generalization of a classic set in which each amount in the interval  $[0, 1]$  is permitted to belong to it. A triangular fuzzy number is shown as  $\tilde{M} = (a, b, c)$  in which the parameters  $a$ ,  $b$ , and  $c$ , respectively, express the least possible amount, the most probable amount, and the most possible amount for the desired number, and this number can change between  $a$  and  $c$ . Triangular fuzzy number function has been indicated in the following section.

$$\mu_{\tilde{M}}^{-}(x) = \begin{cases} 0, & x < a, \\ \frac{x-a}{b-a}, & a \leq x \leq b, \\ \frac{c-x}{c-b}, & b \leq x \leq c, \\ 0, & x > c. \end{cases} \quad (3)$$

In order to develop Fuzzy Network Data Envelopment Analysis, suppose that the inputs are intermediate variables and outputs are in the form of

$$\begin{aligned} \tilde{X}_{ij} &= (X_{ij}^L, X_{ij}^M, X_{ij}^U), \\ \tilde{z}_p^{(t)} &= (z_p^{(t)L}, \tilde{z}_p^{(t)M}, \tilde{z}_p^{(t)U}), \\ \tilde{Y}_{rj} &= (Y_{rj}^L, Y_{rj}^M, Y_{rj}^U). \end{aligned} \quad (4)$$

the system total efficiency in case of the  $k^{\text{th}}$  DMU. In order to calculate the lower and the upper boundary for the system total efficiency, the concept of “ $\alpha$ -cut” [16] is used. In the level of “ $\alpha$ -cut,” the lower and the upper boundary of the input variables, intermediate variables, and outputs are calculated by the following relations:

On the basis of the said concepts, suppose that  $E_k^L$  and  $E_k^U$ , respectively, are the lower and the upper boundary for

$$\begin{aligned} (X_{ij})_{\alpha}^L &= X_{ij}^L + \alpha(X_{ij}^M - X_{ij}^L), \quad j = 1, 2, \dots, n, i = 1, 2, \dots, m, \\ (X_{ij})_{\alpha}^U &= X_{ij}^U - \alpha(X_{ij}^U - X_{ij}^M), \quad j = 1, 2, \dots, n, i = 1, 2, \dots, m, \\ (z_{pj}^{(t)})_{\alpha}^L &= z_{pj}^{(t)L} + \alpha(z_{pj}^{(t)M} - z_{pj}^{(t)L}), \quad j = 1, 2, \dots, n, t = 1, 2, \dots, h - 1, \\ (z_{pj}^{(t)})_{\alpha}^U &= z_{pj}^{(t)U} - \alpha(z_{pj}^{(t)U} - z_{pj}^{(t)M}), \quad j = 1, 2, \dots, n, t = 1, 2, \dots, h - 1, \\ (Y_{rj})_{\alpha}^L &= Y_{rj}^L + \alpha(Y_{rj}^M - Y_{rj}^L), \quad j = 1, 2, \dots, n, r = 1, 2, \dots, s, \\ (Y_{rj})_{\alpha}^U &= Y_{rj}^U - \alpha(Y_{rj}^U - Y_{rj}^M), \quad j = 1, 2, \dots, n, r = 1, 2, \dots, s. \end{aligned} \quad (5)$$

At the level of “ $\alpha$ -cut”, the upper boundary for the whole system efficiency and its lower boundary are calculated by equations (6) and (7):

$$\begin{aligned} E_k^U &= \text{Max} \sum_{r=1}^s u_r (Y_{rk})_{\alpha}^U, \\ \text{S.t. } \sum_{i=1}^m \vartheta_i (X_{ik})_{\alpha}^L &= 1, \\ \sum_{r=1}^s u_r (Y_{rj})_{\alpha}^U - \sum_{i=1}^m \vartheta_i (X_{ij})_{\alpha}^L &\leq 0, \quad j = 1, 2, \dots, n, \\ \sum_{r=1}^s u_r (Y_{rkj})_{\alpha}^L - \sum_{i=1}^m \vartheta_i (X_{ij})_{\alpha}^U &\leq 0, \quad j = 1, 2, \dots, n, j \neq k, \\ \sum_{p=1}^{q_1} w_p^{(1)} Z_{pj}^{(1)} - \sum_{i=1}^m \vartheta_i (X_{ij})_{\alpha}^L &\leq 0, \quad j = 1, 2, \dots, n, \\ \sum_{p=1}^{q_1} w_p^{(1)} Z_{pj}^{(1)} - \sum_{i=1}^m \vartheta_i (X_{ij})_{\alpha}^U &\leq 0, \quad j = 1, 2, \dots, n, j \neq k, \\ \sum_{p=1}^{q_t} w_p^{(t)} Z_{pj}^{(t)} - \sum_{p=1}^{q_{(t-1)}} w_p^{(t-1)} Z_{pj}^{(t-1)} &\leq 0, \quad t = 2, 3, \dots, h - 1, j = 1, 2, \dots, n, \\ \sum_{r=1}^s u_r (Y_{rj})_{\alpha}^U - \sum_{p=1}^{q_{(h-1)}} w_p^{(h-1)} Z_{pj}^{(h-1)} &\leq 0, \quad j = 1, 2, \dots, n, \\ \sum_{r=1}^s u_r (Y_{rj})_{\alpha}^L - \sum_{p=1}^{q_{(h-1)}} w_p^{(h-1)} Z_{pj}^{(h-1)} &\leq 0, \quad j = 1, 2, \dots, n, j \neq k, \\ (z_{pj}^{(t)})_{\alpha}^L \leq Z_{pj}^{(t)} \leq (z_{pj}^{(t)})_{\alpha}^U &, \quad t = 1, 2, \dots, h - 1, j = 1, 2, \dots, n, \\ u_r, \vartheta_i, w_p^{(t)} \geq 0, \quad \forall r, i, p, t, \end{aligned} \quad (6)$$

$$\begin{aligned}
E_k^L &= \text{Max} \sum_{r=1}^s u_r (Y_{rk})_\alpha^L, \\
\text{S.t. } \sum_{i=1}^m \vartheta_i (X_{ik})_\alpha^U &= 1, \\
\sum_{r=1}^s u_r (Y_{rj})_\alpha^L - \sum_{i=1}^m \vartheta_i (X_{ij})_\alpha^U &\leq 0, \quad j = 1, 2, \dots, n, \\
\sum_{r=1}^s u_r (Y_{rj})_\alpha^U - \sum_{i=1}^m \vartheta_i (X_{ij})_\alpha^L &\leq 0, \quad j = 1, 2, \dots, n, j \neq k, \\
\sum_{p=1}^{q_1} w_p^{(1)} Z_{pj}^{(1)} - \sum_{i=1}^m \vartheta_i (X_{ij})_\alpha^U &\leq 0, \quad j = 1, 2, \dots, n, \\
\sum_{p=1}^{q_1} w_p^{(1)} Z_{pj}^{(1)} - \sum_{i=1}^m \vartheta_i (X_{ij})_\alpha^L &\leq 0, \quad j = 1, 2, \dots, n, j \neq k, \\
\sum_{p=1}^{q_t} w_p^{(t)} Z_{pj}^{(t)} - \sum_{p=1}^{q_{(t-1)}} w_p^{(t-1)} Z_{pj}^{(t-1)} &\leq 0, \quad t = 2, 3, \dots, h-1, j = 1, 2, \dots, n, \\
\sum_{r=1}^s u_r (Y_{rj})_\alpha^L - \sum_{p=1}^{q_{(h-1)}} w_p^{(h-1)} Z_{pj}^{(h-1)} &\leq 0, \quad j = 1, 2, \dots, n, \\
\sum_{r=1}^s u_r (Y_{rj})_\alpha^U - \sum_{p=1}^{q_{(h-1)}} w_p^{(h-1)} Z_{pj}^{(h-1)} &\leq 0, \quad j = 1, 2, \dots, n, j \neq k, \\
(z_{pj}^{(t)})_\alpha^L \leq Z_{pj}^{(t)} \leq (z_{pj}^{(t)})_\alpha^U, \quad t = 1, 2, \dots, h-1, j = 1, 2, \dots, n, \\
u_r, \vartheta_i, w_p^{(t)} &\geq 0, \quad \forall r, i, p, t.
\end{aligned} \tag{7}$$

The models (6) and (7) are nonlinear because in these models, the equation of  $w_p^{(t)} Z_{pj}^{(t)}$ ,  $t = 1, 2, \dots, h-1$ , which is the multiple of 2 variables is nonlinear. In order to linearize

these models, changing the variables and the following equations are used:

$$\begin{aligned}
f_{pj}^{(t)} &= w_p^{(t)} Z_{pj}^{(t)}, \quad t = 1, 2, \dots, h-1, j = 1, 2, \dots, n, \\
w_p^{(t)} (z_{pj}^{(t)})_\alpha^L &\leq f_{pj}^{(t)} \leq w_p^{(t)} (z_{pj}^{(t)})_\alpha^U, \quad t = 1, 2, \dots, h-1, j = 1, 2, \dots, n, \\
(z_{pj}^{(t)})_\alpha^L &= z_{pj}^{(t)L} + \alpha(z_{pj}^{(t)M} - z_{pj}^{(t)L}), \quad j = 1, 2, \dots, n, t = 1, 2, \dots, h-1, \\
(z_{pj}^{(t)})_\alpha^U &= z_{pj}^{(t)U} - \alpha(z_{pj}^{(t)U} - z_{pj}^{(t)M}), \quad j = 1, 2, \dots, n, t = 1, 2, \dots, h-1.
\end{aligned} \tag{8}$$

By exerting the above equations and equation (5), models (6) and (7) are, respectively, changed to models (9) and (10):

$$\begin{aligned}
E_k^U &= \text{Max} \sum_{r=1}^s u_r (Y_{rk}^U - \alpha(Y_{rk}^U - Y_{rk}^M)), \\
\text{S.t. } \sum_{i=1}^m \vartheta_i (X_{ik}^L + \alpha(X_{ik}^M - X_{ik}^L)) &= 1, \\
\sum_{r=1}^s u_r (Y_{rj}^U - \alpha(Y_{rj}^U - Y_{rj}^M)) - \sum_{i=1}^m \vartheta_i (X_{ij}^L + \alpha(X_{ij}^M - X_{ij}^L)) &\leq 0, \quad j = 1, 2, \dots, n, \\
\sum_{r=1}^s u_r (Y_{rj}^L + \alpha(Y_{rj}^M - Y_{rj}^L)) - \sum_{i=1}^m \vartheta_i (X_{ij}^U - \alpha(X_{ij}^U - X_{ij}^M)) &\leq 0, \quad j = 1, 2, \dots, n, j \neq k, \\
\sum_{p=1}^{q_1} f_{pj}^{(1)} - \sum_{i=1}^m \vartheta_i (X_{ij}^L + \alpha(X_{ij}^M - X_{ij}^L)) &\leq 0, \quad j = 1, 2, \dots, n, \\
\sum_{p=1}^{q_1} f_{pj}^{(1)} - \sum_{i=1}^m \vartheta_i (X_{ij}^U - \alpha(X_{ij}^U - X_{ij}^M)) &\leq 0, \quad j = 1, 2, \dots, n, j \neq k, \\
\sum_{p=1}^{q_t} f_{pj}^{(t)} - \sum_{p=1}^{q_{(t-1)}} f_{pj}^{(t-1)} &\leq 0, \quad t = 2, 3, \dots, h-1, j = 1, 2, \dots, n, \\
\sum_{r=1}^s u_r (Y_{rj}^U - \alpha(Y_{rj}^U - Y_{rj}^M)) - \sum_{p=1}^{q_{(h-1)}} f_{pj}^{(h-1)} &\leq 0, \quad j = 1, 2, \dots, n, \\
\sum_{r=1}^s u_r (Y_{rj}^L + \alpha(Y_{rj}^M - Y_{rj}^L)) - \sum_{p=1}^{q_{(h-1)}} f_{pj}^{(h-1)} &\leq 0, \quad j = 1, 2, \dots, n, j \neq k, \\
w_p^{(t)} (z_{pj}^{(t)L} + \alpha(z_{pj}^{(t)M} - z_{pj}^{(t)L})) \leq f_{pj}^{(t)} \leq w_p^{(t)} (z_{pj}^{(t)U} - \alpha(z_{pj}^{(t)U} - z_{pj}^{(t)M})), & \quad t = 1, 2, \dots, h-1, j = 1, 2, \dots, n, \\
u_r, \vartheta_i, w_p^{(t)}, f_{pj}^{(t)} \geq 0, \quad \forall r, i, p, t. &
\end{aligned}$$

(9)

$$\begin{aligned}
E_k^L &= \text{Max} \sum_{r=1}^s u_r (Y_{rk}^L + \alpha(Y_{rk}^M - Y_{rk}^L)), \\
\text{S.t. } &\sum_{i=1}^m \vartheta_i (X_{ik}^U - \alpha(X_{ik}^U - X_{ik}^M)) = 1, \\
&\sum_{r=1}^s u_r (Y_{rj}^L + \alpha(Y_{rj}^M - Y_{rj}^L)) - \sum_{i=1}^m \vartheta_i (X_{ij}^U - \alpha(X_{ij}^U - X_{ij}^M)) \leq 0, \quad j = 1, 2, \dots, n, \\
&\sum_{r=1}^s u_r (Y_{rk}^U - \alpha(Y_{rk}^U - Y_{rk}^M)) - \sum_{i=1}^m \vartheta_i (X_{ij}^L + \alpha(X_{ij}^M - X_{ij}^L)) \leq 0, \quad j = 1, 2, \dots, n, j \neq k, \\
&\sum_{p=1}^{q_1} f_{pj}^{(1)} - \sum_{i=1}^m \vartheta_i (X_{ij}^U - \alpha(X_{ij}^U - X_{ij}^M)) \leq 0, \quad j = 1, 2, \dots, n, \\
&\sum_{p=1}^{q_1} f_{pj}^{(1)} - \sum_{i=1}^m \vartheta_i (X_{ij}^L + \alpha(X_{ij}^M - X_{ij}^L)) \leq 0, \quad j = 1, 2, \dots, n, j \neq k, \\
&\sum_{p=1}^{q_t} f_{pj}^{(t)} - \sum_{p=1}^{q_{(t-1)}} f_{pj}^{(t-1)} \leq 0, \quad t = 2, 3, \dots, h-1, j = 1, 2, \dots, n, \\
&\sum_{r=1}^s u_r (Y_{rk}^L) - \sum_{p=1}^{q_{(h-1)}} f_{pj}^{(h-1)} \leq 0, \quad j = 1, 2, \dots, n, \\
&\sum_{r=1}^s u_r (Y_{rk}^U - \alpha(Y_{rk}^U - Y_{rk}^M)) - \sum_{p=1}^{q_{(h-1)}} f_{pj}^{(h-1)} \leq 0, \quad j = 1, 2, \dots, n, j \neq k, \\
&w_p^{(t)} (z_{pj}^{(t)L} + \alpha(z_{pj}^{(t)M} - z_{pj}^{(t)L})) \leq f_{pj}^{(t)}, \\
&u_r, \vartheta_i, w_p^{(t)}, f_{pj}^{(t)} \geq 0, \quad \forall r, i, p, t.
\end{aligned} \tag{10}$$

Mathematical planning models of (9) and (10) are linear and parametrical models in terms of  $\alpha$ -cut level.

### 3. EFQM-Network DEA Suggested Model

In this research, the organization excellence model is considered as 4-stage envelope analysis model. The four stages include leadership (the 1st stage), activities related to the employees, policy, strategy, and participation (the 2<sup>nd</sup> stage), processes (the 3<sup>rd</sup> stage), and conclusions (the 4<sup>th</sup> stage). Thereafter, with regard to 32 existing subcriteria in the EFQM excellence model, input and output variables have been specified for each one of the four stages. Figure 2 indicates the research performance framework.

In the following, each one of the stages mentioned in Figure 2 is analyzed.

The organizational excellence model is a methodical framework for evaluation of organizations' operation in the two fields of processes and their obtained results. Achievements resulted from assessment in this model include organization's strong points and its improvable fields, and for achieving the improvements, a list of the prioritized plans is suggested as well. Criteria of this model are divided into two groups: (a) empowerments: these are the factors which empower the organization for achieving to excellent results; (b) conclusions: they express the achievements obtained from appropriate performance of the empowerments.

The organization excellence model is a tool that creates an idea for the organization operation based on 9 criteria of which 5 criteria are in the fields of empowerments including criteria such as leadership, policy, and strategy, management of man power (employees), sources, and companies, and processes and four criteria are in the fields of conclusions, consisting of the client conclusions, employees' conclusions, society conclusions, and key conclusions of the performance. In the EFQM model, the criteria have 1000 points totally (500 points for empowerments and 500 points for conclusions). On the basis of Figure 3, the point share for each criterion has been specified out of 1000 points. In other words, in case that an organization becomes successful to materialize this model completely in its organization, it can get 1000 points. Each major criterion in the EFQM excellence model has several subcriteria. Table 2 indicates main criteria, subcriteria, and utilized symbol for each subcriterion.

The EFQM-Fuzzy Network DEA suggestive model is a four-stage model, and its stages have been derived from the sections of EFQM excellence model. In the first stage, 5 indicators for EFQM excellence model leadership have been considered, whereas nature of these indicators is "profit" type, so they are regarded as output variables for the first stage. From one side, based on the research of Liu and colleagues [29], an input variable with the amount of  $\bar{X}_1 = (1, 1, 1)$  has been considered as the input variable of this



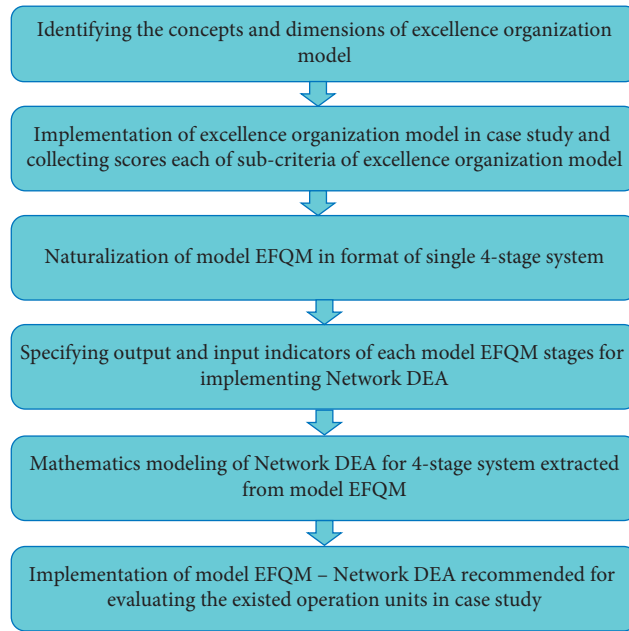


FIGURE 2: Research performance framework.

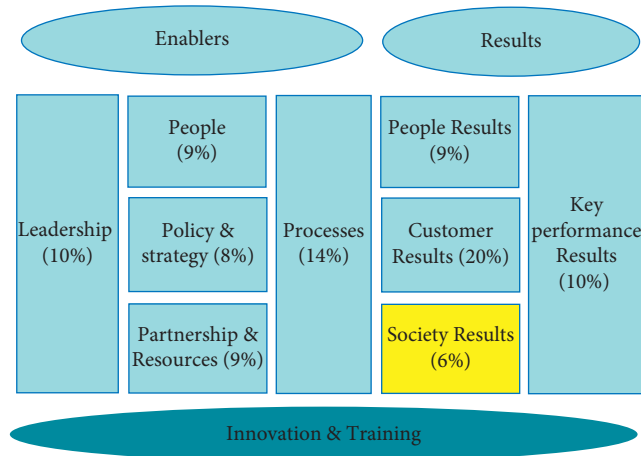


FIGURE 3: EFQM excellence model.

stage for the whole DMUs, that is, system total input as well. Five output variables of the first stage are regarded as input.

Variables for the second stage: the second stage of this system consists of employees’ activities, policy, strategy, participation, and sources. Therefore, the output variable of the second stage includes 14 variables which are the same subcriteria related to the employees, policy, strategy, partnership, and sources in the EFQM excellence model. These 14 variables are considered as input for the 3<sup>rd</sup> stage as well. The third stage is processes’ system, and this stage has also 5 outputs which are the same subcriteria of the processes in the excellence model. Five outputs of this stage are considered as inputs for the 4<sup>th</sup> or conclusions stage. At end, conclusions subcriteria in the EFQM excellence model are

considered as outputs for the 4<sup>th</sup> stage and the whole system outputs. Schematic EFQM-Network DEA suggestive model is shown in Figure 4. The symbols for input and output variables used in this figure for different stages have been analyzed in Table 2 formerly.

With regard to model (9), fuzzy network data envelopment analysis for calculating the upper boundary of 4-stage system efficiency is as follows. On the basis of Liu and colleagues’ research [29], in model (11), an input variable with the fuzzy amount of  $\tilde{X}_1 = (1, 1, 1)$  is used as the sole system total input. On this basis, the upper boundary of the whole system efficiency for the  $k^{\text{th}}$  DMU is shown as  $E_k^U$  which is obtained through solving the following planning model:

TABLE 2: Criteria and subcriteria in the EFQM excellence model.

Criteria	Subcriteria	Notation
Leadership	1a. Leaders develop the mission, values, and ethics and act as role models	$\bar{z}_1^{(1)}$
	1b. Leaders define, monitor, review, and drive the improvement of the organization's management system and performance	$\bar{z}_2^{(1)}$
	1c. Leaders engage with external stakeholders	$\bar{z}_3^{(1)}$
	1d. Leaders reinforce a culture of excellence with the organization's people	$\bar{z}_4^{(1)}$
	1e. Leaders ensure that the organization is flexible and manage change effectively	$\bar{z}_5^{(1)}$
Strategy	2a. Strategy is based on understanding the needs and expectations of both stakeholders and the external environment	$\bar{z}_1^{(2)}$
	2b. Strategy is based on understanding internal performance and capabilities	$\bar{z}_2^{(2)}$
	2c. Strategy and supporting policies are developed, reviewed, and updated	$\bar{z}_3^{(2)}$
	2d. Strategy and supporting policies are communicated, implemented, and monitored	$\bar{z}_4^{(2)}$
People	3a. People's plans support the organization's strategy	$\bar{z}_5^{(2)}$
	3b. People's knowledge and capabilities are developed	$\bar{z}_6^{(2)}$
	3c. People are aligned, involved, and empowered	$\bar{z}_7^{(2)}$
	3d. People communicate effectively throughout the organization	$\bar{z}_8^{(2)}$
	3e. People are rewarded, recognized, and cared for	$\bar{z}_9^{(2)}$
Partnerships and resources	4a. Partners and suppliers are managed for sustainable benefit	$\bar{z}_{10}^{(2)}$
	4b. Finances are managed to secure sustained success	$\bar{z}_{11}^{(2)}$
	4c. Buildings, equipment, materials, and natural resources are managed in a sustainable way	$\bar{z}_{12}^{(2)}$
	4d. Technology is managed to support the delivery of strategy	$\bar{z}_{13}^{(2)}$
	4e. Information and knowledge are managed to support effective decision-making and to build the organization's capability	$\bar{z}_{14}^{(2)}$
Processes, products & services	5a. Processes are designed and managed to optimize stakeholder value	$\bar{z}_1^{(3)}$
	5b. Products and services are developed to create optimum value for customer	$\bar{z}_2^{(3)}$
	5c. Products and services are effectively promoted and marketed	$\bar{z}_3^{(3)}$
	5d. Products and services are produced, delivered, and managed	$\bar{z}_4^{(3)}$
	5e. Customer relationships are managed and enhanced	$\bar{z}_5^{(3)}$
Customer results	6a. Perception measures	$\bar{Y}_1$
	6b. Performance indicators	$\bar{Y}_2$
People results	7a. Perception measures	$\bar{Y}_3$
	7b. Performance indicators	$\bar{Y}_4$
Society results	8a. Perception measures	$\bar{Y}_5$
	8b. Performance indicators	$\bar{Y}_6$
Key performance results	9a. Key performance outcomes	$\bar{Y}_7$
	9b. Key performance indicators	$\bar{Y}_8$

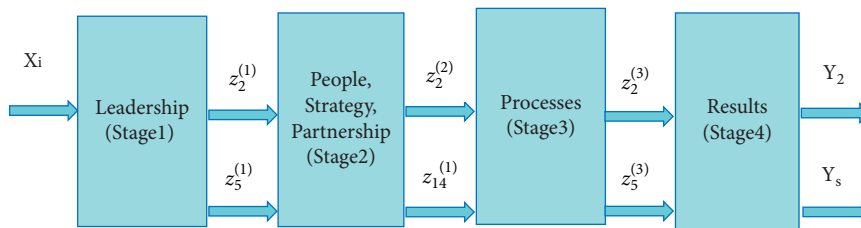


FIGURE 4: The structure of the proposed EFQM-Fuzzy Network DEA model.

$$E_k^U = \text{Max} \sum_{r=1}^8 u_r (Y_{rk}^U - \alpha(Y_{rk}^U - Y_{rk}^M)),$$

$$\text{S.t.} \sum_{r=1}^8 u_r (Y_{rj}^U - \alpha(Y_{rj}^U - Y_{rj}^M)) \leq 1, \quad j = 1, 2, \dots, 10,$$

$$\sum_{r=1}^5 u_r (Y_{rj}^L + \alpha(Y_{rj}^M - Y_{rj}^L)) \leq 1, \quad j = 1, 2, \dots, 10, j \neq k,$$

$$\sum_{p=1}^5 f_{pj}^{(1)} \leq 1, \quad j = 1, 2, \dots, 10,$$

$$\sum_{p=1}^{14} f_{pj}^{(2)} - \sum_{p=1}^5 f_{pj}^{(1)} \leq 0, \quad j = 1, 2, \dots, 10,$$

$$\sum_{p=1}^5 f_{pj}^{(3)} - \sum_{p=1}^{14} f_{pj}^{(2)} \leq 0, \quad j = 1, 2, \dots, 10, \tag{11}$$

$$\sum_{r=1}^8 u_r (Y_{rj}^U - \alpha(Y_{rj}^U - Y_{rj}^M)) - \sum_{p=1}^5 f_{pj}^{(3)} \leq 0, \quad j = 1, 2, \dots, 10,$$

$$\sum_{r=1}^8 u_r (Y_{rj}^L + \alpha(Y_{rj}^M - Y_{rj}^L)) - \sum_{p=1}^5 f_{pj}^{(3)} \leq 0, \quad j = 1, 2, \dots, 10, j \neq k,$$

$$w_p^{(1)} (z_{pj}^{(1)L} + \alpha(z_{pj}^{(1)M} - z_{pj}^{(1)L})) \leq f_{pj}^{(1)} \leq w_p^{(1)} (z_{pj}^{(1)U} - \alpha(z_{pj}^{(1)U} - z_{pj}^{(1)M})), \quad p = 1, 2, \dots, 5, j = 1, 2, \dots, 10,$$

$$w_p^{(2)} (z_{pj}^{(2)L} + \alpha(z_{pj}^{(2)M} - z_{pj}^{(2)L})) \leq f_{pj}^{(2)} \leq w_p^{(2)} (z_{pj}^{(2)U} - \alpha(z_{pj}^{(2)U} - z_{pj}^{(2)M})), \quad p = 1, 2, \dots, 14, j = 1, 2, \dots, 10,$$

$$w_p^{(3)} (z_{pj}^{(3)L} + \alpha(z_{pj}^{(3)M} - z_{pj}^{(3)L})) \leq f_{pj}^{(3)} \leq w_p^{(3)} (z_{pj}^{(3)U} - \alpha(z_{pj}^{(3)U} - z_{pj}^{(3)M})), \quad p = 1, 2, \dots, 5, j = 1, 2, \dots, 10,$$

$$u_r, \vartheta_i, w_p^{(1)}, w_p^{(2)}, w_p^{(3)} \geq 0, \quad \forall r, i, p.$$

After solving the above model for the  $k^{\text{th}}$  DMU, the whole system efficiency and the efficiency for various stages

of the system for this DMU are calculated from the following equations:

$$\begin{aligned}
E_k^L &= \text{Max} \sum_{r=1}^8 \sum_{r=1}^8 u_r (Y_{rk}^L + \alpha(Y_{rk}^M - Y_{rk}^L)), \\
\text{S.t. } \sum_{r=1}^8 u_r (Y_{rj}^L + \alpha(Y_{rj}^M - Y_{rj}^L)) &\leq 1, \quad j = 1, 2, \dots, 10, \\
\sum_{r=1}^5 u_r (Y_{rj}^U - \alpha(Y_{rj}^U - Y_{rj}^M)) &\leq 1, \quad j = 1, 2, \dots, 10, j \neq k, \\
\sum_{p=1}^5 f_{pj}^{(1)} &\leq 1, \quad j = 1, 2, \dots, 10, \\
\sum_{p=1}^{14} f_{pj}^{(2)} - \sum_{p=1}^5 f_{pj}^{(1)} &\leq 0, \quad j = 1, 2, \dots, 10, \\
\sum_{p=1}^5 f_{pj}^{(3)} - \sum_{p=1}^{14} f_{pj}^{(2)} &\leq 0, \quad j = 1, 2, \dots, 10, \\
\sum_{r=1}^8 u_r (Y_{rj}^L + \alpha(Y_{rj}^M - Y_{rj}^L)) - \sum_{p=1}^5 f_{pj}^{(3)} &\leq 0, \quad j = 1, 2, \dots, 10, \\
\sum_{r=1}^8 u_r (Y_{rj}^U - \alpha(Y_{rj}^U - Y_{rj}^M)) - \sum_{p=1}^5 f_{pj}^{(3)} &\leq 0, \quad j = 1, 2, \dots, 10, j \neq k, \\
w_p^{(1)} (z_{pj}^{(1)L} + \alpha(z_{pj}^{(1)M} - z_{pj}^{(1)L})) &\leq f_{pj}^{(1)} \leq w_p^{(1)} (z_{pj}^{(1)U} - \alpha(z_{pj}^{(1)U} - z_{pj}^{(1)M})), \quad p = 1, 2, \dots, 5, j = 1, 2, \dots, 10, \\
w_p^{(2)} (z_{pj}^{(2)L} + \alpha(z_{pj}^{(2)M} - z_{pj}^{(2)L})) &\leq f_{pj}^{(2)} \leq w_p^{(2)} (z_{pj}^{(2)U} - \alpha(z_{pj}^{(2)U} - z_{pj}^{(2)M})), \quad p = 1, 2, \dots, 14, j = 1, 2, \dots, 10, \\
w_p^{(3)} (z_{pj}^{(3)L} + \alpha(z_{pj}^{(3)M} - z_{pj}^{(3)L})) &\leq f_{pj}^{(3)} \leq w_p^{(3)} (z_{pj}^{(3)U} - \alpha(z_{pj}^{(3)U} - z_{pj}^{(3)M})), \quad p = 1, 2, \dots, 5, j = 1, 2, \dots, 10, \\
u_r, \vartheta_i, w_p^{(1)}, w_p^{(2)}, w_p^{(3)} &\geq 0, \quad \forall r, i, p.
\end{aligned} \tag{12}$$

#### 4. Implementation

In this section, the suggestive EFQM-Fuzzy Network DEA model in the project management goal holding is implemented. In this model, we intend by application of fuzzy network data envelopment analysis technique and also European quality management standard to assess and study operation of productivity for project management goal holding in 10 companies during different time intervals.

The procedure of model designing is in this form that, at first, DMU decision-making units are determined from which their operation shall be assessed. The 10 companies are as follows: Kandovan Pars Qharb Company: DMU1; Faradid Nema Company: DMU2; Tamandan Masir Iran Company: DMU3; Garno Tadbiran Company: DMU4; Atarodian Rahro Company: DMU5; Abadrahan Dashti Pars Company: DMU6; Rahvar Khalije Fars Company: DMU7; Hezar rahe Iran Company: DMU8; Farbar Tanvar Company: DMU9; and Sazian gostar Company: DMU10.

The abovementioned decision-making units are, respectively, indicated by DMU1, DMU2, ..., DMU10. For implementing the suggestive model, at first, the status of each section in subcriteria of the EFQM excellence model shall be specified. For this purpose, a questionnaire and collection of experts' views were used. After completion of questionnaires, point for each subcriteria of the EFQM

excellence model is specified in the form of fuzzy numbers. After collecting data, linear planning models (11) and (12) are implemented on the collected data. In order to determine the upper boundary for the total system efficiency, model (11) is executed for each DMU separately. Meanwhile, the lower boundary for the total system efficiency is obtained by solving model (12) for each DMU in various  $\alpha$  levels. The results obtained from implementation of suggestive models (11) and (12) are reported in Table 3 and Figure 5. In Table 3, the lower boundary and the upper boundary for the total system efficiency in case of each DMU have been reported in terms of  $\alpha$  based on fuzzy data network analysis models (11) and (12).

The reported results in Table 3 and Figures 5 and 6 indicate that, within  $\alpha$ -cut levels, the amounts of 0, 0.25, and 0.5 related to DMU7 have dedicated the best efficiency amounts to themselves. The lower and the upper boundary for the total system efficiency are equal to one in this decision-making unit. Moreover, the results indicate that the lower and the upper boundary for DMU efficiency are reduced by increasing  $\alpha$ -cut level. Also, at  $\alpha$ -cut level equal to 1, the equal amounts exist for lower and upper boundaries regarding the total system efficiency of DMUs. In this level of  $\alpha$ , the model for fuzzy data envelopment analysis is changed to definite equal model because the lower and the upper boundary for input variables data, intermediate variables,

TABLE 3: The total efficiency of DMUs at different  $\alpha$ -cut levels.

DMUs	$\alpha = 0$		$\alpha = 0.25$		$\alpha = 0.5$		$\alpha = 0.75$		$\alpha = 1$	
	$E_k^L$	$E_k^U$	$E_k^L$	$E_k^U$	$E_k^L$	$E_k^U$	$E_k^L$	$E_k^U$	$E_k^L$	$E_k^U$
DMU1	0.992	1	0.926	0.973	0.842	0.873	0.756	0.77	0.668	0.668
DMU2	0.691	0.913	0.679	0.839	0.635	0.753	0.586	0.642	0.531	0.531
DMU3	0.691	0.913	0.921	1	0.838	0.888	0.752	0.774	0.61	0.61
DMU4	0.978	1	0.963	0.999	0.881	0.922	0.752	0.764	0.599	0.599
DMU5	0.589	0.781	0.575	0.679	0.526	0.592	0.481	0.517	0.443	0.443
DMU6	0.937	1	0.926	0.999	0.875	0.875	0.751	0.751	0.642	0.642
DMU7	1	1	1	1	1	1	0.964	0.981	0.846	0.846
DMU8	0.823	1	0.835	0.954	0.822	0.878	0.743	0.763	0.643	0.643
DMU9	0.61	0.782	0.616	0.728	0.599	0.649	0.542	0.56	0.47	0.47
DMU10	1	1	1	1	0.983	1	0.874	0.894	0.754	0.754

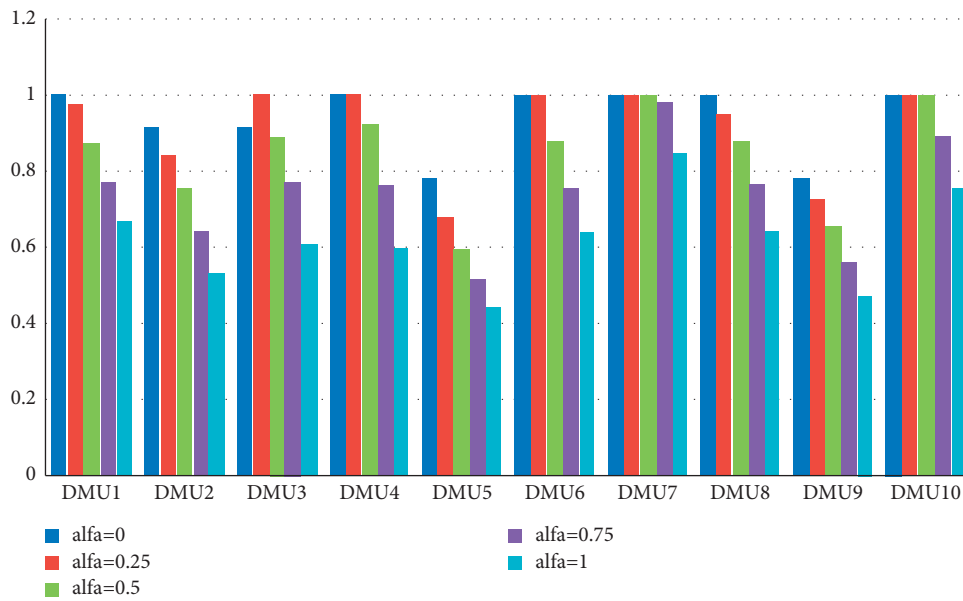


FIGURE 5: The upper bound of total efficiency at different  $\alpha$ -cut levels.

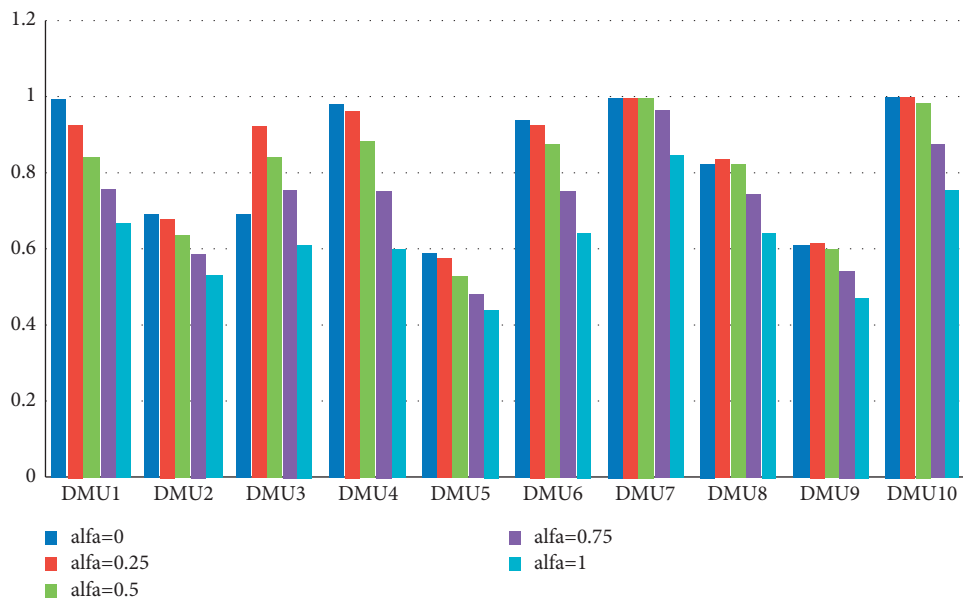


FIGURE 6: The lower bound of total efficiency at different  $\alpha$ -cut levels.

TABLE 4: The efficiency of EFQM stages at  $\alpha = 0$ .

	Stage 1: leadership		Stage 2: people, strategy, and partnership		Stage 3: processes		Stage 4: results	
	LB	UB	LB	UB	LB	UB	LB	UB
DMU1	0.992	1	1	1	1	1	1	1
DMU2	0.748	0.913	1	1	1	1	0.924	1
DMU3	0.947	1	1	1	0.996	1	1	1
DMU4	0.978	1	1	1	1	1	1	1
DMU5	0.736	0.781	1	1	1	1	0.8	1
DMU6	0.937	1	1	1	1	1	1	1
DMU7	1	1	1	1	1	1	1	1
DMU8	0.856	1	1	1	0.962	1	1	1
DMU9	0.716	0.782	1	1	1	1	0.852	1
DMU10	1	1	1	1	1	1	1	1

LB, lower bound efficiency; UB, upper bound efficiency.

and output variables in the  $\alpha$ -cut level equal to 1 are the same based on equation (6) and they are equal to the most probable ones.

Tables 4–8 indicate the lower and the upper boundary for each stage of the EFQM model at different  $\alpha$ -cut levels. On the basis of Tables 4 and 3, at  $\alpha$ -cut level equal to zero, it can be concluded that the lower and the upper bound for total efficiency and also total efficiency at different  $\alpha$ -cut levels of the EFQM model for the companies' number 7 and 10 are equal to 1. Thus, at this  $\alpha$  level, these two companies are the best companies concerning efficiency. On the basis of Tables 4, the second state efficiency for EFQM model is equal to 1 for all the companies. In other words, at  $\alpha$ -cut level equal to zero, the status of individuals, sources, and partnership is very appropriate concerning efficiency for all the companies. At  $\alpha$ -cut level equal to 0.25, the companies with number 7 and 10 are the best companies as well (Tables 3 and 5). Furthermore, at this  $\alpha$  level, the lower and the upper bound for the 3<sup>rd</sup> stage of EFQM model, i.e., the processes sector, are equal to one for all the companies, and it can be stated that, at  $\alpha$ -cut level equal to 0.25, all the companies have good status in the processes sector.

With regard to Tables 3 and 6, at  $\alpha$ -cut level equal to 0.5, only in company number 7, the lower and the upper bound for total efficiency and different stages' efficiency of the EFQM model are equal to one. At this  $\alpha$  level, the lower and the upper bound for leadership stage efficiency are equal to one for the companies' number 3, 7, and 10, but other companies are inefficient in leadership section. In the 2<sup>nd</sup> stage of EFQM model, i.e., individuals section, sources, and partnership, all the companies are efficient except the companies 3 and 10. In the processes section, i.e., the 3<sup>rd</sup> stage of EFQM model, only company 3 is inefficient and all the other companies are efficient. In the conclusions section, only the companies 2, 5, and 9 are inefficient.

Regarding Tables 3 and 7, at  $\alpha$ -cut level equal to 0.75, only in the company number 7, the lower and the upper bound for total efficiency and different stages efficiency of EFQM model are equal to one as well. At this  $\alpha$  level, the lower and the upper bound for leadership stage efficiency are equal to one for the companies' number 7 and 10, but other

companies are inefficient in leadership section. At the 2<sup>nd</sup> stage of EFQM model, i.e., individuals section, sources, and partnership, all the other companies except 7 and 10 are efficient. In the processes section, i.e., the 3<sup>rd</sup> stage of EFQM model, all the companies except 3 and 8 are efficient. In conclusions section, i.e., the 4<sup>th</sup> stage of EFQM model, all the companies 2, 5, 8, and 9 are inefficient, but other companies are efficient.

At  $\alpha$ -cut level equal to one, the results obtained are reported in Tables 3 and 8. At this  $\alpha$  level, the lower and the upper bound for efficiency are equal because the indefinite model for fuzzy data envelopment analysis is changed into an equal definite model, wherein the lower and the upper bound for the data related to operational variables become equal, and the whole correspond to the most probable amounts. At this  $\alpha$  level, the companies except 3, 7, and 10, respectively, have dedicated the highest rate of total efficiency to themselves. These companies' efficiency rates are, respectively, 0.846, 0.754, and 0.668.

Concerning Table 8, at  $\alpha$ -cut level equal to one, the efficiency rate for different stages of the EFQM model indicates that, in the leadership section (stage 1), company 7 has the best efficiency. The leadership section efficiency rate is equal to one in this company. The other companies' efficiency rate is less than one for the leadership stage. Thus, these companies can improve the leadership status in their company by modeling the indicators related to the leadership section in company 7. Considering the second-stage efficiency rate by using Table 8, which is related to the employees, policy, and partnership, many companies have good status. Efficiency of this stage is equal to one for companies 3, 4, 7, 8, and 6, and the remaining companies in this stage are inefficient. These six remaining companies should have improved their efficiency at the second stage of EFQM model by modeling from the status of employees, policies, and partnership of efficient companies in this section. In the processes area of EFQM model, 7 companies are efficient and only 3 companies, 3, 8, and 9, are inefficient. Moreover, in the conclusions stage of EFQM model, except company 2 and 9 which are inefficient, other companies are efficient.

TABLE 5: The efficiency of EFQM stages at  $\alpha = 0.25$ .

	Stage 1: leadership		Stage 2: people, strategy, and partnership		Stage 3: processes		Stage 4: results	
	LB	UB	LB	UB	LB	UB	LB	UB
DMU1	0.926	0.973	1	1	1	1	1	1
DMU2	0.751	0.839	1	1	1	1	0.903	1
DMU3	0.939	1	0.981	1	1	1	1	1
DMU4	0.963	0.999	1	1	1	1	1	1
DMU5	0.648	0.679	1	1	1	1	0.887	1
DMU6	0.926	0.999	1	1	1	1	1	1
DMU7	1	1	1	1	1	1	1	1
DMU8	0.835	0.954	1	1	1	1	1	1
DMU9	0.686	0.728	1	1	1	1	0.899	1
DMU10	1	1	1	1	1	1	1	1

TABLE 6: The efficiency of EFQM stages at  $\alpha = 0.5$ .

	Stage 1: leadership		Stage 2: people, strategy, and partnership		Stage 3: processes		Stage 4: results	
	LB	UB	LB	UB	LB	UB	LB	UB
DMU1	0.842	0.873	1	1	1	1	1	1
DMU2	0.738	0.766	1	1	1	1	0.862	0.984
DMU3	1	1	0.864	0.888	0.969	1	1	1
DMU4	0.881	0.922	1	1	1	1	1	1
DMU5	0.572	0.592	1	1	1	1	0.919	1
DMU6	0.875	0.875	1	1	1	1	1	1
DMU7	1	1	1	1	1	1	1	1
DMU8	0.822	0.878	1	1	1	1	1	1
DMU9	0.642	0.649	1	1	1	1	0.933	1
DMU10	1	1	0.983	1	1	1	1	1

TABLE 7: The efficiency of EFQM stages at  $\alpha = 0.75$ .

	Stage 1: leadership		Stage 2: people, strategy, and partnership		Stage 3: processes		Stage 4: results	
	LB	UB	LB	UB	LB	UB	LB	UB
DMU1	0.756	0.77	1	1	1	1	1	1
DMU2	0.753	0.753	1	1	1	1	0.778	0.852
DMU3	0.919	0.92	1	1	0.818	0.845	1	1
DMU4	0.752	0.764	1	1	1	1	1	1
DMU5	0.514	0.517	1	1	1	1	0.937	1
DMU6	0.751	0.751	1	1	1	1	1	1
DMU7	1	1	0.964	0.981	1	1	1	1
DMU8	0.763	0.764	1	1	0.997	1	0.975	1
DMU9	0.624	0.624	1	1	1	1	0.86	0.897
DMU10	1	1	0.874	0.897	1	1	1	1

TABLE 8: The efficiency of EFQM stages at  $\alpha = 1$ .

	Stage 1: leadership		Stage 2: people, strategy, and partnership		Stage 3: processes		Stage 4: results	
	LB	UB	LB	UB	LB	UB	LB	UB
DMU1	0.668	0.668	1	1	1	1	1	1
DMU2	0.706	0.706	1	1	1	1	0.752	0.752
DMU3	0.902	0.902	0.976	0.976	0.693	0.693	1	1
DMU4	0.683	0.683	0.876	0.876	1	1	1	1
DMU5	0.443	0.443	1	1	1	1	1	1
DMU6	0.642	0.642	1	1	1	1	1	1
DMU7	1	1	0.846	0.846	1	1	1	1
DMU8	0.748	0.748	1	1	0.859	0.859	1	1
DMU9	0.574	0.574	1	1	0.943	0.943	0.869	0.869
DMU10	0.897	0.897	0.84	0.84	1	1	1	1

## 5. Conclusion

Evaluating organization efficiency based on the EFQM model is one of the strategic managerial tools in many organizations. The classic DEA models were designed to work with deterministic data and cannot deal with uncertainties in their inputs. The techniques developed so far for fuzzy performance evaluation are also very limited. Given that the inputs and outputs of a real system are not always definite and accurate and that some data can only be expressed in vague verbal and subjective terms, the use of fuzzy sets in modeling is inevitable. Fuzzy sets, which include ambiguous sets with inaccurate boundaries, were first introduced by Zadeh [30] with the aim of creating a simpler model for complex and ambiguous systems.

In this paper, a fuzzy network data envelopment analysis model has been suggested for assessment of organization efficiency on the basis of EFQM model. For this purpose, at first, the EFQM excellence model has been considered within the framework of a four-stage system. Then, each one of the existing 32 subcriteria in the EFQM model has been considered as input, output, and intermediate variables for the four-stage system. On this basis, a network data envelopment analysis model has been suggested for the four-stage system. Fuzzy theory and concepts were used for observing and modeling the noncertainties in consideration of the existing noncertainties in the experts' views regarding evaluation of the status for EFQM excellence model subcriteria. Therefore, fuzzy copy for fuzzy data envelopment analysis model has been developed based on the concept of  $\alpha$ -cut for EFQM four-stage system.

The developed fuzzy model is able to calculate the lower and the upper bound for the system total efficiency as well as system various stages' efficiency. The suggested EFQM-Fuzzy Network DEA model was used for assessing the efficiency of organizational units in a case study.

Finally, it should be noted that each proposed model has limitations, and researchers can provide a more effective and efficient model in the future to use intuitive fuzzy tools. [31].

Atanassov [32] introduced intuitive fuzzy logic in 1983 with the development of fuzzy logic. With the development of the application of intuitive fuzzy logic, several studies have used this logic in the DEA approach.

## Data Availability

The data used are included within the article.

## Conflicts of Interest

The authors declare that they have no conflicts of interest.

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