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Research Article

Modelling the logistic processes using fuzzy decision approach

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Abstract

Logistic processes deal with the information about producing and distributing goods and services from one place to another to fulfill the customer requirements. Every kind of business requires the proper functioning of logistic processes for the success of company or organization. In retail businesses, facility location for logistic processes serves as a backbone and the success or a failure of the company depends upon the geographical location of the company. It is a multiple criteria decision making problem involves multiple criteria to analyze the proper location of a company. In this research work, at first, we developed a multi criteria based structural model in retail facility location selection based on logistic processes. Then by using fuzzy modelling technique, the criteria are converted into triangular fuzzy numbers. We have adopted the technique of order preference similarity to ideal solutions for finding the best alternative. We have also applied the sensitivity analysis on the suggested modelling technique and found the same alternative as best with high degree of certainty which confirms the reliability of the proposed modelling technique.

Keywords: Retail logistic processes, Facility location, Decision making, Triangular fuzzy numbers, Best alternative.

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1. Introduction

Logistic processes deal with the movement of goods, material and other resources like energy and people between the point of origin and point of consumption in order to provide reliable customer service Tseng et al., [22]. It covers the affiliation between the production and the movement of products. It includes the integration of information, inventory, material management and services. The success or failure of any company or organization depends upon the handling of these processes through construction, consumption, storage and disposal. An effective logistic process also depends upon the proper geographical location of all the resources within the organization Mudambi [16].

The main function of logistic processes is to make decisions about manufacturing and distributing goods and services to customers or end users Rushton [18].As part of these processes, locating the right product at right place is the main function of any kind of these processes. It involves the integration of supplies, transportation, warehousing and customer service station. Among all the processes, the purpose of logistics processes is to make decisions about the movement of products to deliver at right time to the right customer Christopher [5].

For any logistic process, site location has a key role which involves multiple factors to analyze for any company or organization Dornier [6].Facility location selection plays a vital role in the strategic decision for any kind of logistic process. It is not very easy to change the location very often. Choosing the suitable facility among a particular set of alternatives is a challenging work requiring both qualitative and quantitative factors surrounded by the other activities of an organization or a company.It plays an important role in a strategic design of a company. It is an extensive and persistent subject, affecting several operational and logistical decisions, and the locational projects generally involve long term investments. Hence a successful facility location for operating the logistic processes would enable a leading edge to the company. On the other hand, a bad facility location is burden and it may damage the company. Once the mistake is made for the location of facility, it becomes tremendously difficult and costly to change it especially in large organizations. Thus, the decision makers mandatory select not only the well performing facility location for operating the logistic processes, but also a profitable facility for the lifetime of a company Mintzberg et al., [13]. For operating the logistic processes in retail, facility location is a key element Mentzeret et al., [12]. It has a strategic importance in making decisions. Selection of site is a strategic decision which is difficult to return. It is considered as a backbone of the whole logistic processes as the end product is finally sent in the retail market. The success or failure of the company or firm depends upon the geographical location of the organization. Due to complicated decision making, the selection of location is essential. A proper site location depends upon the decision-making process where the strategies are planned. There involve many factors that affect the facility location. Thus, it is a multi-criteria decision making process. The main factors that influence the location are terms of lease, cost of development, accessibility, lead time, parking area facility, population coverage and security risk. It is a long-term management process involves the strategic decision making analysis. Business decision makers always work with inadequate and uncertain data. Modelling of logistic processes for facility location is a multiple criteria decision making problem involves several factors. It examines both quantitative and qualitative factors, which are mostly based on uncertain data. Therefore, the conditions under uncertainty are handled by using multiple criteria decision making. While some decisions are quite easy to make, other decisions can be very hard to make, and generally causes a loss of energy and strength. Alike, the information or facts fluctuates very much that are needed for adequate decision making process. Decision making in retail depends upon the judgment of decision makers who proposed their opinion as a strategic partner of the company or organization Abdi et al., [1]. There are different approaches for making decisions.

1.1. Decision analysis. The objective of decision analysis is to develop techniques and help decision makers but not substitute the decision makers. Therefore, decision analysis can be recognized as the process and policy of modelling, weighting and choosing an appropriate action for the given decision problem Kikeret et al., [10]. Decision analysis procedure generally precedes a comprehensive range of tools and a simple methodology in which decision maker breakdowns the problem into controllable parts in order to make it simple. During this development, the decision maker got a good awareness to the problem, analysis complex conditions and regulates an action which is companionable with their values and knowledge.

1.2. Multiple criteria decision making. Decision making in the occurrence of multiple and non-commensurable criteria is called multi-criteria decision making Monghasemi et al., [15]. Logically, in most of the circumstances the criteria are qualitative as well as quantitative that offers uncertainty in decision making process. There are severe practical restrictions in real world decisionmaking scenario because of the existence of vagueness and integral inaccuracy in the formation of criteria. To tackle such kind of problems, fuzzy decision approach is used.

To solve composite decision making problem in an organized way, fuzzy decision approach supports decision makers in reliable and productive way. For the modelling of vagueness on criteria, fuzzy set theory makes it possible to mathematically describe an accurate way. Fuzzy set theory is marked as the birth of new mathematical discipline. It helps to get more realistic mathematical models that can handle the real-world problems. Therefore, this theory is considered as a new way of modelling the decision problems as it offers organized tools to deal with the imprecision present in human judgment. To deal with the qualitative data, mostly in the form of linguistic variable, fuzzy set theory makes it possible to transform them into numbers by using the concept of membership functions and helps decision makers to deal with ambiguity. This theory is basically designed to mathematically present the vagueness and uncertainty inherent to decision to decision making problems. It provides organized tools to handle ambiguity. Fuzzy set theory deals very precisely for this kind of problems Chen et al., [4]. Therefore, the primary objective of this research is to select the best facility location for logistic processes by using the modelling technique of fuzzy decision approach, to tackle the problem of uncertainty and ambiguity. The research methodology is based on fuzzy decision approach for the modelling of logistic processes. In this research work, we applied the concepts of fuzzy set theory to express the opinion of decision makers in linguistic terms to overcome uncertainty for the estimation of qualitative factors. The linguistic judgment is then transformed into fuzzy number. Finally, multiple criteria decision making model based on fuzzy sets theory and fuzzy Topsis has been used to select the best facility location for logistic processes. To deal with conflicting and non-commensurable criteria, the proposed model is applied through triangular fuzzy numbers. Sensitivity analysis is also presented at the end to check out the consistency of the proposed modelling technique.

Under many real-world situations, crisp data is inadequate to deal with real life problems since human judgement are vague and cannot be estimated with exact numeric values. To resolve the ambiguity frequently arising in information from human judgement, fuzzy set theory has been corporate in many multiple criteria decision making problems including Topsis. It is the most classical method for solving multi-criteria decision making problem, was first developed by Hwang and Yoon in 1981.It was further modified by Lai and Liu in 1993. It is based on the principle that the chosen alternative should have the longest distance from the negative ideal solution that maximize the cost criteria and minimize the benefit criteria; and the shortest distance from the positive ideal solution that is the solution that maximize the benefit criteria and minimize the cost criteria. In fuzzy Topsis, all the ratings and weights are defined by means of linguistic variables.A triangular fuzzy number can be denoted as (e, f, g). A fuzzy multi-criteria decision making matrix is constructed as follows, in which possible alternatives are $X_{11}, X_{12}, ..., X_{nm}$ and evaluation criteria are presented as $K_1, K_2, ..., K_m$.

$$D_S = \begin{array}{c} \begin{array}{cccc} K_1 & K_2 & \cdots & K_m \end{array} \\ \begin{bmatrix} X_{11} & X_{12} & \cdots & X_{1m} \\ X_{21} & X_{22} & \cdots & X_{2m} \\ \vdots & \vdots & \cdots & \vdots \\ X_{n1} & X_{n2} & \cdots & X_{nm} \end{bmatrix} \end{array}$$

where $K_1, K_2, ..., K_m$ denotes the different choices for alternative and $X_{11}, ..., X_{nm}$ are the different combinations of criteria and alternatives ratings. The best non-fuzzy number denoted by BNF and crisp values for triangular fuzzy numbers are calculated as

$$C_v = \frac{e + (4 \times f) + g}{6} \tag{1.1}$$

where e, f and g are the corresponding fuzzy numbers and C_v represents the crisp value. After normalization, fuzzy decision matrix is constructed as

$$R = \left[n_{ij}\right]_{m \times n} \quad i = 1, 2, ..., m; j = 1, 2, ..., n.$$

where,

$$n_{ij} = \left(\frac{e_{ij}}{g_j^*}, \frac{f_{ij}}{g_j^*}, \frac{g_{ij}}{g_j^*}\right), \quad g_j^* \neq 0 \; and \; g_j^* = \max(g_{ij}) \quad (\text{profit criteria})$$

And

$$n_{ij} = \left(\frac{e_j^-}{e_{ij}}, \frac{e_j^-}{f_{ij}}, \frac{e_j^-}{g_{ij}}\right), \quad e_{ij} \neq 0, \; f_{ij} \neq 0, \; g_{ij} \neq 0, \; e_j^- = \min(e_{ij}) \quad (\text{price criteria})$$

$$N_j = \frac{X_{ij}}{\sqrt{\sum X_{ij}^2}}, \quad X_{ij} \neq 0 \tag{1.2}$$

Where X_{ij} possible alternatives. Fuzzy positive ideal solution and fuzzy negative ideal solution of the alternatives are calculated as:

$$M^+ = max(N_w) \quad and \quad M^- = min(N_w)$$

Where,

$$N_w = W_{ij} \times \frac{X_{ij}}{\sqrt{\sum X_{ij}^2}}, \quad X_{ij}^2 \neq 0, \quad i = 1, 2, ..., m \; ; j = 1, 2, ..., n.$$

From the fuzzy positive ideal solution and fuzzy negative ideal solution, Euclidean distance for each alternative is given by:

$$D^+(X_j) = \sqrt{\sum_{j=1}^{m} \left\{ W_{ij} \times \frac{X_{ij}}{\sqrt{\sum X_{ij}^2}} - max\left(W_{ij} \times \frac{X_{ij}}{\sqrt{\sum X_{ij}^2}} \right) \right\}^2}, \quad X_{ij}^2 \neq 0$$

and

$$D^-(X_j) = \sqrt{\sum_{j=1}^{m} \left\{ W_{ij} \times \frac{X_{ij}}{\sqrt{\sum X_{ij}^2}} - min\left(W_{ij} \times \frac{X_{ij}}{\sqrt{\sum X_{ij}^2}} \right) \right\}^2}, \quad X_{ij}^2 \neq 0$$

Closeness coefficient CC^+ for each alternative from the distance of (FPIS) and (FNIS) is computed as follows:

$$CC^+ = \frac{D^+(X_j)}{D^+(X_j) + D^-(X_j)}, \quad D^+(X_j) \neq 0, \; D^-(X_j) \neq 0. \tag{1.3}$$

After the identification of location based on closeness coefficient, ranks are provided for each alternative and on the bases of these ranking positions, best alternative is selected.

2. Numerical computation

Multi-criteria decision making method has been used under fuzzy surrounding for the selection of facility location as best alternative in retail logistics. The present research work is based on primary data collection. As the research is based on the decision analysis for logistics processes under fuzzy decision approach, data was collected from the decision makers who operate the logistic processes management in the company. For the application of fuzzy decision approach, fuzzy Topsis model has been used to evaluate and select the most suitable location for the general medical and cash and carry D.Watson store in Islamabad. Different criteria have been developed for the selection of best facility location in retail logistic processes for three alternative places as G-13 markaz Islamabad, G-15 markaz Islamabad and I-14 markaz Islamabad.

2.1. Selection criteria. Modelling of logistic processes in retail for facility location is a complex multi criteria problem. At first stage, we have developed multiple criteria for the alternative places on the basis of strategic planning made by the decision makers for the selection of facility location in retail logistic processes. For evaluating the best possible location in retail logistics, the necessary criteria are computed. Criterion 1 represented terms of lease, criterion 2 represented cost of development, criterion 3 represented the cost of improvement , criterion 4 represented the equipment cost , criterion 5 represented by accessibility, visibility of location represented as criterion 6,criterion 7 shown population coverage, criterion 8 presented the future growth and development, criterion 9 illustrated the distance from competitors, criterion 10 represented the number of located facilities, criterion 11 shown quality of competitors, criterion 12 shown the availability of staff, criterion 3 presented the lead time, criterion 14 presented parking area facility and criterion 15 shown the security risk. A group of 4 decision makers is made to express their personal judgement in linguistic term, for estimating importance ratings for the alternatives.

Table 1. Fuzzy linguistic terms for rating of alternatives

Linguistic term for rating	Fuzzy numbers
Very less suitable	(0,0,0.25)
Less suitable	(0,0.25,0.5)
Medium suitable	(0.25,0.5,0.75)
Highly suitable	(0.5,0.75,1)
Very highly suitable	(0.75,0.75,1)

To provide weightage among different alternatives, four decision makers provide their personal judgment. The following five-member linguistic scale for weighting among each criterion are given where Very Low (VL), Low (L), Medium (M), High (H) and Very High (VH) has been developed.

Table 2. Linguistic terms for priority weights for each criterion

Linguistic variables	Fuzzy numbers
Very Low	(0.00,0.00,0.25)
Low	(0.00,0.25,0.50)
Medium	(0.25,0.50,0.75)
High	(0.50,0.75,1)
Very high	(0.75,1.00,1.00)

Four decision makers or experts allocated weights to each criterion according to their own preferences.

Table 3. Fuzzy importance weights of indices allocated by DMs in linguistic scale

Criteria	DM1	DM2	DM3	DM4
K_1	VH	H	VH	VH
K_2	H	M	L	H
K_3	L	L	L	M
K_4	L	L	L	M
K_5	H	VH	H	VH
K_6	H	VH	H	VH
K_7	M	H	M	M
K_8	M	M	M	H
K_9	L	VL	L	L
K_{10}	VL	L	L	M
K_{11}	L	M	M	M
K_{12}	H	VH	VH	H
K_{13}	VL	M	VL	M
K_{14}	M	H	H	H
K_{15}	H	VH	H	H

Here three different locations are represented as alternatives. Alternative 1 shown by 1 A which represents G-13 Markaz Islamabad, Alternative 2 shown by 2 A which represents G-15 Markaz Islamabad and Alternative 3 shown by 3 A which represents I-14 Markaz Islamabad. Decision makers allocated their preferences in linguistic terms as NS, LS, MS, HS, and VHS, for alternative 1 which are shown in table 4.

Table 4. Rating for alternative 1 in terms of linguistic scale

Criteria	DM1	DM2	DM3	DM4
K_1	VHS	VHS	VHS	VHS
K_2	HS	HS	MS	HS
K_3	LS	HS	HS	MS
K_4	MS	HS	HS	MS
K_5	HS	VHS	VHS	VHS
K_6	HS	HS	HS	VHS
K_7	MS	MS	MS	MS
K_8	MS	HS	HS	HS
K_9	LS	MS	LS	LS
K_{10}	VLS	MS	LS	LS
K_{11}	LS	MS	MS	MS
K_{12}	HS	HS	HS	HS
K_{13}	VLS	MS	HS	MS
K_{14}	HS	HS	VHS	HS
K_{15}	HS	MS	MS	HS

Using the fuzzy functioning rules in equation (1.1) and (1.2), combined fuzzy weights and aggregated fuzzy rating for every selected criterion are estimated. Linguistic variables are then converted into fuzzy numbers. The calculated values of aggregated fuzzy ratings for each alternative are shown in the given table.

Table 5. Aggregated importance ratings for the alternatives

Criteria	Alternatives		
	A1	A2	A3
K_1	(0.75,1,1)	(0.25,0.5,0.75)	(0.5,0.75,0.9375)
K_2	(0.4375,0.6875,0.9375)	(0.1875,0.4375,0.6875)	(0.3125,0.5625,0.8125)
K_3	(0.375,0.625,0.875)	(0.0625,0.25,0.5)	(0.375,0.625,0.875)
K_4	(0.375,0.625,0.875)	(0.1875,0.4375,0.6875)	(0.3125,0.5625,0.8125)
K_5	(0.6875,0.9375,1)	(0.4375,0.6875,0.9375)	(0.1875,0.375,0.625)
K_6	(0.5625,0.8125,1)	(0.25,0.5,0.6875)	(0.5,0.75,1)
K_7	(0.25,0.5,0.75)	(0.125,0.375,0.625)	(0.1875,0.4375,0.6875)
K_8	(0.4375,0.6875,0.9375)	(0.3125,0.5625,0.8125)	(0.4375,0.6875,0.9375)
K_9	(0.0625,0.3125,0.5625)	(0.125,0.3125,0.5625)	(0.1875,0.4375,0.6875)
K_{10}	(0.1875,0.375,0.625)	(0,0.1875,0.4375)	(0.125,0.25,0.5)
K_{11}	(0.1875,0.4375,0.6875)	(0.125,0.3125,0.5625)	(0,0.25,0.5)
K_{12}	(0.5,0.75,1)	(0.3125,0.5625,0.8125)	(0.3125,0.5625,0.8125)
K_{13}	(0.25,0.4375,0.6875)	(0.375,0.625,0.875)	(0.375,0.625,0.875)
K_{14}	(0.5,0.75,1)	(0.25,0.5,0.75)	(0.4375,0.6875,0.9375)
K_{15}	(0.375,0.625,0.875)	(0.125,0.3125,0.5625)	(0.3125,0.5625,0.8125)

The estimated importance ratings and preority weights are transformed the indices into crisp values.
Crisp values for the 3 alternatives based on 15 criteria are given in the following table.

Table 6. Fuzzy multi-criteria decision matrix

Criteria	Alternatives		
	A1	A2	A3
K_1	0.916667	0.5	0.729167
K_2	0.6875	0.4375	0.5625
K_3	0.625	0.270833	0.625
K_4	0.625	0.43750	0.5625
K_5	0.875	0.6875	0.3955833
K_6	0.791667	0.479167	0.75
K_7	0.5	0.375	0.4375
K_8	0.6875	0.5625	0.6875
K_9	0.3125	0.333333	0.4375
K_{10}	0.395833	0.208333	0.291667
K_{11}	0.4375	0.3333	0.25
K_{12}	0.75	0.5625	0.5625
K_{13}	0.458333	0.625	0.625
K_{14}	0.75	0.5	0.6875
K_{15}	0.625	0.333333	0.5625

Table 7. Positive and negative ideal solutions

Criteria	PIS	NIS
K_1	0.652288	0.355793
K_2	0.390552	0.248533
K_3	0.2112757	0.091552
K_4	0.206056	0.144239
K_5	0.632804	0.286268
K_6	0.5677	0.343608
K_7	0.409616	0.307212
K_8	0.344282	0.281685
K_9	0.136879	0.097771
K_{10}	0.193037	0.101598
K_{11}	0.309267	0.176724
K_{12}	0.585953	0.439465
K_{13}	0.17001	0.124674
K_{14}	0.427271	0.284848
K_{15}	0.554224	0.295586

We have computed fuzzy positive ideal solution and fuzzy negative ideal solution from the weighted fuzzy multi-criteria normalized decision matrix where positive ideal solution represented the maximum values and negative ideal solution represents the minimum values shown in table.

From the fuzzy positive ideal solution and fuzzy negative ideal solution, which are agreeing to the technique of Topsis, we calculated the Euclidean distance for each alternative which has shown in table 8 below.

Table 8. Calculated Euclidean distance

Alternatives	Positive distance	Negative distance
A1	0.059873	0.667464
A2	0.576823	0.223744
A3	0.439108	0.387128

According to the closeness coefficient, ranks are given below:

Table 9. Calculated Euclidean distance

Alternatives	Closeness coefficient	Ranking
A1	0.917681	1
A2	0.279482	3
A3	0.468544	2

Figure 1. Closeness coefficient

3. Application of sensitivity analysis on the proposed modelling technique

Sensitivity analysis is a systematic review which involves the sequence of decisions applied on the pre-specified study to analyze the results of the whole process under consideration and to make final decision. sensitivity analysis referred that the overall results are not affected by the other decisions, which are conducted for reviewing the process, the results of the appraisal can be regarded with the higher degree of assurance. On the other hand, conflicting results shows the uncertainty and imprecision in decision making analysis. In this case, sensitivity analysis examines the particular decisions which are greatly influence on the findings of review.

In our case, to check out the accuracy of the proposed fuzzy modelling technique on logistic processes for facility location, sensitivity analysis is conducted. Sensitivity analysis is then applied on the same alternatives for facility location. After developing the best facility location for logistic processes using fuzzy modelling technique for decision analysis with the help of four decision makers, the decision makers are then again requested to assign weights for the three alternatives for reviewing the overall process and to make final decision on the proposed work. As described before that facility location plays the key role in logistic processes. Within the logistic processes, the most important research area is strategic decision planning and thus there are multiple factors involved in the planning of facility location for logistic processes. Once the decision is implemented on the company or on an organization, it is not easy to change the facility location again because it impacts on the significant level of company cost and it effects the revenue generation capabilities of an organization. Therefore, we conducted sensitivity analysis in which decision makers give their personal judgment once again for assigning the weights to perform sensitivity analysis.

3.1. Weight assigned by decision makers. The four decision makers once again requested to assign weights in linguistic terms for multiple criteria made for facility location selection in logistic processes. The decision makers have shown their decisions about the given criteria in linguistic terms which are shown in table 9. Fifteen criteria are made for the selection of facility location among logistic processes K_1 shows terms of lease, K_2 shows cost of development, K_3 shows cost of improvement, K_4 shows equipment cost, K_5 shows accessibility, K_6 shows visibility of location, K_7 gives population coverage, K_8 gives future growth and development, K_9 illustrates the distance from competitors, K_{10} presents number of located facilities, K_{11} shows quality of competitors, K_{12} shows availability of staff,K_{13} shows lead time, K_{14} shows parking area facility and K_{15} shows security risk.

Table 10. Weight assigned by decision makers

Criteria	DM1	DM2	DM3	DM4
K_1	H	VH	H	H
K_2	L	M	H	L
K_3	L	L	M	VL
K_4	VL	L	L	VL
K_5	VH	H	VH	VH
K_6	H	H	H	VH
K_7	H	M	VH	H
K_8	M	H	H	H
K_9	L	L	M	L
K_{10}	M	M	H	VL
K_{11}	L	L	VH	L
K_{12}	H	H	H	H
K_{13}	L	M	M	L
K_{14}	H	VH	VH	VH
K_{15}	H	H	L	H

We then estimated the aggregated priority weights by using equation (1.2) and the results are presented in the following table.

Table 11. Aggregated priority weight

Criteria	Aggregated weights
K_1	(0.5625 ,0.8125 ,1)
K_2	(0.1875,0.4375,0.6875)
K_3	(0.0625,0.25,0.5)
K_4	(0,0.1875,0.4375)
K_5	(0.6875,0.9375,1)
K_6	(0.5625,0.8125,1)
K_7	(0.5625,0.8125,1)
K_8	(0.375,0.625,0.875)
K_9	(0.1875,0.4375,0.6875)
K_{10}	(0.1875,0.4375,0.6875)
K_{11}	(0.1875,0.4375,0.625)
K_{12}	(0.5,0.75,1)
K_{13}	(0.125,0.3125,0.5625)
K_{14}	(0.6875,0.9375,1)
K_{15}	(0.375,0.625,0.87500)

By applying the same steps using equations (1.1), (1.2) and (1.3),we have been calculated the fuzzy normalized matrices, positive and negative ideal solution and found the closeness coefficient. The result has presented in the following figure.

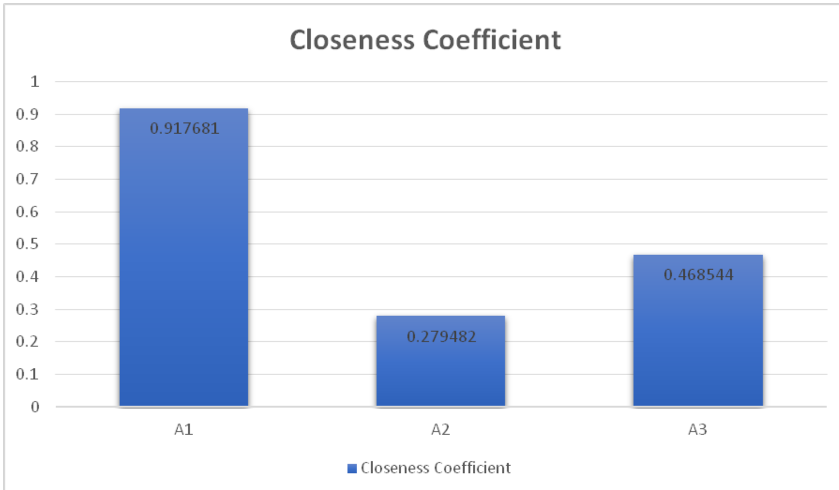

Figure 2. Closeness coefficient

4. Conclusion

In any business environment, decision making for logistic processes is essential. The operations on logistics processes are based on the multi criteria decision making analysis and criteria are conflicted based on the problem which is under consideration as the decisions. In this research work, the fuzzy modelling of logistic processes is conducted in retail facility location among the alternatives and selected the most suitable location facility and the results are discussed in detail. In section 3, by using fuzzy Topsis technique with triangular fuzzy numbers best facility location is estimated. Different fuzzy rules are used for making multiple criteria decision analysis. Decision matrix is normalized for comparing the criteria and through closeness coefficient, alternatives are ranked and selected the alternative 1 as most suitable place. In section 4, sensitivity analysis is conducted by using the same modelling technique and reviewing the whole process to check out the degree of assurance for the selection of location.For both analysis, the same alternative is chosen as a most suitable place and associates with higher degree of closeness coefficient which represents that the applied modelling technique of fuzzy Topsis for selecting the best location is the most suitable one because same alternative is chosen which is G-13 Markaz Islamabad and the result shown ranking as $A_1 > A_3 > A_2$. It is analyzed that proposed fuzzy modelling technique can be used for locating the facility location in any company or organization for operating the logistic processes.

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