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FUZZY MODEL FOR PRIORITIZING DISTRIBUTION CENTER WITH MULTIPLE CRITERIA, A CASE STUDY

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ABSTRACT:
A company must deliver or distribute lots of diversified products to several distribution centers throughout the country from its storages or distribution department. 'Distribution center selection problem' is concerned with how to select the ultimate distribution centers from the potential set so that decision can be taken promptly based on optimized input criteria. However, it is not only a very complicated and demanding task for decision makers to select the most beneficial distribution center, but also it implicates uncertainty and produces erroneous results if single criterion is considered. As traditional methods are not very appropriate to analyze the priority with multiple criterions, the decision makers of the company require an efficient, reliable and promising tool to help them in selecting the best distribution center. This paper proposes a new method for prioritizing the distribution center by using MATLAB Fuzzy Logic Tool box to help the distribution department in selecting the most deserved distribution center. The main task in the proposed model involves determining the numerical score for distribution centers considering their respective performance in various qualitative and quantitative evaluation criteria and then selecting the most beneficial distribution center having highest score. Thus best distribution center for a local big Ice-cream company was found and it was finally known that the company used the same distribution center by thumb rule. Thus it can be said that the administration of the company got a technically sound basis for selection.

Keywords: Fuzzy Logic, Supply Chain Management, MATLAB, Distribution process of goods.

1. Introduction:

A distribution center is that through which a company or an organization delivers its products or services to the potential customers. As customers are the main focus point of an organization and their demands are served by the distribution centers, so the distribution centers deserve considerable attention of management. A dedicated distribution management system is often required for smooth flow of operations in distribution centers. A distribution center acts as a regional central point / place for the distribution of its products / services ultimately to the customers of a company / organization in a particular region. So, the performance of distribution centers directly or indirectly, affects the image of the organization. Distribution centers are set up strategically throughout the country. Some distribution centers may not be fruitful for the company. But it might be necessary to establish from the viewpoint of the competitive advantage. So it is essential to evaluate and prioritize the distribution centers based on their performance and beneficence. Apparently it seems to the management of distribution centers that it is an easy job but the situation becomes critical when several distribution centers submit their demands at a time and the organization do not have sufficient inventory of products to meet the demands of all the distribution centers. The management has to take decision like which demand of which distribution center will have to be satisfied first. And that makes complex the whole situation. So, a logical and mathematical model for this type of decision making can be very convenient and useful to the managers and through this decision makers can raise their confidence level in time of decision making.

Fuzzy Logic Toolbox in MATLAB is a tool for solving problems with multiple criteria. This paper presents a methodology which is based on fuzzy logic approach to provide a better way of decision making on prioritizing the distribution centers that will dictate which center should be delivered first. The most important factors like demand, sales, profit contribution, lead time and transportation cost are taken into account in modeling the problem. The result shows that the prioritization of distribution centers varies with the variations in the considered situation. The outcome of this model will represent a distinct numerical ranking value for each of the distribution centers. As multiple criteria decision making is quite complex, it is hoped that this modeling approach will surely be an outstanding helping hand for the decision makers.

2. Methodology of the study / research:

In order to carry out this study, steps that have been followed are mentioned below:

i. Identification of multiple criteria which influence the priority ranking of the distribution centers across the country.
ii. Defining the rules by some basic logic and conceptions for relating the inputs with the output.
iii. Selecting the membership function and range for each criteria and sub criteria (i.e. low, medium, high)

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iv. Evaluating the surface for effective and valid development of the rules generated during the research.
v. Developing the data and finding the output decision for prioritizing the distribution center.

3. Basics of Fuzzy Modeling:

3.1 Fuzzy Set Theory:

Zadeh (1965) came out with the fuzzy set theory to deal with vagueness and uncertainty in decision making in order to enhance precision. Thus the vague data may be represented using fuzzy numbers, which can be further subjected to mathematical operation in fuzzy domain. Thus fuzzy members can be represented by its membership grade ranging between 0 and 1. A triangular fuzzy number (TFN) M is shown in figure:

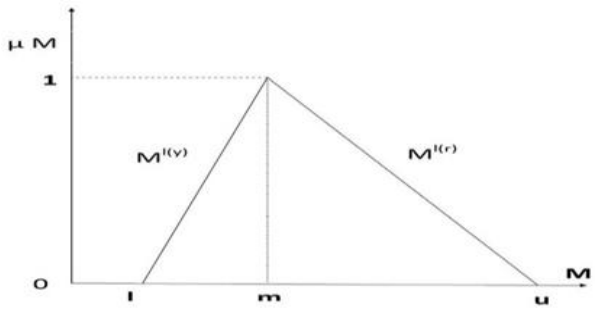

Fig.1: A Triangular Fuzzy Number

A TFN is denoted simply as (l/m, m/u) or (l, m, u), represented the smallest value, the most promising value and the largest possible value respectively. The TFN having liner representation on left and right side can be defined in terms of its membership function as

$$\mu(x/M) = \begin{cases} 0, & x<1, \\ (x-l)/(m-l), & l \le x \le m, \\ (u-x)/(u-m) & m \le x \le u, \\ 0, & x>u, \end{cases}$$

A fuzzy member with its corresponding left and right representation of each degree of membership is as below:

$\tilde{M}=(M^{l(y)}, M^{l(r)})= (l +(m-l)y, u+(m-u)y), y \in [0,1]$

Where l(y) and l (r), denotes the left side representation and the right side representation of fuzzy number respectively.

The fuzzy summation and fuzzy subtraction of any two TFN are also TFNs, but the multiplication of any two TFNs is only approximate TFNs. The data can be assessed using the linguistic scale along with corresponding triangular fuzzy scale.

If $M_1= (a_1, b_1, c_1)$ and $M_2= (a_2, b_2, c_2)$ are two TFNs, then their operational laws can be expressed as follows:

$M_1+M_2= a_1+ a_2, b_1+b_2, c_1+c_2$

$M_1-M_2= a_1-a_2, b_1-b_2, c_1-c_2$

$M_1*M_2=a_1a_2, b_1b_2, c_1c_2$

$\lambda *M_1 =\lambda a_1, \lambda b_1, \lambda c_1$ where $\lambda > 0, \lambda \in R$

$M_1^{-1} = (1/c_1, 1/b_1, 1/a_1)$

3.2 Fuzzy inference system (FIS):

Fuzzy inference system is also known as fuzzy rule based system, fuzzy models, fuzzy associative memories (FAM), or fuzzy controllers when used as controllers.

i. A rule base containing a number the membership function
ii. A database which defines the membership functions
iii. A decisions-making unit which performs the inference
iv. A fuzzification interface which transforms the crisp inputs
v. A defuzzification interface which transform the fuzzy

Usually, the rule base and the database are jointly referred to as the **knowledge base.**

The steps of fuzzy reasoning (inference operations upon fuzzy if-then rules) performed by fuzzy inference systems are

i. Compare the input variables with the membership functions on the premise part to obtain the membership values (or compatibility measures) of each linguistic label. (This step is often called fuzzification).
ii. Combine (through a specific T-norm operator, usually multiplication or min) the membership values on the premise part to get firing strength (weight) of each rule.
iii. Generate the qualified consequent (either fuzzy or crisp) of each rule depending on the firing strength.
iv. Aggregate the qualified consequence to produce a crisp output. (This step is called defuzzification.)

4. Prioritize Distribution Centers:

Distribution refers to the steps taken to move and store a product from the supplier stage to a customer stage in the supply chain. Distribution is a key driver of the overall profitability of a firm because it affects both the supply chain cost and the customer experience directly.

A distribution center is a principal part, the order processing element, of the entire order fulfillment process. Distribution centers are usually thought of as being demand driven. So when we prioritize ranking of the distribution centers we only consider demand. But the demand is the only one of many factors that affect the overall profitability of the firms for prioritizing the distribution centers. When assessing and selecting the distribution center according to priority the following factors other than quoted demand must be considered:

a. Demand
b. Sales
c. Profit-Margin
d. Lead-Time
e. Transportation-Cost

Distribution centers must be prioritized on each of these factors because they all affect the total profitability and effective functioning of the firms.

Local Ice-cream Industries Limited is a renowned ice-cream industry in Bangladesh. For its smooth flow of operation and distribution across the country, the company has set up 16 distribution centers at different locations of the country. The whole country is served through these distribution centers. The company's 16 distribution centers are –

1. Dhaka North	2. Dhaka South
3. Dhaka East	4. Dhaka West1
5. Dhaka West2	6. Dhaka Institute
7. Dhaka Trolley	8. Khulna
9. Barisal	10. Jessore
11. Rangpur	12. Bogra
13. Rajshahi	14. Comilla
15. Sylhet	16. Chittagong

Here in our thesis, we have developed a model by using Fuzzy logic multi-criteria decision making (MCDM) and using MATLAB. Different distribution centers have been ranked/prioritized based on those criterions. The combined effect of all these criterions on different distribution centers is shown and specific ranking point is attached to the centers.

5. Rule Formation:

In the proposed model, five input variables are used to prioritize distribution center of a company. The five variables are Demand, Sales volume, Lead time, Profit margin, Transportation cost. All of them have three divisions- High, Medium, Low. So there may be many combinations to formulate different rules using the input, the total number of rules in this model is 3X3X3X3X3 or 243. Rules are generated with five stated inputs using "and" command.

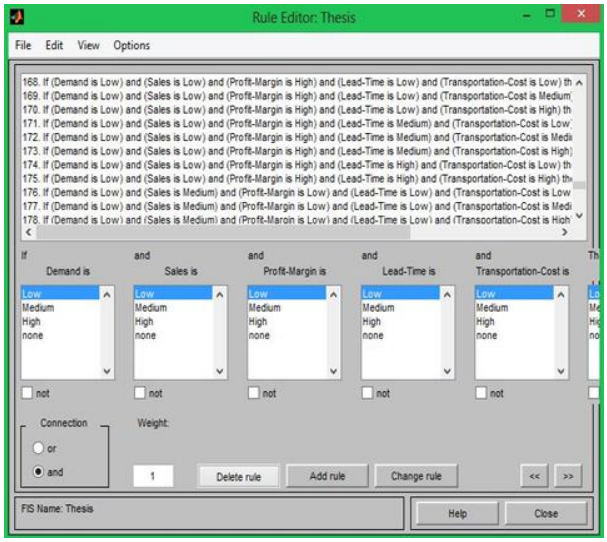

Fig.2: Rule editor

In rules generation, weighted method is used (between 0 – 1). Here one (1) is used for highest importance and lower than one (1) is used to identify relatively lower importance respectively. Like 0.7 is described lower weightage than 0.85.

For instance, comparing two DCs, criteria's for the first one are high demand, low sales, low profit-margin, low lead-time and high transportation-cost then priority-ranking is low (0.74) i.e. weightage value is 0.74. On the other hand, criteria's for the second one are high demand, high sales, high profit-margin, medium lead-time and low transportation-cost then priority-ranking is high(1) i.e. weightage value is 1.

6. Surface Viewer:

Surface actually represents the three dimensional relationship between various input and output. The variation in output against the input variables depends on the developed rules. The very random fluctuations in surface represent the weakness and at the same time indicate erroneous development of the rules generated. With a view to representing the sustainability and strength of the developed rule the surfaces should exhibit an approximate ascending and descending pattern. Throughout our work, we tried our best to ensure a reasonable approximate for ascending and descending pattern. Even though, the surface represented in our model exhibit some sort of ups and downs, but it can be considered as almost correct because all of the rules could not have been generated due to time constraint. If all of the possible rules could have been developed, it can be said for surity that the surface would have been more accurate. But, Generating such number of huge rules would be not only tedious but also time consuming and perhaps infeasible to some extent.

Surface analysis from some selected inputs which was obtained from MATLAB Fuzzy Toolbox is given below in figure 3 and 4.

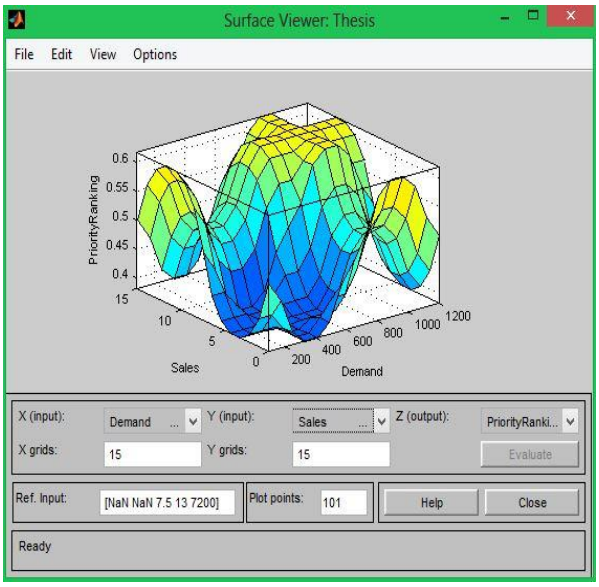

Fig.3: Surface for Demand vs Sales

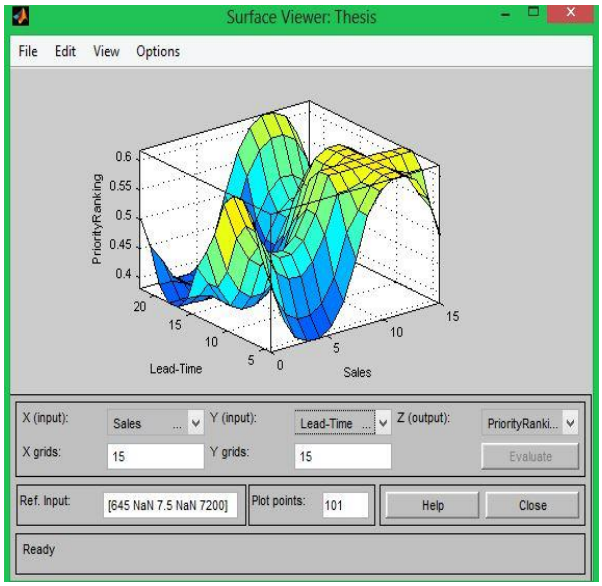

Fig.4: Surface for Sales vs Lead Time

7. Result and Analysis:

In this section, priority ranking of the distribution center has been determined. This priority ranking represents the distribution center based on the predetermined input criterions. To determine the ranking, Fuzzy toolbox of MATLAB software has been used. Finally, from this priority ranking the most beneficial distribution center for delivering the ordered amount has been selected.

From our observation, we have seen that **(table-1)** the most beneficial distribution center is "Dhaka East" whose priority ranking is 0.747.

The applied fuzzy logic on "Dhaka East" distribution center is shown below:

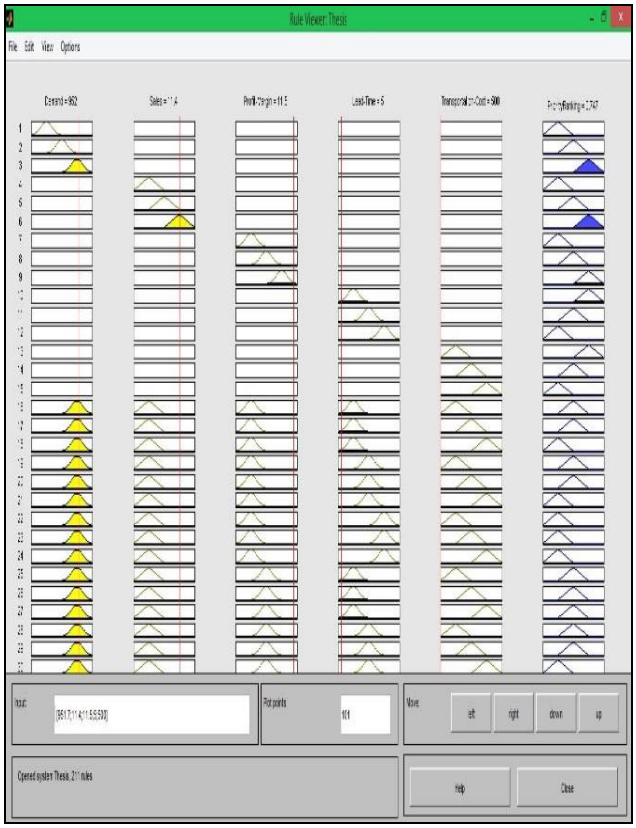

Fig.5: Highest ranked distribution center

Table 1: Priority Evaluation of Distribution Centers Based On MCDM

Center No.	Distribution Centre	Input Variables					Priority Ranking
		Demand (m^3)	Sales (%)	Profit (%)	Lead time (hrs.)	Transportation cost (Taka)	
1	Dhaka North	1127.026	13.5	7	6	5340	0.582
2	Dhaka South	1193.813	14.3	9.5	6	800	0.733
3	Dhaka East	951.711	11.4	11.5	5	500	**0.747**
4	Dhaka West1	989.2785	11.85	8	6	800	0.624
5	Dhaka West2	955.8852	11.45	7.5	6	500	0.619
6	Dhaka Institute	108.5284	1.3	5	6	500	0.42
7	Dhaka Trolley	91.83176	1.1	5.5	6	800	0.42
8	Khulna	258.7986	3.1	4	20	13620	0.25
9	Barisal	166.9668	2	4	16	13620	0.31
10	Jessore	166.9668	2	4	15	13620	0.368
11	Rangpur	166.9668	2	4	11	13670	0.46
12	Bogra	175.3152	2.1	5	9	9590	0.5
13	Rajshahi	166.9668	2	4	11	11630	0.444
14	Comilla	705.4349	8.45	6.2	8	5160	0.528
15	Sylhet	267.1469	3.2	6.8	11	9940	0.443
16	Chittagong	855.7051	10.25	8	18	10000	0.496

8. Conclusion:

Prioritization of the distribution center is undoubtedly crucial for any company when order is placed by several distribution centers at a time. The company might not have sufficient inventory of finished product to fulfill the order of all the ordering distribution centers. The company may fall in a dilemma to decide which distribution center's demand will be met and delivered first. Prioritizing the distribution center depends on multiple criterions, we think, massive uncertainty can be involved in this regard. At present, many companies use thumb rule and their past experiences to decide about such complex situation. But it costs a lot of time, mental pressure, decision might be wrong and there is no scientific and logical method to make decisions on it. This uncertain characteristic affiliated with the prioritization of the distribution centers leads to the utilization of fuzzy logic which facilitates the prioritization process by making it credible and accurate. During the generation of the model, at first some criteria have been determined based on which prioritized distribution center has been evaluated. Two hundred and forty three rules have been generated to provide relationship between five inputs and output that is for priority ranking. Finally, output has been calculated numerically and this output was generated according to the rules developed in fuzzy toolbox. The decision regarding prioritizing distribution centers is given by the Mamdani FIS. To generate the output data, all necessary data have been collected from Local Ice Cream Company. At the end of the work, this numerical output has been converted into the alphabetical output with the help of a code developed in MATLAB. In a nutshell, the result obtained represents the prioritized distribution center according to the criteria those have been adopted in the model. The accuracy of the output may be improved by considering many more criteria and those criteria may be varied from company to company. But, In general this is a generalized model and can be applied in different company with the proper determination of the input variables.

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