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# Evaluation of Hospital Performance Using a Combined Model of Balanced Scorecard and Fuzzy Data Envelopment Analysis

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**Abstract**

**Introduction:** Hospitals are considered as the most important consumer units in the healthcare sector and are one of the main organizations providing health care services. Therefore, efficiency assessment is very important in hospital sectors. Besides, in order to be able to develop and compete, hospitals need a performance evaluation system to evaluate the efficiency and effectiveness of their programs, processes, and human resources. The aim of this paper was to assess the efficiency of hospitals by a combined model of balanced scorecard-fuzzy data envelopment analysis (BSC-fuzzy DEA).

**Methods:** The present study was a descriptive-analytical study that was conducted to assess the efficiency of 8 hospitals in Qazvin province in 2018. The required data were collected through historical data and a questionnaire. 30 experts, including hospital managers and staff, and patients were randomly chosen to collect data in each hospital. The methods used in this study were balanced scorecard (BSC) for determining performance indicators in hospitals and fuzzy data envelopment analysis for assessing the efficiency score of hospitals. Data were analyzed by GAMS software version 23.5.1.

**Results:** The results of applying fuzzy DEA revealed that Amiralmomenin Hospital, Bu Ali Clinic, and 22 Bahman Hospital have the best performances among Qazvin hospitals. The technical efficiency scores of these hospitals under the uncertainty level of α=0.75 are 1.72, 1.58, and 1.53, respectively.

**Conclusion:** The use of BSC measures in four perspectives of customer, financial, internal processes and growth, and innovation reflects the overall strategic objectives of the hospitals in the performance evaluation process. Furthermore, applying the BSC and fuzzy DEA methods provides a comprehensive performance assessment tool for hospitals, and helps decision makers to obtain more accurate planning to expand the capacity of health services and save the resources.

**Keywords:** Hospitals, Balanced scorecard, Performance, Indicator

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## Introduction

In recent years, a variety of research studies in the field of healthcare performance evaluation have been conducted. Most of the studies have mainly focused onhospital performance evaluation. European Foundation for Quality Management (EFQM) is a well-known model for performance measurement in organizations. It has been applied for performance evaluation in many studies. For instance, Tabibi et al. (1) evaluated the performance of Ayatollah Kashani hospital based on the EFQM Excellence Model. EFQM model is composed of two parts, the criteria for the evaluation process and criteria for evaluation of results. In another study, the performance of Hashemi Nejad hospital haas been evaluated based on Malcolm Baldrige analysis models (2). Sajadi et al. (3) began to self-evaluate the performance of hospitals and educational-medical centers in Isfahan University of Medical Sciences. In their study, the main objectives were self-assessment based on the excellence model. In the first stage, they attempted to understand the current state of the organization and determine its strengths and weaknesses and then they tried to reinforce the strengths, eliminate defects and improve the organization performance. However, the findings of this study failed to determine the strengths and weaknesses of the center under investigation and serve as a guide for decision-making and managing policies. Based on the findings, the researchers also showed that taking organization excellence and superiority into account is necessary, especially in regard to two criteria of staff and the community. Besides, in order to perform a systematic and accurate self-evaluation, it is essential to design and deliver more training programs.

DEA models and balanced scorecard are efficient tools for assessing the efficiency score of decision making units (4). The Balanced Scorecard technique is a management technique that helps the managers track their growing and declining activities from different perspectives. This technique helps the managers to obtain a comprehensive framework for interpreting and translating the vision and strategy of the organization in the form of a set of performance indicators. The core of the scorecard is strategic goals and vision of organizations. They are, in fact, the basis for the formation of the four perspectives of balanced scorecard: financial, customer, growth and innovation, and internal processes. Application of this method for performance assessment of hospitals can be seen in several studies. For instance, Zelman et al. (5) used the balanced scorecard to evaluate the performance of hospitals in China. They found that the use of BSC method was effective in identifying the problems and barriers in order to improve treatment services. Bruce et al. (6) applied the BSC to evaluate the performance of health care organizations. In their study, the use of this technique was found to be helpful in presenting the quality of the current conditions as well as providing appropriate strategies to improve the quality.

This study applied a combined model of balanced scorecard and fuzzy data envelopment analysis for evaluating the performance of hospitals in Qazvin province. Combining these two methods will help us to take advantage of both methods, simultaneously. In other words, the balanced scorecard method is utilized to extract a comprehensive list of hospital performance indicators in four perspectives of BSC, including financial, customer, growth and innovation, and internal perspectives. Furthermore, fuzzy data envelopment analysis as an effective tool in the field of performance evaluation was applied to evaluate the efficiency of the hospitals.

## Methods

In this section, BSC and fuzzy DEA are used as two useful methods for hospital performance assessment. In other words, this study takes the features of the BSC and fuzzy DEA simultaneously to evaluate the hospital's performance. The steps of applying the combined model of BSC-fuzzy DEA are shown in Figure 1. The BSC is implemented in order to achieve a fully comprehensive set of criteria for performance evaluation of the four perspectives. Determining performance indicators based on four perspectives of BSC is the first step of implementing the BSC-fuzzy DEA model, as shown in Figure 1. Furthermore, the fuzzy DEA method has been used to measure the technical efficiency of hospitals under uncertainty. Fuzzy DEA requires the definition of inputs and outputs that form the second step of applying the BSC-fuzzy DEA model, as shown in Figure 1. The third and fourth steps of applying the BSC-fuzzy DEA model are collecting data and applying fuzzy DEA models. Figure 1 shows the steps of implementing the combined model of BSC and fuzzy DEA in order to assess the efficiency score of hospitals.

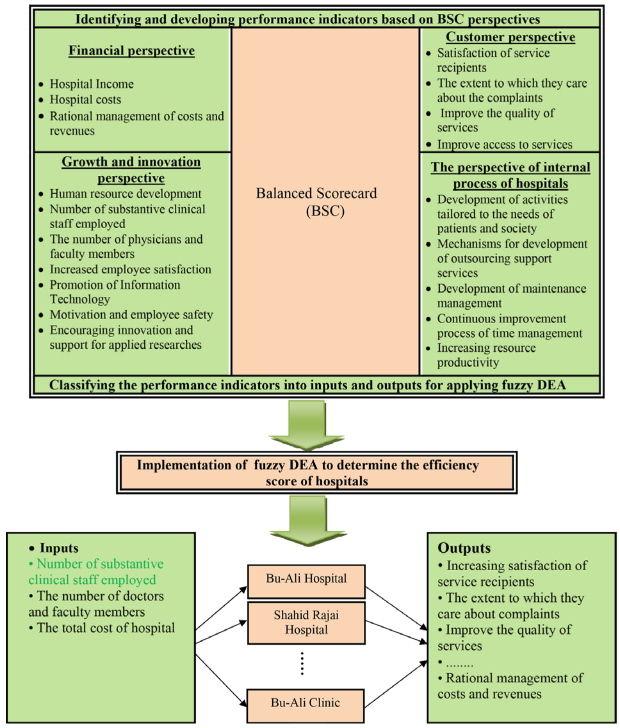


**Figure 1:** The steps of applying the combined model of BSC-fuzzy DEA

The steps of applying the BSC-fuzzy DEA model are as follows:

○ In the first step, the hospital performance evaluation indicators in Qazvin province are determined in four perspectives of BSC method, namely, customer, internal processes, financial and development, and innovation perspectives. The performance indicators are found based on the corresponding literature as well as expert opinions (7-8).

Hospital income and hospital costs are considered as two performance indicators in the financial perspective by Yuen and Ng (7). Furthermore, Nasiripour et al. (8) introduced rational management of the costs and revenues as the other criterion in the financial perspective. Therefore, this study utilized these three indicators in the financial perspective, as shown in Figure 1.

According to Yuen and Ng (7) and Nasiripour et al. (8), the following performance indicators can be considered in the growth and innovation perspective in the BSC method.

√ Human resource development (8)

√ The number of substantive clinical staff employed (7)

√ The number of doctors and faculty members. This criterion is recommended by the experts to be considered in this perspective.

√ Increase inemployee satisfaction (8)

√ Promotion of information technology (8)

√ Motivation and employee safety (8)

√ Encouraging innovation and support for applied researches (8)

Nasiripour et al. (8) introduced five performance indicators in the perspective of the internal process of hospitals. They are as follows:

√ Development of activities tailored to the needs of patients and society (8)

√ Mechanisms for development of outsourcing support services (8)

√ Development of Maintenance Management (8)

√ Continuous improvement process of time management (8)

√ Increase in resource productivity (8)

Finally, according to Nasiripour et al. (8), the following performance indicators are considered in the customer perspective in BSC method.

√ Satisfaction of service recipients (8)

√ The extent to which they care about the complaints (8)

√ Improvement of the quality of services (8)

√ Improvement of the access to services (8)

Figure 1 shows the aforementioned hospital performance indicators, which are extracted based on the BSC.

○ In the second step, the identified performance indicators should be classified into two categories (input and output indicators) for applying fuzzy DEA models. In this study, input and output indicators have been determined based on the literature and expert opinions. For instance, according to Jahangiri (9), the total costs and number of staff are considered as input indicators for hospital performance assessment when applying DEA models. Therefore, the number of substantive clinical staff employed, the total cost of the hospital and number of doctors and faculty members are considered as three input indicators in this study. Furthermore, satisfaction of service recipients and hospital revenue are considered as output indicators in DEA applications (9). They are also utilized as output indicators in this study.

In DEA terminology, inputs are those of indicators that satisfy the property of "the smaller the better" and outputs are those of indicators that satisfy the property of "the larger the better" (10). Therefore, the other criteria used in this study are classified into inputs and outputs based on these definitions. According to these definitions and literature, the inputs and outputs used in this study are as follows:

Inputs:

√ Number of substantive clinical staff employed (9)

√ The total cost of hospital (9)

√ Number of doctors and faculty members (9)

Outputs:

√ Satisfaction of service recipients (9)

√ The extent to which they care about the complaints

√ Improving the quality of services

√ Improving access to services

√ Hospital revenue (9)

√ Rational management of costs and revenues

√ Development of activities tailored to the needs of patients and society

√ Creation of the necessary mechanisms for developing outsourcing support services

√ Development of maintenance management

√ Continuous improvement process of time management

√ Increased resource productivity

√ Human resource development

√ Increased employee satisfaction

√ Promotion of information technology

√ Increased motivation and employee safety

√ Encouragemen of innovation and support of applied research

○ In the third step, a questionnaire was designed to collect the expert opinions about qualitative performance indicators. The data of quantitative performance indicators such as the number of substantive clinical staff employed, the total cost of the hospital, and the number of doctors and faculty memberswere collected from historical data in each hospital. The other performance indicators were

$$\begin{aligned}
\max \quad & \sum_{r=1}^{s} u_r \left( y_{rp}^l, y_{rp}^m, y_{rp}^u \right) \\
s.t. \quad & \sum_{i=1}^{m} v_i \left( x_{ip}^l, x_{ip}^m, x_{ip}^u \right) = 1 \quad ; \quad \forall i \\
& \sum_{r=1}^{s} u_r \left( y_{rj}^l, y_{rj}^m, y_{rj}^u \right) - \sum_{i=1}^{m} v_i \left( x_{ij}^l, x_{ij}^m, x_{ij}^u \right) \le 0 \quad ; \quad \forall j \\
& u_r, v_i \ge 0 \quad ; \quad \forall r, i
\end{aligned} \tag{1}$$

qualitative in nature. Therefore, 5 point Likert Scale questions were added to the questionnaire to obtain the ratings of each qualitative indicator. In each hospital, 30 questionnaires were distributed among hospital managers, staff and patients to collect the respected data. After collecting data, they were converted to the corresponding fuzzy numbers, according to Table 1.

**Table 1:** Linguistic scales and corresponding fuzzy numbers for rating qualitative indicators (11)

| Linguistic variables | The triangular fuzzy number |
|---|---|
| Very Low | (0, 0, 0.2) |
| Low | (0, 0.2, 0.4) |
| Average | (0.3, 0.5, 0.7) |
| High | (0.6, 0.8, 1) |
| Very high | (0.8, 1, 1) |

○ In the fourth step, the efficiency score of each hospital was obtained by applying fuzzy DEA models and coded in GAMS softwar, version 23.5.1. The fuzzy DEA models applied in this study were first developed by Saaty et al. (11). More details on the fuzzy DEA models introduced by Saaty et al. (11) are presented in the next section.

### *1. Fuzzy DEA Model*

In this section, the fuzzy DEA model introduced by Saaty et al. (11) is described. Suppose $\tilde{x} = \left(x^l, x^m, x^u\right)$ and $\tilde{y} = \left(y^l, y^m, y^u\right)$ denote inputs and outputs, respectively. The basic model of data envelopment analysis in fuzzy environment is written as follows (11):

This is not a linear model. There are several ways to convert a fuzzy non-linear model into a fuzzy linear model. The most common of them is α-cut method. α-cut in fuzzy set is a subset of the elements which are either greater or equal to α, according to their membership functions. This subset is denoted by $A_\alpha$ and shown in equation (2):

$$A_\alpha = \{x \mid \mu_A(x) > \alpha\} \qquad (2)$$

Based on the concept of α-cut, the fuzzy set can be represented as an ordinary set. Figure 2 shows the concept of α-cut graphically.

Considering the membership function of a triangular fuzzy number, and showing the numerical value of $\tilde{A}$ by $\tilde{A} = \left(A^l, A^m, A^u\right)$, α-cut fuzzy number can be achieved through equation (3).

$$A^\alpha = (\alpha A^m + (1-\alpha)A^l, \alpha A^m + (1-\alpha)A^u) \qquad (3)$$

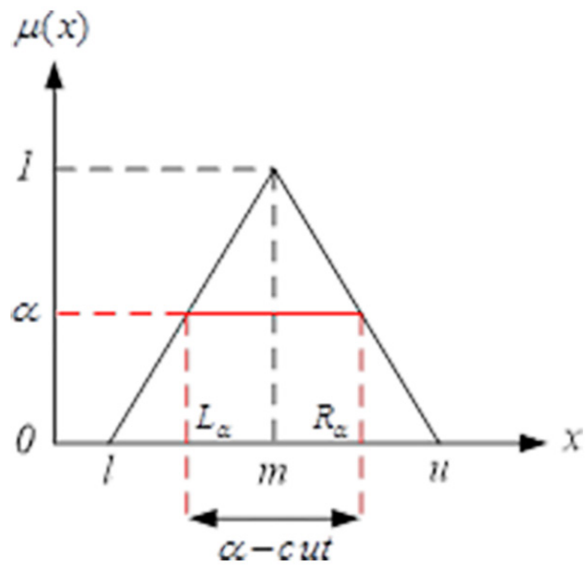


**Figure 2:** α-cut triangular fuzzy number

According to the definition of α-cut of a triangular fuzzy number and its application to triangular fuzzy numbers $\tilde{x} = \left(x^l, x^m, x^u\right)$ and $\tilde{y} = \left(y^l, y^m, y^u\right)$, we obtained the following equations:

$$x^\alpha = (\alpha x^m + (1-\alpha)x^l, \alpha x^m + (1-\alpha)x^u)$$
$$y^\alpha = (\alpha y^m + (1-\alpha)y^l, \alpha y^m + (1-\alpha)y^u)$$

According to the aforementioned definitions, model (1) can be converted into the following model.

$$\begin{aligned} \max\ & \sum_{r=1}^{s} u_r(\alpha y_{rp}^m + (1-\alpha)y_{rp}^l, \alpha y_{rp}^m + (1-\alpha)y_{rp}^u) \\ s.t.\ & \sum_{i=1}^{m} v_i\left(\alpha x_{ip}^m + (1-\alpha)x_{ip}^l, \alpha x_{ip}^m + (1-\alpha)x_{ip}^u\right) = 1 \quad ; \quad \forall i \qquad (4) \\ & \sum_{r=1}^{s} u_r\left(\alpha y_{rj}^m + (1-\alpha)y_{rj}^l, \alpha y_{rj}^m + (1-\alpha)y_{rj}^u\right) - \sum_{i=1}^{m} v_i\left(\alpha x_{ij}^m + (1-\alpha)x_{ij}^l, \alpha x_{ij}^m + (1-\alpha)x_{ij}^u\right) \le 0 \quad ; \quad \forall j \\ & u_r, v_i \ge 0 \quad ; \quad \forall r, i \end{aligned}$$

Model (4) is an interval programming model which is non-linear. This model is converted into a non-linear programming model by doing the following conversions (11).

$$(\alpha y_{rj}^m + (1-\alpha)y_{rj}^l, \alpha y_{rj}^m + (1-\alpha)y_{rj}^u) \equiv \alpha y_{rj}^m + (1-\alpha)y_{rj}^l \le \hat{y}_{rj} \le \alpha y_{rj}^m + (1-\alpha)y_{rj}^u$$
$$(\alpha x_{ij}^m + (1-\alpha)x_{ij}^l, \alpha x_{ij}^m + (1-\alpha)x_{ij}^u) \equiv \alpha x_{ij}^m + (1-\alpha)x_{ij}^l \le \hat{x}_{ij} \le \alpha x_{ij}^m + (1-\alpha)x_{ij}^u$$

The rationale behind these transformations is that we replace any interval by a variable with a range of value that is equal to the corresponding interval. As seen below, the following non-linear interval model has been transformed into a merely non-linear one (11):

$$
\begin{aligned}
\max\ & \sum_{r=1}^{s} u_r \hat{y}_{rp} \\
s.t.\ & \sum_{i=1}^{m} v_i \hat{x}_{ip} = 1 \qquad (5) \\
& \sum_{r=1}^{s} u_r \hat{y}_{rj} - \sum_{i=1}^{m} v_i \hat{x}_{ij} \le 0 \quad ; \quad \forall j \\
& \alpha y_{rj}^{m} + (1-\alpha) y_{rj}^{l} \le \hat{y}_{rj} \le \alpha y_{rj}^{m} + (1-\alpha) y_{rj}^{u} \quad ; \quad \forall r \\
& \alpha x_{ij}^{m} + (1-\alpha) x_{ij}^{l} \le \hat{x}_{ij} \le \alpha x_{ij}^{m} + (1-\alpha) x_{ij}^{u} \quad ; \quad \forall i \\
& u_r, v_i \ge 0 \quad ; \quad \forall r, i
\end{aligned}
$$

With a quick glance, model (5) can be converted into a linear mathematical programming model. By applying the changes to the following variables, linear programming model for fuzzy data envelopment analysis can be obtained.

$$
\hat{y}_{rj} \lambda_j = Y_{rj}
$$

$$
\hat{x}_{ij} \lambda_j = X_{ij}
$$

Model (6) is a linear programming model of fuzzy DEA (11).

$$
\begin{aligned}
\max\ & \sum_{r=1}^{s} Y_{rp} \\
s.t.\ & \sum_{i=1}^{m} X_{ip} = 1 \qquad (6) \\
& \sum_{r=1}^{s} Y_{rj} - \sum_{i=1}^{m} X_{ij} \le 0 \quad ; \quad \forall j \\
& u_r \left( \alpha y_{rj}^{m} + (1-\alpha) y_{rj}^{l} \right) \le Y_{rj} \le u_r \left( \alpha y_{rj}^{m} + (1-\alpha) y_{rj}^{u} \right) \quad ; \quad \forall r \\
& v_i \left( \alpha x_{ij}^{m} + (1-\alpha) x_{ij}^{l} \right) \le X_{ij} \le v_i \left( \alpha x_{ij}^{m} + (1-\alpha) x_{ij}^{u} \right) \quad ; \quad \forall i \\
& u_r, v_i \ge 0 \quad ; \quad \forall r, i
\end{aligned}
$$

Model (6) does not have the capability of ranking DUMs and only shows the efficiency score of DMUs. Therefore, the following part will be devoted to the fuzzy DEA model that has the ability of ranking DMUs.

## 2. Fuzzy DEA Ranking Model

The standard model of DEA allocates each DMU an efficiency value between zero and one. Based on the degree of efficiency, only inefficient DMU ($\theta^{*} < 1$) can be ranked and the difference among efficient DMUs ($\theta^{*} = 1$) cannot be identified. For a complete ranking of DMUs, certain methods have been proposed by the researchers. However, these methods do not cover fuzzy conditions. This study uses the proposed method of Saaty et al. (11) for complete ranking of DMUs in fuzzy environment. The initial model for ranking DMUs can be written as follows (11).

$$
\begin{aligned}
& Min\, Z = \theta \\
& S.t. \quad \theta \tilde{x}_{ip} \ge \sum_{j=1}^{n} \lambda_j \tilde{x}_j \\
& \qquad \tilde{y}_p \le \sum_{j=1}^{n} \lambda_j \tilde{y}_j \qquad (7)
\end{aligned}
$$

where "~" represents fuzzy numbers.

Now, according to the definition, if we use triangular fuzzy numbers $\tilde{x}_{ij} = \left( x_j^{l}, x_j^{m}, x_j^{u} \right)$ and $\tilde{y}_{ij} = \left( y_j^{l}, y_j^{m}, y_j^{u} \right)$, model (5) can be rewritten as follows (11).

$$
\begin{aligned}
\min\ & Z = \theta_p \\
s.t.\ & \theta \left( x_{ip}^{l}, x_{ip}^{m}, x_{ip}^{u} \right) \ge \sum_{j=1}^{n} \lambda_j \left( x_{ij}^{l}, x_{ij}^{m}, x_{ij}^{u} \right) \quad ; \quad \forall i \qquad (8) \\
& \left( y_{rp}^{l}, y_{rp}^{m}, y_{rp}^{u} \right) \le \sum_{j=1}^{n} \lambda_j \left( y_{rj}^{l}, y_{rj}^{m}, y_{rj}^{u} \right) \quad ; \quad \forall r \\
& \lambda_j \ge 0 \quad ; \quad \forall j
\end{aligned}
$$

To perform model 8, we use the concept of α-cut. By applying this concept to the fuzzy numbers, model (8) can be converted into the following interval programming model (11).

$$
\begin{aligned}
\min\ & Z = \theta_p \\
s.t.\ & \theta \left( \alpha x_{ip}^{m} + (1-\alpha) x_{ip}^{l}, \alpha x_{ip}^{m} + (1-\alpha) x_{ip}^{u} \right) \ge \sum_{j=1}^{n} \lambda_j \left( \alpha x_{ij}^{m} + (1-\alpha) x_{ij}^{l}, \alpha x_{ij}^{m} + (1-\alpha) x_{ij}^{u} \right) \quad ; \quad \forall i \qquad (9) \\
& \left( \alpha y_{rp}^{m} + (1-\alpha) y_{rp}^{l}, \alpha y_{rp}^{m} + (1-\alpha) y_{rp}^{u} \right) \le \sum_{j=1}^{n} \lambda_j \left( \alpha y_{rj}^{m} + (1-\alpha) y_{rj}^{l}, \alpha y_{rj}^{m} + (1-\alpha) y_{rj}^{u} \right) \quad ; \quad \forall r \\
& \lambda_j \ge 0 \quad ; \quad \forall j
\end{aligned}
$$

In ranking DMUs, the lower and higher levels of inputs (that is the best part of a DMU) are compared with the inner part of the efficient frontier. In this case, if the best part of DMU is outside the efficiency frontier, the efficiency of DMU will be more than one. Then, this idea will be used to rank DMUs.

In model (9), the best part of DMU is $\left( \alpha X_p^{m} + (1-\alpha) X_p^{l}, \alpha X_p^{m} + (1-\alpha \right)$, and the inner efficient frontier is $\left( \sum_{j=1}^{n} \lambda_j (\alpha X_j^{m} + (1-\alpha) X_j^{l}) \sum_{j=1}^{n} \lambda_j (\alpha X_j^{m} + (1-\alpha) X \right.$.

Now, according to the above description, the final model for ranking DMUs can be written as follows (11):

$$\begin{aligned} &\min\ Z=\theta \\ &s.t.\quad \theta\left(\alpha x_{ip}^{m}+(1-\alpha)x_{ip}^{l}\right)\geq\sum_{j=1}^{n}\lambda_j\left(\alpha x_{ip}^{m}+(1-\alpha)x_{ip}^{u}\right)\quad ;\quad \forall i \qquad (10)\\ &\left(\alpha y_{rp}^{m}+(1-\alpha)y_{rp}^{l}\right)\geq\sum_{j=1}^{n}\lambda_j\left(\alpha y_{rp}^{m}+(1-\alpha)y_{rp}^{u}\right)\quad ;\quad \forall r\\ &\lambda_j\geq 0 \end{aligned}$$

Model (10) is a parametric programming model whose parameter is $\alpha\in[0,1]$. Thus, fuzzy non-linear programming (9) can be converted into parametric programming model (10). It is noteworthy that model (10) has an optimal value for each α. Therefore, a table of optimum solutions can be provided based on α.

## Results

The combined BSC-fuzzy DEA model is applied in this section for hospital performance evaluations in Gazvin province. Hospitals surveyed in this research include 7 hospitals and a clinic in Qazvin Province: Bu-Ali, Shahid Rajai, Qods, Kosar, Amiralmomenin, 22 Bahman, Velayat, and Bu-Ali Clinic.

After designing the questionnaires, data of the hospital performance indicators in Qazvin province were collected. The domain of this research is all hospitals in Qazvin province, so statistical sampling is not the basis of the research. The method of data collection in this research is similar to Tueysuez and Kahraman' methodology (12), which used 11 IT managers in their research to assess information technology risks. In this study, 30 experts, including hospital managers and staff, were used to collect data. After collecting the data, data pre-processing was performed, using Table 1, and finally the fuzzy numbers of the respected performance indicators were obtained. Appendix (1) reports the fuzzy numbers of performance indicators in Qazvin hospitals.

By performing model 6, which is coded in GAMS 23.5.1 software, the efficiency score of hospitals was achieved. The fuzzy DEA model should be applied for each of the hospitals, separately.

The efficiency score resultswe obtained and reported at different levels of α in Table 2 and Figure 3. Table 2 shows the efficiency score of hospitals in Qazvin province. The higher the efficiency,the better the hospital's performance. Hospital efficiency scores at different alpha levels is reported in Table 2. At each alpha level, hospitals can be prioritized based on their efficiency scores. The ranking of hospitals at each level of alpha will have similar ranking results. As shown in Table 2, the efficiency of many hospitals equaled to 1 at α=1, and the model used to calculate efficiency did not have the capability of ranking efficient units. However, with reduced α-level, the distinction between the efficiency of hospitals was more clearly identified. For instance, at α=0.75, Amiralmomenin hospital and Bu-Ali clinic had the highest efficiency scores and were identified as the best hospitals. In addition, at this level of alpha, Kosar hospital and Velayat hospital obtained the lowest efficiency scores among hospitals and received the worst rankings.

At level α=0, Amiralmomenin hospital and Bu-Ali clinic had the highest efficiency scores and were the best hospitals. At this level of alpha, Kosar hospital and Velayat hospital showed the lowest efficiency scores among hospitals and received the worst rankings, again. In sum, the rankings of hospitals based on their efficiency scores at different levels of alpha are as follows:

1) Amiralmomenin Hospital
2) Bu Ali Clinic
3) 22 Bahman Hospital
4) Qods Hospital
5) Bu-Ali Hospital
6) Shahid Rajai Hospital
7) Kosar hospital
8) Velayat hospital

It is worth mentioning that a clinic, namely Bu Ali clinic, was compared with several hospitals when talking about efficiency. Data envelopment analysis is a tool for measuring the relative efficiency of several homogenous DMUs that utilize the same inputs to generate the same outputs. In the traditional method of data envelopment analysis, DMUs are viewed

**Table 2: Efficiency scores of Qazvin hospitals at different levels of alpha**

| Hospital | Efficiency score | | | | |
|---|---|---|---|---|---|
| | α=0 | α=0.25 | α=0.5 | α=0.75 | α=1 |
| Bu-Ali Hospital | 1.69 | 1.56 | 1.40 | 1.21 | 1 |
| Shahid Rajai Hospital | 1.42 | 1.36 | 1.25 | 1.11 | 1 |
| Quds hospital | 1.90 | 1.73 | 1.50 | 1.28 | 1 |
| Kosar hospital | 1.36 | 1.21 | 1.04 | 0.89 | 0.73 |
| Amiralmomenin Hospital | 2.33 | 2.19 | 1.83 | 1.72 | 1 |
| 22 Bahman Hospital | 2.05 | 1.97 | 1.55 | 1.53 | 1 |
| Velayat hospital | 1.21 | 1.18 | 1.14 | 1.09 | 1 |
| Bu Ali Clinic | 2.24 | 2.12 | 1.66 | 1.58 | 1 |

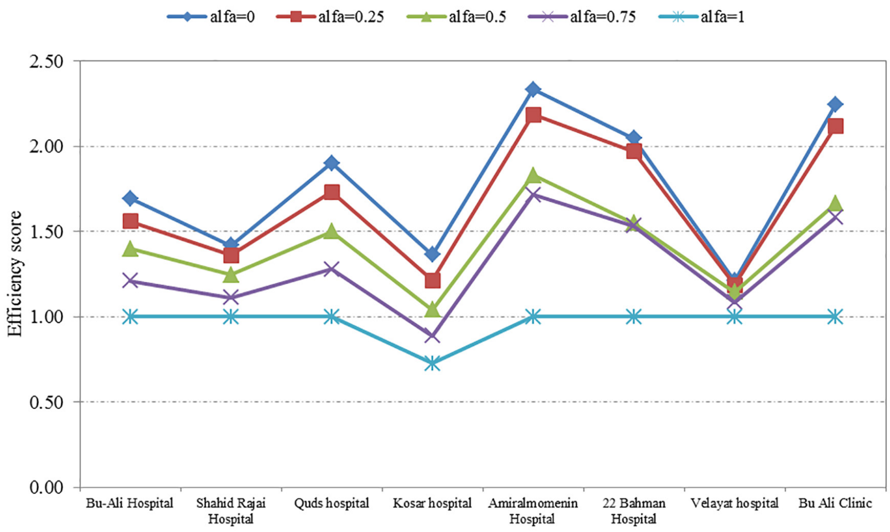


**Figure 3:** Efficiency score of Qazvin hospitals at different levels of alpha

as a black box; therefore, their internal structure is generally ignored. Therefore, it is reasonable to compare a clinic with hospitals, according to the DEA terminology.

Figure 3 shows the efficiency score of hospitals at different levels of alpha. In other words, Figure 3 shows the efficiency score of hospitals graphically. Based on this Figure, a hospital with more efficiency score will have a higher performance than other hospitals. As seen in Figure 3, Amiralmomenin Hospital had the most efficiency score at each level of alfa; hence, it is the best hospital based on the efficiency score. In addition, Bu Ali Clinic and 22 Bahman Hospital had the second and third ranks in terms of their efficiency scores, respectively, and had the best performance after Amiralmomenin Hospital. Likewise, the priority of other hospitals can be obtained in Figure 3.

## Discussion

The aim of this paper was to evaluate the performance of hospitals in Qazvin province by the combined model of balanced scorecard and fuzzy data envelopment analysis. Many researches have used balanced scorecard and data envelopment analysis to evaluate the hospital performance separately. For instance, Ersoy et al. (13) studied the technical efficiency of health service branches with data envelopment analysis. This study was one of the first attempts to analyze the technical efficiency, using DEA in the field of health care. Al-Shammari (14) offered a multi-criteria data envelopment analysis to measure the efficiency of 15 treatment branches. Krigia et al. (15) benefited from DEA to measure the technical efficiency of 54 health care branches in Kenya. Clement et al. (16) analyzed the performance results of the medical branches, using a DEA model. Azadeh et al. (17) analyzed the performance and allocation of resources in different parts of Shariati hospital, using DEA models. Also, Pelone et al. (18) reviewed the performance evaluation in primary care and then began to evaluate the performance of primary care using data envelopment analysis. The DEA method has been used to calculate the technical efficiency of health posts in Guatemala. In this study, 34 health posts were evaluated using 19 performance indices (19). In other studies, the efficiency of primary care was evaluated, using data envelopment analysis (20-21). In one of the studies related to this area, restricted data envelopment analysis has been used to evaluate the performance of rural primary care in Greece (22). Safdar et al. (23) used data envelopment analysis to evaluate the queue processes in their health centers.

Some studies utilized just balanced scorecard to assess the performance of hospitals. For example, Chen et al. (24) and Lin et al. (25) applied the balanced scorecard to measure the performance of Chinese and Japanese hospitals. Application of the balanced scorecard for hospital performance assessment can be seen in Teklehaimanot et al. (26) and Zamil et al.'s studies (27).

According to the aforementioned discussion, it seems that the combined model of balanced scorecard and fuzzy data envelopment analysis can be useful in evaluating the hospitals because of obtaining a comprehensive list of performance indicators by BSC method and considering the existing uncertainty in the experts' opinions by fuzzy concepts. Using the combined model of balanced scorecard and fuzzy data envelopment analysis in this study and its application in measuring the relative efficiency of hospitals is a new approach that enables high level managers of hospitals to recognize their performance status in each of the four perspectives of a balanced scorecard, and compare their performance with other hospitals. Another feature of the application of the BSC-fuzzy DEA model is that hospitals with a weaker performance than others can modify their weaknesses in each of the dimensions of the BSC, either qualitatively or quantitatively.

## Conclusion

The purpose of this study was to evaluate the performance of hospitals in Qazvin province. Because of the importance of the performance evaluation of health services, this article has used the BSC and fuzzy DEA methods to evaluate the performance of hospitals in Qazvin province.

A strength of this study is that it utilized the BSC to obtain a comperehensive list of performance indicators in hospitals. The other strength of this study refers to the utilization of the fuzzy form of DEA to reflect the uncertainty in the experts' opinions about performance indicators. This point has been neglected in many researches in the field of hospital performance management. As mentioned earlier, DMUs are considered as a black box in DEA terminology, while they may have a hierarchical and multi-level structure or an internal network of activities and decisions in many cases. This limits the application of DEA for hospital performance assessment. Therefore, utilizing fuzzy network DEA that enables us to consider internal activities and processes of DMUs is an interesting topic for the future research.

**Conflict of Interest:** None declared.

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**Appendix (1):** Fuzzy input and output indicators

| Fuzzy input indicators | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Hospital name | The total cost of hospital | | | Number of substantive clinical staff employed | | | The number of doctors and faculty members | | |
| | The pessimistic value | The most likely value | The optimistic value | The pessimistic value | The most likely value | The optimistic value | The pessimistic value | The most likely value | The optimistic value |
| Bu-Ali Hospital | 118676967500 | 183681099428 | 256829925424 | 330 | 342 | 350 | 65 | 65 | 65 |
| Shahid Rajai Hospital | 92548672351 | 132353533359 | 189098068347 | 486 | 493 | 510 | 41 | 41 | 41 |
| Quds hospital | 57542512822 | 82917207967 | 175876345657 | 200 | 206 | 210 | 28 | 28 | 28 |
| Kosar hospital | 72625704671 | 102125435353 | 124649838786 | 238 | 247 | 251 | 35 | 35 | 35 |
| Amiralmomenin Hospital | 2385456200 | 3407794571 | 57778977150 | 170 | 170 | 170 | 14 | 14 | 14 |
| 22 Bahman Hospital | 9865215432 | 14094082616 | 23957397703 | 114 | 118 | 120 | 21 | 21 | 21 |
| Velayat hospital | 140776340149 | 140776340149 | 140776340149 | 466 | 466 | 466 | 38 | 38 | 38 |
| Bu Ali Clinic | 8277019463 | 9171193185 | 63148735130 | 43 | 45 | 50 | 20 | 20 | 20 |

| Fuzzy output indicators | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Hospital name | Satisfaction of service recipients | | | The complaints handling | | | Improving the quality of services | | |
| | The pessimistic value | The most likely value | The optimistic value | The pessimistic value | The most likely value | The optimistic value | The pessimistic value | The most likely value | The optimistic value |
| Bu-Ali Hospital | 0.400 | 0.567 | 0.767 | 0.300 | 0.500 | 0.700 | 0.350 | 0.550 | 0.750 |
| Shahid Rajai Hospital | 0.300 | 0.467 | 0.667 | 0.300 | 0.467 | 0.667 | 0.533 | 0.733 | 0.900 |
| Quds hospital | 0.300 | 0.433 | 0.633 | 0.300 | 0.433 | 0.633 | 0.300 | 0.467 | 0.667 |
| Kosar hospital | 0.250 | 0.450 | 0.650 | 0.200 | 0.400 | 0.600 | 0.150 | 0.350 | 0.550 |
| Amiralmomenin Hospital | 0.300 | 0.467 | 0.667 | 0.200 | 0.367 | 0.567 | 0.300 | 0.467 | 0.667 |
| 22 Bahman Hospital | 0.250 | 0.417 | 0.617 | 0.250 | 0.417 | 0.617 | 0.200 | 0.367 | 0.567 |
| Velayat hospital | 0.150 | 0.283 | 0.483 | 0.150 | 0.317 | 0.517 | 0.250 | 0.417 | 0.617 |
| Bu Ali Clinic | 0.350 | 0.517 | 0.717 | 0.300 | 0.500 | 0.700 | 0.450 | 0.650 | 0.850 |

| Continued | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Hospital name | Improving access to services | | | Development of activities tailored to the needs of patients and society | | | Creating the necessary mechanisms for developing outsourcing support services | | |
| | The pessimistic value | The most likely value | The optimistic value | The pessimistic value | The most likely value | The optimistic value | The pessimistic value | The most likely value | The optimistic value |
| Bu-Ali Hospital | 0.300 | 0.500 | 0.700 | 0.400 | 0.600 | 0.800 | 0.250 | 0.450 | 0.650 |
| Shahid Rajai Hospital | 0.533 | 0.733 | 0.900 | 0.500 | 0.700 | 0.900 | 0.450 | 0.650 | 0.850 |
| Quds hospital | 0.250 | 0.417 | 0.617 | 0.100 | 0.267 | 0.467 | 0.100 | 0.300 | 0.500 |
| Kosar hospital | 0.150 | 0.350 | 0.550 | 0.150 | 0.350 | 0.550 | 0.150 | 0.350 | 0.550 |
| Amiralmomenin Hospital | 0.350 | 0.517 | 0.717 | 0.050 | 0.250 | 0.450 | 0.050 | 0.217 | 0.417 |
| 22 Bahman Hospital | 0.150 | 0.283 | 0.483 | 0.000 | 0.133 | 0.333 | 0.000 | 0.133 | 0.333 |
| Velayat hospital | 0.400 | 0.600 | 0.800 | 0.533 | 0.733 | 0.900 | 0.300 | 0.500 | 0.700 |
| Bu Ali Clinic | 0.350 | 0.550 | 0.750 | 0.567 | 0.767 | 0.900 | 0.500 | 0.700 | 0.900 |

| Continued | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Hospital name | Development of Maintenance Management | | | Continuous improvement process of time management | | | Increasing resource productivity | | |
| | The pessimistic value | The most likely value | The optimistic value | The pessimistic value | The most likely value | The optimistic value | The pessimistic value | The most likely value | The optimistic value |
| Bu-Ali Hospital | 0.150 | 0.350 | 0.550 | 0.350 | 0.550 | 0.750 | 0.300 | 0.500 | 0.700 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Shahid Rajai Hospital | 0.500 | 0.700 | 0.900 | 0.400 | 0.600 | 0.800 | 0.583 | 0.783 | 0.950 |
| Quds hospital | 0.300 | 0.500 | 0.700 | 0.400 | 0.600 | 0.800 | 0.360 | 0.560 | 0.760 |
| Kosar hospital | 0.200 | 0.400 | 0.600 | 0.150 | 0.350 | 0.550 | 0.200 | 0.400 | 0.600 |
| Amiralmomenin Hospital | 0.150 | 0.317 | 0.517 | 0.300 | 0.500 | 0.700 | 0.467 | 0.667 | 0.800 |
| 22 Bahman Hospital | 0.200 | 0.367 | 0.567 | 0.200 | 0.367 | 0.567 | 0.100 | 0.267 | 0.467 |
| Velayat hospital | 0.200 | 0.400 | 0.600 | 0.383 | 0.583 | 0.750 | 0.420 | 0.620 | 0.820 |
| Bu Ali Clinic | 0.400 | 0.600 | 0.800 | 0.200 | 0.400 | 0.600 | 0.250 | 0.417 | 0.617 |

**Continued**

| Hospital name | Human Resource Development | | | Increased employee satisfaction | | | Promotion of Information Technology | | |
|---|---|---|---|---|---|---|---|---|---|
| | The pessimistic value | The most likely value | The optimistic value | The pessimistic value | The most likely value | The optimistic value | The pessimistic value | The most likely value | The optimistic value |
| Bu-Ali Hospital | 0.300 | 0.500 | 0.700 | 0.100 | 0.300 | 0.500 | 0.050 | 0.217 | 0.417 |
| Shahid Rajai Hospital | 0.300 | 0.433 | 0.633 | 0.300 | 0.467 | 0.667 | 0.350 | 0.550 | 0.750 |
| Quds hospital | 0.250 | 0.450 | 0.650 | 0.350 | 0.550 | 0.750 | 0.250 | 0.450 | 0.650 |
| Kosar hospital | 0.000 | 0.100 | 0.300 | 0.050 | 0.217 | 0.417 | 0.100 | 0.267 | 0.467 |
| Amiralmomenin Hospital | 0.150 | 0.317 | 0.517 | 0.200 | 0.367 | 0.567 | 0.100 | 0.233 | 0.433 |
| 22 Bahman Hospital | 0.200 | 0.400 | 0.600 | 0.100 | 0.300 | 0.500 | 0.200 | 0.400 | 0.600 |
| Velayat hospital | 0.050 | 0.217 | 0.417 | 0.050 | 0.217 | 0.417 | 0.200 | 0.367 | 0.567 |
| Bu Ali Clinic | 0.250 | 0.417 | 0.617 | 0.350 | 0.550 | 0.750 | 0.350 | 0.550 | 0.750 |

**Continued**

| Hospital name | Increased motivation and employee safety | | | Encouraging innovation and supporting applied research | | | Rational management of costs and revenues | | |
|---|---|---|---|---|---|---|---|---|---|
| | The pessimistic value | The most likely value | The optimistic value | The pessimistic value | The most likely value | The optimistic value | The pessimistic value | The most likely value | The optimistic value |
| Bu-Ali Hospital | 0.200 | 0.400 | 0.600 | 0.200 | 0.400 | 0.600 | 0.250 | 0.450 | 0.650 |
| Shahid Rajai Hospital | 0.300 | 0.467 | 0.667 | 0.250 | 0.383 | 0.583 | 0.400 | 0.600 | 0.800 |
| Quds hospital | 0.250 | 0.450 | 0.650 | 0.150 | 0.350 | 0.550 | 0.200 | 0.400 | 0.600 |
| Kosar hospital | 0.150 | 0.350 | 0.550 | 0.150 | 0.317 | 0.517 | 0.100 | 0.267 | 0.467 |
| Amiralmomenin Hospital | 0.300 | 0.500 | 0.700 | 0.100 | 0.300 | 0.500 | 0.300 | 0.500 | 0.700 |
| 22 Bahman Hospital | 0.150 | 0.317 | 0.517 | 0.350 | 0.550 | 0.750 | 0.250 | 0.450 | 0.650 |
| Velayat hospital | 0.100 | 0.233 | 0.433 | 0.200 | 0.367 | 0.567 | 0.150 | 0.317 | 0.517 |
| Bu Ali Clinic | 0.300 | 0.500 | 0.700 | 0.200 | 0.367 | 0.567 | 0.300 | 0.500 | 0.700 |

**Continued**

| Hospital name | Hospital revenue | | |
|---|---|---|---|
| | The pessimistic value | The most likely value | The optimistic value |
| Bu-Ali Hospital | 111502209182 | 159860441703 | 186396809273 |
| Shahid Rajai Hospital | 55128666741 | 77369812597 | 87154578084 |
| Quds hospital | 44221884656 | 61798237720 | 63004839948 |
| Kosar hospital | 37506848500 | 51725642571 | 65940573169 |
| Amiralmomenin Hospital | 8112223745 | 11420553876 | 12184745616 |
| 22 Bahman Hospital | 1378266491 | 1826093558 | 2277642927 |
| Velayat hospital | 82662982896 | 82662982896 | 82662982896 |
| Bu Ali Clinic | 5362265261 | 7111534028 | 7826093558 |