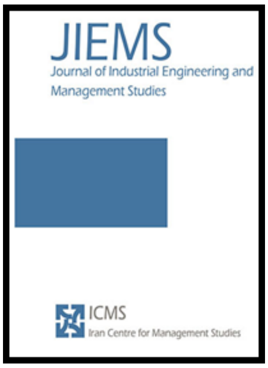
JIEMS
Journal of Industrial Engineering and Management Studies

Vol. 8, No. 1, 2021, pp. 218-239

DOI: 10.22116/jiems.2020.226032.1352

www.jiems.icms.ac.ir



Determining the optimal portfolio for healthcare processes management using a hybrid decision-making approach

Armin Cheraghalipour[1], Emad Roghanian[1,*]

Abstract
Due to the increasing progress in various industries, paying attention to the internal processes of the organizations is more visible to stay on the competitive scene. Therefore, many organizations attempt to simplify and evaluate their internal processes using re-engineering. By reviewing the conducted studies, it can be stated that one of the existing problems in the implementation of re-engineering projects is the selection of the optimal portfolio of processes. Hence, this study aims to provide a bi-objective mathematical model for selecting processes in the re-engineering project by considering two key assumptions include improvement in achieving organizational goals and staff resistance. To this end, first, the impact of processes on organizational goals is specified by experts and then the goals' weights are obtained using a fuzzy Best Worst Method. Finally, the proposed model is solved by an augmented ε-constraint method and the optimal portfolio of processes is selected. Also, a public Hospital of Sari as a real-world case study is employed to set the values of model parameters. Finally, the obtained results are reported and using a sensitivity analysis, several directions are provided. The results show that changes in the staff resistance directly affects the second objective function, while changes in the improvement created by each process affect the first objective function. Also, changes in costs have little effect on either objective functions.

Keywords: optimal portfolio; healthcare processes management; augmented ε-constraint method; fuzzy best worst method; sensitivity analysis.

Received: April 2020-08

Revised: September 2020-16

Accepted: September 2020-21

1. Introduction

In the past, when the environment was relatively stable, most organizations were content to take small and gradual changes in their processes for the advantage of opportunities. But over time, organizations have come to realize that gradual change is not the only solution to their current problems and sometimes it is necessary to make fundamental changes in their organization to survive. Today, these fundamental changes are known around the world as the re-engineering process (Darmani and Hanafizadeh, 2013).

* Corresponding author; e_roghanian@kntu.ac.ir
[1] Department of Industrial Engineering, K. N. Toosi University of Technology, Tehran, Iran.

Despite the increasing use of re-engineering of business processes by organizations to improve their performance, statistics show that 50 to 70 percent of these projects have failed worldwide and remained unfinished. In ministries, state-owned and semi-state-owned companies, re-engineering has never been implemented, or if it has entered the implementation phase, only 25% of the work has been done. So, these results indicate a high risk of this process (Jafar Tarokh et al., 2008). Besides, one of the most important and difficult steps in a re-engineering project is to select the processes that have the most benefit for the organization (Crowe et al., 1997).

Healthcare organizations are currently facing many challenges, such as providing effective services, achieving strategic positions, and improving their processes (Sadeghi et al., 2017). They have to re-engineer their processes to deal with external forces such as technological advances, the growing needs of patients, the process of globalization, and political and economic factors (Rabbani et al., 2016). Therefore, healthcare organizations need to improve treatment, eliminate non-value-added tasks, reduce time and costs, and treat more patients effectively (Musa and Othman, 2016).

In recent years, we have witnessed a lot of dissatisfaction in hospitals due to the high number of low-income people visiting public hospitals in the country. At a public Hospital in Sari, there are also problems such as lack of facilities, prolonged treatment and discharge, increased costs, and ultimately patient dissatisfaction. Therefore, this research can be useful for hospital management to improve the performance of the organization by re-engineering the processes, reviewing, modifying, or eliminating existing processes. By conducting this research, processes are selected for re-engineering which has the greatest advantage for the organization, and hospital management can achieve better services and save time and cost. Therefore, this study seeks to offer a bi-objective model for choosing processes in the re-engineering project by seeing two important assumptions contain improvement in achieving organizational goals and staff resistance. At first, the impact of processes on organizational goals is identified by experts and then weights of goals are gotten by a fuzzy Best Worst Method. As a final point, the suggested model is solved using the augmented ε-constraint method and the optimal portfolio of processes is nominated. Finally, the obtained results are reported and using a sensitivity analysis, several directions are delivered.

Therefore, the goals and importance of this research along with its contributions are discussed follows. An important goal of this research is to find an optimal portfolio for healthcare processes management using a hybrid decision-making approach. The proposed framework is used for choosing processes in the re-engineering project by seeing two important assumptions that contain improvement in achieving organizational goals and staff resistance. On the other hand, this study is of great importance due to the lack of a suitable framework for the re-engineering of hospital processes. Based on the research gaps of this area that reviewed in the next section, it is clear that some vital assumptions such as prerequisite of processes, staff resistance, and selecting an optimal portfolio of processes are neglected in the literature and this study attempts to cover these gaps.

Other sections of the paper are organized as follows. Section 2 provides a brief review of done works in this field and finally, the novelties are highlighted based on the research gaps. Also, the descriptions of the problem, proposed framework, used solution methods, and model formulation are presented in section 3. Also, the value of parameters and case study are reported in section 4. Besides, section 5 represents the computational results includes results and discussion and sensitivity analysis. Finally, the conclusion and several directions for future researches are provided in section 6.

2. Literature review

This section tries to review the related works of determining the optimal portfolio in the re-engineering process and finally, the novelties are highlighted based on the research gaps. Business re-engineering processes is an operation in which the current tasks of the organization are replaced by the main processes of the business, and therefore, the organization moves from a task-oriented to a process-oriented procedure. This speeds up the business process, reduces costs, and making the organization more competitive. Knowing the benefits and features of re-engineering can be very effective for the organization (AbdEllatif et al., 2018). The idea of process re-engineering is to make businesses more efficient and effective, more flexible, and more responsive to organizations' stakeholders. The BPR movement was formed with the public publication of an article in 1990. In this article, Davenport and Short (1990) stated that re-designing the process and using IT can transform organizations and optimize business processes significantly. They defined business re-engineering processes as "analyzing and designing workflows and processes within and between organizations" and called the combination of IT and business redesign in this way a new industry engineering. Their five-step methodology for business re-engineering processes was defined as Figure 1.

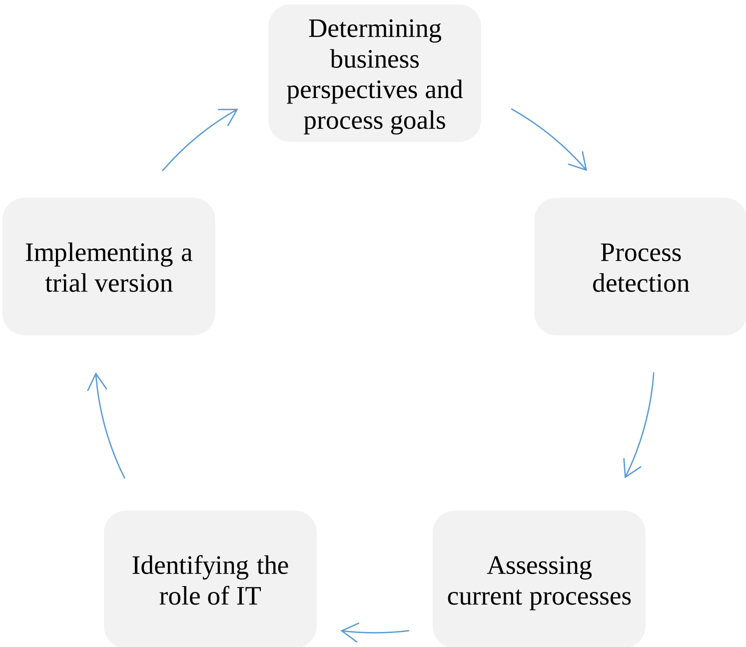


Figure 1. The five-step methodology of business re-engineering processes (Davenport and Short, 1990)

Kettinger and Teng (1998) also published another study that looked at successful business re-engineering processes projects in 1998. From their point of view, it was necessary to examine the two perspectives of workflow processes and organizational culture in re-engineering business processes. They concluded that the fundamental nature of change in organizations (changes in all seven perspectives) was directly related to the success of projects. By examining the results of the implementing previous method, they eliminated its weaknesses and corrected the business re-engineering processes steps as follows: 1) Process evaluation, 2) Process change, 3) Social and technical design, 4) Development of process perspective, 5) Analyzing the existing process, 6) Project preparation and 7) Identifying re-engineering opportunities. From this research, it can be concluded that processes and technical design are not the factors of business re-engineering processes success, while social design (promoting culture), implementation process change, and ability to evaluate the re-engineering process are the factors affecting successful business re-engineering process implementation. Management of changes and the human implement section are more important than the solutions.

As one of the pioneer studies in the re-engineering process, Crowe et al. (1997) attempt to select a business process strategically for the re-engineering project. The study aims to be a starting point for the re-engineering project and surveys to help decision-makers to determine their strategic macro goals and evaluate how business processes are conducted within the organization. The information obtained is an input for a chart-based system that shows which processes need to be reconstructed. In another study, Kwak and Lee (2002) implemented re-engineering in healthcare systems that used multi-criteria mathematical planning include the analytic hierarchy process and goal programming for analyzing their proposed framework. They used the proposed framework to design and effectively plan the re-engineering of processes in the United States healthcare system.

In a study, Hanafizadeh and Osouli (2011) selected the re-engineering process by measuring the degree of change, some of which lead to high resistance and ultimately project failure. They used scenario-based analysis to choose the optimal portfolio in a consulting engineering company. Following this study, Darmani and Hanafizadeh (2013) provided a model to identify the best portfolio for re-engineering processes using a new methodology that integrated the concept of portfolio selection and re-engineering project by placing additional risk constraints and increasing their rate of return. They used TOPSIS and MATLAB approaches to solve the framework for a metallurgical laboratory in Iran. Musa and Othman (2016) reviewed the literature on re-engineering business processes in healthcare. They analyzed the articles until 2014 from the perspective of re-engineering methods and approaches and assessed the level of re-engineering development of processes in healthcare organizations. They work found the related research gaps and it can be useful for researchers of this field. Hakim et al. (2016) also presented a mathematical model for selecting processes in the re-engineering problem under the fuzzy theory. They help to choose the right processes for re-engineering by considering maximum satisfaction, time, and cost. They used a hybrid approach consist of quality function deployment and goal programming to evaluate the proposed problem.

Bhaskar (2018) researched business re-engineering as a tool for managing production, arguing that when processes become old and inefficient, they cannot deliver the desired results, so they need to be redesigned and replaced. In this research, a series of production processes and a framework for modeling are presented and it is confirmed that a business re-engineering process is a management tool that can change or replace inefficient processes. Onjure et al. (2018) conducted a study investigating the impact of the business re-engineering process on e-commerce strategy by Kenya's commercial banks, which faced with survival challenges due to competitive pressure. Re-engineering business processes are used to deal with banking challenges, minimize operating costs, outsourcing, and investment. This research had been done through information management analysis, project management, and the excellence process. The results show a significant and positive impact and relationship in different directions. This study recommends that banks change their strategic approach to business analysis.

Here, several related papers are reviewed in Table 1 to find researches gaps. To this end, these researches are compared with the current study in terms of several key assumptions such as prerequisite of processes, staff resistance, processes improvement, budget constraint, selecting an optimal portfolio of processes, processes executed time, changing costs of processes, and the used solution approaches.

Table 1. Reviewing related papers to find researches gaps

Reference	Processes assumptions							Solution approaches	Field
	Prerequisite	**Staff resistance**	**Improvement**	**Budget constraint**	**Optimal portfolio**	**Executed time**	**Changing costs**		
(Crowe et al., 1997)			*			*		Chart-based system	Business
(Kwak and Lee, 2002)			*	*		*	*	Analytic hierarchy process and goal programming	Healthcare
(Borgianni et al., 2010)			*	*		*	*	Kano model	Footwear sector
(Lee et al., 2011)			*	*		*		Scenario-based analysis	Business
(Hanafizadeh and Osouli, 2011)		*	*		*		*	Scenario-based analysis	Consulting company
(Ostadi et al., 2011)			*			*	*	Practical measurement method	Business
(Bertolini et al., 2011)			*			*	*	What-if analysis and Delphi methodology	Healthcare
(Bevilacqua et al., 2012)			*	*		*	*	IDEF0 Technique	Municipality
(Darmani and Hanafizadeh, 2013)			*		*		*	TOPSIS and MATLAB	Metallurgical laboratory
(Nicholds and Mo, 2015)			*			*	*	Decision Support Tool	Business
(Hakim et al., 2016)			*	*		*	*	Goal programming and QFD	Business
(Bhaskar, 2018)			*	*		*	*	Critical literature analysis	Business
(Onjure et al., 2018)			*	*			*	Statistical approach	Commercial banks
(Zomparelli et al., 2018)			*	*		*	*	Analytic hierarchy process	Business
(Lotlikar et al., 2018)			*			*		Statistical approach	Healthcare
(Dachyar and Sanjiwo, 2018)			*	*		*		Scenario-based analysis and IDEF0 Technique	Oil and Gas
(Song et al., 2019)				*	*		*	Multi-criteria decision making	Urban project
(Greenfield et al., 2019)			*	*			*	Measurement of quality	Healthcare
(Tavana et al., 2019)			*	*	*		*	Fuzzy inference system and analytic hierarchy process	Urban project
This study	*	*	*	*	*	*	*	Augmented ε-constraint and fuzzy best worst method	Healthcare

Based on this table, it can be shown that several key assumptions such as prerequisite of processes, staff resistance, and selecting an optimal portfolio of processes are neglected in the literature and this study attempts to cover these gaps. For instance, the prerequisite of processes is not reported in these studies, staff resistance only reported in one of these researches, and selecting an optimal portfolio of processes is considered in only four researches. Therefore, the important goal of this research is to discover an optimal portfolio for healthcare processes management considering these vital assumptions using a hybrid decision-making approach. On the other hand, this study is of great importance due to the lack of a suitable framework for the re-engineering of hospital processes.

The study also used a combined multi-criteria decision-making methodology that has the following advantages. In the first phase, the best-worst method is used, which is a formula for calculating the discrepancy rate to check the validity of comparisons. This method has several outstanding features compared to other multi-criteria decision-making methods (Rezaei, 2015). For example, it requires less comparative data and it leads to more stable comparisons and provides more reliable answers (Rezaei et al., 2016). On the other hand, the use of fuzzy numbers brings the problem closer to the real world (Arabsheybani et al., 2018). In the second phase also the augmented version of the ε-constraint method has been used that covers the weaknesses of the original version of this method and has a relative advantage over its counterpart methods (Gholami et al., 2019; Roghanian and Cheraghalipour, 2019).

3. Problem description

In this research, we seek to provide a tool for evaluating the readiness of organizations to re-engineer their organizational processes using identified criteria. To this end, a hybrid framework consists of a multi-criteria decision-making (MCDM) method, and a bi-objective mathematical model is designed. In this way, after collecting the criteria and goals of the organization from the experts' opinions and research background, the values of some of the parameters used in the mathematical model are determined using the MCDM method. Then, the proposed bi-objective model can be solved and the obtained results are reported. The main steps of the proposed hybrid framework are illustrated in Figure 2.

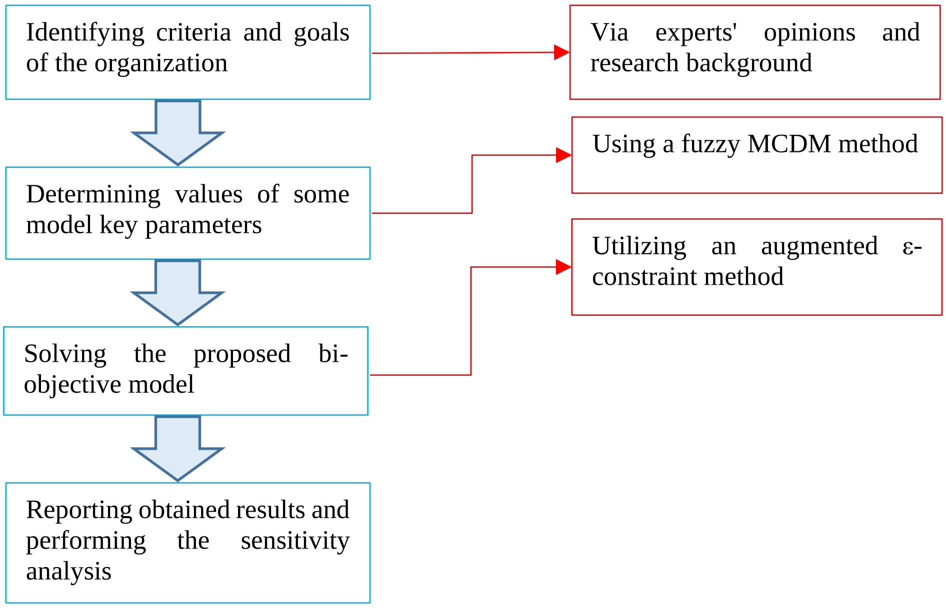


Figure 2. Illustration of the proposed hybrid framework

Finally, to explain the mechanism of this proposed framework, the following sub-sections describe each step separately.

3.1. Identifying the criteria and goals of the organization

In this section, we present and describe the proposed processes and goals among the existing goals and processes of a nominated Hospital in Sari to evaluate and prioritize them for re-engineering. Using experts' opinions and consultation with hospital members, four objectives were identified as reported in Table 2, including reducing patients' residence time, reducing hospital total costs, updating hospital processes, and increasing the quality of providing services. Moreover, twelve activities such as emergency unit processes, clinic processes, admission processes, assistance and discharge processes, along with others are considered to evaluate the proposed framework. More information about these activities is provided in Table 3.

Table 2. The main identified goals of the nominated Hospital

Index	**Organization's goal**
O_1	Reducing patients' residence time
O_2	Reducing hospital total costs
O_3	Updating hospital processes
O_4	Increasing the quality of providing services

Table 3. The main identified criteria of the nominated Hospital

Index	Activity name	Index	Activity name
A_1	Emergency unit processes	A_7	Endoscopic processes
A_2	Clinic processes	A_8	Pathological processes
A_3	Admission processes	A_9	Electroencephalogram processes
A_4	wards processes	A_{10}	Laboratory processes
A_5	Operating room processes	A_{11}	Orthopedic processes
A_6	Assistance and discharge processes	A_{12}	Medical imaging processes

3.2. The fuzzy best-worst method

Fuzzy numbers can represent ambiguous parameters and quantities of mathematical models in engineering problems (Babaee Tirkolaee et al., 2020). These numbers represent the uncertainties in determining these parameters in their forms (Zadeh, 1965). Triangular fuzzy numbers are mainly used to solve engineering problems because of their linearity and simple computation. The (a_l, a_m, a_u) represents a simple example of a triangular fuzzy number. The triangular fuzzy number A with membership function $\mu_A(x)$ on the space R is defined as the relation (1) and is also shown in Figure 3.

$$A = \mu_A(x) = \begin{cases} \dfrac{x - a_1}{a_M - a_1} & , a_1 \le x \le a_M \\ \dfrac{x - a_2}{a_M - a_2} & , a_M \le x \le a_2 \\ 0 & others \end{cases} \quad (1)$$

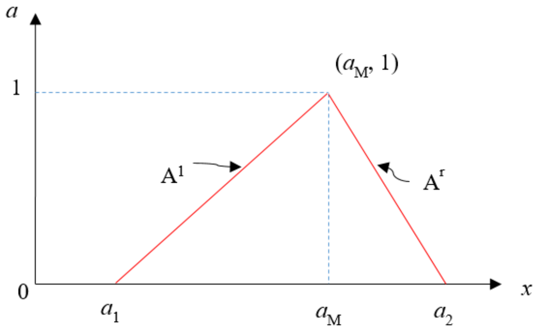


Figure 3. Illustration of the triangular fuzzy number *A*

Besides, the best worst method (BWM) was suggested by (Rezaei, 2015) and the fuzzy version of this method was presented by (Tian et al., 2018). This method was used in various studies such as (Cheraghalipour et al., 2018; Cheraghalipour and Farsad, 2018). In this method, the best and worst criteria are identified by the decision-maker and the pairwise comparison is performed between these two criteria and other criteria. More information about this used method is presented in (Tian et al., 2018), and here only the final model (2) is presented.

$$\text{Min}\ \psi \quad (2)$$

$$\frac{(\omega_B^l, \omega_B^m, \omega_B^u)}{(\omega_i^l, \omega_i^m, \omega_i^u)} - (a_{Bi}^l, a_{Bi}^m, a_{Bi}^u) \le \psi$$

$$\frac{(\omega_i^l, \omega_i^m, \omega_i^u)}{(\omega_W^l, \omega_W^m, \omega_W^u)} - (a_{iW}^l, a_{iW}^m, a_{iW}^u) \leq \psi$$
$$\sum_{i=1}^{I} S(\omega_i) = 1$$
$$\omega_i^l \leq \omega_i^m \leq \omega_i^u$$
$$\omega_i^l \geq 0$$
$$S(\omega_i) = \frac{\omega_i^l + 4\omega_i^m + \omega_i^u}{6}$$

Where, $(a^l_{iW}, a^m_{iW}, a^u_{iW})$ is a fuzzy priority of index i over the worst index. Also, $(a^l_{Bi}, a^m_{Bi}, a^u_{Bi})$ is a fuzzy priority of best index over the index i. Furthermore, $(\omega^l_i, \omega^m_i, \omega^u_i)$ and ω_i represent the fuzzy weight and defuzzy weight of index i, respectively. Also, the expert used the following fuzzy numbers to judge processes (see Table 4).

Table 4. The main fuzzy numbers used for judging processes

Preferences	Relatively equal	Not important	Almost important	Important	Very important	Quite important
Fuzzy numbers	(1,1,1)	(0.67,1,1.5)	(1.5,2,2.5)	(2.5,3,3.5)	(3.5,4,4.5)	(4.5,5,5.5)

3.3. Augmented ε-constraint method

In this section, a brief explanation of the augmented ε-constraint method is presented and more information about it is existed in (Mavrotas, 2009). This method is applied to deal with the proposed problem with two objective functions. The main structure of augmented ε-constraint is described follows. This method converts a multi-objective problem to a single objective problem and other objective functions are transferred to the constraints (Paydar et al., 2017). So, the first objective function is nominated as a single objective of this model, and the second one is transferred to the limitations. In this method, we need the optimal value of each objective function that can be obtained by solving the problem as a single objective problem. Then the following model (3) can be presented. Where, $r_p = f_p^{max} - f_p^{min}$ and $[f_p^{max}, f_p^{min}]$ are the ideal and non-ideal values of objective function p, respectively.

$$\text{Max: } f_1(x) + \varepsilon \times \left(\frac{s_2}{r_2} + \frac{s_3}{r_3} + \cdots + \frac{s_p}{r_p}\right) \tag{3}$$
$$f_2(x) = e_2 + s_2$$
$$f_3(x) = e_3 + s_3$$
$$\vdots$$
$$f_p(x) = e_p + s_p$$
$$x \in X, s_i \in R^+$$

Furthermore, the following equation is used to achieve q_i Pareto solutions and ε is assumed a small number between $[10^{-3}, 10^{-6}]$. Finally, based on the obtained q_i Pareto solutions, a Pareto front can be achieved (see equation (4)). For more information about this method, the readers are advised to see the following studies (Babaee Tirkolaee et al., 2019; Hosseini, 2019).

$$e_i^k = f_i^{max} - \frac{r_i}{q_i} \times k \qquad k = 0, 1, \dots, q_i \tag{4}$$

3.4. Model formulation

In this model, processes are re-engineered to create maximum value for the organization and minimize employee resistance. For this purpose, the index *j* is considered for re-engineering various hospital activities. Also, the organization has *n* main qualitative goals and the model calculations are performed over *t* periods.

Sets:

J	Set of hospital activities (*j*=1, 2, …, *J*)
T	Set of time periods (*t*=1, 2, …, *T*)
N	Set of the main qualitative goals (*n*=1, 2, …, *N*)

Parameters:

P_j	The amount of improvement created by activity *j*
ω_n	The weight of the organization's n^{th} goal obtained by fuzzy BWM
λ_{jn}	The impact of the activity *j* on the realization of the organization's n^{th} goal
V_j	The amount of staff resistance to change activity *j*
C_j	The cost of changing the activity *j*
B	The budget intended to improve activities
d_j	the time needed to execute the activity *j*
Q	The maximum number of activities that can be selected

Decision variables:

X_{jt}	A binary decision variable which takes the value of 1 if the activity *j* is started in time *t*, and otherwise it takes the value of 0.

Based on the above-mentioned properties, the proposed bi-objective mathematical model can be formulated as below that attempts to find the optimal portfolio for healthcare processes management.

Objective functions:

$$Obj_1 = \text{Max} \sum_{t=1}^{T-1} \sum_{j=1}^{J} P_j \times X_{jt} \tag{5}$$

$$Obj_2 = \text{Min} \sum_{t=1}^{T-1} \sum_{j=1}^{J} V_j \times X_{jt} \tag{6}$$

Subject to:

$$\sum_{t=1}^{T-1} X_{jt} \le 1 \qquad \forall\, j \in J \tag{7}$$

$$\sum_{t=1}^{T-1} \sum_{j=1}^{J} C_j \times X_{jt} \le B \tag{8}$$

$$\sum_{t=1}^{T-1}\sum_{j=1}^{J} X_{jt} \leq Q \tag{9}$$

$$\sum_{t=1}^{T-1}\left(t+d_j\right)\times X_{jt} \leq T \qquad \forall\, j \in J \tag{10}$$

$$\sum_{t=1}^{T-1}\left(t+d_j\right)\times X_{jt} \leq \sum_{t=1}^{T} t\times X_{it} \qquad \forall\, j,i \in J \quad \&\, j \text{ is prerequisite of } i \tag{11}$$

$$P_j = \sum_{j=1}^{J} \omega_n \times \lambda_{jn} \qquad \forall\, n \in N \tag{12}$$

$$X_{jt} \in \{0,1\} \qquad \forall\, j \in J \;\&\; t \in T \tag{13}$$

The objective function (5) tries to maximize the amount of improvement per activity if the activity can be started in a specific period. Also, the second objective function (6) minimize staff resistance for implementation of hospital re-engineering project. The first limitation (7) shows that each activity can be selected only once in different periods. The constraint (8) indicates that the cost of implementing re-engineering does not exceed a certain amount or the set budget. The constraint (9) specifies a limitation in the number of activities that can be re-engineered due to staff resistance. The limitation (10) relates to the length of the re-engineering based on the volume of activities. The constraint (11) is related to prerequisite activities. The constraint (12) shows that the amount of improvement created by each activity is obtained by multiplying the goals weight of the organization and the impact of the activities on the realization of these goals. Finally, the last constraint (13) indicates that the decision variables are binary.

4. Case study

In this study, a case study is proposed to validate the proposed model and framework. For this purpose, one of the public hospitals in Sari city located in Mazandaran province has been selected to collect information for the parameters of the mathematical model and the goals and processes used in the fuzzy best-worst method. In section (3.1), the goals and processes used in the fuzzy best worst method are identified, and here the other parameters of the proposed mathematical model are evaluated.

In the proposed mathematical model, those processes are selected for re-engineering which creates the maximum value for the hospital. To this end, values such as the amount of improvement created by each process (P_j), the weight of each goal of the hospital (ω_n), the amount of staff resistance to change processes (V_j), the cost of the process change (C_j), the budget for improving processes (B), the time required to execute processes (d_j), the total time to improve processes (T), and the maximum number of selected processes (Q) must be set as model parameters. These values were determined by the opinions of experts and in consultation with hospital members and are presented in Tables 5 to 6.

Table 5. The values of C_j (million rials), d_j (month), and V_j (%) along with processes information

Process #	Process name	Proposed process for re-engineering	Prerequisite	V_j	C_j	d_j
1	Emergency unit processes	Add a few new ambulances	-	0.03	5000	5
2	Clinic processes	Add a general practitioner and two beds	1	0.04	4800	4
3	Admission processes	Improving admission efficiency using the POS device instead of receiving cash	2	0.06	5750	3
4	wards processes	Improve clinical procedures and add a few experienced nurses	2, 3	0.09	6250	4
5	Operating room processes	Accelerate the receipt of equipment from CSR	2	0.03	7500	8
6	Assistance and discharge processes	Assistance to disabled patients financially and faster discharge of the dead	3	0.025	3450	3
7	Endoscopic processes	Establish a new system	2	0.10	5140	5
8	Pathological processes	Establish a new system	2	0.05	6570	3
9	Electroencephalogram processes	Accelerate response to emergency patients	2	0.07	7800	4
10	Laboratory processes	Improving acceptance efficiency and accelerating accountability	2	0.03	8500	7
11	Orthopedic processes	Adding experienced staff to more responding to patients	2	0.06	5600	6
12	Medical imaging processes	Establish a new system	2	0.05	4500	5

As it is known, the values of some parameters are presented in Table 5 according to the opinions of experts, and the values of Q, T, and B are assumed with 10 processes, 24 months, and 80 billion rials, respectively. Also, the values of the impact of processes on goal achievement (λ_{jn}) are presented in Table 6 and the weight of hospital goals (ω_n) is obtained by the fuzzy best worst method, which ultimately the amount of improvement created by each process (P_j) can be obtained using equation (13).

Table 6. Values of process impact in achieving goals (λ_{jn})

Process #	Goals			
	1	2	3	4
1	0.40	0.25	0.09	0.37
2	0.30	0.15	0.15	0.45
3	0.35	0.17	0.14	0.50
4	0.20	0.25	0.25	0.46
5	0.20	0.30	0.25	0.68
6	0.35	0.14	0.14	0.25
7	0.08	0.06	0.16	0.37
8	0.08	0.10	0.24	0.45
9	0.12	0.19	0.35	0.65
10	0.10	0.25	0.30	0.45
11	0.15	0.20	0.27	0.38
12	0.18	0.30	0.15	0.52

5. Computational results

In this section, after setting the parameters and specifying the processes and goals, the obtained results are reported. To do this, first, the fuzzy best-worst method is used to determine the weight of each of the hospital goals (ω_n) and then the amount of improvement created by each process (P_j) can be obtained using equation (13). Finally, using the parameters of the previous section, and the obtained values of P_j, the proposed bi-objective mathematical model is solved using the augmented ε-constraint method. It should be noted that Lingo software is used to

solve the fuzzy best worst method and augmented ε-constraint model. Also, all these calculations have been performed on a personal computer with the following configuration.
Processor: Intel (R) Core (TM) i5-5200U CPU @ 2.20 GHz 2.20 GHz
RAM: 4.00 GB
System type: 64-bit Operating System
Operating system: Windows 10 Pro.

5.1. Results and discussion

At first, the fuzzy best-worst method should be performed to conclude the weight of the hospital goals (ω_n) and the amount of improvement created by each process (P_j). The hospital intends to find the weight of each of the existing goals (ω_n) include reducing patients' residence time (O_1), reducing hospital total costs (O_2), updating hospital processes (O_3), and increasing the quality of providing services (O_4) using the fuzzy best-worst method. According to the second step of this method, the experts chose reducing hospital total costs (O_2) as the best index and updating hospital processes (O_3) as the worst index. In the next step, the values of fuzzy verbal comparisons by one of the decision-makers is offered for fuzzy preferences of the best index compared to all other indices (see Table 7). Likewise, the values of fuzzy verbal comparisons by one of the decision-makers is offered for fuzzy preferences of all indices compared to the worst index (see Table 8).

Table 7. Fuzzy verbal comparisons of the best index compared to all other indices

Best index	Other indices			
	O_1	**O_2**	**O_3**	**O_4**
O_2	(0.67,1,1.5)	(1,1,1)	(3.5,4,4.5)	(1.5,2,2.5)

Table 8. Fuzzy verbal comparisons of the all indices compared to worst index

Other indices	Worst index (O_3)
O_1	(2.5,3,3.5)
O_2	(3.5,4,4.5)
O_3	(1,1,1)
O_4	(1.5,2,2.5)

Then, according to the above analysis, to obtain the optimal fuzzy weight of all indices, the following nonlinear optimization problem with the mentioned limitations can be made using the equation (2).

$$\text{Min}\ \psi$$
$$s.t.\begin{cases} l_2 - 0.67u_1 \le \psi \times u_1 & l_2 - 0.67u_1 \ge -\psi \times u_1 \\ m_2 - m_1 \le \psi \times m_1 & m_2 - m_1 \ge -\psi \times m_1 \\ u_2 - 1.5l_1 \le \psi \times l_1 & u_2 - 1.5l_1 \ge -\psi \times l_1 \\ l_2 - 3.5u_3 \le \psi \times u_3 & l_2 - 3.5u_3 \ge -\psi \times u_3 \\ m_2 - 4m_3 \le \psi \times m_3 & m_2 - 4m_3 \ge -\psi \times m_3 \\ u_2 - 4.5l_3 \le \psi \times l_3 & u_2 - 4.5l_3 \ge -\psi \times l_3 \\ l_2 - 1.5u_4 \le \psi \times u_4 & l_2 - 1.5u_4 \ge -\psi \times u_4 \\ m_2 - 2m_4 \le \psi \times m_4 & m_2 - 2m_4 \ge -\psi \times m_4 \\ u_2 - 2.5l_4 \le \psi \times l_4 & u_2 - 2.5l_4 \ge -\psi \times l_4 \\ l_1 - 2.5u_3 \le \psi \times u_3 & l_1 - 2.5u_3 \ge -\psi \times u_3 \\ m_1 - 3m_3 \le \psi \times m_3 & m_1 - 3m_3 \ge -\psi \times m_3 \\ u_1 - 3.5l_3 \le \psi \times l_3 & u_1 - 3.5l_3 \ge -\psi \times l_3 \\ l_4 - 1.5u_3 \le \psi \times u_3 & l_4 - 1.5u_3 \ge -\psi \times u_3 \\ m_4 - 2m_3 \le \psi \times m_3 & m_4 - 2m_3 \ge -\psi \times m_3 \\ u_4 - 2.5l_3 \le \psi \times l_3 & u_4 - 2.5l_3 \ge -\psi \times l_3 \\ l_1 \le m_1 \le u_1 & l_2 \le m_2 \le u_2 \\ l_3 \le m_3 \le u_3 & l_4 \le m_4 \le u_4 \\ l_1 \ge 0, l_2 \ge 0, l_3 \ge 0, l_4 \ge 0 & \\ \psi \ge 0 & \end{cases} \quad (14)$$
$$\frac{(l_1 + 4m_1 + u_1)}{6} + \frac{(l_2 + 4m_2 + u_2)}{6} + \frac{(l_3 + 4m_3 + u_3)}{6} + \frac{(l_4 + 4m_4 + u_4)}{6} = 1$$

By solving the equation (14), the optimal weights of the four goals (O_1, O_2, O_3, and O_4) are calculated. Based on the results, ψ^* is equal to 0.2145, and the optimal fuzzy weights and defuzzy weights of the four goals are illustrated in Table 9. It should be noted that the defuzzy weights are obtained using the averages of fuzzy weights.

Table 9. The optimal fuzzy and defuzzy weights of the hospital's goals

Goal #	$\tilde{\omega}_n$	ω_n
1	(0.2568, 0.3202, 0.3816)	0.3199
2	(0.3375, 0.3889, 0.4403)	0.3889
3	(0.1027, 0.1027, 0.1027)	0.1027
4	(0.1622, 0.1834, 0.2348)	0.1884

Finally, the amount of improvement created by each process (P_j) can be obtained using equation (12) that these values are presented in Table 10.

Table 10. The amount of improvement created by each process (P_j)

Process #	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
P_j	0.304	0.255	0.287	0.274	0.334	0.228	0.135	0.174	0.271	0.245	0.225	0.288

After evaluating the model parameters and obtaining P_j values using the fuzzy best worst method, it is time to solve the proposed bi-objective model using the augmented ε-constraint method. Since the proposed model has two objective functions, if an obtained solution is not dominated by other solutions in terms of both objectives, it is a Pareto solution. The computational time of the model by augmented ε-constraint method on Lingo software is 926.24 seconds, and 7 Pareto solutions are generated. These Pareto solutions are presented in Figure 4 and Table 11.

Table 11. The generated Pareto solutions by the augmented ε-constraint method

Solution #	***Obj₁***	***Obj₂***
1	1.92075	0.42587
2	2.26656	0.43325
3	2.47850	0.44236
4	2.68572	0.45324
5	**2.7094**	**0.4850**
6	2.75435	0.49235
7	2.81069	0.51752

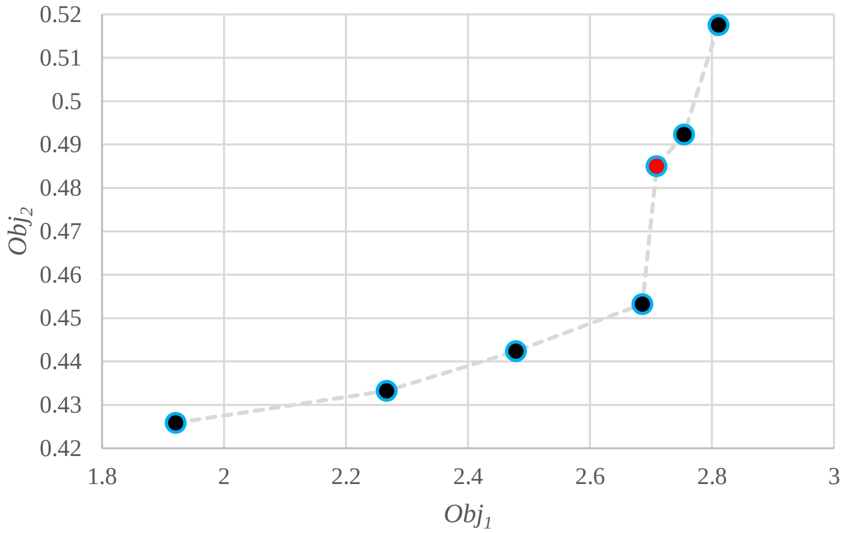


Figure 4. The obtained Pareto front by the augmented ε-constraint method

Since we do not have one solution in multi-objective models and there are several Pareto solutions, so the selection of one solution from Pareto front is done by the managers of the organization and experts. Therefore, solution number five from Table 11 is selected as the proper solution for this organization. This selected solution is bold in Table 11 and has a different color in Figure 4. Finally, the variables values for this nominated Pareto solution (solution number five) are presented in Table 12. As is shown, this table contains values of X (j, t) per various j and t along with values of two objective functions. The values of X (j, t) indicate which processes have been selected and when they start in a period. Simply put, it shows the optimal portfolio of hospital processes improvement using re-engineering.

Table 12. The variables values for this nominated Pareto solution (solution number five)

Variable	Value	Variable	Value	Variable	Value	Variable	Value	Variable	Value	Variable	Value
OBJ1	2.709	X(2,23)	0	X(4,23)	0	X(6,23)	0	X(8,23)	0	X(10,23)	0
OBJ2	0.485	X(2,24)	0	X(4,24)	0	X(6,24)	0	X(8,24)	0	X(10,24)	0
X(1,1)	1	X(3,1)	0	X(5,1)	0	X(7,1)	0	X(9,1)	0	X(11,1)	0
X(1,2)	0	X(3,2)	0	X(5,2)	0	X(7,2)	0	X(9,2)	0	X(11,2)	0
X(1,3)	0	X(3,3)	0	X(5,3)	0	X(7,3)	0	X(9,3)	0	X(11,3)	0
X(1,4)	0	X(3,4)	0	X(5,4)	0	X(7,4)	0	X(9,4)	0	X(11,4)	0
X(1,5)	0	X(3,5)	0	X(5,5)	0	X(7,5)	0	X(9,5)	0	X(11,5)	0
X(1,6)	0	X(3,6)	0	X(5,6)	0	X(7,6)	0	X(9,6)	0	X(11,6)	0
X(1,7)	0	X(3,7)	0	X(5,7)	0	X(7,7)	0	X(9,7)	0	X(11,7)	0
X(1,8)	0	X(3,8)	0	X(5,8)	0	X(7,8)	0	X(9,8)	0	X(11,8)	0
X(1,9)	0	X(3,9)	0	X(5,9)	0	X(7,9)	0	X(9,9)	0	X(11,9)	0
X(1,10)	0	X(3,10)	0	X(5,10)	0	X(7,10)	0	X(9,10)	0	X(11,10)	0
X(1,11)	0	X(3,11)	0	X(5,11)	0	X(7,11)	0	X(9,11)	1	X(11,11)	0
X(1,12)	0	X(3,12)	0	X(5,12)	0	X(7,12)	0	X(9,12)	0	X(11,12)	0
X(1,13)	0	X(3,13)	0	X(5,13)	1	X(7,13)	0	X(9,13)	0	X(11,13)	0
X(1,14)	0	X(3,14)	0	X(5,14)	0	X(7,14)	0	X(9,14)	0	X(11,14)	0
X(1,15)	0	X(3,15)	0	X(5,15)	0	X(7,15)	0	X(9,15)	0	X(11,15)	0
X(1,16)	0	X(3,16)	0	X(5,16)	0	X(7,16)	0	X(9,16)	0	X(11,16)	0
X(1,17)	0	X(3,17)	1	X(5,17)	0	X(7,17)	0	X(9,17)	0	X(11,17)	0
X(1,18)	0	X(3,18)	0	X(5,18)	0	X(7,18)	0	X(9,18)	0	X(11,18)	1
X(1,19)	0	X(3,19)	0	X(5,19)	0	X(7,19)	0	X(9,19)	0	X(11,19)	0
X(1,20)	0	X(3,20)	0	X(5,20)	0	X(7,20)	0	X(9,20)	0	X(11,20)	0
X(1,21)	0	X(3,21)	0	X(5,21)	0	X(7,21)	0	X(9,21)	0	X(11,21)	0
X(1,22)	0	X(3,22)	0	X(5,22)	0	X(7,22)	0	X(9,22)	0	X(11,22)	0
X(1,23)	0	X(3,23)	0	X(5,23)	0	X(7,23)	0	X(9,23)	0	X(11,23)	0
X(1,24)	0	X(3,24)	0	X(5,24)	0	X(7,24)	0	X(9,24)	0	X(11,24)	0
X(2,1)	0	X(4,1)	0	X(6,1)	0	X(8,1)	0	X(10,1)	0	X(12,1)	0
X(2,2)	0	X(4,2)	0	X(6,2)	0	X(8,2)	0	X(10,2)	0	X(12,2)	0
X(2,3)	0	X(4,3)	0	X(6,3)	0	X(8,3)	0	X(10,3)	0	X(12,3)	0
X(2,4)	0	X(4,4)	0	X(6,4)	0	X(8,4)	0	X(10,4)	0	X(12,4)	0
X(2,5)	0	X(4,5)	0	X(6,5)	0	X(8,5)	0	X(10,5)	0	X(12,5)	0
X(2,6)	1	X(4,6)	0	X(6,6)	0	X(8,6)	0	X(10,6)	0	X(12,6)	0
X(2,7)	0	X(4,7)	0	X(6,7)	0	X(8,7)	0	X(10,7)	0	X(12,7)	0
X(2,8)	0	X(4,8)	0	X(6,8)	0	X(8,8)	0	X(10,8)	0	X(12,8)	0
X(2,9)	0	X(4,9)	0	X(6,9)	0	X(8,9)	0	X(10,9)	0	X(12,9)	0
X(2,10)	0	X(4,10)	0	X(6,10)	0	X(8,10)	0	X(10,10)	0	X(12,10)	0
X(2,11)	0	X(4,11)	0	X(6,11)	0	X(8,11)	0	X(10,11)	0	X(12,11)	0
X(2,12)	0	X(4,12)	0	X(6,12)	0	X(8,12)	0	X(10,12)	1	X(12,12)	0
X(2,13)	0	X(4,13)	0	X(6,13)	0	X(8,13)	0	X(10,13)	0	X(12,13)	0
X(2,14)	0	X(4,14)	0	X(6,14)	0	X(8,14)	0	X(10,14)	0	X(12,14)	0
X(2,15)	0	X(4,15)	0	X(6,15)	0	X(8,15)	0	X(10,15)	0	X(12,15)	1
X(2,16)	0	X(4,16)	0	X(6,16)	0	X(8,16)	0	X(10,16)	0	X(12,16)	0
X(2,17)	0	X(4,17)	0	X(6,17)	0	X(8,17)	0	X(10,17)	0	X(12,17)	0
X(2,18)	0	X(4,18)	0	X(6,18)	0	X(8,18)	0	X(10,18)	0	X(12,18)	0
X(2,19)	0	X(4,19)	0	X(6,19)	0	X(8,19)	0	X(10,19)	0	X(12,19)	0
X(2,20)	0	X(4,20)	1	X(6,20)	0	X(8,20)	0	X(10,20)	0	X(12,20)	0
X(2,21)	0	X(4,21)	0	X(6,21)	1	X(8,21)	0	X(10,21)	0	X(12,21)	0
X(2,22)	0	X(4,22)	0	X(6,22)	0	X(8,22)	0	X(10,22)	0	X(12,22)	0

Based on the results of Table 12, the start times of nominated activities are clear. In other words, 10 activities include emergency unit processes, clinic processes, admission processes, wards processes, operating room processes, assistance, and discharge processes, electroencephalogram processes, laboratory processes, orthopedic processes, and medical imaging processes have been selected and their starting point is the 1^{st}, 6^{th}, 17^{th}, 20^{th}, 13^{th}, 21^{th}, 11^{th}, 12^{th}, 18^{th}, and 15^{th} months, respectively. So, by using the values of d_j and prerequisite activities, the related Gantt chart can be illustrated in Figure 5. This figure shows the start times, the times required to complete the re-engineering, and the prerequisites for the activities. So, in this optimal portfolio, the values of the first and second objective functions are 2.7094 and 0.4850, respectively.

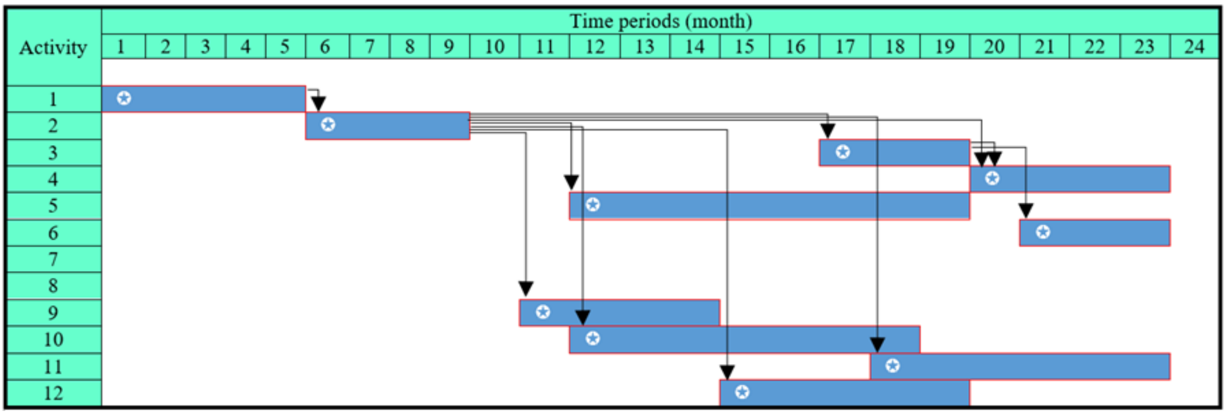


Figure 5. The related Gantt chart of the optimal portfolio for healthcare processes management (*Q*=10)

Besides, if the maximum number of activities that can be selected (*Q*) be equal to 12, the following portfolio and scheduling can be achieved. Similarly, its related Gantt chart can be illustrated in Figure 6. This figure shows also the start times, the times required to complete the re-engineering and the prerequisites for all activities. So, in this optimal portfolio, the values of the first and second objective functions are 3.020 and 0.6350, respectively.

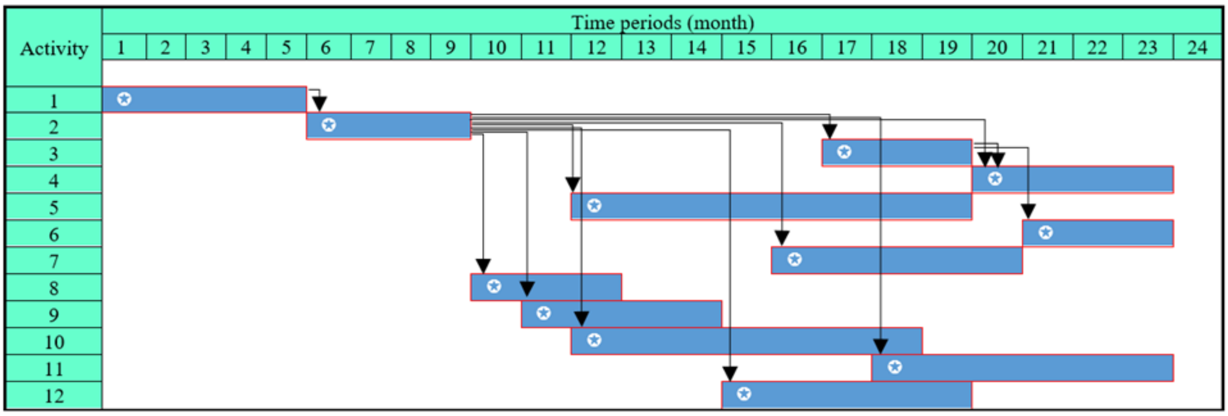


Figure 6. The related Gantt chart of the optimal portfolio for healthcare processes management (*Q*=12)

5.2. Sensitivity analysis

After solving the proposed bi-objective model using the augmented ε-constraint method, seven Pareto solutions were generated, and the solution number 5 was selected by the experts as an acceptable solution for their organization. In this section, to further evaluate the mathematical model and the proposed hybrid framework, the sensitivity analysis has been performed on several cases that comparisons and results of this analysis can be used by hospital managers. In these cases, some values such as the staff resistance to change processes (V_j), the cost of changing processes (C_j), and the amount of improvement created by changing processes (P_j) are changed to determine its effect on model resolution. The specifications of these cases are presented in Table 13.

Table 13. Results of sensitivity analysis by augmented ε-constraint for solution number five

Case #	Parameters for sensitivity analysis			Objective value		Changes compared to standard mode	
	V_j	C_j	P_j	Obj_1	Obj_2	Obj_1	Obj_2
1	-	-	-	2.7094	0.4850	-	-
2	20% increase	20% decrease	20% decrease	2.2027	0.5883	18.7% decrease	21.3% increase
3	20% decrease	20% increase	-	2.6742	0.3817	1.3% decrease	21.3% decrease
4	30% increase	-	20% increase	3.2513	0.6305	20% increase	30% increase
5	-	20% increase	20% decrease	2.1323	0.4787	21.3% decrease	1.3% decrease
6	20% decrease	20% increase	20% increase	3.2865	0.3943	21.3% increase	18.7% decrease

It should be noted that to determine these changes correctly, all these changes in the model have been solved only for solution number five of Table 11 compared to the standard mode. According to this sensitivity analysis, it is clear that the rate of the changes of V_j directly affects the second objective function, while the rate of the changes of P_j affects the first objective function of the proposed model. But changes in C_j have little effect on either objective functions, so reducing it reduces both objective functions. For better realizing the reaction of the standard solution versus case changes of sensitivity analysis, Figure 7 is illustrated.

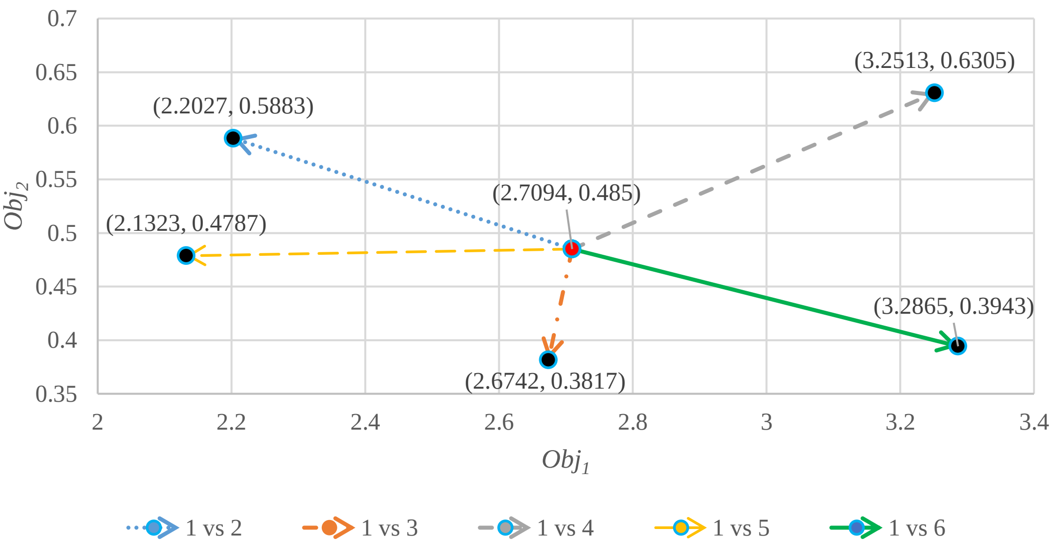


Figure 7. The reaction of the standard solution versus cases changes of sensitivity analysis

As shown in this figure, the standard solution (solution number five of Table 11) is located in the center of the chart and is distinguished by red color and its objectives values are (2.7094, 0.4850). Moreover, other points of this chart show the changes in the standard solution per various cases of Table 13. In this figure when used 1 vs *k*, it represents the changes in standard solution case number 1 per case number *k*. For instance, 1 vs 3 represents the changes in standard solution case number 1 per case number 3. Moreover, based on the results of Table 13, the difference in the standard value of both objective functions versus case changes can be observed. To better demonstrate these behaviors two line charts are illustrated. Figure 8 shows the difference in the standard value of obj_1 versus case changes and likewise, Figure 9 shows the difference in the standard value of obj_2 versus case changes.

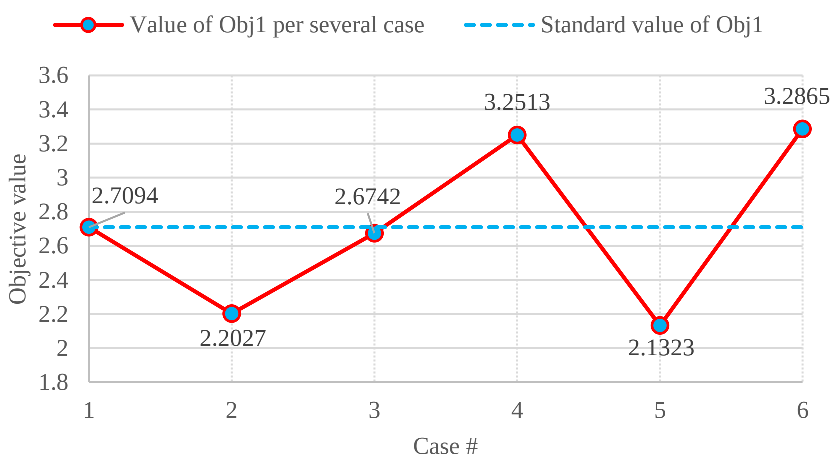


Figure 8. The difference in the standard value of *obj*$_1$ versus case changes

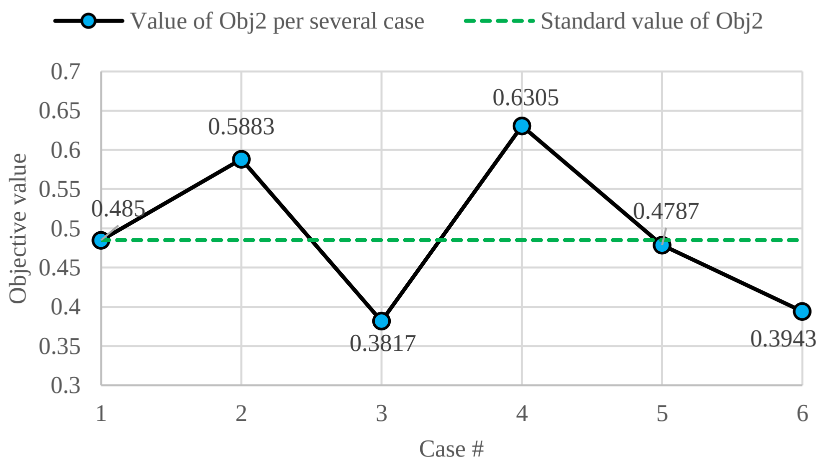


Figure 9. The difference in the standard value of *obj*$_2$ versus case changes

In line with these figures, it is observed that the changes of V_j directly affects the second objective, while the changes of P_j affects the first objective. But changes in C_j have little effect on either objective functions. Therefore, based on these observations, three critical parameters are found and the managers of the organization can be able to make a proper decision for determining optimal portfolio for healthcare processes management using this strong hybrid decision-making approach. Finally, using these reports and observations some managerial insights are provided in the next sub-section to shows the importance and practical aspects of this study.

5.3. Managerial insights

Existing managerial decision-making implements for determining optimal portfolio for healthcare processes management, notice low levels of strategic participation that caused lower levels of re-engineering performance, hence, managers are not able to select the proper portfolio in their healthcare process. Besides, there is no suitable approach for increasing levels of strategic participation of hospitals to enhance monitoring and evaluating re-engineering performance. Besides, operational aspects as another important issue in managerial decision-making tools are raised. So, the hospital criteria must be included operational aspects of staff such as quality and time that caused to their effects on re-engineering performance. Besides, the arrangement of strategic and operational aspects can help hospitals to achieve better re-engineering performance, and hence, portfolio evaluation and monitoring actions should conform to multiple dimensions of re-engineering performance.

This research attempts to propose a comprehensive framework based on fuzzy BWM and augmented ε-constraint approaches for managers to determine the optimal portfolio for healthcare processes management considering both strategic and operational aspects of the hospital criteria. Finally, the following insights can be suggested based on the obtained results, sensitivity analysis, and observations.

- Since the proposed methodology can find an optimal portfolio for healthcare processes management considering the prerequisites of the activities, this leads to having a combined portfolio and scheduling plan for the hospital. Also, the obtained Gantt chart can help the scheduling selected activities of the optimal portfolio for the re-engineering process.
- The proposed framework considers pairwise comparison numbers in fuzzy mode, which can lead to the proximity of the problem to the real-world. On the other hand, implementing this powerful proposed framework is very simple and does not have the computational complexity that causes the program to lag.
- By adapting the sensitivity analysis, three critical parameters such as the staff resistance to change processes (V_j), the cost of changing processes (C_j), and the amount of improvement created by changing processes (P_j) are found. The results show that the changes of V_j directly affects the second objective, while the changes of P_j affects the first objective. Moreover, changes in C_j have little effect on either objective functions. Therefore, the hospital managers can make a proper decision for determining the optimal portfolio for healthcare processes management based on an appropriate estimate of costs and budget available of the organization to implement the re-engineering process.

6. Conclusion

Given the importance mentioned in the previous sections of the study, it can be seen that the re-engineering of processes plays a significant role in improving the performance of various organizations, including hospitals. Moreover, choosing the optimal portfolio for healthcare processes management can help to identify effective processes in this organization to improve its situation, which ultimately leads to the success of the re-engineering process. For this purpose, in this study, first, the goals and processes affecting hospital process management under a case study were described and then the values of the proposed model parameters were presented. Then, using the fuzzy best worst method and performing its nonlinear optimization problem in Lingo software, the optimal weights of the goals were determined. Finally, using these optimal weights, the amount of improvement created by each process was determined. After that, the proposed bi-objective model was solved using the augmented ε-constraint method, and an analysis of these results was performed. Since the model had two objective functions and the obtained solutions were compared in such a way that a suggested solution should be better in both objective functions than other solutions, if the preference between the solutions could not be determined, we called them Pareto or non-dominated solutions. After the implementation of the Model, seven Pareto solutions were obtained, and information about them was provided. Also, according to the opinions of the managers and experts of the organization, one of these Pareto solutions was extracted as the optimal response. According to it, it was determined which processes were selected and when they started from the period, which shows the optimal portfolio of processes to improve the condition of the hospital using re-engineering. The sensitivity analysis was also used for further research and exploration. To this end, several cases were considered that in these cases, some values such as the staff resistance to change processes, the cost of changing processes, and the amount of improvement created by changing processes were changed to determine their effects on model behavior. Therefore, comparisons and results of the analysis can be useful for hospital managers.

Since the information used as the values of the parameters in the proposed model is related to the geographical location of the case study, this information may not be effective for other areas and this raised as a limitation of this research. Also, some suggestions for future works are provided as follows. Since high computational time was observed when solving the mathematical model using Lingo software, so in larger dimensions of this problem, the performance of exact methods will be reduced and in a very long time it will give us the local optimal solution. So using meta-heuristic algorithms will be efficient and useful. Also considering other assumptions in the proposed model, such as uncertain or fuzzy processes times, Political and governmental considerations, and work shifts of staff and nurses can be helpful for organizations.

References

AbdEllatif, M., Farhan, M.S., and Shehata, N.S., (2018). "Overcoming business process reengineering obstacles using ontology-based knowledge map methodology", *Future Computing and Informatics Journal*, Vol. 3, No. 1, pp. 7–28.

Arabsheybani, A., Paydar, M.M., and Safaei, A.S., (2018). "An integrated fuzzy MOORA method and FMEA technique for sustainable supplier selection considering quantity discounts and supplier's risk", *Journal of Cleaner Production*, Vol. 190, pp. 577–591.

Babaee Tirkolaee, E., Hadian, S., and Golpira, H., (2019). "A novel multi-objective model for two-echelon green routing problem of perishable products with intermediate depots", *Journal of Industrial Engineering and Management Studies*, Vol. 6, No. 2, pp. 196–213.

Babaee Tirkolaee, E., Mardani, A., Dashtian, Z., Soltani, M., and Weber, G.-W., (2020). "A novel hybrid method using fuzzy decision making and multi-objective programming for sustainable-reliable supplier selection in two-echelon supply chain design", *Journal of Cleaner Production*, Vol. 250, p. 119517.

Bertolini, M., Bevilacqua, M., Ciarapica, F.E., and Giacchetta, G., (2011). "Business process re-engineering in healthcare management: a case study", *Business Process Management Journal*, Vol. 17, No. 1, pp. 42–66.

Bevilacqua, M., Ciarapica, F.E., and Paciarotti, C., (2012). "Business Process Reengineering of emergency management procedures: A case study", *Safety Science*, Vol. 50, No. 5, pp. 1368–1376.

Bhaskar, L., (2018). "Business process reengineering: A process based management tool", *Serbian Journal of Management*, Vol. 13, No. 1, pp. 63–87.

Borgianni, Y., Cascini, G., and Rotini, F., (2010). "Process value analysis for business process re-engineering", *Proceedings of the Institution of Mechanical Engineers, Part B: Journal of Engineering Manufacture*, Vol. 224, No. 2, pp. 305–327.

Cheraghalipour, A., and Farsad, S., (2018). "A bi-objective sustainable supplier selection and order allocation considering quantity discounts under disruption risks: A case study in plastic industry", *Computers & Industrial Engineering*, Vol. 118, pp. 237–250.

Cheraghalipour, A., Paydar, M.M., and Hajiaghaei-keshteli, M., (2018). "Applying a hybrid BWM-VIKOR approach to supplier selection: a case study in the Iranian agricultural implements industry", *International Journal of Applied Decision Sciences*, Vol. 11, No. 3, pp. 274–301.

Crowe, T.J., Rathi, K., and Rolfes, J.D., (1997). "Selecting business process reengineering projects strategically", *Computers & Industrial Engineering*, Vol. 33, No. 1–2, pp. 157–160.

Dachyar, M., and Sanjiwo, Z.A.H., (2018). "Business process re-engineering of engineering procurement construction (epc) project in oil and gas industry in indonesia", *Indian Journal of Science and Technology*, Vol. 11, No. 9, pp. 1–8.

Darmani, A., and Hanafizadeh, P., (2013). "Business process portfolio selection in re-engineering projects", *Business Process Management Journal*, Vol. 19, No. 6, pp. 892–916.

Davenport, T.H., and Short, J.E., (1990). "The new industrial engineering:information technology and business process redesign", *Sloan Management Review*, Vol. 31, No. 4, pp. 11–27.

Gholami, F., Paydar, M.M., Hajiaghaei-Keshteli, M., and Cheraghalipour, A., (2019). "A multi-objective robust supply chain design considering reliability", *Journal of Industrial and Production Engineering*, Vol. 36, No. 6, pp. 385–400.

Greenfield, D., Lawrence, S.A., Kellner, A., Townsend, K., and Wilkinson, A., (2019). "Health service accreditation stimulating change in clinical care and human resource management processes: A study of 311 Australian hospitals", *Health Policy*, Vol. 123, No. 7, pp. 661–665.

Hakim, A., Gheitasi, M., and Soltani, F., (2016). "Fuzzy model on selecting processes in Business Process Reengineering", *Business Process Management Journal*, Vol. 22, No. 6, pp. 1118–1138.

Hanafizadeh, P., and Osouli, E., (2011). "Process selection in re-engineering by measuring degree of change", *Business Process Management Journal*, Vol. 17, No. 2, pp. 284–310.

Hosseini, S.M.H., (2019). "A bi-objective model for the assembly flow shop scheduling problem with sequence dependent setup times and considering energy consumption", *Journal of Industrial Engineering and Management Studies*, Vol. 6, No. 2, pp. 44–64.

Jafar Tarokh, M., Sharifi, E., and Nazemi, E., (2008). "Survey of BPR experiences in Iran: reasons for success and failure", *Journal of Business & Industrial Marketing*, Vol. 23, No. 5, pp. 350–362.

Kettinger, W.J., and Teng, J.T.C., (1998). "Aligning BPR to strategy: a framework for analysis", *Long Range Planning*, Vol. 31, No. 1, pp. 93–107.

Kwak, N.., and Lee, C.W., (2002). "Business process reengineering for health-care system using multicriteria mathematical programming", *European Journal of Operational Research*, Vol. 140, No. 2, pp. 447–458.

Lee, Y., Chu, P., and Tseng, H., (2011). "Corporate performance of ICT-enabled business process re-engineering", *Industrial Management & Data Systems*, Vol. 111, No. 5, pp. 735–754.

Lotlikar, V., Dsouza, B., Kamath, R., and Apuri, N., (2018). "Business Process Re-engineering for Bed Allocation Process in a Tertiary Care Hospital in Mumbai", *Journal of Health Management*, Vol. 20, No. 2, pp. 136–143.

Mavrotas, G., (2009). "Effective implementation of the ε-constraint method in Multi-Objective Mathematical Programming problems", *Applied Mathematics and Computation*, Vol. 213, No. 2, pp. 455–465.

Musa, M.A., and Othman, M.S., (2016). "Business Process Reengineering in Healthcare: Literature Review on the Methodologies and Approaches", *Review of European Studies*, Vol. 8, No. 1, p. 20.

Nicholds, B.A., and Mo, J.P.T., (2015). "Risk Assessment of Business Process Re-Engineering Projects", *Open Journal of Social Sciences*, Vol. 03, No. 03, pp. 30–34.

Onjure, C.O., M. Wanyoike, D., and Mungatu, J., (2018). "Influence of Business Process Reengineering on Electronic Commerce Strategy as Adopted by Commercial Banks in Kenya", *International Journal of Innovative Research and Development*, Vol. 7, No. 1, pp. 180–200.

Ostadi, B., Aghdasi, M., and Alibabaei, A., (2011). "An examination of the influences of desired organisational capabilities in the preparation stage of business process re-engineering projects", *International Journal of Production Research*, Vol. 49, No. 17, pp. 5333–5354.

Paydar, M.M., Babaveisi, V., and Safaei, A.S., (2017). "An engine oil closed-loop supply chain design considering collection risk", *Computers & Chemical Engineering*, Vol. 104, pp. 38–55.

Rabbani, M., Heidari, N., and Farrokhi Asl, H., (2016). "A Bootstrap Interval Robust Data Envelopment Analysis for Estimate Efficiency and Ranking Hospitals", *Journal of Industrial Engineering and Management Studies*, Vol. 3, No. 2, pp. 107–122.

Rezaei, J., (2015). "Best-worst multi-criteria decision-making method", *Omega*, Elsevier, Vol. 53, pp. 49–57.

Rezaei, J., Nispeling, T., Sarkis, J., and Tavasszy, L., (2016). "A supplier selection life cycle approach integrating traditional and environmental criteria using the best worst method", *Journal of Cleaner Production*, Elsevier Ltd, Vol. 135, pp. 577–588.

Roghanian, E., and Cheraghalipour, A., (2019). "Addressing a set of meta-heuristics to solve a multi-objective model for closed-loop citrus supply chain considering CO2 emissions", *Journal of Cleaner Production*, Vol. 239, p. 118081.

Sadeghi, M., Niloofar, P., Ziaee, M., and Mojaradi, Z., (2017). "An innovative algorithm for planning and scheduling healthcare units with the aim of reducing the length of stay for patients (Case study: Cardiac SurgeryWard of Razavi Hospital of Mashhad)", *Journal of Industrial Engineering and Management Studies*, Vol. 4, No. 1, pp. 90–104.

Song, S., Yang, F., and Xia, Q., (2019). "Multi-criteria project portfolio selection and scheduling problem based on acceptability analysis", *Computers & Industrial Engineering*, Vol. 135, pp. 793–799.

Tavana, M., Khosrojerdi, G., Mina, H., and Rahman, A., (2019). "A hybrid mathematical programming model for optimal project portfolio selection using fuzzy inference system and analytic hierarchy process", *Evaluation and Program Planning*, Vol. 77, p. 101703.

Tian, Z., Wang, J., and Zhang, H., (2018). "An integrated approach for failure mode and effects analysis based on fuzzy best-worst, relative entropy, and VIKOR methods", *Applied Soft Computing*, Vol. 72, pp. 636–646.

Zadeh, L.A., (1965). "Fuzzy sets", *Information and Control*, Vol. 8, No. 3, pp. 338–353.

Zomparelli, F., Petrillo, L., Salvo, B. Di, and Petrillo, A., (2018). "Re-engineering and Relocation of manufacturing process through a simulative and multicriteria decision model", *IFAC-PapersOnLine*, Vol. 51, No. 11, pp. 1649–1654.

This article can be cited: Cheraghalipour, A., Roghanian, E., (2021). "Determining the optimal portfolio for healthcare processes management using a hybrid decision-making approach", *Journal of Industrial Engineering and Management Studies*, Vol. 8, No. 1, pp. 218-239.