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Abstract: With the latest production of vaccines at the conclusion of clinical trials in India, one of the next steps is to administer this vaccine to the consumer. The supply must be specifically positioned to ensure optimal distribution, and it also optimises the transportation cost. The significant concern of the location of facilities is a major logistic extent of decision-making for the vaccine distribution. How the material is passed to customers is one of the vital characteristics of a conversion process (manufacturing system). This fact involves deciding where the building or facility should be located. In this paper, the fuzzy cluster technology provides such optimised locations. Subsequently the optimal positions have been determined, the goal is to find the lowest transportation cost by FLLP. We report on experimental studies by taking artificial data from the current warehouse to prove feasibility and showing that the proposed solution is applicable.

Keywords: Covid-19; facility location problem; optimisation; fuzzy clustering; fuzzy linear programming problem.

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1 Introduction

The most effective method of avoiding and/or managing infectious disease outbreaks is vaccination. This surgical technique also poses a host of technical concerns. In recent years, a growing curiosity in the conceptual implications of vaccinations has been shown to the Operations Research/Operations Managing community. We could have a Cov-19 vaccine by this year, with around eight applicants completing the completion of drug testing. The next challenge, though, is to get the vaccines securely shipped to specific locations and finally to hospitals and clinics. Since certain Covid-19 vaccines demand varying climates and different manipulation techniques, the cold chain infrastructure, including transport and storage equipment and processes, are a vital factor before delivered to the masses. The WHO claims that cold chain is a system of keeping and delivering vaccines from the production point to the usage point.

A variety of factors can cause a shortage of vaccines. Export monopoly, complicated production procedures, expanded control of processing plants, unexpected changes in demand and decreased producers are the most commonly cited reasons for vaccine shortages [1–5]. The final delivery operation is administering the vaccines from the manufacturer to the customers. At the time of preparation of vaccines, store the vaccines in suitable places for monitoring. The vaccine distribution system includes an effective overall framework, an analysis of the demand rate and inventory needs, and selection of appropriate vaccine distribution sites.

Healthcare facility (HCF) is one of the major strategic problems for healthcare services, emergency relief and humanitarian logistics, received substantial interest from the working academic community over nearly four decades. The paper [6] includes tables with detailed statistics on HCF position problems for 10 dimensions. In order to address the needs of people impacted by disasters, a model [7] was developed to assess the quantity and position of the delivery centres in the aid system and the amount of relief supplies to be handled at each manufacturing facility. The goal of the paper [8] was to undertake a survey on the position of facilities associated to immediate relief warehousing, concentrating on all aspects of data modelling and problem categories, and to address the pre-and post-disaster situations related to the location of facilities, such as the location of distribution centres, stores, hospitals, debris disposal sites and medical centres. An integrated facility location (IFLP) problem was described in An et al. [9] that incorporates risks of facility disruption, obstruction of en-route transport and delay of in-facility queuing into a single issue. The primary factors considered for the selection of the location of the humanitarian relief warehouse as requirements for AHP are empirically specified in Roh et al. [10].

In several fields of research, clusters are found [11–16]. Clustering analysis is an important method that is used when deciding the optimum position for a facility. A clustered ant colony algorithm [17] was addressed in order to solve the more complicated location routing problem. A complete 52 algorithm [18] for reducing the supply chain disturbances. To correctly produce position clustering based on different hierarchical validation requirements, a fuzzy integration and clustering approach was used. Then a similar approach to assess and pick the best candidate for each cluster can be applied for order collection. Customers are classified according to their duties and assigned to the nearest facility available. In Klose [19], the clustering method was contrasted with other general purpose clustering algorithms. They also demonstrate how the combination location and riding problem can be solved using an iterative heuristic approach. The problem with several facilities is to classify the locations with medical waste. To solve continuous multiple facility position issues, an artificial bee colony (ABC) algorithm [20] was proposed for cluster analysis. To solve for the healthcare waste disposal site in Istanbul, the ABC clustering algorithm was implemented.

Strategies of clustering are classified into two divisions: partitioning and hierarchical. Partitional clustering decomposes disjoint clusters into sections [21–23].The K-means clustering algorithm allows for the efficient clustering of data. As a consequence, the issue of ambiguous boundaries can be solved by fuzzy clustering. Fuzzy clustering requires taking action with confusion, softness, and ambiguity. The Fuzzy c-means algorithm [24,25], which is common in many important fields, is the most widely used clustering algorithm. If FCM is used instead of HCM, greater results would be obtained. FCM algorithms suggested by Bezdak [26] are one of the most commonly used clustering algorithms since it preserves more knowledge than hard classification. FCM is the extension of Dunn [27] whereby its 'fuzzy ISODATA' algorithm is based. In this paper, we find the locations for the vaccine warehouse. We use the FCM algorithm to determine the suitable positions for the various areas. Then afterwards, we find the Euclidean distance in between the warehouse and the users, that is, the hospital/clink. Owing to the ambiguity, the supply of the vaccine which differ as well as the demand for the vaccine varies based on the area. Therefore, in times of fiscal limitations to find the lowest transportation cost is the most important. In specific circumstances, the uncertainty in creating a correctly organised supply chain for the organisation should in effect not be ignored. This uncertainty is usually connected to the supply of goods, market demand, etc., [28]. We also set out to introduce the concept of triangular fuzzy numbers in this paper to characterise the vaccine's different supply and demands.

In addition to worldview of abstract ideas, fuzzy numbers often have applications in the real world. Optimisation of problems with multiple objectives is described in paper [29]. The non-dominant Pareto optimum solutions are stored in a fixed-size archive in the method. Any optimisation problems can be overcome more easily by using fuzzy numbers. A triangular fuzzy number (FTN) subtraction and division system was introduced in Gerami Seresht and Fayek [30]. Furthermore, several revised operations are in progress for the promotion and optimisations of FLP triangular and trapezoidal fuzzy numbers [31–34]. Two models [35] have been introduced to reduce the overall expense of the product with a view to minimising the manufacturer's implementation costs. Supply chain is also found in Majumder et al. [36], where a batch plant manufactures goods and distributes to customers. Chandrawat et al. [37], a simulation and optimisation study was conducted using the FLP method, with a fuzzy number of symmetrical and right angle triangles. The right angle triangular fuzzy number was used to describe the membership grade of the optimised fuzzy LPP. Using triangular fuzzy numbers to create reputation criteria [13,14] ways to assess credibility for the extraction of the industrial system. The coefficient parameters of the objective function and solvent values of the R.H.S. are used in these articles [15,16] to resolve FLP issues with symmetrical trapezoidal quantities. In this paper, we demonstrate that this variations with a fuzzy triangular number. With this information, we propose a new FLPP with fuzzy triangular numbers. In order to optimise the cost so as to meet demand at all sites, this proposed strategy is used.

The paper is structured as follows. The problem is described in Section 2, and the model is formulated. In Section 3, we present comprehensive mathematical implementations of the existing algorithms and the new proposed process. In section 4, we take the artificial dataset of the current warehouses and perform the experiment of study. In Section 5, we conclude with our observations and future directions for study.

2 Problem definition and proposed model

Flu viruses are associated to the cold seasons and transmission of infectious illnesses. The flu impacts millions of individuals and leads each year to thousands of deaths. This year's fall and winter (i.e., 2020), the world's population, along with COVID-19, will be threatened. Although there are many variants of the flu virus and the mutated virus vaccine is developed and delivered annually [38], one of the problems is that the vaccine is available and it is manufactured and sold in a limited number of countries.

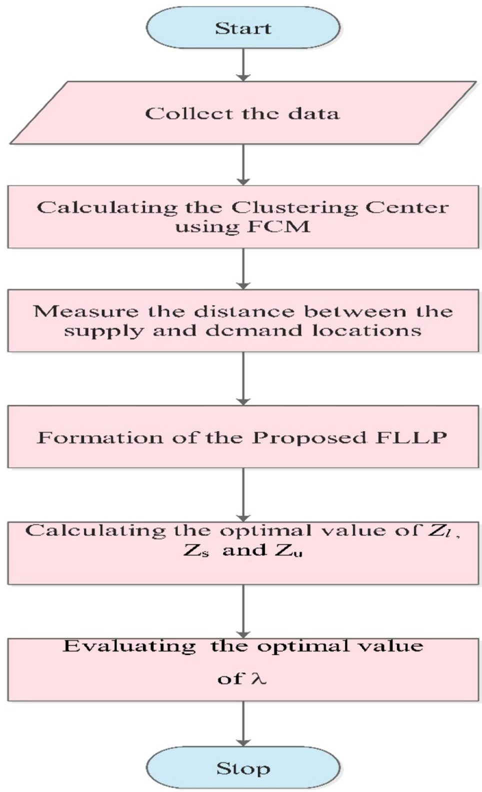
Many nations are unable to have flu vaccinations due to seasonal deficiencies. It is important to establish successful national plans in order to distribute vaccines equitably. The distribution in which more vulnerable individuals have priority than others is as important as the optimum allocation of individuals. This paper implements fuzzy c-mean clustering for the accurate estimate of influenza vaccines to various groups of citizens. A compromise between promoting society and customer support is required for the application. The delivery location (i.e., the distribution centre) and certain demand locations are two stages of the supply chain: (i.e., city, state, etc.).To obtain an optimum supply point which is the desired point that has a minimum distance from the demand point. Therefore, the cost of transportation should be minimal. The health experts group people according to their predetermined desires. This classification would calculate the vaccine prescription for each point of demand. However, in a practical situation, the supply and demand for vaccines could vary. We also suggested a fuzzy linear programming problem via a fuzzy triangular number to minimise transport costs in such circumstances. The proposed model is used to equitably distribute the vaccines across demand points according to the following assumptions:

- number of the cluster centre are pre-defined
- the distance between the supply point and demand point should be Euclidean distance
- to find the minimum transportation cost
- there is a multi-period distribution model with one single product
- the availability of the optimal location of supply points are available
- there is the range of the availability of the supply and demand of the product.

2.1 Limitations of proposed method

- We would not be able to determine the ideal clustering centre for the noise datasets using the proposed approach.
- In FLLP, this proposed approach is restricted to fuzzy triangular numbers.
- The proposed methodology addresses a specific sort of group LP problem using fuzzy numbers in the R.H.S of constraints.

Figure 1 The mechanism of the proposed method (see online version for colours)



2.2 *Contributions of the proposed methodology*

- To determine the most cost-effective mode of transportation in an uncertain situation.
- Distribution system efficiency is impacted by this selection.
- The location of consumers and the infrastructure necessary to satisfy their expectations with the least amount of cost and time are other critical aspects (Figures 1, 2 and 5).

3 Mathematical modelling

In this section we first discuss the about the fuzzy c-means (FCM) algorithm and then we discuss about the proposed fuzzy linear programming problem.

3.1 *Fuzzy c-mean clustering*

A statistical method in which experimental datasets are grouped according to similarities [20] is fuzzy clustering. The clustering technique that enables one collection of data to be used in two or more clusters is FCM. This technique was introduced in 1973 by Dunn [21] and improved in 1981 by Bezdak [22] and was also widely used to identify a pattern.

The dataset x_k is separated by FCM algorithm into N clusters [20]. The Clustering of the v_j and μ_{jk}^m centres is by reducing the cost function. The objective function of FCM, mathematically, can be formulated as

$$\min J_{fcm} = \sum_{k=1}^{N}\sum_{j=1}^{c} \mu_{jk}^m \| x_k - v_j \|^2 \tag{1}$$

where, μ_{jk} is the membership grade of x_k to the nth clusters, the $m > 1$ parameter of fuzzification controls the membership's softness. Higher mask estimating capacity for $m = 2$ has been recognised in Celebi [21]. The fuzzy partitioning process is carried out by an iterative optimisation of the objective function shown above, with the updating of membership functions μ_{jk} and cluster centre v_j by:

$$v_j = \frac{\sum_{k=1}^{n} \mu_{jk}^m x_{jk}}{\sum_{k=1}^{n} \mu_{jk}^m} \quad c \epsilon N \tag{2}$$

$$\mu_{jk} = \begin{cases} \left[\sum_{i=1}^{c} \left(\frac{\| x_k - v_j \|}{\| x_k - v_i \|} \right)^{\frac{2}{m-1}} \right]^{-1} & \text{if } \|x_k - v_j\| > 0, \forall j \\ 1 & \text{if } \| x_k - v_j \| = 0 \\ 0 & \text{if } \exists i \neq j \quad \| x_k - v_j \| = 0 \end{cases} \tag{3}$$

The calculation is based on such steps:

Step-1: Initialization-$U = [u_{ij}]$ matrix, $U^{(0)}$.

Step-2: Centroid calculation – When each point in the dataset is assigned to a cluster, it is needed to recalculate the new v_i^1 , $i \in \mathbb{N}$ centroids.

Step-3: Updating of Membership function-Update $U^{(k)}$, $U^{(k+1)}$.

Step-4: If $\| U^{(k+1)} - U^{(k)} \| < \in$ then STOP; otherwise return to step 2.

3.2 Fuzzy linear programming

Zimmermann [39] had proposed the standard form fuzzy linear programming in which they taken right hand side solution value as the fuzzy right triangle number. It mean according to him uncertainty is occurs only in right hand sides, But in certain situation, uncertainty will occurs in both sides. So in this paper we proposed the Standard FLP through the composite fuzzy triangular number which is represent the uncertain situation of the right-hand side solution values. The standard form fuzzy linear programming is represented by

$$\text{Max } \mathcal{Z} = \sum_{j=1}^{n} c_j x_j$$
$$\text{Subject to} \sum_{j=1}^{n} \alpha_{ij} x_j \leq \tilde{\eta}_i \tag{4}$$
$$\text{where, } x_j \geq 0, i, j \in \mathbb{N}$$

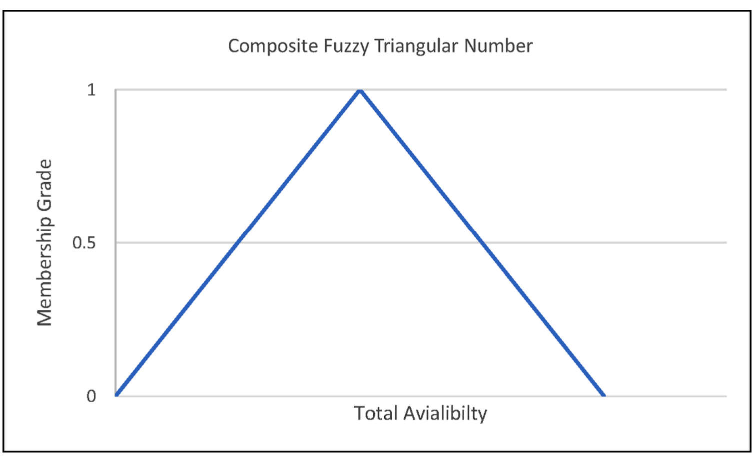
where, $\tilde{\eta}_i$ $(\eta_i - p_i \sim \eta_i \sim \eta_i + p_k)$ is considered to be the composite fuzzy triangular number as indicated in equation (4) in accordance with the standard form of FLP consequence of increased and decreased availability of restrictions. Thus, the membership function for $\tilde{b}_i$ is defined as follows:

$$\tilde{\eta}_i = \begin{cases} 1 & \text{when } x = \eta_i \\ \dfrac{x - \eta_i + p_i}{p_i} & \text{when } \eta_i - p_i \leq x \leq \eta_i \\ \dfrac{\eta_i + p_k - x}{p_k} & \text{when } \eta_i \leq x \leq \eta_i + p_k \\ 0 & \text{otherwise} \end{cases} \tag{5}$$

The coefficient on the right side is the membership function, i.e., the availability of restrictions. Where $x \epsilon \ R$.

The values of $\tilde{\eta}_i$ according to their membership function are graphically represented as:

Figure 2 Membership grade of total availability in the triangular fuzzy LPP (see online version for colours)



3.2.1 *Solution methodology*

According to the composite fuzzy triangular number $\tilde{\eta}_i$ $(\eta_i - p_i \sim \eta_i \sim \eta_i + p_k)$ the general structure of the optimal values of the lower, static and upper bounds is defined below:

The lower bound ($\mathcal{Z}_l$) –

$$\text{Max } \mathcal{Z}_l = \sum_{j=1}^{n} c_j x_j$$

$$\text{Subject to} \sum_{j=1}^{n} a_{ij} x_j \le \eta_i - p_i \tag{6}$$

$$\text{where, } x_j \ge 0, i, j \in \mathbb{N}$$

The static bound ($\mathcal{Z}_s$) –

$$\text{Max } \mathcal{Z}_s = \sum_{j=1}^{n} c_j x_j$$

$$\text{Subject to} \sum_{j=1}^{n} a_{ij} x_j \le \eta_i \tag{7}$$

$$\text{where, } x_j \ge 0, i, j \in \mathbb{N}$$

The upper bound ($\mathcal{Z}_u$) –

$$\text{Max } \mathcal{Z}_u = \sum_{j=1}^{n} c_j x_j$$

$$\text{Subject to} \sum_{j=1}^{n} a_{ij} x_j \le \eta_i + p_k \tag{8}$$

$$\text{where, } x_j \ge 0, i, j \in \mathbb{N}$$

The solution for lower and upper bounds of LPP's is obtained by the Simplex method. To find the two different optimised fuzzy LPP model will be obtained by using these lower and upper bounds

3.2.2 *Optimised composite triangular fuzzy LPP model-I*

$$\begin{gathered}
\textit{Max } \lambda, \text{ Subject to} \\
\lambda(\mathcal{Z}_s - \mathcal{Z}_l) - \sum_{j=1}^{n} c_j x_j \le -\mathcal{Z}_l \\
\lambda(p_i) + \sum_{j=1}^{n} a_{ij} x_j \le \eta_i, \\
\lambda(\mathcal{Z}_u - \mathcal{Z}_s) - \sum_{j=1}^{n} c_j x_j \le -\mathcal{Z}_s \\
\lambda(p_i) + \sum_{j=1}^{n} a_{ij} x_j \le \eta_i + p_k, \\
\lambda(\mathcal{Z}_u - \mathcal{Z}_l) - \sum_{j=1}^{n} c_j x_j \le -\mathcal{Z}_l \\
\lambda(p_i + p_k) + \sum_{j=1}^{n} a_{ij} x_j \le \eta_i + p_k, x_j \ge 0
\end{gathered} \tag{9}$$

4 Experiment result and discussion

In this section, we discuss a problem in which we find the proposed plant i (location centres) by FCM clustering method. After finding the location site j we find the distance matrix from the plant $\boldsymbol{i}$ to proposed potential site $\boldsymbol{j}$, then we find the optimal total cost with the help of the transportation method.

Example 4.1

An organisation has warehouses for life saving drugs at 30 different location whose coordinates are given in Table 1. The organisation is in the process of locating critical central warehouses which will distribute drugs to all the existing warehouses on emergency request. Find the numbers of optimum location of the new facility (warehouse) based on Fuzzy C-means clustering concept.

The data are also shown in Figure 3. Assume that we want to determine a fuzzy pseudo partition with two clusters (i.e., $c = 3$). Assume further that we choose $m = 2$, $\epsilon > 0.00001$; $\| \, . \, \|$ is the Euclidean distance, and the initial fuzzy pseudo partitions $U^{(0)} = [U_1, U_2, U_3]$ with membership grade shown in Table 2.

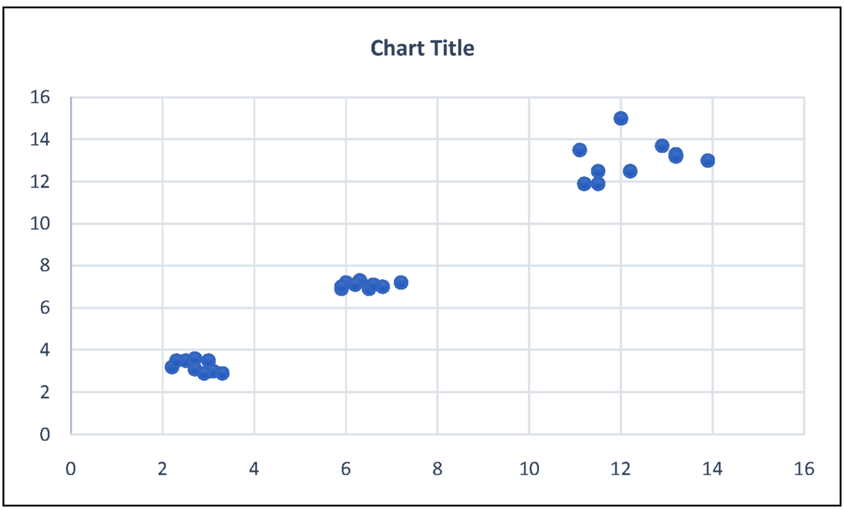
Table 1 Show the geographical coordinates of the existing warehouse

Existing warehouse number	*Coordinates of centroids*
1	(2.5, 3.5)
2	(2.7, 3.6)
3	(2.2, 3.2)
4	(3.0, 3.0)
5	(2.7, 3.1)
6	(2.3, 3.5)
7	(3.1, 3.0)
8	(3.3, 2.9)
9	(3.0, 3.5)
10	(2.9, 2.9)
11	(6.0, 7.2)
12	(6.5, 7.0)
13	(5.9, 6.9)
14	(6.3, 7.3)
15	(5.9, 7.0)
16	(6.8, 7.0)
17	(6.5, 6.9)
18	(6.2, 7.1)
19	(7.2, 7.2)
20	(6.6, 7.1)
21	(11.1, 13.5)

Table 1 Show the geographical coordinates of the existing warehouse (continued)

Existing warehouse number	*Coordinates of centroids*
22	(12.2, 12.5)
23	(11.5, 11.9)
24	(13.2, 13.3)
25	(11.5, 12.5)
26	(12.0, 15.0)
27	(13.2, 13.2)
28	(11.2, 11.9)
29	(12.9, 13.7)
30	(13.9, 13.0)

Figure 3 Show the geographical location of the existing warehouses (see online version for colours)



Then, the algorithm stops for $t = 6$, because max $\{ \mid u_{ij}^{k+1} - u_{ij}^{k} \mid \} < 3.8545^{-7}$ and we obtain the pseudo partition defined in Table 1, the two clusters are

$$V_1 = (2.77, 3.22),\ V_2 = (6.39, 7.07) \text{ and } V_3 = (12.29, 13.05)$$
$$J_m = 92.6823.$$

Now, the organisation has three new facilities (warehouses) W_1, W_2 and W_3 which supply to 30 warehouses at $H_1, H_2, H_3, \ldots, H_{30}$. Due the uncertainty of the demand and supply the availability of the drugs might be vary. This variation is represented by the fuzzy triangular number.

The availability of the drugs of W_1, W_2 and W_3 are **(330, 400, 460)** units, **(200, 260, 300)** units and **(273, 340, 447)** units respectively. The monthly requirement for the warehouses are also represented by the fuzzy triangular number, so the demand of $H_1, H_2, H_3, \ldots, H_{30}$ are **(30, 40, 50)** units, **(25, 30, 40)** units, **(15, 20, 25)** units, …, and **(12, 20, 29)** units, respectively. Company wants to make sure they keep a steady, adequate flow of drugs to the existing warehouses to capitalise the demand of the consumers. Secondary, but still important, is to minimise the cost of transportation. The distance between the new warehouses and existing warehouses shown in Table 3. The average haul cost is $1 per mile for both loaded and empty trucks.

Table 2 Initial membership grade to the input data

Input data		*Membership function for fuzzy clustering*		
X_1	X_2	U_1	U_2	U_3
2.5	3.5	0.9	0.05	0.05
2.7	3.6	0.89	0.055	0.055
2.2	3.2	0.88	0.06	0.06
3.0	3.0	0.87	0.065	0.065
2.7	3.1	0.86	0.07	0.07
2.3	3.5	0.84	0.09	0.07
3.1	3.0	0.81	0.11	0.08
3.3	2.9	0.8	0.1	0.1
3.0	3.5	0.79	0.11	0.1
2.9	2.9	0.75	0.15	0.1
6.0	7.2	0.05	0.9	0.05
6.5	7.0	0.055	0.89	0.055
5.9	6.9	0.06	0.88	0.06
6.3	7.3	0.065	0.87	0.065
5.9	7.0	0.07	0.86	0.07
6.8	7.0	0.09	0.84	0.07
6.5	6.9	0.11	0.81	0.08
6.2	7.1	0.1	0.8	0.1
7.2	7.2	0.11	0.79	0.1
6.6	7.1	0.15	0.75	0.1
11.1	13.5	0.05	0.05	0.9
12.2	12.5	0.055	0.055	0.89
11.5	11.9	0.06	0.06	0.88
13.2	13.3	0.065	0.065	0.87
11.5	12.5	0.07	0.07	0.86
12.0	15.0	0.07	0.09	0.84
13.2	13.2	0.08	0.11	0.81
11.2	11.9	0.1	0.1	0.8
12.9	13.7	0.1	0.11	0.79
13.9	13.0	0.1	0.15	0.75

The data are shown below.

Table 3 Distance between the new warehouses to existing warehouses

Warehouses	*Distance matrix [d]* — *Factories* W_1	W_2	W_3	*Requirement*
H_1	0.39	5.28	13.68	(30, 40, 50)
H_2	0.38	5.07	13.46	(25, 30, 40)
H_3	0.57	5.71	14.10	(15, 20, 25)
H_4	0.32	5.30	13.69	(5, 10, 15)
H_5	0.14	5.42	13.82	(40, 50, 60)
H_6	0.55	5.43	13.82	(52, 60, 66)
H_7	0.40	5.24	13.62	(64, 70, 76)
H_8	0.62	5.19	13.56	(7, 10, 15)
H_9	0.36	4.93	13.32	(16, 20, 23)
H_{10}	0.35	5.44	13.83	(26, 30, 38)
H_{11}	5.12	0.41	8.59	(31, 40, 46)
H_{12}	5.31	0.13	8.37	(22, 25, 31)
H_{13}	4.83	0.52	8.87	(29, 35, 42)
H_{14}	5.39	0.24	8.30	(38, 45, 52)
H_{15}	4.91	0.50	8.80	(11, 15, 23)
H_{16}	5.52	0.41	8.17	(16, 25, 32)
H_{17}	5.24	0.20	8.45	(28, 35, 44)
H_{18}	5.18	0.19	8.51	(36,45, 53)
H_{19}	5.95	0.82	7.75	(30, 35, 40)
H_{20}	5.45	0.21	8.23	(24,30, 35)
H_{21}	13.23	7.97	1.27	(10, 20, 26)
H_{22}	13.22	7.95	0.56	(27, 30, 38)
H_{23}	12.31	7.03	1.39	(13, 20, 28)
H_{24}	14.5	9.23	0.95	(50, 60,70)
H_{25}	12.74	7.45	0.96	(42, 50, 57)
H_{26}	14.96	9.71	1.97	(37, 40, 44)
H_{27}	14.43	9.96	0.92	(11, 20, 26)
H_{28}	12.1	6.81	1.58	(22, 30, 35)
H_{29}	14.57	9.29	0.89	(34, 40, 48)
H_{30}	14.81	9.57	1.61	(12, 20, 29)
Production	**(330, 400, 460)**	**(200, 260, 300)**	**(273, 340, 447)**	**(803, 1000, 1207)**

4.1 Modelling for system of optimal solution

We can set up the FLP of the equations ((6)–((8) for cost minimisation in such a way as to satisfy the demands of existing warehouses.

We can formulate the problem in equation ((10) as: Let X_{ij} = Transportations costs from new site i to existing j

$$i = 1,2,3 \left(\text{new sites}\right) j = 1,2,\ldots,30 \left(\text{existing sites}\right)$$

Objective function

$$\begin{aligned} \text{Min } z = \ & 0.39x_{11} + \cdots + 14.81x_{130} + \cdots + 5.28x_{21} + \cdots + 9.57x_{230} \\ & + \cdots + 13.68x_{31} + \cdots + 1.67x_{330} \\ & x_{11} + x_{12} + \cdots + x_{130} \leq \widetilde{F_1} \\ & x_{21} + x_{22} + \ldots + x_{230} \leq \widetilde{F_2} \\ & x_{31} + x_{32} + \ldots + x_{330} \leq \widetilde{F_3} \\ & x_{11} + x_{21} + x_{31} \geq \widetilde{L_1} \\ & x_{12} + x_{22} + x_{32} \geq \widetilde{L_2} \\ & \vdots \\ & x_{130} + x_{230} + x_{330} \geq \widetilde{L_{30}} \end{aligned} \tag{10}$$

4.2 Numerical results

Using the equations (6)–(8) of the proposed FLP the optimal value of the lower bound (**Z_l**) is **933.22**, static bound (**Z_s**) is **1067.90** and the upper bound (**Z_u**) = **1440.50**. The value of X_{ij} are shown in Tables 4–6.

Table 4 Show optimal value of the lower bound (**Z_l**) of **X_{ij}**

Existing warehouses/new warehouses	W_1	W_2	W_3
H_1	30	0	0
H_2	2	23	0
H_3	0	0	15
H_4	5	0	0
H_5	0	40	0
H_6	0	0	52
H_7	64	0	0
H_8	0	0	7
H_9	0	0	16
H_{10}	26	0	0
H_{11}	0	31	0
H_{12}	0	0	22
H_{13}	29	0	0

Table 4 Show optimal value of the lower bound (Z_l) of X_{ij} (continued)

Existing warehouses/new warehouses	W_1	W_2	W_3
H_{14}	0	20	18
H_{15}	0	0	11
H_{16}	16	0	0
H_{17}	0	28	0
H_{18}	0	0	36
H_{19}	30	0	0
H_{20}	0	24	0
H_{21}	0	0	10
H_{22}	27	0	0
H_{23}	0	0	13
H_{24}	0	0	50
H_{25}	42	0	0
H_{26}	37	0	0
H_{27}	0	0	11
H_{28}	22	0	0
H_{29}	0	34	0
H_{30}	0	0	12

Table 5 Show optimal value of the static bound (Z_s) of X_{ij}

Existing warehouses/new warehouses	W_1	W_2	W_3
H_1	40	5	0
H_2	10	0	0
H_3	70	0	0
H_4	30	0	0
H_5	35	0	0
H_6	25	0	0
H_7	35	0	0
H_8	30	0	0
H_9	50	40	0
H_{10}	30	0	0
H_{11}	0	25	0
H_{12}	0	50	0
H_{13}	0	0	0
H_{14}	0	40	0
H_{15}	0	40	0
H_{16}	0	35	0
H_{17}	0	30	0
H_{18}	0	0	0

Table 5 Show optimal value of the static bound (Z_s) of $\boldsymbol{X_{ij}}$ (continued)

Existing warehouses/new warehouses	W_1	W_2	W_3
H_{19}	0	0	0
H_{20}	0	40	0
H_{21}	0	0	20
H_{22}	0	0	60
H_{23}	0	10	20
H_{24}	0	0	25
H_{25}	0	5	15
H_{26}	0	0	45
H_{27}	0	0	20
H_{28}	0	20	60
H_{29}	0	0	20
H_{30}	0	0	20

Table 6 Show optimal value of the upper bound (Z_u) of $\boldsymbol{X_{ij}}$

Existing warehouses/new warehouses	W_1	W_2	W_3
H_1	50	0	0
H_2	15	0	0
H_3	76	0	0
H_4	38	0	0
H_5	42	0	0
H_6	32	0	0
H_7	40	0	0
H_8	38	0	0
H_9	57	37	0
H_{10}	35	0	0
H_{11}	0	40	0
H_{12}	0	60	0
H_{13}	0	0	0
H_{14}	0	46	0
H_{15}	0	20	0
H_{16}	0	44	0
H_{17}	0	35	0
H_{18}	0	0	0
H_{19}	0	7	0
H_{20}	0	48	0
H_{21}	0	0	25
H_{22}	0	0	66

Table 6 Show optimal value of the upper bound (Z_u) of $\boldsymbol{X}_{ij}$ (continued)

Existing warehouses/new warehouses	W_1	W_2	W_3
H_{23}	0	15	23
H_{24}	0	0	31
H_{25}	0	32	23
H_{26}	0	0	53
H_{27}	0	0	26
H_{28}	0	28	70
H_{29}	0	0	26
H_{30}	0	0	29

4.3 *Optimised composite triangular fuzzy LPP model*

The optimised fuzzy linear programming problem (OFLPP) has been constructed defined in equation (9) using the lower, static, and upper bound is shown in equation (11):

$$\text{Max } Z = \gamma$$

$$\text{Subject to}$$

$$372.60\gamma-(-0.39x_{11}-\ldots-14.81x_{130}-\ldots-5.28x_{21}-\ldots-9.57x_{230} \\ -\ldots-13.68x_{31}-\ldots-1.67x_{330})\le -1067.90$$

$$60\gamma+x_{11}+x_{12}+\ldots+x_{130}\le 460$$

$$40\gamma+x_{21}+x_{22}+\ldots+x_{230}\le 300$$

$$107\gamma+x_{31}+x_{32}+\ldots+x_{330}\le 447$$

$$10\gamma-x_{11}-x_{21}-x_{31}\le -50$$

$$10\gamma-x_{12}-x_{22}-x_{32}\le -40$$

$$\vdots$$

$$\vdots$$

$$9\gamma-x_{130}-x_{230}-x_{330}\le -29$$

$$507.26\gamma-(-0.39x_{11}-\ldots+14.81x_{130}+\ldots+5.28x_{21}+\ldots+9.57x_{230} \\ +\ldots+13.68x_{31}+\ldots+1.67x_{330})\le -933.22$$

$$130\gamma+x_{11}+x_{12}+\ldots+x_{130}\le 460$$

$$100\gamma+x_{21}+x_{22}+\ldots+x_{230}\le 300$$

$$174\gamma+x_{31}+x_{32}+\ldots+x_{330}\le 447$$

$$20\gamma-x_{11}-x_{21}-x_{31}\le -50$$

$$15\gamma - x_{12} - x_{22} - x_{32} \leq -40$$

$$\vdots$$

$$17\gamma - x_{130} - x_{230} - x_{330} \leq -29$$

$$134.68\gamma - (-0.39x_{11} - \ldots - 14.81x_{130} - \ldots + 5.28x_{21} - \ldots - 9.57x_{230}$$
$$- \ldots - 13.68x_{31} - \ldots - 1.67x_{330}) \leq -933.22$$

$$70\gamma + x_{11} + x_{12} + \ldots + x_{130} \leq 400$$

$$60\gamma + x_{21} + x_{22} + \ldots + x_{230} \leq 260$$

$$67\gamma + x_{31} + x_{32} + \ldots + x_{330} \leq 340$$

$$10\gamma - x_{11} - x_{21} - x_{31} \leq -40$$

$$5\gamma - x_{12} - x_{22} - x_{32} \leq -30$$

$$\vdots$$

$$8\gamma - x_{130} - x_{230} - x_{330} \leq -20 \tag{11}$$

Table 7 Show optimal value of the proposed FLP of $\boldsymbol{X}_{ij}$

Existing warehouses/new warehouses	W_1	W_2	W_3
H_1	32	0	0
H_2	25	0	0
H_3	18	0	0
H_4	8	0	0
H_5	42	0	0
H_6	56	0	0
H_7	66	0	0
H_8	9	0	0
H_9	20	0	0
H_{10}	27	0	0
H_{11}	0	37	0
H_{12}	0	23	0
H_{13}	0	31	0
H_{14}	0	40	0
H_{15}	0	12	0
H_{16}	0	21	0
H_{17}	0	28	0
H_{18}	0	39	0

Table 7 Show optimal value of the proposed FLP of X_{ij} (continued)

Existing warehouses/new warehouses	W_1	W_2	W_3
H_{19}	0	33	0
H_{20}	0	28	0
H_{21}	0	0	17
H_{22}	0	0	28
H_{23}	0	0	15
H_{24}	0	0	52
H_{25}	0	0	45
H_{26}	0	0	39
H_{27}	0	0	17
H_{28}	0	0	28
H_{29}	0	0	34
H_{30}	0	0	14

Figure 3 indicates that 888.84 vaccinations at $\gamma = 0.4153$ are available in an ideal situation. Table 7 displays the shipping costs from newly located W_1, W_2 and W_3 to current warehouses H_1, H_2, H_3, …, H_{30}. The calculated gross transportation cost is \$564.37.

Figure 4 Show the optimal value of γ for minimal transportation cost (see online version for colours)

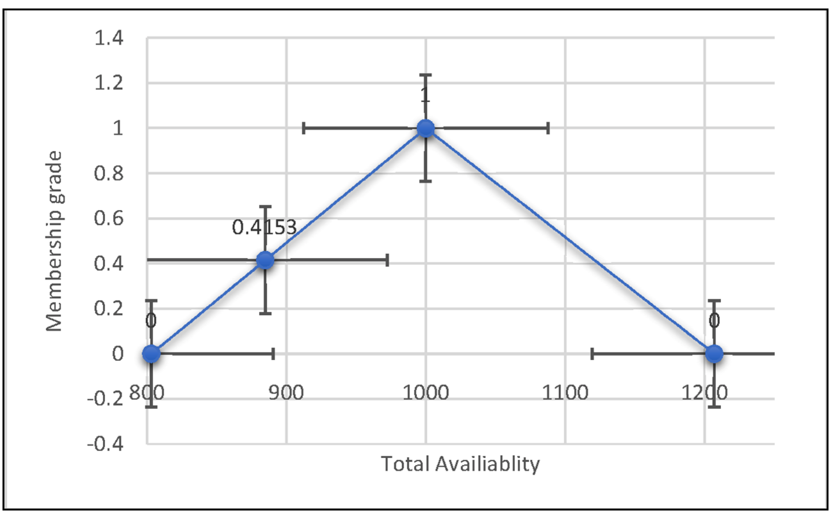
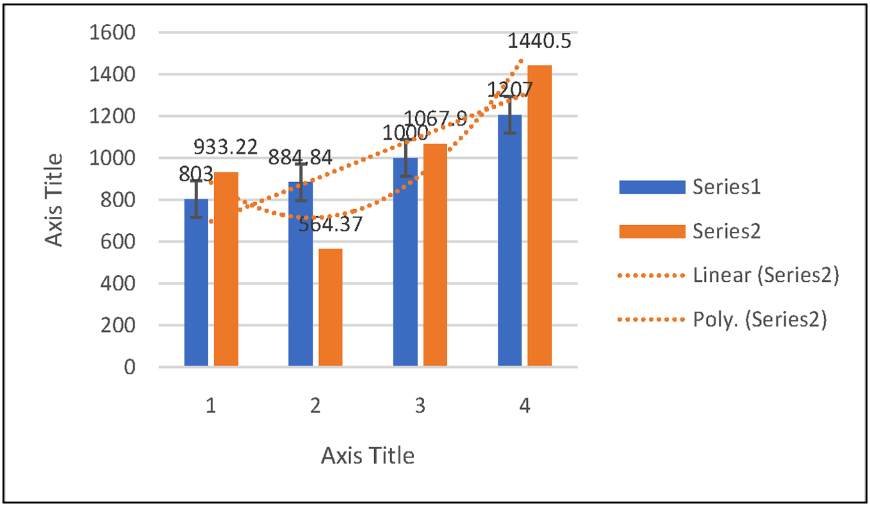


Figure 4 shows that the optimum transport cost correlates to the availability of the stock. With the support of the FLP conversational process described in equations (6)–(8), in which we calculate the cost of transport from the current warehouses to the current warehouse for the lower bound, the static bound and the upper bound. That demonstrates that, as the availability of the commodity increases, the cost of transport also is rising.

But we have the support of the proposed FLP, provided the equation (9) provided the optimum cost of travel. This indicates that the cost of transport is less than the availability of the product. This also fulfilled the overall demand of the consumer.

Figure 5 Comparison of transportation cost and availability of the vaccine (see online version for colours)



5 Conclusion and future work

In this paper, we apply the FCM algorithms to find the optimum location of vaccine delivery warehouses in current warehouses/hospitals. Secondly, our key goal is to minimise the cost of travel from the new site to current facilities in such a manner that the measured new sites meet the needs of existing locations. We have therefore suggested a new FLP problem, which has yielded a spectacular outcome. In the future, we will try to locate positions using better FCM algorithms using various distance metrics and apply new fuzzy linear programming problems using other fuzzy numbers that describe real-world scenarios.

Declaration of competing interest

Authors declare that they have no established conflicting commercial interests or personal associations that may have appeared in this paper.

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