Provide a mathematical model for a specific order to the drug supplier in the supply chain

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ABSTRACT

Production systems must increase the productivity of their organizations day to day, in this section, the issue of proper selection of suppliers is discussed. Suppliers of industrial organizations usually produce parts and the task of management is to select the right suppliers. The selection of suppliers can be associated with resilience indicators and thus significantly reduce the likelihood of malfunctions. The purpose of this study is to investigate the situation in which there are a number of suppliers from whom orders should be placed and also the orders should be such that the chain has good resilience. In this study, the community of managers of pharmaceutical companies have been selected through snowball sampling.

Structural relationships between indicators were determined using DEMATEL method to determine the importance of each resilience factor in determining the resilient supplier and fuzzy ANP method was used to prioritize each supplier based on the identified criteria and then by presenting a planning model. Integrated number for optimal order allocation to suppliers introduced and described using the results of this study to identify supply chain resilience as a criterion for supplier prioritization and order allocation, selection of suppliers in this company and other companies Similarly, by collecting the required information of the models to be done systematically and scientifically.

Keywords:

fuzzy numbers, Fuzzy AHP, Fuzzy DEMATEL.

1. Introduction

Due to various advances in industry, companies have tended to invest in more advanced equipment and technologies. Therefore, benefiting from productivity in different industries plays an essential role in the development of the organization. Production systems should increase the productivity process in their organizations day by day, in this section, the issue of proper selection of suppliers is discussed. Suppliers of industrial organizations usually produce parts and the task of management is the appropriate choice of suppliers. The selection of suppliers can be associated with resilience indicators and thus significantly reduce the likelihood of malfunctions. The goal of resilient suppliers is to reduce these disorders. [1] If suppliers do not have adequate resilience, in today's competitive market, businesses will not only be doomed but the entire system will suffer. In this study, the choice of supplier in terms of resilience is considered. Will be paid. If the goal is to select only one supplier, the policy is usually to choose the best, but in the case of multiple suppliers, it will matter how many suppliers are ordered. [2] Any disruption in the supply chain can cause many problems for everyone involved in the chain. These events can have a significant impact on business. With the globalization of the economy, companies and organizations have moved towards wider joint activities day by day. Although there are still many shortcomings in various organizations. [3] Because suppliers are outside the organization, they can carry many external risks for any organization that must be carefully assessed and calculated. The concept of supply chain resilience was first popularized by Shafi. [4] Therefore, paying attention to the concept of resilience is one of the most important issues that should be considered in supply chain studies. The theory of fuzzy sets was first introduced by (Zadeh, 1965) and uses verbal variables in the decision-making process. After the introduction of fuzzy sets, (Bellman and Zadeh, 1970) it has been used in multi-fuzzy decision making to solve the reduction of the accuracy of the evaluation of the weight of the indicators and the rate of options based on the indicators. Verbal variables are variables whose value is expressed linguistically. Verbal variables are a useful concept and tool in complex situations and are used quantitatively in the absence of sufficient reasons to express and describe the variables (Zadeh, 1975). For example, "significance" is a verbal variable whose values include trivial, slightly important, relatively important, important, and very important. These linguistic values can be expressed by triangular fuzzy numbers. For example, insignificant (0, 0.1, 0.3), slightly important (0, 0.2, 0.5), relatively important (0.3, 0.45, 0.7), important (5 / 0, 0.7, 0.8), very important (0.7, 0.9, 1). Decision makers / experts must have a thorough understanding of the meaning of these verbal values and their corresponding fuzzy numbers before assigning verbal values to various factors. [5]

2. Research method

A) Experimental background

The basics of supplier selection and order allocation have been investigated using the two main approaches of multi-criteria decision making and mathematical planning. In Mathematical Planning, Weber et al. (1991) conducted a comprehensive review of multi-item supplier selection, multiple suppliers, resource constraints, and discount amounts [4]. In Dahil (2003), a multi-objective integer programming model (MOMIP1) was developed to determine the number of suppliers and the order quantity [6]. Shahbandarzadeh and Pikam (2015) presented a weighted multi-objective fuzzy planning model to determine the optimal purchase amount from suppliers [7]. In a research, a two-stage model with a fuzzy approach to supplier selection and order allocation was discussed, so that in the first stage, a fuzzy multi-objective model was used to evaluate and select a supplier according to subjective actions, and in the second stage, The ideal planning approach was used to determine the amount of order allocated to the supplier and the maximum-minimization method was used to convert the fuzzy multi-objective model to a fuzzy one-purpose model [8]. Terp and Sarkis (2016) presented an integer planning model for supplier selection and procurement allocation under sustainability considerations [9]. Hassani and Mohammadi Tabar (2018) presented a multi-cycle model for determining the number of orders in a three-tier supply chain considering the possibility of simultaneous ordering [10]. In the multi-criteria decision-making category, Eidi and Bakhtiari (2016) addressed the issue of evaluating and selecting suppliers in a green supply chain using a hierarchical fuzzy TOPSIS method based on alpha levels in a case study [11]. In a similar study, by combining two approaches of network analysis process (ANP and Vickor, the ranking of suppliers in a fuzzy environment was studied [12].

Namdar et al. Have developed the design and structure of resilient supply chains with a focus on strategies that reduce the impact of disruptions on customers. The selection of suppliers is based on the characteristics that make the supply chain resilient. Selected suppliers are called resilient suppliers. Resilient suppliers are suppliers who are able to supply the required materials and products with good quality, reasonable economic rates, with sufficient flexibility to respond to changes in demand, with minimal risk of delivery time. And without endangering safety and the environment. [15]

Arsalan Zahed studied the effect of integration on supply chain resilience in supply chain performance in large manufacturing companies in Pakistan and concluded that the integration of domestic and foreign supply chain members can reduce the impact of supply chain disruptions due to uncertainty. (14)

Alessandra Wake et al. In 2021 in an article Three questions about resilient supply chain including 1. What is a resilient supply chain? 2. Why do companies need to build a resilient supply chain? 3. How to create flexibility? And show the most effective way to create flexibility by reviewing some short case studies that have been purposefully selected to present and implement practically some of the different techniques used to create flexibility. (13)

B) Fuzzy dimethyl The Dematel method was first developed by BMA in Geneva in 1971. At that time, this tool was used to study complex problems and solve them. Is complex / Demeter's method considering complex systems and directly compares the relationships between different factors in the system / This method uses a matrix to show all direct and indirect relationships and the level of influence between the factors / In addition It also provides a visual structure in the form of a cause-and-effect diagram to show the relationships between factors and simplify the problem for decision making (19). The fuzzy version of Dematel is more suitable than the non-fuzzy version to reduce uncertainty and have reliable results. After the overall purpose of the decision problem and the elements were evaluated and a group of experts were properly selected. We now describe the steps to implement this method.

1) Definition of the Fuzzy Language Scale Used to Evaluate System Elements The language variable defines five evaluation languages, each positive with a triangular fuzzy number a = ((L_{ij}, M_{ij}, U_{ij}) Are related, as shown in Table 5. (18)

Table 1. Verbal variables and fuzzy numbers

Verbal variables	Triangular fuzzy numbers
Very little importance	(0،0،0/25)
Low importance	(0، 0/25، 0/5)
Medium importance	(0/25، 0/5، 0/75)
important	(0/5، 0/75، 1)
Very important	(0/75 ،1 ،1)

2) The construction of the initial decision matrix A is in fact derived from the simple mean of all the opinions that a = ((L_{ij}, M_{ij}, U_{ij}) are the dimensions of a triangular fuzzy number. (16)

$$A = \begin{bmatrix} a_{11} & a_{12} & a_{13} & \cdots & a_{1n} \\ a_{21} & a_{22} & a_{23} & \cdots & a_{2n} \\ \cdots & \cdots & \cdots & \cdots & \cdots \\ \cdots & \cdots & \cdots & \cdots & \cdots \\ a_{n1} & a_{n2} & a_{n3} & \cdots & a_{nn} \end{bmatrix}$$

Relationship (1)

Normalization of matrix A to matrix S, Equation 2 is used for normalization. (17)

Relationship (2)

$S = s \times A$

$$s = \min\left[\frac{1}{\max\limits_i \sum_{j=1}^{n} |a_{ij}|}, \frac{1}{\max\limits_j \sum_{i=1}^{n} |a_{ij}|}\right]$$

$$R_i = \left[\sum_{i=1}^{n} m_{ij}\right]_{1\times n}$$

3) In this step, the matrix M for each fuzzy limit a = ((L_{ij}, M_{ij}, U_{ij}) is calculated by Equation 3.

$M = S(I - S)^{-1}$

Relationship (3)

Then each of the lower, middle and upper bounds is combined and a new matrix is obtained.

Relationship (4)

$$\bar{A}=\begin{bmatrix}\bar{a}_{11} & \bar{a}_{12} & \bar{a}_{13} & \dots & \bar{a}_{1n}\\ \bar{a}_{21} & \bar{a}_{22} & \bar{a}_{23} & \dots & \bar{a}_{2n}\\ \dots & \dots & \dots & \dots & \dots\\ \dots & \dots & \dots & \dots & \dots\\ \bar{a}_{n1} & \bar{a}_{n2} & \bar{a}_{n3} & \dots & \bar{a}_{nn}\end{bmatrix}$$

4) Each a_{ij} of the matrix a_{ij} using the interface 4 becomes a definite number. (16)

Relationship (5)

$$V=\frac{(I+4M+U)}{6})$$

5) The sum of line elements for each factor indicates the degree of influence of that factor on other factors of the system (the degree of influence of variables).

The sum of the column elements for each factor indicates the degree to which that factor is affected by other factors in the system (the degree to which variables are affected). Which is shown in Table

Relationship (7)

$$R_i=\left[\sum_{i=1}^{n} m_{ij}\right]_{1\times n}$$

$$D_i=\left[\sum_{j=1}^{n} m_{ij}\right]_{n\times 1}$$

They used the CFCS model proposed by Apprevik and Zang for decapsulation. Due to the computational complexity of this method, a shift in the target occurred. Most subsequent researchers limited the fuzzy computations of the MCDM technique to the CFCS decoupling algorithm. This means that the opinions of experts are fuzzily entered into the direct communication matrix. The same matrix is then fuzzy with the CFCS pattern. The resulting definite matrix is selected as the initial matrix and the other steps continue in the definite method. The steps for implementing this method are as follows.

The CFCS method consists of a five-step algorithm as follows: Step 1: Normalization of values:

$$\Phi_{min}^{max}=\max u_{ij}^{t}-\min l_{ij}^{t} \quad (8)$$

$$l_{ij}^{n}=\frac{\left(l_{ij}^{t}-\min l_{ij}^{t}\right)}{\Phi_{min}^{max}} \quad 9$$

$$m_{ij}^{n}=\frac{\left(m_{ij}^{t}-\min l_{ij}^{t}\right)}{\Phi_{min}^{max}} \quad 10$$

$$u_{ij}^{n}=\frac{\left(u_{ij}^{t}-\min l_{ij}^{t}\right)}{\Phi_{min}^{max}} \quad 11$$

$$l_{ij}^{s}=\frac{m_{ij}^{n}}{\left(1+m_{ij}^{n}-l_{ij}^{n}\right)} \quad 12$$

$$u_{ij}^{s}=\frac{u_{ij}^{n}}{\left(1+u_{ij}^{n}-m_{ij}^{n}\right)} \quad 13$$

The maximum value of the upper limit is subtracted from the minimum value of the lower limit to calculate the minimum to maximum interval.

Calculate the total normalized definite value

$$x_{ij}=\frac{\left[l_{ij}^{s}*\left(1-l_{ij}^{s}\right)+u_{ij}^{s}*u_{ij}^{s}\right]}{\left[1-l_{ij}^{s}+u_{ij}^{s}\right]} \quad 14$$

Calculate definite values Relationship (6)

$$Z_{ij}=\min l_{ij}^{n}+\left(x_{ij}*\Phi_{min}^{max}\right) \quad 15$$

According to the identification of 24 indicators, they are numbered based on 1c to 24c and subsequent analyzes are performed based on this approach.

Table2:patten of meaningful relationship

12C	11C	10C	9C	8C	7C	6C	5C	4C	3C	2C	1C	T
1	0	1	0	1	1	0	0	0	1	0	0	**1C**
1	0	1	0	1	0	0	0	0	1	0	0	**2C**
0	1	1	1	1	1	1	0	0	0	0	1	**3C**
0	0	1	0	0	0	1	1	0	0	1	1	**4C**
1	0	0	0	0	0	0	1	0	0	0	0	**5C**
1	0	1	1	1	0	1	1	1	1	1	0	**6C**
1	1	0	1	0	1	1	0	1	0	0	1	**7C**
0	0	0	0	0	0	0	1	0	1	1	1	**8C**
1	1	1	0	0	1	1	1	1	0	0	0	**9C**
1	1	0	1	1	1	1	1	1	1	1	1	**10C**
0	0	1	0	1	1	1	1	1	1	1	0	**11C**
1	0	1	0	1	0	0	0	0	1	0	1	**12C**
1	1	1	1	1	1	1	0	0	0	0	0	**13C**
1	0	0	0	0	1	1	1	1	0	1	1	**14C**
0	0	0	0	0	0	0	1	0	0	0	0	**15C**
1	0	1	1	1	0	0	0	1	1	1	1	**16C**
0	1	0	1	0	1	1	0	1	0	0	1	**17C**
0	0	0	0	0	0	0	0	0	1	1	1	**18C**
1	1	0	1	0	0	0	0	0	0	0	0	**19C**
1	1	0	1	1	1	1	1	1	1	1	1	**20C**
0	1	0	0	0	0	1	1	1	1	1	1	**21C**
1	0	1	1	0	1	0	0	0	0	0	0	**22C**
0	0	1	1	1	1	1	0	1	1	1	1	**23C**
1	0	1	1	1	1	1	1	0	1	1	0	**24C**

24C	23C	22C	21C	20C	19C	18C	17C	16C	15C	14C	13C	T
1	1	1	1	1	0	0	1	0	1	1	0	**1C**
1	0	0	0	1	1	1	1	1	1	0	1	**2C**
0	0	1	0	0	1	1	1	1	1	1	1	**3C**
1	0	1	0	1	1	0	1	1	0	1	1	**4C**
1	1	1	1	1	0	0	0	0	1	1	1	**5C**
0	0	0	0	0	1	1	0	1	1	0	1	**6C**
0	0	0	0	0	1	1	0	1	1	0	0	**7C**
1	1	1	0	0	1	1	1	1	0	1	0	**8C**
1	0	1	1	1	0	0	0	0	1	0	0	**9C**
0	0	0	0	0	0	0	1	1	0	0	0	**10C**
1	0	0	0	0	0	0	0	1	0	0	1	**11C**
0	0	1	0	1	1	0	1	1	0	0	1	**12C**
0	1	1	1	1	1	0	0	1	0	1	0	**13C**
0	1	0	1	0	0	0	0	1	0	1	1	**14C**
1	1	1	1	1	0	1	1	0	0	1	1	**15C**
0	1	0	0	1	1	1	0	1	1	0	1	**16C**
0	1	0	1	0	1	1	0	1	1	1	1	**17C**
0	1	1	1	0	1	1	0	1	1	1	0	**18C**
1	1	1	1	1	1	0	1	0	1	0	0	**19C**
0	1	0	0	0	0	1	1	1	1	0	0	**20C**
0	1	0	1	0	0	1	1	0	1	1	1	**21C**
1	1	1	1	0	1	1	1	0	1	0	0	22C
0	0	0	0	1	1	0	0	0	0	1	0	23C
1	1	0	1	0	0	1	0	0	1	0	0	24C

Table 3. Resilience indicators identified in the pharmaceutical industry.

Resilience index	Code	Resilience index	Code
Order delivery time	C1	Service flexibility	C13
Delivery reliability	C2	Emergency order processing	C14
Quality of distribution network	C3	Ability to reduce costs	C15
transport cost	C4	Product volume flexibility	C16
Order cost	C5	exchange rate	C17

Resilience index	Code	Resilience index	Code
Manpower costs	C6	Sanctions	C18
Inventory cost	C7	Political factors	C19
Insurance coverage	C8	Government laws and regulations	C20
Reputation and performance history	C9	natural disaster	C21
Technology development for the future	C10	Fake drugs	C22
Safety	C11	Taxation	C23
Transparency	C12	War	C24

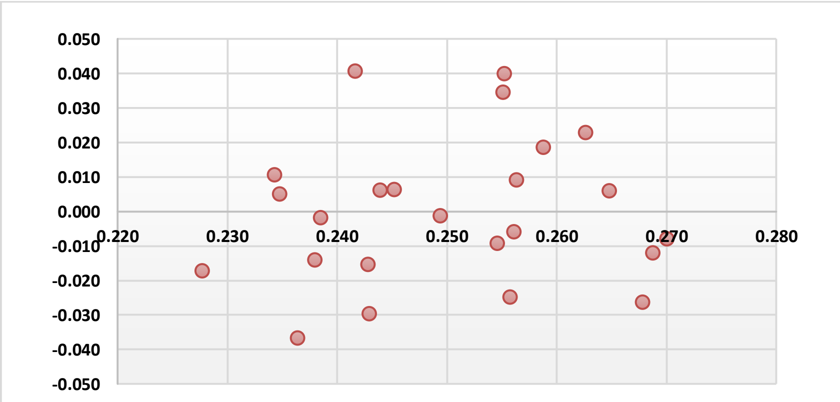


Figure 1 Diagram of the relationship of each of the factors

C) Triangular fuzzy numbers

According to fuzzy set theory, a fuzzy number is a special fuzzy set as $\tilde{A}$ = x ∈R / $\mu_{\tilde{A}}$ (x) in which x accepts the real values of the member of the set R and its membership function as $\mu_{\tilde{A}}$ (x) is. A triangular fuzzy number A with the membership function of linear fractions μA is defined as Equation (3-1):

(16)

$$\mu_x(x) = \begin{cases} (x-l)/(m-l) & l \le x < m \\ 1 & x = m \\ (u-x)/(u-m) & m < x \le u \\ 0 & otherwise \end{cases}$$

l: Lower bound
m: The most probable case
u: High boundary
Which can be represented as a triangular fuzzy number (l, m, u). Figure 3-2 shows this membership function.

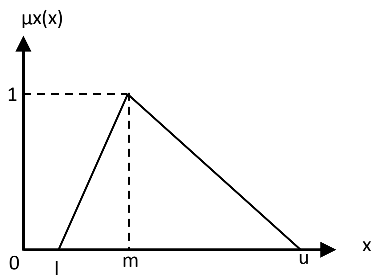


Figure (2) Triangular fuzzy number (Hourly, 1970)

In this study, verbal variables have been fuzzy to determine the importance of the indicators according to the triangular fuzzy numbers in Figure 2.

D) ANP method

The term ANP stands for Analytical Network Process. The network analysis process or ANP is another series of decision-making techniques that is very similar to the AHP method. Each method is based on a series of hypotheses. For example, if the criteria are independent of each other and pairwise comparisons are possible, the appropriate decision model is the AHP model, but if the criteria are not independent, the ANP method is better (Semanligolo, 2016). In this method, network analysis allows the decision maker to build a network instead of a hierarchy. This also makes it possible to examine the internal relationship between the elements. The nodes in this network are equivalent to criteria or options, and the branches that connect these nodes are also equivalent to their degree of interdependence. Determining the relationships in the network structure or determining the degree of importance of interdependencies between criteria and options is the most important task of the network analysis method. Communication and dependency can be in the form of communication between different levels of the network externally or internally.

First the formation of a modified dimatel matrix

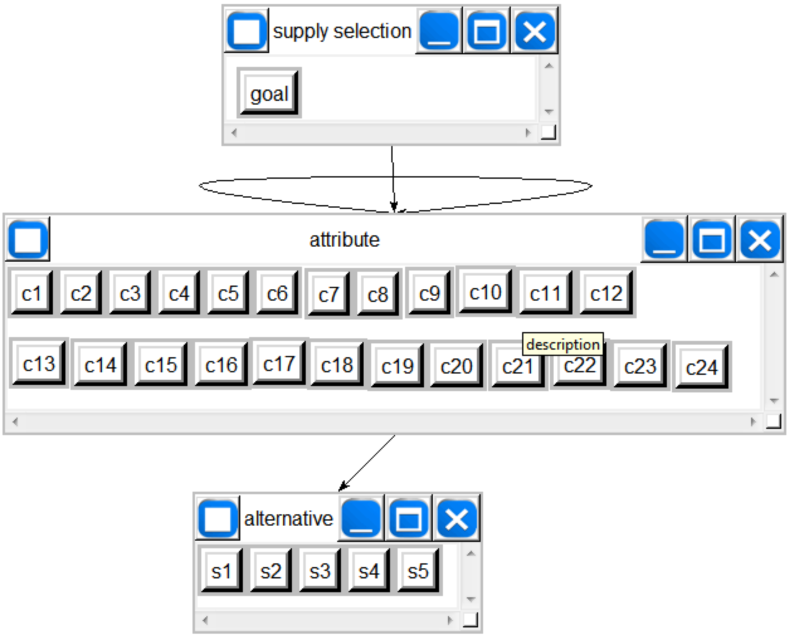


Figure (3) modified dematel

Then form a pairwise comparison matrix

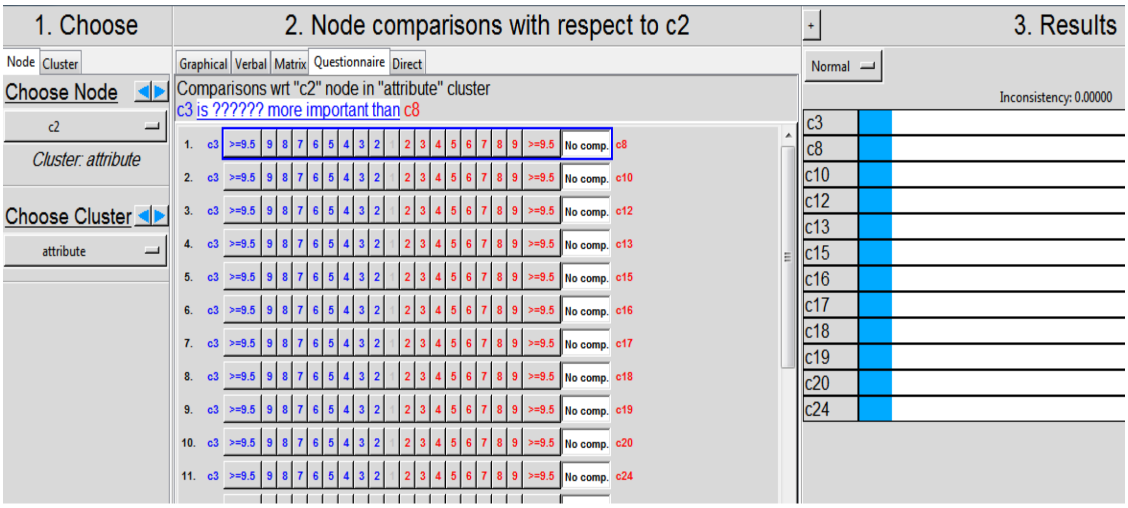
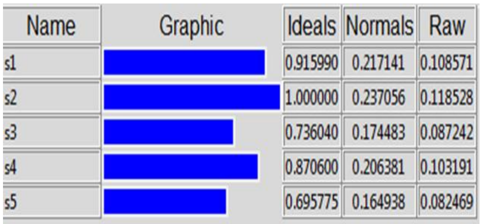


Figure4 formation of pairwise comparison matrix

The relative importance of each member of the set at its own level is similar to the hierarchical analysis method using a set of pairwise comparisons, the results of which are shown in Figure 1.



Name	Graphic	Ideals	Normals	Raw
s1		0.915990	0.217141	0.108571
s2		1.000000	0.237056	0.118528
s3		0.736040	0.174483	0.087242
s4		0.870600	0.206381	0.103191
s5		0.695775	0.164938	0.082469

Chart 1 - Supplier Ranking

Indices and collections

i: Supplier Index i = 1, 2…, n
j: Supply index j = 1, 2…, m
k: k feature of each supply k = 1, 2…, Kj
r: r's feature of each supplier r = 1, 2…, R

parameters:

The value of the k characteristic of the product j of the supplier i: aijk Is equal to 1 if supplier i supplies product j otherwise it is zero.

Supplier risk i Ri
The minimum value expected by the supplier from the sum of product features j aj
The cost of providing the package offered by the supplier i Ci
Transportation cost of supplier i TCi
Quality r’s supplier feature i qir

Decision variables:

$X_{1:}$ Select a supplier in the first step
$Y_{i:}$ Selecting a supplier in the second step

Mathematical model:

(17) $Z_1 = \max \sum_i \sum_r q_{ir} X_i$
(18) $Z_2 = \min \sum_i (C_i + TC_i) y_i$
(19) $Z_3 = \min \sum_i \tilde{R}_i y_i$
(20) $X_i \leq M\lambda_i \quad \forall i$
(21) $1 \leq \sum_i b_{ij} X_i \leq n_j \quad \forall i$
(22) $a_j - \sum_k a_{ijk} \leq M(1 - \lambda_i)$
(23) $y_i \leq M X_i \quad \forall i$
(24) $X_i \in \{0,1\} \quad y_i \in \{0,1\} \quad \lambda \in \{0,1\}$
(25) $\sum_i b_{ij} y_i = 1 \quad \forall i$

Constraints 1 and 2 imply that if the sum of the weights of the characteristics of the item proposed by the supplier is less than the total weight considered by the buyer for that item, then the supplier will be excluded from the supply situation. For example, we consider 4 attributes for each item. Supplier 1 sends us 4 features. We calculate its score based on Multi-Index Decision Methods (ANP) and compare it with the score we have assigned to that item. If the score of items 1 of Supplier 1 is greater than or equal to the score intended for our item 1, the left of limit 1 is negative and therefore can choose values 0 and one, and supplier 1 can be selected. But if the left side is positive, that is, our score is higher than the supplier's score, then Landa must be zero, and in limit 2, the smaller X is equal to zero, which is chosen to be zero, and the supplier is not selected. Constraint 3 indicates that the maximum number of suppliers for an item is equal to the number specified by the buyer, which is true if the number of suppliers bidding for that item is less than this number, and if there is more, the model in the first stage, it chooses the maximum amount determined by the buyer means N_j, constraint 4 indicates that only the suppliers in the second stage are evaluated who are selected in the first stage. Constraint 5 also means that only one supplier can be selected to supply each item to meet the constraint. Constraints 1 and 2 indicate that the total weight of the item properties offered by the supplier is less than the total weight considered by the buyer for that item Then that supplier goes out of supply. For example, we consider 4 attributes for each item. Supplier 1 sends us 4 features. We calculate its score based on Multi-Index Decision Methods (ANP) and compare it with the score we have assigned to that item. If the score of items 1 of Supplier 1 is greater than or equal to the score intended for our item 1, the left of limit 1 is negative and therefore can choose values 0 and one, and supplier 1 can be selected. But if the left side is positive, that is, our score is higher than the supplier's score, then Landa must be zero, and in limit 2, the smaller X is equal to zero, which is chosen to be zero, and the supplier is not selected. Constraint 3 indicates that the maximum number of suppliers for an item is equal to the number specified by the buyer, which is true if the number of suppliers bidding for that item is less than this number, and if there is more, the model in the first stage, it chooses the maximum amount determined by the buyer, N_j, constraint 4 indicates that only the suppliers in the second stage are evaluated who are selected in the first stage. Constraint 5 also means meeting only one supplier to meet each item in order to meet the constraint.

Research results and suggestions

Considering that so far, the selection of suppliers has been done according to the needs of the company and in order to satisfy it, based on the intuitive judgments of the experts and the experts have been comparing the suppliers based on their own judgments, it is suggested from now on using the results of this study, the selection of suppliers in this company and other similar companies, by collecting the information required by the models to be done systematically and scientifically.

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