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Performance Evaluation of Organizations Based on Human Factor Engineering Using Fuzzy Data Envelopment Analysis (FDEA)

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ABSTRACT

With the growing rate of incidents at the workplace and the consequent increase of staff's dissatisfaction, this study attempts to examine an integrated ergonomic system in a pharmaceutical company. In this study, the organization performance is assessed at different levels. First, an ergonomic questionnaire determines the most effective factors in the efficiency of the system by the means of fuzzy data envelopment analysis (FDEA). The best FDEA model is selected by making perturbation in the data and calculating the correlation between rankings. Then, a standard questionnaire is distributed among the customers and the most important factor in customer satisfaction is discovered. At last, suppliers are ranked based on the most important criteria using Hierarchical TOPSIS method. Next, the most influential factors managers and expert's performance in health, safety and environment section are measured and strategies are proposed for performance improvement. The information obtained from performance evaluation can identify the worker's performance efficiency.

Practitioner Summary

Quality improvement and cost reduction are necessary to survive in this competitive environment. The focus on cost reduction and implementation of novel approaches without a

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systematic method have unsavory complications which impose higher costs. Therefore, considering human factors and macro ergonomic-based factors in the organization is critical for aligning management goals and staff's goals before making any decisions in the organization.

1. Introduction and literature review

Irrelevant system design between humans and machines might reduce safety and cause management errors. Management errors and damaging factors of the work environment might cause human error and environmental risks. Unexpected events in technological systems might occur in different fields. In recent years, different methods and approaches have been proposed to encounter unexpected events by focusing on the application of management systems. Definition and implementation of an isolated system cannot guarantee the enhancement of system's safety [1]. Thus, it is required to create an appropriate integral system for continuous control and monitoring of unexpected events. Therefore, it is recognized that health, safety, environment, and macro-ergonomic systems require continuous and systematic efforts to achieve stable success. Managers of various industries try to enhance their interactions with staff and improve the staff's health, safety, and job satisfaction in order to increase profitability [2,3].

Ergonomics is an important and considerable concept in industry and managers of various industries also try to maintain health and safety of their staff in addition to the researchers' efforts to improve human interactions with the surrounding contexts. One can certainly acknowledge that human resource is the most valuable capital of each job unit and productive and industrial units; therefore, the realization of stable development requires attention. In many industries, ergonomics is mainly adopted to decrease the epidemic of occupational lesions and costly insurances [4]. Although some other non-ergonomics factors might impact on the performance of the workers, for instance, types of food can increase their anxiety, those factors don't fit in our study purposes [5,6].

Although the reduction of occupational lesions and enhancement of workers' health are the important reasons for applying ergonomics, it is a negative approach. Management is coerced to apply ergonomic tasks to decrease occupational lesions. The main concern is when this negative approach dominates and industry leaders neglect what could be an important factor in applying ergonomics, which is increasing efficiency. Development of ergonomic knowledge in designing jobs, industrial procedures and products can be proposed in terms of efficiency which will result in significant accomplishments [7].

Managers are often unwary of improper work conditions and even what can increase efficiency. Staff usually become adapted to improper work conditions, but at the cost of increased producing time, low-quality product and increase of the epidemic of occupational lesions. On the other hand, ergonomics is closely related to industrial safety. Safety of factories increases if each of the following conditions is met: workers can understand the risks, there are warning alarms in work environment, controlling the equipment is easy, the workers are in good body conditions, noise and other irritating factors are decreased, there is an agreement between workers and the manager, and discipline and cleanliness of the job shop are observed. Ergonomic practices are slightly different from conventional ergonomics since approaches in industrial safety are mainly mechanical. Ergonomics can enhance management through decision-making, behavior, perception, and workers' attitude [8].

The organizational environment has increasingly attracted attention in the past few years. This action in ergonomics is called macro-ergonomics [9]. According to this definition, macro-ergonomics is defined as an interface technology among human-organization-environment-machine. Macro-ergonomics considers all four components of social-technical systems, but its main focus is placed on organizational design with the employed technology, such that system-human performance is enhanced. Macro-ergonomics is a top-down approach for designing an organization and working systems and design of human-machine and human-environment interfaces. Ergonomics is investigated in an organizational environment which deeply affects the proportionality of evaluations. Organizations' policies affect the design of ergonomics according to the communication patterns, decentralization of responsibilities and job allocation. Macro-ergonomics had become forgotten and few pieces of research were conducted on it till recently. Some researchers have studied the performance measurement of macro-ergonomics and have introduced the 4 following indices for performance measurement:

Ergonomic performance indices related to customer (the number of products with effective design, the number of products with application capability proportional to standard, products' value-added for customers) [10].

Ergonomic performance indices related to staff (working ability index through answering a number of questions based on work requirements and health conditions of staff, employment capacity index, and employment opportunities in a specific section of the industry, results of the questionnaire related to satisfaction, individual motivation and growth) [11]. Ergonomic performance indices related to shareholders and masters of the company (increasing the market's share, successful change of management, signs of continuous enhancement, and better conditions for cooperative stakeholders) [12]. Ergonomic performance indices related to society (reducing the unemployment rate by the corporate, reducing early retirement, reducing events' rate in complex systems, solutions' rate through cooperative ergonomic) [13].

In new researches, other factors are proposed for macro-ergonomics by [14], which are used in this survey as well:

- Information flow
- Communication with managers
- Organizational regulations effectiveness
- Safety
- Learning
- Decision-making speed and control ability
- Work pressure and stress
- System's efficiency
- Teamwork
- Flexibility
- Self-operating

- Redesign
- satisfaction
- Physical problem
- Display and controllers
- Workplace condition

The review of the related literature showed that ergonomic performance indices related to customer and ergonomic performance indices related to staff have not been taken into account simultaneously in a system. Thus, according to the importance of micro and macro ergonomic concepts, especially in pharmaceutical industries, it was decided to investigate the concepts associated with micro and macro ergonomics in a pharmaceutical corporation. For this purpose, a questionnaire was arranged by consulting experts of this field and was distributed among managers and administrators of micro and macro ergonomic section. In this questionnaire, all concepts regarding micro and macro ergonomics are covered and managers are asked about how micro and macro ergonomics are implemented in their organization. In the first step, the questionnaire is verified and validated by experts and operators, the effect of factors on effectiveness is studied. In the final step, the most effective factors in system effectiveness are defined and customer satisfaction is investigated.

The paper is organized as follows. In section 2, the methodology used in this paper is presented. In sections 3, the experiment is run, and the algorithm is solved for a real case study. Section 4 is dealt with the conclusion and section 6 includes the references.

2. Methodology

First, data envelopment analysis and fuzzy data envelopment analysis have been brought and, then, the hierarchal TOPSIS method is described. Next, the related factors and criteria that have been investigated in the three parts of determining the most important ergonomic factors, customer satisfaction, and supplier selection are described. The proposed algorithm for the conduct of this research is presented in Figure 1.

2.1. Data envelopment analysis (DEA)

Every organization should employ scientific patterns for performance measurement to apply correct management so that it can measure its functionality. One of the efficient tools that have realized this issue is data envelopment analysis method.

Data envelopments analysis is a method based on linear scheduling that calculates the relative efficiency of units with common inputs and outputs. Data envelopment analysis method was first designed to evaluate decision-making units like schools and hospitals which employed multiple inputs for producing multiple outputs. Now, this method is used in many research centers around the world and has become the origin of many novel ideas and developments. This method's capability and application have been verified, and its application in many areas has made it a suitable method for modeling scientific procedures. This method is now verified in terms of capability and application and it is a suitable method to be applied in modeling scientific procedures. In addition, its experimental nature and lack of extra assumptions in it make it a good choice for estimating efficiency boundary for non-profit, private and even government sections. This method is used to rank and analyze decision-making units like hospitals, schools, universities, cities, banks, refineries, power plants, etc. In addition, data envelopment analysis is a non-parametric method that employs linear scheduling for calculating the efficiency of decision-making units. Efficiency value is between 0 and 1 [15].

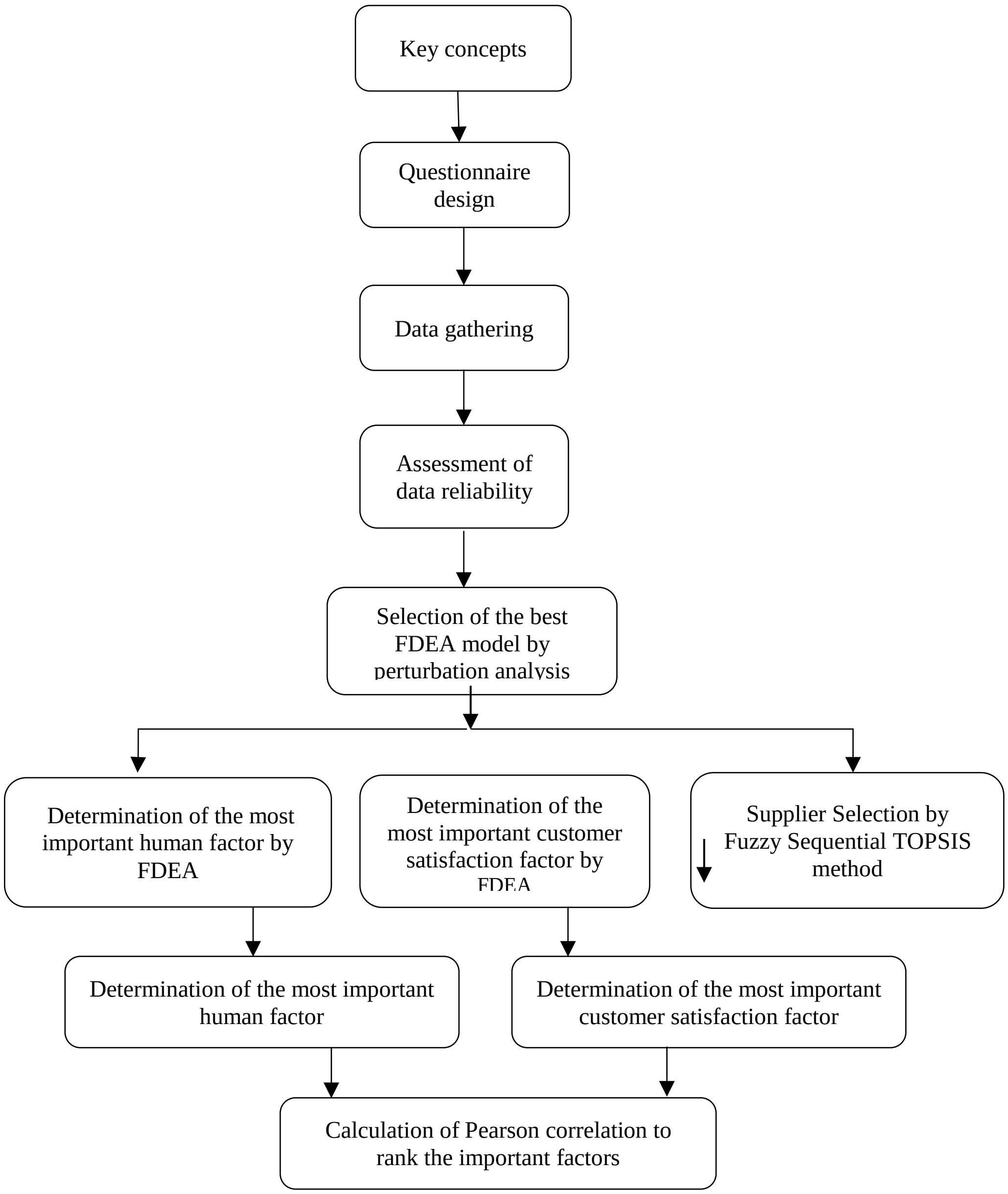

Fig. 1. Flowchart of this stud.

In this method, the weighted ratio of outputs over inputs is used to calculate efficiency. Here, weights take arbitrary values to maximize efficiency boundary of the systems, provided that the selected weights for the corporation are considered in efficiency calculation of other corporations and their efficiency does not exceed 1. BCC and CCR are two main DEA models which are used in this paper [16].

2.2 Fuzzy data envelopment analysis

FDEA phase can be considered as a common way to solve the related problems caused by the uncertainty in qualitative data sets. The reason to use this method is that many indicators of decision-making units act as judges and have an uncertain nature [17]. Applied fuzzy BCC model for ranking decision-making units can be presented as a model (6):

In the following model, indices i, r, and j represent inputs, outputs, and layout alternatives, respectively. The fuzzy input indicators are average waiting time in the queues, average machine utilization in each stage, average time-in system, shape ratio, and distance. The fuzzy output indicators are the three qualitative indicators (accessibility, flexibility, and maintenance) and adjacency. This is because inputs should be reduced, while outputs should be increased in optimization problems.

$$\min \theta \tag{1}$$
$$s.t.$$
$$\tilde{y}_{rp} \leq \sum_{j=1}^{n} \tau_i \tilde{y}_{rj} \;, \qquad \mathrm{r} = 1, 2, \ldots, \mathrm{s};$$
$$\theta \tilde{x}_{rp} \geq \sum_{j=1}^{n} \tau_i \tilde{x}_{ij} \;, \qquad \mathrm{i} = 1, 2, \ldots, \mathrm{m};$$
$$\sum_{i=1}^{n} \tau_j \;= 1 \qquad j = 1,2, \ldots, n$$

Using this model is due to the uncertainty of the problem's data. Therefore, a tool is required to match this model with the desired situation. FDEA is a tool that evaluates performance under uncertainty and employs fuzzy sets theory to analyze uncertain data. Saati et al. [17] proposed a fuzzy DEA version using triangular data. $\tilde{x}_{ij} = \left(x_{ij}^{m}, x_{ij}^{l}, x_{ij}^{u}\right)$, $\tilde{y}_{ij} = \left(y_{ij}^{m}, y_{ij}^{l}, y_{ij}^{u}\right)$ are the data used in this model [17]. They proposed a novel idea using alpha cuts in FDEA version and converted them to certain intervals and selected a point in distance variables to meet limitations and an objective function.

$$\min \theta \tag{2}$$
$$s.t$$
$$\theta\left(\alpha x_{ip}^{m} + (1-\alpha) x_{ip}^{p}\right) \geq \sum_{j=1}^{n} \tau_i \left(\alpha x_{ij}^{m} + (1-\alpha) x_{rj}^{p}\right) \qquad i = 1, \ldots, m$$
$$\alpha y_{rp}^{m} + (1-\alpha) x_{rp}^{o} \leq \sum_{j=1}^{n} \tau_j \left(\alpha y_{rj}^{m} + (1-\alpha) x_{rj}^{p}\right) \qquad r = 1, \ldots, s$$

$$\sum_{j=1}^{n} \tau_j = 1 \qquad \tau_j \geq 0 \;, \quad j = 1, \ldots, n$$

In model (2), α is a parameter belonging to the interval [0, 1]. The model may be known as a parametric linear programming model that can be used to obtain an optimal solution for any values of α. Considering that the aim of this research is the analysis of the efficiency of decision-making units on the basis of the output parameters, the output-oriented BCC model is also used and efficiency and rating of each DMU are also obtained based on model (6) for different α values. Since α shows the uncertainty of data, there is higher uncertainty in the problem as the alpha level approaches zero. In contrast, the closer α to one, the higher the certainty of data and the fuzzy system gets closer to a certain system.

2.3 Fuzzy sequential TOPSIS method

In this study, a linguistic scale associated with the importance of criteria and rating is based on 5-fold and 7- fold scale, respectively as shown in Tables 1 and 2 [18].

Table 1
Linguistic scale for comparing criteria.

Linguistic scale for importance	Triangular fuzzy number
Equal importance	(1,1,1)
Weak importance	(4,3,2)
High importance	(6,5,4)
Dominant importance	(8,7,6)
Absolute importance	(10,9,8)

Table 2
Linguistic scale for comparing the alternatives**.**

Linguistic scale for importance	Triangular fuzzy number
Very weak	(0.1,0,0)
Weak	(0.3,0.1,0)
Moderately weak	(0.5,0.3,0.1)
Moderate	(0.7,0.5,0.3)
Moderately good	(0.9,0.7,0.5)
Good	(1,0.9,0.7)
Very good	(1,0.9,0.9)

In order to prevent ambiguity caused by uncertainty, decision-making fuzzy numbers are used. Among the fuzzy numbers, fuzzy triangular numbers have been identified as a tool suitable for quantifying the uncertainty in decision-making due to sensory appeal and performance in calculations [19]. Since triangular fuzzy numbers have more applications, they are used here.

A triangular fuzzy number is represented by $\tilde{A}$= (l,m,u) where l, m and u show the least possible value, most likely value and highest possible value of a fuzzy event, respectively.

Multi-index decision-making methods are official approaches that are used to organize information and evaluate decisions in problems with opposing objectives. These methods help decision-makers to perceive the comprehensive evaluation results and use the results systematically. Multi-index decision-making methods are widely used in research fields and various researchers have proposed different approaches of multi-index decision-making [20].

TOPSIS method was first introduced by Hwang and Yoon [20]. According to this technique, the best option is as close as possible to the positive ideal solution and is the farthest in distance to the negative ideal solution. The positive ideal solution is a solution with maximum profit and minimum loss, and negative ideal solution is a solution with minimum profit and maximum cost. However, if the sequential structure of the problem contains more than three levels, TOPSIS cannot be used and sequential TOPSIS is proposed. In this method, equation (3) is first used to question the main criteria's weight and sub-criteria's weight.

$$\tilde{I}_C = \begin{matrix} C_1 \\ C_1 \\ \vdots \\ C_j \\ \vdots \\ C_n \end{matrix} \begin{bmatrix} \tilde{w}_1 \\ \tilde{w}_2 \\ \vdots \\ \tilde{w}_j \\ \vdots \\ \tilde{w}_n \end{bmatrix} \qquad \tilde{I}_{SC}^{j} = \begin{matrix} SC_{j1} \\ SC_{j2} \\ \vdots \\ SC_{jl} \\ \vdots \\ SC_{jr_j} \end{matrix} \begin{bmatrix} \tilde{w}_{j1} \\ \tilde{w}_{j2} \\ \vdots \\ \tilde{w}_{jl} \\ \vdots \\ \tilde{w}_{jr_j} \end{bmatrix} \qquad , j=1, 2,\dots,n \tag{3}$$

Result of evaluating the options under sub-criteria would be a matrix ($\tilde{I}_A$() which is shown in equation (4).

$$\tilde{I}_A = \begin{matrix} \\ A_1 \\ A_1 \\ \vdots \\ A_i \\ \vdots \\ A_m \end{matrix} \begin{matrix} SC_{11} & SC_{12} & \cdots & SC_{1r_1} & \cdots & SC_{jl} & \cdots & SC_{nr_n} \\ \tilde{C}_{111} & \tilde{C}_{112} & \cdots & \tilde{C}_{11r_1} & \cdots & \tilde{C}_{1jl} & \cdots & \tilde{C}_{1nr_n} \\ \tilde{C}_{211} & \tilde{C}_{112} & \cdots & \tilde{C}_{21r_1} & \cdots & \tilde{C}_{2jl} & \cdots & \tilde{C}_{2nr_n} \\ \vdots & \vdots & & \vdots & & \vdots & & \vdots \\ \tilde{C}_{i11} & \tilde{C}_{i12} & \cdots & \tilde{C}_{i1r_1} & & \tilde{C}_{2jl} & \cdots & \tilde{C}_{inr_n} \\ \vdots & \vdots & & \vdots & & \vdots & & \vdots \\ \tilde{C}_{m11} & \tilde{C}_{m12} & \cdots & \tilde{C}_{m1r_1} & \cdots & \tilde{C}_{mjl} & \cdots & \tilde{C}_{mnr_n} \end{matrix} \tag{4}$$

Then, the fuzzy decision-making matrix should be transformed into a comparable scale and become normalized. There are several methods for normalizing; Hwang [20] have used linear normalization method. This way, profit, and cost are obtained as expressed by equation (5):

$$\tilde{r}_{ij} = \begin{cases} \left(\frac{a_{ij}}{c_j^+}, \frac{b_{ij}}{c_j^+}, \frac{c_{ij}}{c_j^+}\right) \\ \left(\frac{a_j^-}{c_{ij}}, \frac{a_j^-}{b_{ij}}, \frac{a_j^-}{a_{ij}}\right) \end{cases} \qquad c_j^+ = \max_i c_{ij} \ , \ a_j^- = \max_i a_{ij} \tag{5}$$

Then, the normal weighted matrix is obtained using $\tilde{V}_{ij} = \tilde{r}_{ij}.\tilde{w}_j$. After running the above steps, positive and negative ideal solutions are determined as the best possible option and the worst possible option, respectively. For this purpose, fuzzy numbers are converted into certain numbers such that the option with the highest value is chosen as the positive ideal and the option with the lowest value is chosen as the negative ideal. Then, equation (6) is used to obtain the distance of each option proportional to positive and negative ideals:

$$d_v(\tilde{s}_1, \tilde{s}_2) = \sqrt{\frac{1}{3}(a_1 - a_2)^2 + (b_1 - b_2)^2 + (c_1 - c_2)^2} \quad (6)$$

Finally, it considers the closeness index of two ideal options simultaneously and the ranking index of the options is calculated as below [21].

$$CF = \frac{D_i^-}{D_i^+ + D_i^-} \quad (7)$$

3. Experiment

3.1. Identifying ergonomic factors in the implementation of human factor engineering

Overall, sixteen factors are used to evaluate the performance of the manager regarding human factors and workers' conditions in the workplace. Thirteen of these factors are categorized as macro ergonomic factors and three of them are regarded as micro ergonomic factors as shown in Table 3 [22–25].

Table 3
human factors used in this study.

Number	Factor
1	Information flow
2	Communication with managers
3	Organizational regulations effectiveness
4	Safety
5	Learning
6	Decision-making speed and control ability
7	Work pressure and stress
8	System's efficiency
9	Teamwork
10	Flexibility
11	Self-operating
12	Redesign
13	Satisfaction
14	Physical problem
15	Display and controllers
16	Work condition

3.1.1. Questionnaire design and data collection

Based on the framework proposed in this study, a questionnaire is designed, and data are collected. These data are statistically analyzed and performance of the managers under study is ranked based on the mentioned frameworks and by data envelopment analysis method. Performance of managers and HSE staff are measured and evaluated based on the mentioned frameworks. Finally, at the end of the chapter, the obtained results are proposed. The initial questionnaire was given to the academic supervisors and a number of experts in micro and macro-ergonomic sections of Kimia Fam Company and they were asked to comment about the questionnaire. These comments were used to improve the questionnaire. The questionnaire is designed using different related references [22–27].

After case studies, an initial questionnaire was designed with the assistance of professors, academic consultants, and experts to investigate the desired criteria in terms of macro-ergonomics and resistivity engineering; and to extract individuals' decision-making styles.

After initial experiments, questionnaires were distributed among a group of respondents similar to main the main respondents and were asked to propose their comments about the questionnaire. After applying them to the questionnaires, the final questionnaires became ready.

Table 4 shows the results of Cronbach's alpha calculation for 19 groups of human factor questionnaire. The questions are taken from reliable articles and books [28–33].

Table 4
Reliability of the questionnaire by Cronbach's Alpha.

Factor number	Factor of macro-ergonomics	Cronbach's Alpha
1	Information flow	0.855
2	Communication with managers	0.629
3	Organizational regulations effectiveness	0.٧04
4	Safety	0.766
5	learning	0.696
6	Decision-making speed and control ability	0.844
7	Work pressure and stress	0.643
8	System's efficiency	0.617
9	Teamwork	0.745
10	Flexibility	0.770
11	Self-operating	0.739
12	Redesign	0.770
13	satisfaction	0.809
Factor number	Factor of macro-ergonomics	Cronbach's Alpha
14	Physical problem	0.659
15	Display and controllers	0.737
16	Work condition	0.781

3.1.2. Selection of input and output indicators

A systematic approach is used in data envelopment analysis to evaluate decision-making units since it is assumed that these units consist of several inputs that are converted into outputs via processing. Thus, the factors should be divided into inputs and outputs for evaluation by means of data envelopment analysis. Inputs are the resources used by the system and outputs are the results of system operations [34].

All the factors related to micro and macro-ergonomics, as defined in Table 4, constitute output variables in the first questionnaire, distributed among managers and staff. Since all the above-mentioned factors promote safety and human resources, this study has considered the three inputs, namely age, education, and experience. That is why inputs are held constant. All these factors are merged in the form of a questionnaire.

3.1.3. Performance evaluation by FDEA for human factor questionnaire

Since the values of the factors considered in this study were obtained based on expert opinion, data uncertainty and complexity have been inevitably included. Therefore, the fuzzy DEA model is employed to evaluate performance in the present study. As this study aims to maximize output variables while the inputs are held constant, output-oriented DEA models are selected for performance evaluation. As described in the previous section, different Alpha cuts within the range of [0, 1] are considered and output-oriented BCC and CCR models are conducted for each of them. Then, average efficiency is calculated for each Alpha level and the model with the highest average efficiency is selected. The calculation results are shown in Table 10. As it can be observed, the fuzzy DEA model with the Alpha value of 0.1 has taken up the highest average efficiency; therefore, it is chosen as the preferred model in this study. Considering the Alpha value, the data comes with 90% uncertainty and the assumption regarding the data uncertainty is approved. Therefore, the results obtained in previous steps are verified. After the selection of the preferred model, the efficiencies and ranks of decision-making units were also calculated. The results are presented in Table 5 and Table 6.

Table 5
Average efficiencies for different $\alpha - cuts$.

α Value of	$\alpha = 0.1$		$\alpha = 0.2$		$\alpha = 0.3$		$\alpha = 0.4$		$\alpha = 0.5$	
Model	BCC	CCR	BCC	CCR	BCC	CCR	BCC	CCR	BCC	CCR
Average efficiency	1.131	0.689	1.102	0.679	1.077	0.669	1.056	0.660	1.037	0.651
α Value of	$\alpha = 0.6$		$\alpha = 0.7$		$\alpha = 0.8$		$\alpha = 0.9$		$\alpha = 1$	
Model	BCC	CCR	BCC	CCR	BCC	CCR	BCC	CCR	BCC	CCR
Average efficiency	1.034	0.642	1.006	0.633	0.991	0.624	0.977	0.616	0.963	0.606

Since average efficiency for output-oriented BCC model in 0.1 level has the maximum efficiency, it is chosen as the main model and subsequent analyses are performed based on this model.

3.1.4. Comparison of the results and selection of the best model

In this step, the data are perturbed to choose the most suitable model for performance evaluation. For this purpose, 10 different scenarios are defined in such a way that several decision-making units are chosen for the indices understudy each time and the associated data are perturbed (for perturbing each scenario, 10 percent of the data is selected data and multiplied by 50). Then, all the models have performed once again and the correlation coefficient between the ranking of the main model and the model obtained after the perturbation is calculated. Finally, average correlation coefficients for all scenarios are obtained. Results of this section are presented in Table 7. As it can be observed in the Table, the average correlation coefficient for all scenarios has the maximum value for FDEA (BCC model). Thus, this model is selected as the preferred model for evaluation.

Table 6
Results of fuzzy DEA BCC output-oriented model.

DMU	α =0.1	α =0.2	α =0.3	α =0.4	α =0.5	α =0.6	α =0.7	α =0.8	α =0.9	α =1
1	1.173	1.145	1.120	1.099	1.081	1.081	1.048	1.032	1.016	0.985
2	1.188	1.166	1.136	1.108	1.085	1.085	1.050	1.033	1.016	0.988
3	1.181	1.147	1.122	1.101	1.082	1.082	1.048	1.032	1.016	0.972
4	1.210	1.173	1.142	1.114	1.090	1.090	1.050	1.032	1.016	1.000
5	1.194	1.160	1.130	1.104	1.083	1.083	1.047	1.031	1.015	0.980
6	1.203	1.161	1.127	1.101	1.080	1.080	1.046	1.031	1.015	0.900
7	1.147	1.129	1.112	1.095	1.079	1.079	1.047	1.031	1.015	0.929
8	1.157	1.129	1.106	1.090	1.075	1.075	1.044	1.029	1.015	0.978
9	1.153	1.136	1.117	1.098	1.080	1.080	1.046	1.030	1.015	0.957
10	1.167	1.143	1.120	1.099	1.079	1.079	1.046	1.030	1.015	0.956
11	1.181	1.147	1.122	1.102	1.083	1.083	1.048	1.032	1.016	1.000
12	1.178	1.145	1.115	1.080	1.049	1.049	1.008	0.994	0.983	0.973
13	1.183	1.150	1.124	1.101	1.082	1.082	1.049	1.032	1.016	1.000
14	1.207	1.170	1.138	1.110	1.086	1.086	1.050	1.033	1.016	1.000
15	1.209	1.168	1.135	1.108	1.085	1.085	1.049	1.032	1.016	0.987
16	1.197	1.165	1.135	1.107	1.084	1.084	1.048	1.032	1.016	0.979
17	1.175	1.145	1.121	1.100	1.081	1.081	1.047	1.031	1.016	1.000
18	1.171	1.144	1.121	1.101	1.083	1.083	1.048	1.031	1.016	1.000
19	1.188	1.155	1.128	1.104	1.084	1.084	1.049	1.032	1.016	0.988
20	1.188	1.160	1.128	1.102	1.082	1.082	1.048	1.032	1.016	1.000
21	1.202	1.166	1.135	1.108	1.085	1.085	1.050	1.033	1.016	0.944
22	1.167	1.141	1.117	1.096	1.079	1.079	1.047	1.031	1.015	1.000
23	1.211	1.172	1.139	1.111	1.086	1.086	1.050	1.033	1.016	1.000
24	1.184	1.159	1.137	1.116	1.096	1.096	1.057	1.037	1.018	0.989
25	1.190	1.153	1.123	1.100	1.080	1.080	1.046	1.031	1.015	0.944
26	1.208	1.168	1.134	1.106	1.084	1.084	1.049	1.032	1.016	0.988
27	1.187	1.150	1.123	1.100	1.080	1.080	1.046	1.031	1.015	0.989
28	1.254	1.224	1.194	1.164	1.136	1.136	1.080	1.053	1.026	0.998
29	1.181	1.151	1.126	1.103	1.085	1.085	1.050	1.033	1.017	0.965
30	1.175	1.144	1.119	1.099	1.081	1.081	1.048	1.032	1.016	0.999
31	1.174	1.147	1.123	1.101	1.082	1.082	1.047	1.031	1.016	0.999
32	1.177	1.146	1.121	1.100	1.081	1.081	1.047	1.031	1.016	0.984
33	1.242	1.212	1.184	1.155	1.128	1.128	1.075	1.049	1.024	0.965
34	1.221	1.178	1.146	1.119	1.095	1.095	1.054	1.035	1.018	0.978

Table 7
Comparison of the models.

Model	FDEA-BCC model										Average of coronation coefficients
Scenario number	1	2	3	4	5	6	7	8	9	10	
Coronation coefficient	0.9147	0.9647	0.88914	0.89742	0.96126	0.90827	0.93294	0.96318	0.88162	0.95788	0.917121
Model	FDEA-CCR model										Average of coronation coefficients
Scenario number	1	2	3	4	5	6	7	8	9	10	
Coronation coefficient	0.87930	0.87293	0.89347	0.86568	0.87293	0.89348	0.8929	0.88413	0.82729	0.79367	0.867585

3.1.5. Sensitive analysis

To investigate the impact of these factors on efficiency, paired t-test was run while assuming the equality of the means between the efficiencies obtained from the main model and efficiencies of the models obtained from eliminating each factor. Table 8 shows the p-values of the paired t-test for each factor.

Table 8.
Impact of human factors on system efficiency by p-value.

Factor number	Factor of macro-ergonomics	p-value
1	Age	0.40
2	Education	0.40
3	Experience	0.40
1	Information flow	0.36
2	Communication with managers	0.22
3	Organizational regulations effectiveness	0.46
4	Safety	0.29
5	Learning	0.41
6	Decision-making speed and control ability	0.35
7	Work pressure and stress	0.26
8	System's efficiency	0.38
9	Teamwork	0.39
10	Flexibility	0.27
11	Self-operating	0.28
12	Redesign	0.39
13	Satisfaction	0.47
14	Physical problem	0.44
15	Display and controllers	0.41
16	Work condition	0.43

As can be seen above, since p-values of all factors are smaller than 95% reliability, the null hypostasis is rejected, and it is concluded that all factors affect efficiency. These values are obtained by running paired t-test and assuming zero equality of the main model with the model in which each factor is eliminated.

In the next step, the identification of the most important and most effective factor is desired. For this purpose, each factor is first eliminated, data envelopment analysis is conducted once again, and the obtained results are compared with the results obtained from the main model. In other words, the obtained efficiencies are compared in the presence of each factor and in the absence of the same factor. Then, the Pearson correlation coefficient is calculated and the factor with a minimum correlation coefficient is considered the most important factor. Table 9 shows the correlation coefficient between the main model and the model in which one of the factors is eliminated.

Table 9
The correlation coefficient between the main model and the model with eliminated factors.

Factor number	Human factors	Correlation coefficient
1	Age	0.92
2	Education	0.97
3	Experience	0.97
1	Information flow	0.95
2	Communication with managers	0.82
3	Organizational regulations effectiveness	0.96
4	Safety	0.76
5	Learning	0.95
6	Decision-making speed and control ability	0.92
7	Work pressure and stress	0.82
8	System's efficiency	0.96
9	Teamwork	0.92
10	Flexibility	0.94
11	Self-operating	0.95
12	Workplace Redesign	0.95
13	Satisfaction	0.92
14	Physical problem	0.94
15	Display and controllers	0.93
16	Workplace condition	0.78

Since safety, work pressure and stress and workplace conditions have the lowest correlation coefficient, it is concluded that these factors have the highest impact on efficiency. Figure 2 shows the percent of importance of ergonomic factors. Although all ergonomic factors have a significant influence on the system's efficiency the most important factors are that one with the greater Percent of importance. Percent of the importance of safety 12%, workplace condition 14% and work pressure and stress is 12%.

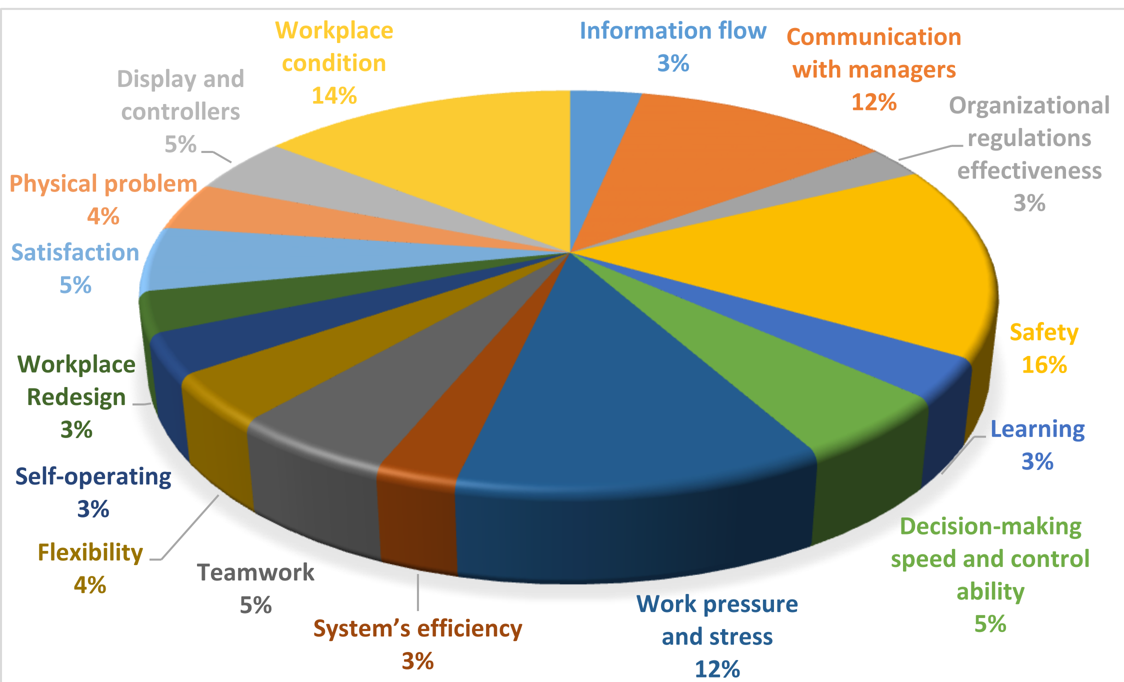

Fig. 2. Weight of ergonomic factors.

3.2. Evaluation of customer satisfaction

In the second questionnaire, the number of purchases, purchased products, and years that the customer is buying from the company constitute the inputs. Specialization, technical support, product's quality, delivery time, competitiveness, loyalty and technology of communicating with customers are considered as outputs [32]. As mentioned in the previous chapter, the items of the questionnaire are classified for these groups based on the proposed algorithm and Cronbach's alpha. If the minimum Cronbach's alpha for all groups is 0.6, the reliability of the questionnaire is verified. Finally, a questionnaire with 40 questions, which are at the 19th step of the algorithm, is considered. Table 10 shows the results of Chronbach's alpha for 11 groups which reflect customer satisfaction.

Table 10
Reliability and validity analysis of customer satisfaction questionnaire**.**

Criteria	Chronbach's alpha
Responsiveness	0.607
Specialization	0.699
Technical support	0.677
Product quality	0.677
Delivery time	0.698
Competitiveness	0.701
loyalty	0.732
CRM technology	0.786
Number of purchases (per year)	0.675
Duration of being a customer	0.672
The number of purchased products	0.707

3.2.1. Performance evaluation by FDEA for human factor questionnaire

Fuzzy DEA model is employed for performance evaluation and the determination of the most effective factor in customer satisfaction. As it can be observed, the fuzzy DEA model with the significance level of 0.1 has taken up the highest average efficiency; therefore, it is selected as the selected model in this study. The level of significance here confirms the assumption pertaining to the uncertainty of the data since the data contains 90% uncertainty. Therefore, the results obtained in previous steps are approved. Efficiency and rankings of decision-making units have been calculated after the selection of the proper model. The results are shown in Table 11 and 12.

Table 11
Average efficiencies for different $\alpha - cuts$.

α Value of	$\alpha = 0.1$		$\alpha = 0.2$		$\alpha = 0.3$		$\alpha = 0.4$		$\alpha = 0.5$	
Model	BCC	CCR	BCC	CCR	BCC	CCR	BCC	CCR	BCC	CCR
Average efficiency	0.991		1.004		1.017		1.031		1.047	
α Value of	$\alpha = 0.6$		$\alpha = 0.7$		$\alpha = 0.8$		$\alpha = 0.9$		$\alpha = 1$	
Model	BCC	CCR	BCC	CCR	BCC	CCR	BCC	CCR	BCC	CCR
Average efficiency	1.063		1.083		1.106		1.166		1.166	

Since average efficiency for output-oriented BCC model in 0.1 level has the maximum efficiency, it is chosen as the main model and subsequent analyses are done based on this model.

Table 12
Results of fuzzy DEA model.

DMU number	α =0.1	α =0.2	α =0.3	α =0.4	α =0.5	α =0.6	α =0.7	α =0.8	α =0.9	α =1
1	1.17	1.17	1.12	1.09	1.07	1.05	1.04	1.02	1.01	1.00
2	1.14	1.14	1.13	1.10	1.08	1.06	1.04	1.03	1.01	1.00
3	1.18	1.18	1.12	1.10	1.08	1.06	1.04	1.02	1.01	1.00
4	1.19	1.19	1.11	1.10	1.08	1.06	1.05	1.03	1.02	1.00
5	1.19	1.19	1.11	1.08	1.07	1.05	1.04	1.03	1.01	1.00
6	1.21	1.21	1.12	1.09	1.08	1.06	1.04	1.03	1.01	1.00
7	1.08	1.08	1.04	1.02	1.01	1.00	0.99	0.98	0.97	0.97
8	1.07	1.07	1.03	1.02	1.01	1.01	1.00	0.99	0.98	0.98
9	1.16	1.16	1.12	1.10	1.08	1.06	1.04	1.03	1.01	1.00
10	1.17	1.17	1.12	1.10	1.07	1.06	1.04	1.03	1.01	1.00
11	1.18	1.18	1.12	1.10	1.08	1.06	1.04	1.03	1.01	1.00
12	1.17	1.17	1.06	1.02	0.98	0.96	0.93	0.92	0.91	0.91
13	1.21	1.21	1.14	1.11	1.09	1.06	1.05	1.03	1.01	1.00
14	1.18	1.18	1.12	1.10	1.08	1.06	1.05	1.03	1.02	1.00
15	1.16	1.16	1.11	1.09	1.07	1.06	1.04	1.03	1.01	1.00
16	1.17	1.17	1.12	1.09	1.08	1.06	1.04	1.03	1.01	1.00
17	1.17	1.17	1.12	1.09	1.08	1.06	1.04	1.03	1.01	1.00
18	1.19	1.19	1.12	1.10	1.09	1.07	1.05	1.03	1.02	1.00
19	1.22	1.22	1.13	1.10	1.08	1.06	1.05	1.03	1.02	1.00

3.2.2. Comparison of the results and selection of the best model

In this step, the data are perturbed to choose the most suitable model for evaluating performance. Since the procedure is the same as the one in the last section, description of it is avoided here, as the results of this section are presented in Table 13. The average correlation coefficient for all scenarios has the maximum value for FDEA (BCC model); thus, this model is chosen as the preferred model for evaluation.

Table 13
Comparison of the models.

Model	FDEA-BCC model										Average of coronation coefficients
Scenario number	1	2	3	4	5	6	7	8	9	10	
Coronation coefficient	0.91477	0.9647	0.889141	0.897421	0.961261	0.908277	0.932946	0.963184	0.881622	0.957886	0.917121
Model	FDEA-CCR model										Average of coronation coefficients
Scenario number	1	2	3	4	5	6	7	8	9	10	
Coronation coefficient	0.879303	0.872933	0.893473	0.865681	0.872937	0.893487	0.89293	0.884134	0.827297	0.793676	**0.867585**

3.2.3. Sensitivity analysis

In order to investigate the impact of these factors on efficiency, the paired t-test is performed under the assumption of the equality of the means between the efficiencies obtained from the main model and efficiencies of the models obtained from eliminating each factor. Table 4-14 shows the p-values of the paired t-test for each factor. As it can be observed in the Table, since the p-values of all the factors are below 5% reliability, the null hypothesis is rejected. It is also concluded that all the factors affect efficiency. These values are obtained as a result of running paired t-test and assuming zero equality of means between the main model and the model in which each factor is eliminated.

In the next step, the most important and most effective factor is identified. For this purpose, each factor is first eliminated, and data envelopment analysis is carried out once again. The obtained results are then compared with the results obtained from the main model. In this regard, the obtained efficiencies in the presence of each factor are compared with those in the absence of the same factor, Pearson correlation coefficient is calculated, and the factor with minimum correlation coefficient is considered as the most important factor. Table 14 shows the correlation coefficient between the main model and the model in which one of the factors is eliminated.

Table 14
Pearson Correlation of each factor.

Criteria	Pearson Correlation
Responsiveness	0.77
Specialization	0.97
Technical support	0.95
Product quality	0.75
Delivery time	0.92
Competitiveness	0.95
Loyalty	0.96
CRM technology	0.92
Number of purchases per year	0.675
Duration of being a customer	0.672
The number of purchased products	0.707

Since product quality and responsibility have the lowest correlation coefficient among the factors, it can be concluded that these factors have the highest impact on efficiency.

3.3 Supplier selection

In this section, the indices and sub-indices for the performance evaluation of suppliers are first introduced. Then, sequential TOPSIS method is used to rank them. Table 10 shows the criteria and sub-criteria of the supplier selection [35].

In the company under study, 22 domestic suppliers supply the materials. The names of these suppliers on the demand of the company are not mentioned and they are not specified by numbers. To evaluate these suppliers, the opinions of 10 expert managers with different priorities have been asked. Table 15 shows the certain weights of these criteria and sub-criteria.

Table 15
Weights of criteria and sub-criteria.

Weight of criteria	Sub-criteria	Weight of sub-criteria
Quality (0.08)	Product's quality	0.02
	Applying a quality control system	0.02
	Quality of after-sales services	0.03
	Satisfaction with products	0.01
Price and delivery conditions (0.16)	Price	0.05
	Expert staff for buying goods	0.03
	Existence of a mechanism for reducing the cost of materials	0.02
	Responsibility	0.06
Technology (0.08)	Technological support	0.05
	Contribution to design	0.03
Organization support (0.09)	Ordering method	0.04
	Responsibility	0.04
	Flexibility in capacity	0.01
On time delivery (0.2)	Using information technology	0.03
	Transfer time	0.05
	Transportation and packaging mechanisms	0.05
	Using information technology	0.07
Green (0.2)	Eco-friendly materials	0.12
	Compliance with environmental standards (ISO 14000)	0.08
Risk (0.1)	Bad reputation	0.04
	Financial risk	0.06
Executive capability (0.09)	Increasing efficiency by using technology	0.02
	Motivational mechanisms	0.03
	Innovative services	0.04

Figure 3 represents the pie chart of the weights of criteria used in this paper for supplier selection.

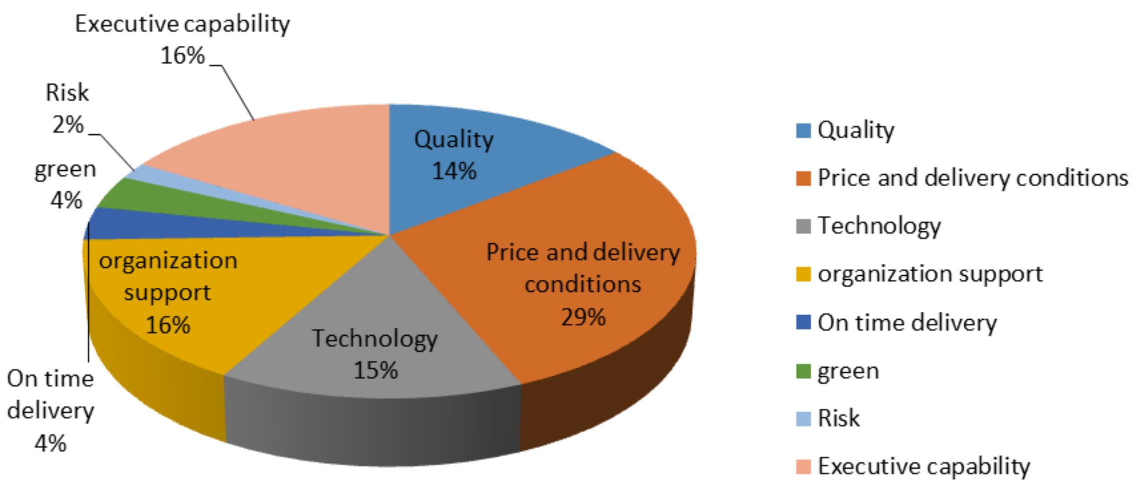

Fig. 3. Weights of supplier selection criteria.

Table 16 shows the ranking of suppliers along with their closeness index.

Table 16
Ranking of the suppliers.

Rank	Supplier	Closeness rate	Rank	Supplier	Closeness rate
1	9	0.91	14	19	0.6234
2	2	0.89	15	18	0.49
3	22	0.860	16	21	0.47
4	16	0.79	17	4	0.465
5	13	0.78	18	17	0.46
6	7	0.76	19	10	0.45
7	20	0.75	20	11	0.432
8	8	0.71	21	15	0.43
9	12	0.69	22	5	0.42
10	1	0.65	14	19	0.6234
11	3	0.645	15	18	0.49
12	14	0.634	16	21	0.47
13	6	0.633	17	4	0.465

4. Conclusion

Since what cannot be measured cannot be managed well, it has been decided to evaluate the performance of an organization in three different levels.

The comprehensive management system of health, safety, and the environment are one of the important sections in the pharmaceutical industry. Considering the increasing demands for keeping up safety issues and environment control, it is important to run the projects associated with micro and macro-ergonomics to effectively improve these factors. Therefore, the increase of the events caused by the work environment, staff's dissatisfaction with the work environment, and physical and mental lesions resulting from the absence of an integral system to control industrial environments, it was decided to study a macro-ergonomic and micro-ergonomic integral system. In this study, performance evaluation of the organization is performed at different levels and the most appropriate fuzzy data envelopment was selected using perturbation analysis model. Since the main purpose is to maximize output variables, first the output-oriented BCC and CRR models were analyzed in different alpha cuts and average efficiency of the models in different levels were calculated. Here, the BCC model in 0.1 alpha level was chosen for performance evaluation. Then, paired t-test was carried out to investigate the impact of factors on system efficiency and finally, the most effective factors of system performance were determined through the calculation of correlation coefficient between the model in the presence of all factors and the model in the absence of factors. In the end, some approaches were proposed to improve performance.

Then, the questionnaire was distributed among customers so that their satisfaction could be estimated. Results of this research can be effectively used by managers. In addition, the indicators were ranked by assigning a weight to each of them in the order of importance. The results declared that safety and workplace conditions have the lowest correlation coefficient; therefore, it can be concluded that these factors have the greatest impact on system efficiency. In addition, product quality and responsibility are the most important factors in customer satisfaction in comparison with other indicators. Then, the suppliers are ranked based on the most important indices by sequential TOPSIS method. In supplier selection, price and delivery conditions, executive capability, and organization support have the highest weight and, thereby, are the most effective factors in the sight of experts for choosing a supplier.

The data obtained from performance evaluation give the manager an exact insight of the micro and macro-ergonomic system so that s/he can control the operators with exact and scientific identification of the items and factors and provide them with a safer environment. Secondly, managers can use the results of this research to design a work environment and ergonomic scheduling. In fact, more accurate solutions and more accurate scheduling result in more savings of time and money. The advantages of this study in comparison with other researches in this area lie in simultaneously considering modeling macro and micro ergonomics factors, modeling human-related factors, considering qualitative parameters and supplier selection.

- We evaluated the performance of a pharmaceutical organization in three different levels.
- For performance evaluation, the most appropriate fuzzy data envelopment was selected using perturbation analysis model.
- The output-oriented BCC and CRR models were analyzed in different alpha cuts and average efficiency of the models at different levels were calculated.
- BCC model in 0.1 alpha level was chosen for performance evaluation.
- Paired t-test was carried out to investigate the impact of factors on system efficiency.
- The questionnaire was distributed among customers so that their satisfaction could be estimated.
- Factors were ranked by assigning a weight to each of them in the order of importance.
- The results declared that safety and workplace conditions have the lowest correlation coefficient; therefore, it can be concluded that these factors have the greatest impact on system efficiency.
- In addition, product quality and responsibility are the most important factors in customer satisfaction in comparison with other indicators.
- Then, the suppliers are ranked based on the most important indices by sequential TOPSIS method. In supplier selection, price and delivery conditions, executive capability, and organization support have the highest weight and, thereby, are the most effective factors in the sight of experts for choosing a supplier.
- Managers can use the results of this research to design work environment and ergonomic scheduling to provide the workers with a safer environment
- The advantages of this study in comparison with other researches in this area lie in simultaneously considering modeling macro and micro ergonomics factors, modeling human-related factors, considering qualitative parameters and supplier selection.

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Appendix

A. Classification of the human factor questionnaire for evaluating Stability and credibility

Factor of macro-ergonomics	Questions
Information flow	1. How do you evaluate the information flow between your own section and other sections? 2. How do you receive the information required from managers and supervisors? 3. How do you receive information from partners? 4. How do available information systems affect your working speed? 5. How do available information systems affect your efficiency? 6. How effective are the available information systems in organizational control? 7. How much are the available information systems helpful in identify the modifying practices? 8. How much do the information systems improve the services? 9. How do you evaluate the accordance of skill requirements for working on information systems with your own skills? 10. How do you evaluate the familiarity with data entry, extraction, modification and revision of information? 11. How understandable are the received messages? 12. Is the information you receive about the error messages adequate? 13. How do you evaluate the accordance of long-term and short-term objectives of the information system with the long-term and short-term objectives of the organization?
Communication with managers	14. How easy can you communicate with your managers and supervisors? 15. How easy can you communicate with your partners?
Organizational regulations effectiveness	16. How necessary is to follow the organization's regulation? 17. How much do you use the available instructions to execute your job? 18. How do you evaluate your focus on the job?
Decision-making speed and control ability	19. How do you evaluate your responsibility while doing your job? 20. How do you evaluate your decision-making speed? 21. How do you evaluate your experience and learning skills while doing your job? 22. How do you evaluate your control skills while doing your job?
Redesign of workplace	23. In your opinion, how can your working environment be improved to increase your safety and convenience? 24. How do you evaluate the arrangement of equipment in your working environment? 25. In your opinion, how much does your organization require enhancement?
System ‘s efficiency	26. How do you evaluate staff’s skills with their duty in the organization? 27. How do you evaluate the cooperation of the management in order to achieve the objectives? 28. How do you evaluate the written instruction in the organization? 29. How effective are quality management/health and safety/ environment system? 30. How effective are the tutorial courses?

Teamwork	31. When the workload is high, do the staff help each other? 32. To follow the schedules effectively, do the staff correct each other's mistakes? 33. Do the staff in your section share information to make a decision on time?
Flexibility	34. Are there any human resources with multiple skills in order to deal with unexpected and emergency events? 35. Do the equipment items have the required flexibility to prevent unexpected events? 36. Are all the rare resources for dealing with unexpected events available?
Self-operating	37. Do you have any special authority to decide without going through sequences? 38. If the system fails unexpectedly, do you have any authority to decide?
Learning	39. Are there any tutorials about the importance of keeping up with safety principles and preventing events like fire, explosion, and other environmental risks? 40. Are there specialized tutorials about jobs? 41. How do you evaluate the growth and development of tutorials on the comprehensiveness of special issues about your job?
Satisfaction	42. Are you satisfied with your salary? 43. How much are you satisfied with your working shift? 44. Are you satisfied with the organizational sequences? 45. Are you satisfied with your job in total? 46. Do you feel occupationally safe in your working environment?
Questions	Factor of macro-ergonomics
Workplace condition	47. Are the outlets and corridors free of obstacles? 48. Are working areas and trails free from network cables and electric systems? 49. Are the entries and exit ways easily accessible? 50. Are the exit ways sufficient? 51. Is there enough space for easy movement? 52. Is it possible to adjust the position's height for different operations? 53. Are the seats' height, lumbar support and arm's rest adjustable? 54. Is it possible to do your job while sitting/standing (user-defined)? 55. Is the arrangement such that additional movements are avoided? Are symmetrical arrangements avoided?
Display and controllers	56. Are the displays and controllers in an appropriate place? 57. Are the most frequently used displays and controllers arranged in one place? 58. Are similar displays and controllers close to each other? 59. Are the labels and safety warning on displays and controllers easily readable? 60. Is the emergency information of the displays installed in appropriate places?
Physical pain	61. Do you feel pain or fatigue in your waist during your daily work? 62. Do you feel pain or fatigue in your arms during your daily work? 63. Do you feel pain or fatigue in your head or neck during your daily work? 64. Do you feel pain or fatigue in your eyes during your daily work?

B. Classification of the customer satisfaction questionnaire for evaluating reliability and validity

Factor	**Questions**
Responsiveness	1. How do you evaluate our responsibility level in transactions? Are you satisfied with the services that the company offers to respond to customers' demands, reproofs, and comments?
Specialization	2. How do you evaluate our specialization in communication and transaction?
Technical support	3. How do you evaluate our technical support in terms of technical services and responding speed?
Product quality	4. How do you evaluate the quality of our services? Are your demands and requirements satisfied with the quality of our services? How do you evaluate our quality management team to satisfy customers' demands?
Delivery time	5. How do you evaluate our performance in terms of on-time delivery and satisfaction of your expectations about the delivery time?
Competitiveness	6. How do you evaluate the competitiveness of our products compared to similar internal and external products in the market? Do the products have enough value proportional to their cost in their life cycle?
Loyalty	7. Will you buy our products in the future, if needed? Will you introduce our products to others?
CRM technology	8. How do you evaluate our technology level in communication? Are you satisfied with the call center's services or our web site?
Number of purchases times per year	9. How many times a year do you buy our products?
Duration of being a customer	10. How many years have you been our customer?
The number of purchased products	11. How many of our products have you bought?