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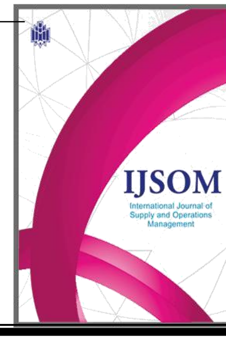

Purchasing Planning and Order Allocation in the Pharmaceutical Sustainable Supply Chain Using the Theoretical-Graph (GT-MP- DM)
(Case Study: Supplying the clotting factor for patients with hemophilia)

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Abstract
In view of the growing environmental consciousness among product users, the issue of product sustainability is one of the challenging tasks being faced by product designers, manufacturers, environmentalists, and decision makers. This article presents a framework for supplier selection from a sustainability perspective. Along with the sustainability criteria, the other criteria and sub-criteria involved in the selection of drug suppliers for patients with hemophilia are investigated, too. Regarding the significance of the clotting agents in the health and life of hemophilia patients, it is especially important to provide and supply this drug from the safe companies and to consider the amount of ordering. The criteria and sub-criteria studied in this article were investigated and concluded through library studies, filed assessments of the experts' comments. For the case study, the desired supplier is determined and the others are ranked through the Graph Theoretical Matrix Permanent Decision Making (GT-MP-DM) Approach. Finally, with presenting the bi-objective mathematical model, the amount of order to the suppliers is determined and then the model is solved by means of fuzzy MAX-MIN method and GAMS software; the model is validated by sensitivity analysis.

Keywords: Pharmaceutical Supplier selection; Sustainable supply chain; Hemophilia patients; Fuzzy Graph Theoretical Approach; Multi Criteria Decision Making.

1. Introduction

Today, the healthcare management industry faces financial challenges and expenditures more than ever. In the U.S., for example, healthcare cost was $3.09 trillion in 2014, and estimated to rise to $3.57 trillion in 2017. Statistics of the healthcare market in the U.S. reveal that about 12.9% of the major cost of healthcare in 2014 was attributed to the pharmaceutical industry (http://www.plunkettresearch.com/health-care-medical-market-research/industry-trends). The industry can be defined as series of operations, processes, and interactions between organizations for discovering, developing and producing medications and drugs (Shah, 2004). Pharmaceutical firms are basically obliged by the powerful regulatory market forces to rethink the way they produce and distribute products, as well as to reimagine the role of the supply chain in driving strategic growth, brand differentiation, and economic value in the health system (Mehralian et al., 2012). The pharmaceutical supply chain needs more consideration compared with other industries such as customized demand of customers, market dynamic factors, weak networks, and governmental policies (Vishwakarma et al., 2016). Assuring the continuous flow of drugs to patients at optimal prices and with minimal delays, insignificant shortages with no errors is valuable in pharmaceutical supply chains (Mehralian et al., 2016).

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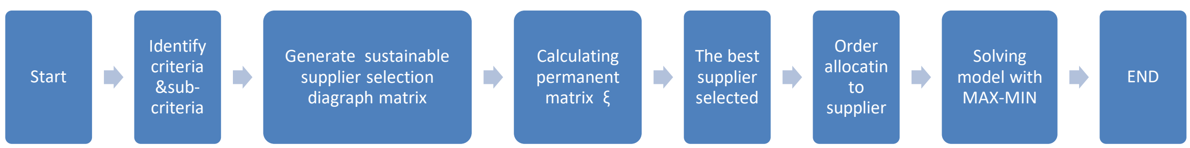
Designing sustainable supply chains, companies must review the impact of supply chain operations on the environment and society because of the increasing environmental, legislative, and social considerations (Govindana et al., 2013). Sustainability is based on economic, environmental, and social dimensions for human development (Ageron et al., 2012; Gopalakrishnan et al., 2012).

The purpose of this study is, therefore, to select a pharmaceutical supplier according to the main concepts of sustainability, i.e. economic, environmental, and social. To this end, we selected and assessed the suppliers with examining the criteria and sub-criteria and using the permanent matrix theoretical graph method; since the studied products are blood factors 7, 8, and 9 fundamentally required by hemophilia patients and used in order to prevent from the internal and external bleedings, only the four suppliers available in four countries of the world were investigated. We aimed to select the best supplier and the order allocation of the clotting factor for hemophilia patients. The rest of the paper is organized as follows: Section 3 presents a comprehensive review of a multi-criteria decision-making technique called Graph Theoretic Matrix Permanent Decision Making (GT-MP-DM). A brief description of its method and current plans are provided. The weights obtained from the first part have been used as the coefficients of one of the model's purposes in the multi-target model. In Section 4, a mathematical model including bi-objectives such as maximizing the purchase value, minimizing the total cost of purchasing drug, minimizing order costs, and minimizing the costs of maintaining drug in the hospital is proposed. Then, considering restrictions like the supplier capacity and meeting the buyer's demand, we have allocated the orders to the suppliers. The solution approach to the sustainable pharmaceutical network model is described in Section 5. To check this model with a real data in a case study, supplying the clotting factor for patients with hemophilia, one of the main pharmaceutical suppliers is chosen and the others are being ranked. Then the order is allocated with the mathematical model, and the model is solved by means of fuzzy MAX-MIN method and GAMS software. The model is validated by sensitivity analysis in Section 6. Finally, Section 7 presents the results and conclusions of the research and suggests some potential works as future studies in the field.



Graphical Abstract

2. Review of the Literature

Most papers on supply chain management from 1990 have investigated relationships between the buyer and seller and the supplier selection criteria. Dickson (1966) was one the first researchers who investigated this issue. Based on a questionnaire completed by 170 purchasing manager, he determined 23 different assessment indices. Among these criteria, price, delivery performance, and quality have been regarded as the most important assessment indices. Weber et al. also reviewed the literature on these criteria. They investigated 74 papers on suppliers' assessment and concluded that quality was the most important index which was followed by delivery performance and price. Kahraman et al. (2003) considered all criteria of suppliers, cost criteria in assessment issue, as well as selection of suppliers, and proposed the hierarchical fuzzy analysis to choose the best suppliers. The limit method was proposed for resolving the issue. Razmi and Ma'qoul (2009) presented the fuzzy model for several products and several periods for selecting the suppliers and purchasing problems along with considering discounts and with capacity and budget restrictions. Esfandiari and Seyf Barqi (2013) presented the multi-objective model to allocate the shares to suppliers when the demand depends on the proposed price by the suppliers. Nazari et al. (2013) considered supplier selection and the issue of allocating orders through the multi-objective two-phase linear planning. Cow et al. (2010) presented a new method based on the neural network and a multi-optional decision-making model to select the green suppliers. Their criteria included quality, timely delivery, and economic, social, and environmental issues. Sifisi and Boypouk Ozkan (2012) investigated a model of green supply chain management to present the assessment framework for the green suppliers. They used a fuzzy combined MNDM model based on fuzzy DEMATEL, ANP, and TOPSIS fuzzy technique in order to evaluate the green suppliers. The main criteria they considered in their paper were organization, economic performance, quality of services, technology, green competence, social responsibilities, and clean production. Conan et al. (2013) investigated the multi-criteria fuzzy decision-making and multi-objective planning for selecting suppliers in the green supply chain based on its economic and environmental criteria. Prasad et al. (2017) developed a hybrid methodology by combining the concepts of Analytical Hierarchy Process (AHP), Data Enveloped Analysis (DEA), and Grey Relational Analysis (GRA) to address the issue of supplier selection from the pool of suppliers.

Thus, from the sustainability perspective , supplier selection in the development process of a new product is a case of multi-criteria decision making (MCDM). Previously, several qualitative and quantitative factors have been addressed for supplier selection during NPD and as such, a high degree of fuzziness and uncertainty is always involved during supplier selection in a NPD environment (Ankush Anand et al., 2018).

Today, many researches are being conducted on the healthcare supply chain. The major challenge of the supply chain in this context is the pressure of healthcare organizations that are seeking for an opportunity to improve the operational yield and reduce costs in order to improve the quality. Management of healthcare supply chain is more complex than other industries due to its influence on peoples' health and also adequate and accurate need of the medical field for the needs of the patient. Some different methods of supply chain have been enacted in recent years, but they have been followed by some challenges. Some of the studies conducted in this area are briefly reviewed here. Hamelmyer (2010) studied the routing of blood products from the blood donation centers to the hospitals in East Australia using integer modeling. Sahin et al. (2007) used the integer modeling to resolve the locating and allocating issues in regionalization of the blood-related services in Turkey. Candal (1980) investigated the policies of multi-objective collecting and distributing with a goal programming method. In his paper, he pointed out that the goal programming is more understandable and its results are easier to be confirmed compared to the simulation. Using this type of modeling, the decision-maker is able to consider different objectives with regard to their priorities and assess the impacts of different decisions. Nagroni et al. (2012) presented a model of optimizing the supply chain network of perishable products. Specifically, they studied a regional blood bank system for its policies of collection, test and processing facilities, storage facilities, distribution centers as well as demands which are usually the hospitals. Their model takes many issues of blood-related supply chains into account including optimal allocation, risk caused by proffers, and reduction of wastes and perished products simultaneous with the satisfaction of the illogical demands.

Based on the literature reviewed above, it seems that very few researchers and practitioners have considered sustainability as a major criterion in supplier selection. Therefore, sustainable supplier selection is a challenging task in a supply chain environment. Although many studies have been conducted on selecting suppliers in the sustainable supply chain, it has not been accurately used in the healthcare area. Moreover, categorizing the criteria and selecting suppliers is especially a new subject in this field that is proposed in the current study. In addition, identifying the health sub-criteria in the theoretic graph method and using its results in mathematical modelling have rarely been considered by researchers.

In this paper, along with the sustainability criteria, the other criteria and sub-criteria involved in the selection of drug suppliers for patients with hemophilia are investigated. Regarding the significance of the clotting agents in the health and life of the hemophilia patients, it is especially important to provide and supply this drug from the safe companies and to consider the amount of ordering. The supply chain in this study involves three levels of supply, distribution and demand (customer) centers as shown in Figure 1.

Figure 1. The pharmaceutical supply chain network

3. The theoretic-graph model using comparing the permanent matrix with the fuzzy approach in GT-MP-DM decision-making

In this paper, we present a comprehensive review of a multi-criteria decision-making technique called GT-MP-DM. A description of its method and current plans are also provided. GT-MP-DM originates from the combined mathematics (mainly the graph theory and matrix inertia), has very favorable characteristics for modeling and solving complex decision-making issues, and investigates the effectiveness of the criteria and sub-criteria for each other. The method of calculating the permanent matrix is similar to determinants, except that all negatives are changed into positives in calculating determinants. We describe how to calculate the permanent matrix and procedures to resolve it below (Baykasoglu A, 2012).

Advantages of Using GT-MP-DM

* The computational method used in the GT-MP-DM approach is relatively simple compared to the other multi-criteria decision-making methods.

* Unlike many other MADM methods, the GT-MP-DM approach includes dependences like ANP.

* The GT-MP-DM approach eases the critical analysis of many qualitative and quantitative features more than the other MADM techniques.

* In the permanent matrix method, a small change in the values of feature leads to significant difference in the result. Thus, clearly the alternative ranking in descending order is easier in it.

* In addition, not only does the GT-MP-DM method provide the possibility of presenting analysis of alternatives, but also makes it possible to visualize the current different criteria and mutual relationships among them using graphic presentations.

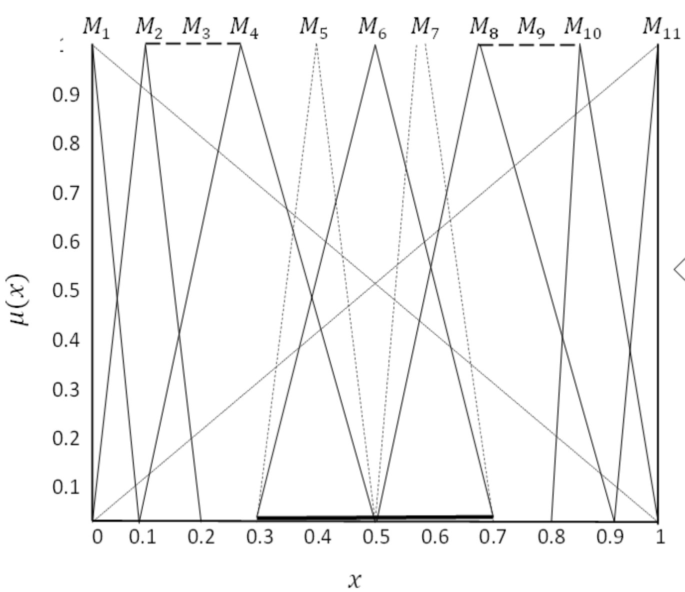
* The permanent matrix provides a better understanding of the criteria and description of resolving the decision-making issue which includes all possible structural components and their relative importance.

Compared to the other MCDM methods, the applications of GT-MP-DM are rare and just a few researchers have used them in their papers.

3.1. Solving the multi-criteria decision-making problem using GT-MP-DM

1. Identifying the criteria and sub-criteria that are part of the multi-criteria decision-making problem

2. Forming Ψ matrix is written based on Equation 1 where its items equal to zero except the main diagonal; and on the same main diagonal, the importance of sub-criteria for the studied supplier is written based on Figure 2. In this table, eleven cases of fuzzy comparison have been calculated and put in order of importance.

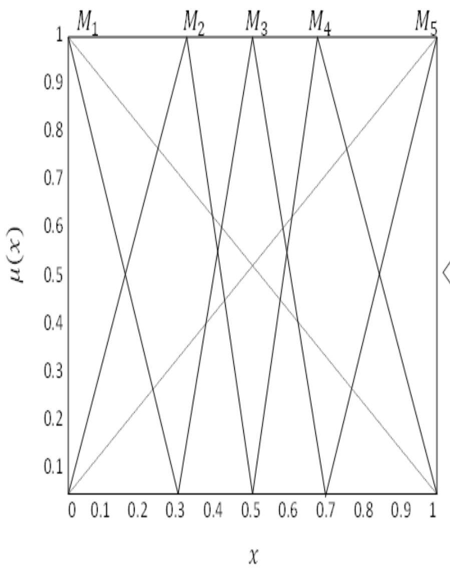


Linguistic term (M_i)	Crisp score
Exceptionally low (M_1)	0.045
Extremely low (M_2)	0.135
Very low (M_3)	0.255
low (M_4)	0.335
Below average (M_5)	0.420
Average (M_6)	0.500
Above average (M_7)	0.590
High (M_8)	0.665
Very high (M_9)	0.745
Extremely high (M_{10})	0.865
Exceptionally high (M_{11})	0.955

Figure 2. Linguistic terms to fuzzy number conversation (11-point scale) for evaluating criteria scores for alter-natives

$$\boldsymbol{\Psi}=\begin{bmatrix}\boldsymbol{C_{11}} & \mathbf{0} & \cdots & \mathbf{0}\\ \mathbf{0} & \boldsymbol{C_{22}} & \vdots & \mathbf{0}\\ \vdots & \cdots & \vdots & \vdots\\ \mathbf{0} & \cdots & \mathbf{0} & \boldsymbol{C_{nn}}\end{bmatrix}$$

3. Forming matrix β is written based on Equation 2 with the main diagonal of zero and the other elements of fuzzy comparison of the sub-criteria: the scores are shown in five cases in Figure 3. The procedure of calculating the fuzzy numbers is shown next to the table.



$$\mu_{M_1}(x)=\begin{cases}1, & x=0\\ (0.3-x)/0.3, & 0\le x\le 0.3\end{cases}$$

$$\mu_{M_2}(x)=\begin{cases}(x-0)/0.25, & 0\le x\le 0.25\\ (0.5-x)/0.25, & 0.25\le x\le 0.5\end{cases}$$

$$\mu_{M_3}(x)=\begin{cases}(x-0.3)/0.2, & 0.3\le x\le 0.5\\ (0.7-x)/0.2, & 0.5\le x\le 0.7\end{cases}$$

$$\mu_{M_4}(x)=\begin{cases}(x-0.5)/0.25, & 0.5\le x\le 0.75\\ (1-x)/0.25, & 0.75\le x\le 1\end{cases}$$

$$\mu_{M_5}(x)=\begin{cases}(x-0.7)/0.3, & 0.7\le x\le 1\\ 1, & x=1\end{cases}$$

Linguistic term (M_i)	Crisp score
Much less important (M_1)	0.115
Less important (M_2)	0.295
Equally important (M_3)	0.495
More important (M_4)	0.695
Very important (M_5)	0.895

Figure 3. Linguistic terms to fuzzy number conversation (5-point scale) for comparing criteria

$$\beta=\begin{bmatrix}0 & r_{12} & \cdots & r_{1n}\\ r_{21} & 0 & \vdots & r_{2n}\\ \vdots & \cdots & \vdots & \vdots\\ r_{n1} & \cdots & 0 & 0\end{bmatrix}$$

4. Forming matrix ξ is written based on Equation 3 which is obtained from matrixes β and Ψ

$$\xi=\psi+\beta=\begin{bmatrix}C_1 & r_{12} & r_{13} & \cdots & r_{1n}\\ r_{21} & C_2 & r_{23} & \cdots & r_{2n}\\ r_{31} & r_{32} & C_3 & \cdots & r_{3n}\\ \cdots & \cdots & \cdots & \cdots & \cdots\\ \vdots & \vdots & \vdots & \vdots & \vdots\\ r_{n1} & r_{n2} & r_{n3} & \cdots & C_n\end{bmatrix}$$

5. Calculating the permanent matrix ξ using the following formula

$$\begin{aligned}\boldsymbol{Per}(\boldsymbol{\xi})=&\prod_{i=1}^{N}\boldsymbol{C_i}+\sum_{i,j,\dots,N}(\boldsymbol{r_{ij}r_{ji}})\boldsymbol{C_kC_l}\dots\boldsymbol{C_N}+\sum_{i,j,\dots,N}(\boldsymbol{r_{ij}r_{jk}r_{ki}}+\boldsymbol{r_{ik}r_{kj}r_{ji}})\boldsymbol{C_lC_n}\dots\boldsymbol{C_N}\\ &+\left\{\sum_{i,j,\dots,N}(\boldsymbol{r_{ij}r_{ji}})(\boldsymbol{r_{kl}r_{lk}})\boldsymbol{C_nC_m}\dots\boldsymbol{C_N}+\sum_{i,j,\dots,N}(\boldsymbol{r_{ij}r_{jk}r_{kl}r_{li}}+\boldsymbol{r_{il}r_{lk}r_{kj}r_{ji}})\boldsymbol{C_lC_n}\dots\boldsymbol{C_N}\right\}\\ &+\left[\sum_{i,j,\dots,N}(\boldsymbol{r_{ij}r_{ji}})(\boldsymbol{r_{kl}r_{ln}r_{nk}}+\boldsymbol{r_{kn}r_{nl}r_{lk}})\boldsymbol{C_mC_o}\dots\boldsymbol{C_N}+\sum_{i,j,\dots,N}(\boldsymbol{r_{ij}r_{jk}r_{kl}r_{ln}r_{ni}}+\boldsymbol{r_{in}r_{nl}r_{lk}r_{kj}r_{ji}})\boldsymbol{C_mC_o}\dots\boldsymbol{C_N}\right]\\ &+\cdots\end{aligned}$$

6. Forming decision matrix whose main diagonal is the permanents obtained from the previous stage and the other elements are comparisons of criteria of the studied supplier selected from the table; each supplier with the largest permanent matrix is selected and the other suppliers are put in the next ranks.

4. The Model of Allocating Orders to the Suppliers

This is a multi-product multi-period multi-supplier planning model. Taking the sustainability factors into account is one of the most important criteria of selecting suppliers in this study. In this model, we intend to obtain the order value allocated to the suppliers in the healthcare area. The target function of this model includes two targets as follows:

4.1. Model's objectives

The model proposed in this study includes two objectives:

- Reduction of the Total Cost

The first target function is minimizing the total cost of purchasing and ordering, maintenance costs and the product supplying and communicating with the suppliers.

- Increasing Purchase Value

The second target function seeks to increase the purchase value through increasing the suppliers' share.

- Model's Hypotheses

The hypotheses of the proposed model

- The desired supply chain in this study involves three levels including supply levels, distribution and demand (customer) centers.
- In addition, this is considered a multi-product and multi-period supply chain.
- The geographical location of the demand and supply places is determined out of the model's range in the operation, but locating the distribution centers is determined by the model.
- The distribution capacity is clear and determined.
- The supplier's capacity is clear and determined.
- Target functions are considered fuzzy.
- The proposed mathematical model has two objectives including minimization of costs and maximization of purchase value.
- Storage possibility has been taken into account in the model.

Because the medication is necessary for the humans' life, there is no possibility of shortage.

- The demand of each period should be responded by the suppliers at the same period. Eth delayed orders are not considered.
- The score obtained for each supplier in the graph method is used as the coefficient of one of the target functions.
- Discounts have not been considered.

Indices

C	Costumer	$(1 < c < C)$
d	distribution center	$(1 < d < D)$
S	Supplier	$(1 < s < S)$
t	time	$(1 < t < T)$

Parameters

O_{st}	The fixed cost of ordering the supplier s in the time period t
$COST^{dist}_{d}$	The cost of operating the distribution center
$COST^{sup\text{-}dist}_{isdt}$	The cost of transferring each product unit i from the supplier s to the distribution center d in time period t
H_{it}	The cost of maintaining each product unit I in the time period t
$COST^{dist\text{-}cus}_{idct}$	The cost of transferring each product unit i rom the distribution center d to customer c in time period t
Cap^{sup}_{ist}	Capacity of supplier s for supplying the product i in time period t
Cap^{dist}_{idt}	The capacity of distribution center d for supplying the product i in time period t
dem_{ict}	Demand of product i from s by customer c in time period t

$FLOW^{sup\text{-}dist}_{isd}$	Maximum transmission flow of product i from supplier s to distribution center d
$FLOW^{dist\text{-}cus}_{idc}$	Maximum transmission flow of product i from distribution center d to the customer c
q_{ist}	The failure rate of product I from supplier s in time period t
Priceist,	The cost of purchasing each unit of product i from the supplier s in time period t
ICist,	The cost of contracting with the supplier s for product i in time period t
TCist,	The cost of finishing the contract with the supplier s for the product i in time period t
Bigm,	The very big number
Priceist,	The cost of purchasing each unit of product i from the supplier s in time period t
Ws,	The score of supplier s from the graph method

Variable, the decision-making variables

y_{ist} The binary variable which indicates the case that the supplier s receives the order for product i in time period t

S_{ist} The binary variable which indicates the case of establishing a contract with supplier s for purchasing product i in time period t

T_{ist} The binary variable that indicates the case of the contract with the supplier s for purchasing product i in time period t is terminated

Y_d The binary variable that indicates the case of operating distribution center d (integer)

X_{isdt} The purchase amount of product i from distribution center d from supplier s in time period t (integer)

X_{idct} The delivery amount of product i from distribution center d to custumer c in time period t (integer)

inv_{ict} The amount of product i existing in the storage of customer c in time period t (integer)

Trn cost,	Transfer cost (positive)
Setup cost,	The cost of establishing the distribution center (positive)
Str cost,	The cost of maintenance (positive)
Sply cost,	The cost of supply and communication with suppliers (positive)

The Mathematical Model
Target Functions

$$\text{Min } Z^{\text{cost}} = \text{Trn Cos t} + \text{Setup Cos t} + \text{Str Cos t} + \text{Sply Cos t}$$

$$\text{Max } Z^{\text{total purchaising value}} = \textstyle\sum_{\text{i.s.d.t}} w_s \times x^{\text{sup}-\text{dist}}_{\text{isdt}}$$

S.t ;

$$\text{Trn Cos t} = \textstyle\sum_{\text{i,s,d,t}} \cos t^{sup-dist}_{isdt} \times x^{\text{sup}-\text{dist}}_{\text{isdt}} + \sum_{\text{i,d,c,t}} \cos t^{dist-cus}_{idct} \times x^{\text{dist}-\text{cus}}_{\text{idct}} \quad (1)$$

$$\text{Setup Cos t} = \textstyle\sum_{\text{d}} \text{cost}^{\text{dist}}_{\text{d}} \times y^{\text{dist}}_{\text{d}} \quad (2)$$

$$\text{Str Cos t} = \textstyle\sum_{\text{i,c,t}} h_{\text{it}} \times \text{inv}_{\text{ict}} \quad (3)$$

$$\text{Sply Cos t} = \textstyle\sum_{\text{i,s,d,t}} \text{price}_{\text{i,s,t}} \times x^{\text{sup}-\text{dist}}_{\text{isdt}} + \sum_{\text{i,s,t}} o_{\text{s,t}} \times y^{\text{sup}}_{\text{ist}} + \sum_{\text{i,s,d,t}} \text{IC}_{\text{i,s,t}} \times S^{\text{sup}}_{\text{ist}} + \sum_{\text{i,s,d,t}} \text{TC}_{\text{i,s,t}} \times T^{\text{sup}}_{\text{ist}} \quad (4)$$

$$\textstyle\sum_{\text{d}} x^{\text{sup}-\text{dist}}_{\text{isdt}} \le cap^{sup}_{ist} \qquad \forall i,s,t \quad (5)$$

$$\textstyle\sum_{\text{c}} x^{\text{dist}-\text{cus}}_{\text{idct}} \le cap^{dist}_{idt} \qquad \forall i,d,t \quad (6)$$

$$\textstyle\sum_{\text{s}} x^{\text{sup}-\text{dist}}_{\text{isdt}} \le cap^{dist}_{idt} \qquad \forall i,d,t \quad (7)$$

$$\textstyle\sum_{\text{s}} x^{\text{sup}-\text{dist}}_{\text{isdt}} \ge \sum_{\text{c}} x^{\text{dist}-\text{cus}}_{\text{idct}} + \sum_{\text{s}} q_{ist} \times x^{\text{sup}-dist}_{isdt} \qquad \forall i,d,t \quad (8)$$

$$inv_{ict} = inv_{ic(t-1)} + \textstyle\sum_{d} x^{dist-cus}_{idct} - \text{dem}_{ict} \qquad \forall i,c,t>1 \quad (9)$$

$$\text{inv}_{ic1} = \textstyle\sum_{d} x^{dist-cus}_{idc1} - \text{dem}_{ic1} \qquad \forall i,c \quad (10)$$

$$\textstyle\sum_{\text{d}} y^{\text{dist}}_{\text{d}} = 1 \quad (11)$$

$$\textstyle\sum_{\text{s}} x^{\text{sup}-\text{dist}}_{\text{isdt}} \le \text{bigm} \times y^{dist}_{d} \qquad \forall i,d,t \quad (12)$$

$$\textstyle\sum_{\text{d}} x^{\text{sup}-\text{dist}}_{\text{isdt}} \le \text{bigm} \times y^{sup}_{i,s,t} \qquad \forall i.s.t \quad (13)$$

$\sum_{s,d} x_{isdt}^{sup-dist} \leq \sum_{s,d} flow_{isd}^{sup-dist} \qquad \forall i,t \qquad (14)$
$\sum_{d,c} x_{idct}^{dist-cus} \leq \sum_{d,c} flow_{idct}^{dist-cus} \qquad \forall i,t \qquad (15)$
$T_{ist}^{sup} = y_{ist}^{sup} - y_{is(t+1)}^{sup} \qquad \forall i,s,t \qquad (16)$
$S_{ist}^{sup} = y_{ist}^{sup} - y_{is(t-1)}^{sup} \qquad \forall i,s,t \qquad (17)$

The aim of presenting the above model can be expressed as following:

The first target function: minimizing the total costs including transportation costs, construction of distribution costs, maintenance and supplying the product and communication with the customers.

The second target function: maximizing the value of purchasing from the suppliers with high score.

The transportation cost, construction of distribution center cost, maintenance cost and the cost of supplying the product and communication with the suppliers are respectively shown in restrictions 1 to 4.

The amount of purchased product from the suppliers should not be more than their capacity. This is shown in restriction (5).

The amount of transferred product from the distribution centers to the customers should not exceed the capacity of the distribution centers, and the amount of the products purchased from the suppliers should not be more than the capacity of the distribution centers; these are respectively shown in restrictions (6) and (7).

Restriction (8) is for controlling the flow of materials between the levels.

Restrictions (9) and (10) are used for balancing the inventory and satisfying the demands.

Restriction (11) ensures that only one distribution center is constructed.

The condition of purchasing from supplier is the construction of te distribution center as well as communicating with the suppliers, which are indicated in restrictions (12) to (13).

Restrictions (14) and (15) are defined for the non-aggression of flow between the levels.

Finally, restrictions (16) and (17) are presented to determine the establishment or cancellation of contracts with the suppliers.

5. Solution by the MAX-MIN method

Many resolving methods have been proposed for solving the multi-objective planning such as MAX-MIN, TH, etc. Today, the fuzzy method is widely considered due to its flexibility and possibility of calculating the satisfaction degree of each of the target functions. The proposed mathematical model in this study is integer linear planning. Since the issue has two heterosexual target functions, we will use the fuzzy method presented by Lin et al. (2004) developed by Amid in 2011 in order to make the target functions and restrictions fuzzy. It is coded by using GAMS software and weighted by the MAX-MIN method; the target functions will turn into a single-objective model, then they will be solved.

The stages of this method are as follows:

1. Determining the best and worst possible answers; to achieve that, each target function must be solved separately and the best and worst possible answer will be calculated using the following formula.

$Z_1^{negative}=\min(a_{11},a_{21}) \qquad Z_2^{negative}=\min(a_{12},a_{22})$

$Z_1^{positive}=\max(a_{11},a_{21}) \qquad Z_2^{positive}=\max(a_{12},a_{22})$

The results are shown in the form of a 2*2 matrix as follows:

$$\begin{array}{cc} & \begin{array}{cc} z_1 & z_2 \end{array} \\ \begin{array}{c} z_1^* \\ z_2^* \end{array} & \begin{pmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{pmatrix} \end{array}$$

2. Calculating the membership function for each of the restrictions based on the following formula:

$$\mu_{Z_l^{max}}(x) = \begin{cases} 1 & Z_l(x) > Z_l^{positive} \\ 0 & Z_l(x) < Z_l^{negative} \\ f_{Z_l^{max}} = \dfrac{Z_l(x) - Z_l^{negative}}{Z_l^{positive} - Z_l^{negative}} \quad , & Z_l^{negative} \leq Z_l(x) \leq Z_l^{positive} \end{cases}$$

$$\mu_{Z_k^{min}}(x) = \begin{cases} 1 & Z_k(x) > Z_k^{positive} \\ 0 & Z_k(x) < Z_k^{negative} \\ f_{\mu_{Z_k^{min}}} = \dfrac{Z_k^{positive} - Z_k(x)}{Z_k^{positive} - Z_k^{negative}} \quad , & Z_k^{negative} \leq Z_k(x) \leq Z_k^{positive} \end{cases}$$

3. Changing the multi-objective function to the following model using the integration max-min function:

MAX λ
S.t;
$W^*\lambda \leq \mu_{zj}$
$\sum wj = 1$
$\lambda \in [0,1]$

4. Solving the max-min single-objective model.

6. Case study: Supplying the clotting factor for patients with hemophilia

The hemophilia A and B are sex-linked diseases in which males are the sick and females are carriers of the disease. Intensity and rate of bleeding in the hemophilia patients is not more than the normal persons, but its time is longer. The blood of hemophilia patients does not have sufficient clotting factor. The most common type of hemophilia is type A and the blood of these patients does not have any factor 8; the blood of patients with hemophilia type B does not have factor 9.

The Required Drugs for Hemophilia Patients: factor IX, factor VII, and factor VIII.

The list of assessed drug suppliers is presented in Table1.

Table 1. The list of assessed drug suppliers

Country	Company name	Supplier's number
USA	TALECRIS Company	**1**
Iran	Samen Pharmaceutical Company	**2**
Korea	GREENCROSS Company	**3**
Colombia	BAXTER Company	**4**

Table 2. The assessed criteria and sub-criteria of suppliers

Source	Abbreviations	Selected sub-criteria	Criterion
All sources	A_1	The extent of using renewable and non-renewable forces	Green competence A
All sources	A_2	Observing environmental standards like ISO 14000	
All sources	A_3	Green transportation and logistic	
All sources	A_4	Using production technology appropriate to the environment	
All sources	A_5	Designing for assessment and eliminating the risky wastes in order to prevent from pollutions and recycling extent	
All sources	A_6	Continuou environmental supervision	
All sources	A_7	Green packing	
All sources	B_1	Training extent of employees and level of communion	Social competences B
All sources	B_2	Respecting human rights of employees	
All sources	B_3	Employment opportunities for people with disabilities	
All sources	B_4	Participation of supplier in charities	
All sources	B_5	Job safety programs	
All sources	B_6	Created job opportunities	
All sources	C_1	Profitability of the supplier	Economic targets C
All sources	C_2	Financial power and weakness of the supplier	
All sources	C_3	The income obtained from recycling	
All sources	C_4	Product's price	
All sources	C_5	Custom costs	
All sources	C_6	Delay cost	
All sources	C_7	Costs of transportation and distribution	
All sources	D_1	Technology and capacity of producing drugs and flexibility of the production line	Production competence and technology capabilities D
All sources	D_2	Experience and brand value of producer	
All sources	D_3	Accessibility to the new technologies and innovation	
All sources	D_4	The pace of development	
All sources	E_1	Quality sustainability	Quality E
All sources	E_2	Quality assurance	
All sources	E_3	Qualitative commitment of manager	
Experts	E_4	Reliability	
Experts	E_5	R & D	
Experts	E_6	Product return rates	
Experts	F_1	Appropriate planning for ordering timely deliveries and planning to deal with delays	Delivery time F
Experts	F_2	Using appropriate strategies in critical and emergency times	
Experts	F_3	Good track record in previous deliveries and meeting pharmaceutical needs	
All sources	F_4	Mechanisms of reducing the process of order to delivery	
All sources	F_5	Designing the network of customer services	

Table 2. Continued

Source	Abbreviations	Selected sub-criteria	Criterion
Experts	G_1	Convenient transportation of medications (maintaining the cold chain)	Health G
Experts	G_2	Maintenance and production of drugs in isolation and disinfection Preventing from the contaminations and bacterial growth	
Experts	G_3	Appropriate packaging and required equipment for injection of drug use	
Experts	G_4	Considering the shelf life and expiration date of drug	
Experts	G_5	Applying appropriate standards of production	
Experts	G_6	Reduction of the risk of transmission of blood diseases through medication	
All sources	H_1	Customers' satisfaction and striving to meet their demands	Customer services H
All sources	H_2	The number of times of compensation and tracking the customers' complaints	
All sources	H_3	Responding speed and behavior towards the customer	
All sources	H_4	Level of communion	
All sources	H_5	Accessibility of the supplier using the web-based internet	
All sources	H_6		
All sources	I_1	Political stability	Risk I
All sources	I_2	Economy of the supplier country	
All sources	I_3	Geographical structure	
All sources	I_4	Terrorism	
All sources	I_5	Weather conditions	
All sources	I_6	Cultural differences	

Graph Chart

In Figure 4 below the graph decision-making is shown. In the figure, the main nine criteria are determined in the form of 9-sides and the desired criterion of each angle is shown with its symbol and the sub-criteria of each of these criteria are related to the corners of the figure. In fact, the figure depicts the aspects and the procedure of solving the decision-making issue.

The Results Obtained from GT-MP-DM

The permanent matrix is calculated for each of the four suppliers and the selected supplier is determined; due to the length of calculations of the resolving method, we just mention the ultimate response of suppliers.

Concerning the first supplier which is the one selected, with regard to the above calculations for the criteria of the sustainability of supply chain, the green competence has the highest impact, which is followed by the economic purposes and social competence; for the other criteria, the order of impacts is as follows: health, customer services, quality, risk, delivery time, producing competence and technology capabilities.

The score of the selected supplier is 3.4 for Samen Pharmaceutical Company. The second ranked company is TALECRIS with the score of 3.36, the third ranked company is BAXTER with the score of 2.16, and the fourth ranked one is GREENCROSS with the score of 1.016 as shown in Table 3.

Hence, Samen pharmaceutical company is ranked first and is prioritized in purchasing the medication; the obtained score for this supplier from the theoretical graph method is placed in the target function of the order value model as the coefficient in order to obtain the order value.

Table 3. The score of supplier with use GT-MP-DM

GT-MP-DM score	Supplier	Country	Rank
3.36	TALECRIS	USA	2
3.4	SAMEN	IRAN	1
2.16	BAXTER	COLOMBIA	3
1.016	GREEN CROSS	KOREA	4

Numerical Results

To resolve the mathematical model, we divided Iran into two areas. Each area has distribution centers, and supplies medications for five regions that are considered our customers. The patients refer to these ten centers for purchasing the drugs. The structure of solving the mathematical model for the case study is given in Figure 5. Four suppliers supply all three types of drug in two single-month periods (factors 7, 8, and 9). The required data for resolving the model is indicated. This data was obtained from the Ministry of Health and Iran's Hemophilia Center.

After entering the data and resolving the model with the max-min method, the following results were obtained:

$$\begin{array}{c} \\ z_1^* \\ z_2^* \end{array} \begin{array}{c} \begin{array}{cc} \quad z_1 & \qquad z_2 \end{array} \\ \begin{pmatrix} 637801 & 97171.2 \\ 1194100.1 & 115872 \end{pmatrix} \end{array}$$

$Z_1^{NEGATIVE}$=637801 , $Z_2^{NEGATIVE}$=97171.2, $Z_1^{POSITIVE}$=1194100.1 , $Z_2^{POSITIVE}$=115872

The Mathematical Model

Objective function

Max $\boldsymbol{\lambda}$

Subjected to:

$$\mu_{Z^{\cos t}} = \frac{1194100.1 - Z^{\cos t}}{1194100.1 - 637801} \geq \lambda \times w_1$$

$$\mu_{Z^{total\ value\ purchasing}} = \frac{Z^{total\ value\ purchasing} - 97171.2}{115872 - 97171.2} \geq \lambda \times w_2$$

The rest of the restrictions are unchanged and the model was solved with W1=W2=0.5, the following results were obtained (Tables 4 to 9).

Table 5. The amount of product i existing in the storage of customer c in time period t

inv_{ict}		1	2
I	**c**	T=1	T=2
1	6		1090
1	8	650	
2	2	420	
2	6	21	
2	7	550	
3	1	210	
3	7	370	
3	10	470	

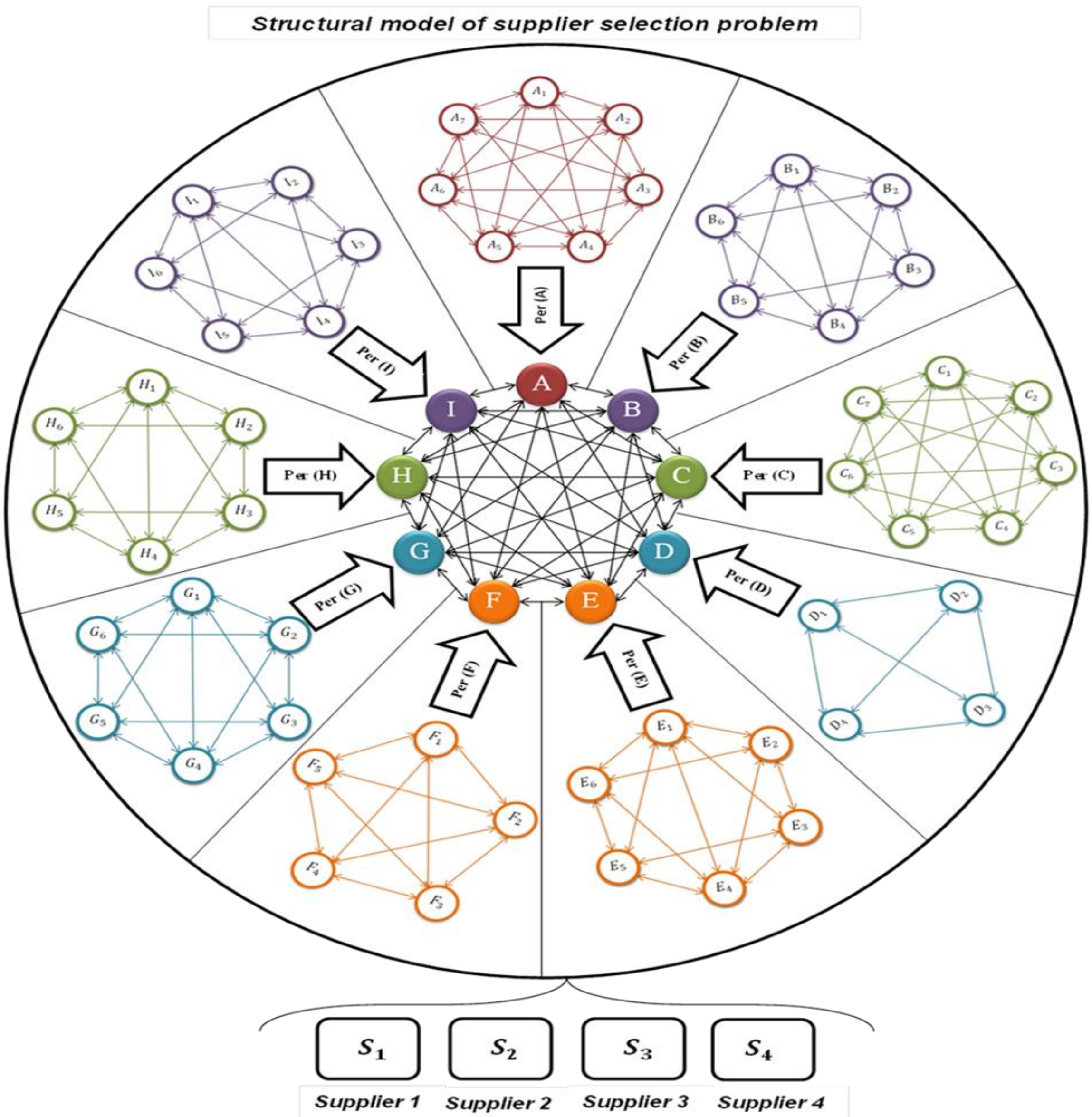


Figure 4. The structural model of sustainable pharmaceutical supplier selection

Table 6. The purchase amount of product i from distribution center d from supplier s in time period t

$x_{isdt}^{sup-dist}$			1	2
1	1	1	6429	6630
1	4	1	1	
2	2	1	5708	4222
2	4	1	1	
3	1	1	4323	
3	2	1		4184

Table 4. The delivery amount of product i from distribution center d to custumer c in time period t

$xt_{idct}^{dist-cus}$				
I	**d**	**c**	T=1	T=2
1	1	1	400	450
1	1	2	450	500
1	1	3	490	540
1	1	4	660	710
1	1	5	540	590
1	1	6	500	1640
1	1	7	650	650
1	1	8	1270	
1	1	9	750	780
1	1	10	700	750
2	1	1	320	370
2	1	2	790	
2	1	3	400	450
2	1	4	580	630
2	1	5	470	520
2	1	6	421	429
2	1	7	1050	
2	1	8	510	560
2	1	9	600	650
2	1	10	550	600
3	1	1	370	
3	1	2	220	270
3	1	3	250	300
3	1	4	470	520
3	1	5	350	400
3	1	6	220	250
3	1	7	690	
3	1	8	350	400
3	1	9	500	550
3	1	10	890	

Table 7. The binary variable which indicates the case of establishing a contract with supplier s for purchasing product i in time period t

S_{ist}^{sup}		1
1	1	1
1	4	1
2	2	1
2	4	1
3	1	1
3	2	1

Table 8. The binary variable which indicates the case that the supplier s receives the order for product i in time t

y_{ist}^{sup}		1	2
1	1	1	1
1	4	1	1
2	2	1	1

Table 9. Continued

y_{ist}^{sup}		1	2
2	4	1	1
3	1	1	1
3	2	1	1

Table 9. The binary variable which indicates the case of the contract with supplier s for purchasing product i in time period t

T_{ist}^{sup}		2
1	1	1
1	4	1
2	2	1
2	4	1
3	1	1
3	2	1

The target function and costs are as follows:
Setup cost=1.2E+5 Sply cost=6.445E+5 Str cost=8549 Trn cost=1.48E+5
Objective1=921211.8, Objective2=106523.8

Sensitivity Analysis

Now the sensitivity of the max-min presented by the weights related to each of the target functions is analyzed in order to assess the impact of each target function on the functions. From the following tables and graphs, it is observed that with increase in the first target function W1 and decrease in the second target function W2, the values of both target functions decrease.

The target function value is shown based on different Ws in Table 10.

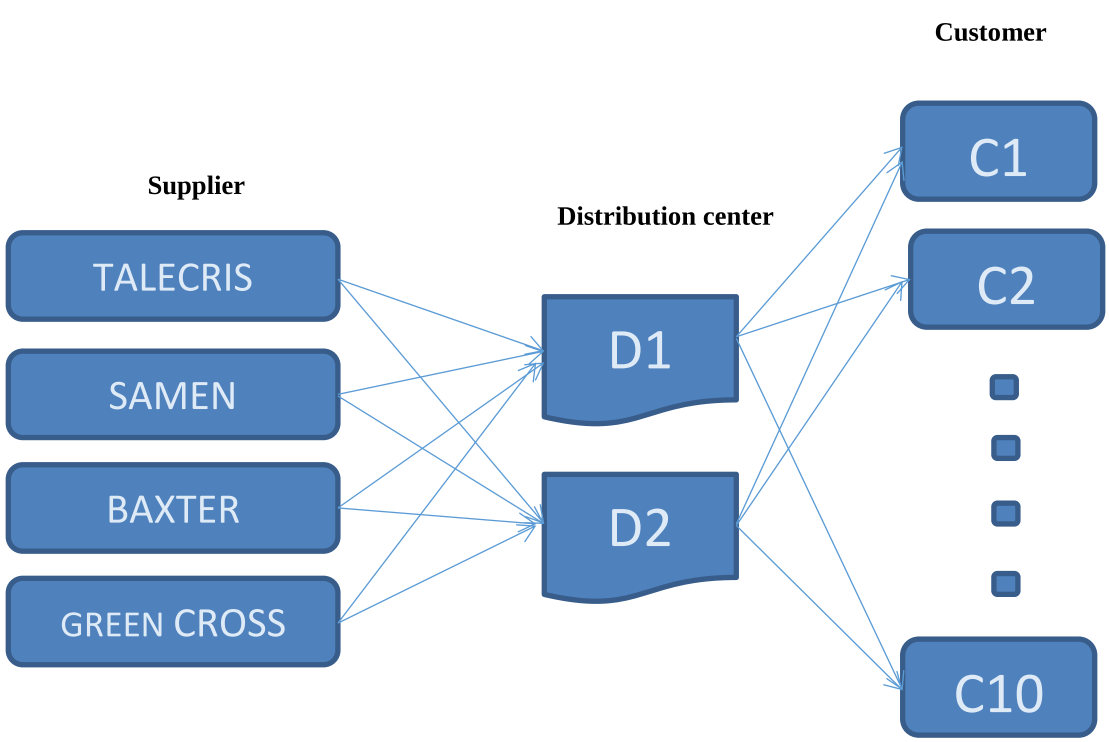
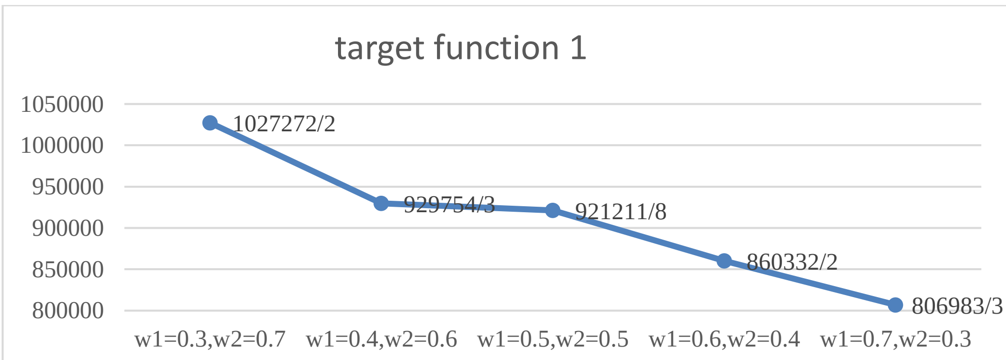


Figure5. The structure of solving the mathematical model for the case study

Table 10. The target function value based on different Ws

Weights		The first target function	The second target function
$w_1 = 0.3$	$w_2 = 0.7$	102727	110263
$w_1 = 0.4$	$w_2 = 0.6$	929754	108866
$w_1 = 0.5$	$w_2 = 0.5$	921211	106523
$w_1 = 0.6$	$w_2 = 0.4$	860332	104653
$w_1 = 0.7$	$w_2 = 0.3$	806983	102781

The sensitivity analysis is depicted in Figure 6.



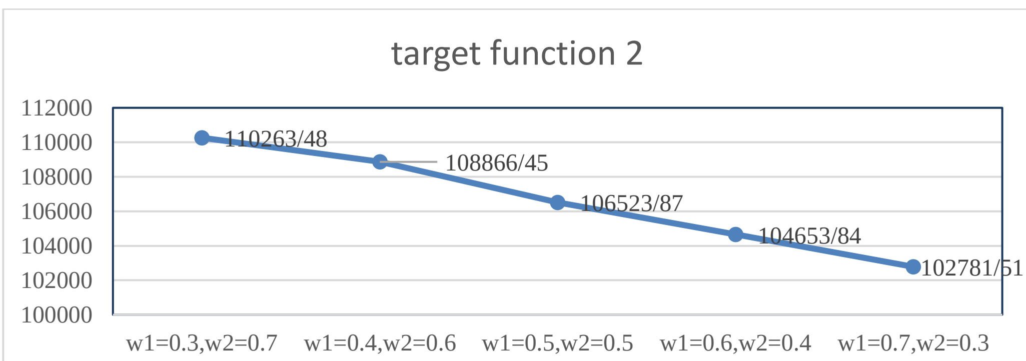


Figure 6. The sensitivity analysis

7. Conclusion

In this study, we selected the suppliers of the clotting agent products for hemophilia patients. Firstly, we reviewed the literature on supply chain, sustainable and green supply chain, healthcare supply chain, and their related fields. Then we investigated papers on the selection of suppliers. In this study, we considered Iran that requires four suppliers for supplying the needed medications of its patients. The distribution centers provide medications from the suppliers and the patients get their required products from the centers. The products include three main blood products, factor 7, 8, and 9. We first identified the criteria and sub-criteria using a questionnaire and interviews with the experts. After identifying the criteria, we weighted and ranked the suppliers through using the network graph (GT-MO-DM) and MATLAB software. The obtained results are as follows: about the first supplier which is the same selected supplier, with regard to the above calculations, the criteria concerning the sustainability of supply chain had the most impact and the economic purposes and social competence had the second highest impact; for the other criteria, the order of their impacts is as follows: healthcare, customer services, quality, risk, delivery time, constructing competence and technology capability. The score of the selected supplier is 3.4 for Samen Pharmaceutical Company. The second ranked company is TALECRIS with the score of 3.36, the third ranked company is BAXTER with the score of 2.16, and the fourth ranked one is GREENCROSS with the score of 1.016.

In the present paper, the mathematical model for the issue of selecting the suppliers of clotting agents is also proposed. In addition to minimizing the total costs of purchasing, ordering, and maintaining, the proposed model seeks to increase the purchase value through increasing the suppliers' share. To solve the model, we used fuzzy max-min method and GAMS; then we analyzed the sensitivity of weights of the target functions. Sensitivity analysis of the weighted max-min model by the weights related to each of the target functions was conducted in order to assess the impact of each target function on other functions. From the tables and graphs, it is observed that with increase in the weight of the first target function W1 and decrease in the weight of the second target function W2, the values of both functions decrease.

Research's Innovation

Although many researches have been conducted on selecting suppliers in the green and sustainable chain, this subject has not been accurately used in the field of healthcare. Moreover, categorization of criteria and sub-criteria, especially in healthcare is a new subject proposed in this study. Identifying and introducing the health criteria and their sub-criteria and using them along with the other criteria as well as using the graph analysis method GT-MP-DM and its results in mathematical modeling have been rarely considered by other researchers.

Suggestions for Further Research

* Several studies can be considered for the GT-MP-DM approach in future, such as investigating the possibility of integrating it with some existing MCDM methods and other analysis methods; this can be very interesting. Comparing GT-MP-DM approach with some MCDM methods can be a very exciting venue of research, too. Performing many tasks is required for MCDM modeling under uncertainty conditions with the GT-MP-DM approach.

* investigating the other green and sustainable sub-criteria in the healthcare field.
* investigating the performance of hospital and suppliers in crisis situations like earthquake and flooding.
* using other meta-heuristics to solve the model or integrating two methods and comparing them with each other.

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