Malaya Journal of Matematik, Vol. 7, No. 4, 669-675, 2019

https://doi.org/10.26637/MJM0704/0009

On fuzzy mathematical modeling in the analysis of distribution of medicines for controlling communicable diseases based on optimization techniques

G. Sivakumar[1], A. Hari Ganesh[2*] and M. Suresh[3]

Abstract

In this paper, we propose the bi–objective fuzzy mathematical model based on optimization technique in order to distribute the available medicines of various diseases to the disease population for minimizing human productivity loss. This paper also aims to minimize the total treatment cost and dosage level of medicines by its effective distribution. The main aim of introducing this model is to minimize the human productivity loss by the effective distribution of various types of available medicines to the disease population in a certain region. Moreover, the paper proposes the ranking index based on distance between new reference point of trapezoid to original point for solving the fuzzy optimization problem arrived from the proposed model by converting the fuzzy problems into crisp one.

Keywords

Multi Objective linear model, fuzzy linear programming problem, fuzzy number, communicable diseases

[1] *Department of Mathematics, A.V.V.M. Sri Pushpam College (Autonomous), Poondi–613503, Thanjavur(Dt), Tamil Nadu, India. (Affiliated to Bharathidasan University, Tiruchirappalli)*

[2] *Department of Mathematics, Poompuhar College (Autonomous), Melaiyur–609107, Nagapattinam(Dt.), Tamil Nadu, India.*

[3] *Department of Mathematics, SRM University, Ramapuram, Chennai–600089, Tamil Nadu, India.*

*__Corresponding author__: [2] gee.yees1966@gmail.com

Article History: Received **12** July **2019**; Accepted **22** October **2019**

Contents

1. Introduction

In India, Ayurveda has been used by most of the population for over 2000 years as their main type of health care. Subsequently, Unani Tibb's influence spread with the increasing Muslim presence in India from the early 11th century. Unani Tibb and Ayurveda have influenced each other since, especially the herbs on which they base their medicines.

In the beginning of 1600s, British arrived in India. Afterward, European medical ideas were promoted by Christian missionaries. Although, local medical practices continued because shipping medical supplies from Britain was expensive and difficult. Moreover, Ayurveda was a cheap and practical health-care system for the local population. However, most British officials and physicians thought traditional systems of medicine would die out because Western medicine was superior. Now a day, various systems of medicines are playing important role in India for providing health care to large section of population. In India it has the unique distinction of having six recognized systems of medicine such as Ayruveda, Siddha, Unani, Yoga, Naturopathy and Homoeopathy which are being chosen by individuals from a vast range of practices, treatments and therapies including the same. It is a well known fact that these systems of medicines always played important role in meeting the global health care needs not only in India.

Although the individuals choosing the various systems of medicine on now a day, the government has the very big responsibility to distribute the available medicines to the disease population for controlling the communicable diseases. There is a wide range of application of mathematical techniques in the field of health care under certain and uncertain environment. To have the idea in this field, a recent survey is made on the application of mathematical methods in health care under certainty and uncertainty.

In 2012, Ahmet F. Ozok [1] tried a risk determination model according to principles of fuzzy logic for a safety and quality medical system. He used fuzzy modeling as a research strategy and developed sum fuzzy membership functions to minimize human error for reducing patient death. Subsequently in the same year, Mayilvaganan and Rajeswari [3] porposed a method which involved to diagnosis the health risk which is related to Blood Pressure. They proposed fuzzy logic control system to represent the parameters which may cause the risk for human health and analysis by using rule base factor under this concept. In 2014, Suman Sankar Bhunia et al. [5] proposed a fuzzy assisted data gathering and alert scheme for healthcare services using Arduino and eHealth sensor kit in their research work. In 2015, Thanh Nguyen et al. [6] proposed a method for evaluating two frequently-used Wisconsin breast cancer and Cleveland heart disease datasets from the UCI Repository for machine learning. Moreover this approach is helpful as a decision support system for medical practitioners in the healthcare practice. In 2016, Gürsel [2] Reviewed and analyzed the application of Fuzzy Logic in healthcare. In his descriptive study, he examined and explained FL applications in healthcare. Recently in the year 2017, we [4, 7–9] proposed an effective single, bi and tri objective fuzzy optimistion models for controlling communicable diseases for healthcare. In these works, we have left to develop a bi objective mathematical model for minimizing the total treatment cost and dosage of medicines to control the communicable diseases spreading in a particular region.

In this work, we have planned to introduce the methodology for the analysis of health care system in an uncertain environment. In particular, the main to introduce such methodology is to distribute the available medicines to disease population in a certain region to control the communicable diseases with minimum cost and dosage through its analysis. Finally the numerical example is to be given for demonstrating the proposed methodology. The work is organized as follows.

2. Preliminaries

This section presents some basic definitions on fuzzy set, fuzzy number, generalized triangular fuzzy number, generalized trapezoidal fuzzy numbers and its operations.

Definition 2.1. *A non empty set which has elements with degree of membership for its belonging is called Fuzzy Set. Mathematically, the fuzzy subset $\tilde{A}$ of a Universal set X is defined as an ordered pair by its membership function. It is denoted as*

$$\tilde{A} = \left\{(x, \mu_{\tilde{A}}(x)) \mid \mu_{\tilde{A}} : X \to [0,1], each x \in \tilde{A}\right\}$$

where the value of $\mu_{\tilde{A}}(x)$ at x shows the degree of membership of x in $\tilde{A}$.

Definition 2.2. *A fuzzy set $\tilde{A}$ is represented as a fuzzy number if it is defined on the universal set of real number R and also possesses at least the following properties:*

(i) *$\tilde{A}$ is convex.*

(ii) *$\tilde{A}$ is normal $\exists x_0 \in R$ such that $\mu_{\tilde{A}}(x_0) = 1$.*

(iii) *$\mu_{\tilde{A}}(x)$ is piecewise continuous.*

(iv) *$\tilde{A}_\alpha$ must be closed interval for every $\alpha \in [0,1]$*

(v) *The support of $\tilde{A}$, must be bounded.*

Definition 2.3. *A fuzzy number $\tilde{A} = (a,b,c,d;w)$ is said to be generalized trapezoidal fuzzy number if its membership function is of the following form:*

$$\mu_{\tilde{A}}(x) = \begin{cases} w\left(\frac{x-a}{b-a}\right), & a \leqslant x \leqslant b \\ w, & b \leqslant x \leqslant c \\ w\left(\frac{x-d}{c-d}\right), & c \leqslant x \leqslant d \\ 0, & otherwise \end{cases}$$

Definition 2.4. *A fuzzy number $\tilde{A} = (a,b,c;w)$ is said to be generalized triangular fuzzy number if its membership function is of the following form:*

$$\mu_{\tilde{A}}(x) = \begin{cases} 0, & x \leqslant a \\ w\left(\frac{x-a}{b-a}\right), & a \leqslant x \leqslant b \\ w\left(\frac{c-x}{c-b}\right), & b \leqslant x \leqslant c \\ 0, & x > c \end{cases}$$

3. Proposed Ranking Method

This section proposes a new distance based ranking method for ordering generalized trapezoidal fuzzy number by converting fuzzy number into a crisp number. In order to introduce a new distance based ranking for ordering fuzzy numbers, the new balancing point of trapezoid is introduced using centroid of centroids. First, the trapezoid corresponding to the generalized trapezoidal fuzzy number $A = (a,b,c,d;w)$, is divided into three triangles AEF, AHD and FHD. The reason for selecting this proposed centroid as a point of reference is that each centroid points ($G_1 = \left(\frac{a+b+c}{3}, \frac{2w}{3}\right)$ of AEF, $G_2 = \left(\frac{3a+c+2d}{6}, \frac{w}{6}\right)$ of AHD and $G_3 = \left(\frac{a+3c+2d}{6}, \frac{w}{2}\right)$ of FHD) are balancing points of three triangles. Therefore, the centroid of these centroids would be a better balancing point of trapezoid.

Consider the generalized trapezoidal fuzzy number $A = (a,b,c,d;w)$. The centroid of the three triangles is

$$G = (x_0, y_0) = \left(\frac{3a+b+3c+2d}{9}, \frac{4w}{9}\right) \tag{3.1}$$

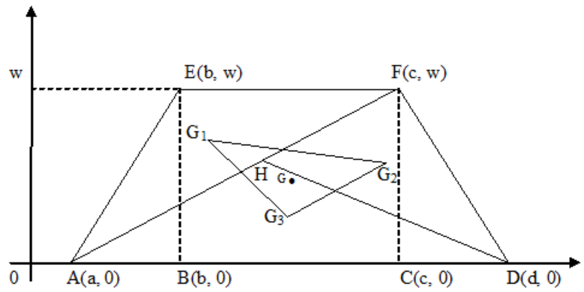

Figure 1. Centroid of centroids of Trapezoidal Fuzzy Number.

As a special case, for triangular fuzzy number $A = (a,b,d;w)$, i.e., $c = b$ the centroid of centroids is given by

$$G = (x_0, y_0) = \left(\frac{3a+4b+2d}{9}, \frac{4w}{9}\right) \tag{3.2}$$

For mapping the set of all generalized trapezoidal and triangular fuzzy numbers to a set of all real number, the ranking function is defined as follows:

$$R(\tilde{A}) = \sqrt{\left(x_0(\tilde{A})\right)^2 + \left(y_0(\tilde{A})\right)^2} \tag{3.3}$$

This is the distance between the centroid of centroids as defined in (3.1) and (3.2) and the original point.

4. Proposed Bi-Objective Linear Model in controlling Communicable Diseases based on treatment cost and dosage

This section proposes a Mathematical Model with two objectives based on fuzzy linear programming problem for minimizing treatment cost and dosage of medicines to the disease population. Furthermore, the section aims to distribute the medicines effectively to the disease population in order to minimize the human productivity loss using the same model.

This model is concerned with finding the overall minimum treatment cost and dosage of medicines for controlling the communicable diseases by the effective distribution of medicines to the disease population.

The data of the model include

- Availability of treatments for various diseases and the size of patients affected by various diseases in a certain region.
- Unit cost and dosage of medicines for treatment (i.e. dosage of medicine and treatment cost per patient)

The functions for calculating the overall minimum treatment cost and dosage of medicines and its constrains are formulated as a bi–objective linear model based on linear programming problem in the following way:

The objective of the problem is that how the various treatments might be distributed to the disease population so as to minimize the overall treatment cost and dosage of medicines. So that, the decision variables are:

x_{ij} is the affordability of the jth treatment to the ith disease, where $i = 1,2,\ldots,m$ and $j = 1,2,\ldots,n$. Totally $m \times n$ variables.

As per the objective of the proposed model the following problem is to be solved to minimize the treatment cost and dosage of medicines.

Consider the treatment i which is to be taken by the disease population who have been affected by the disease j. In this problem, we have notated the unit treatment cost, unit dosage of medicine and affordability of the treatment to the particular disease as c_{ij}, d_{ij}, and x_{ij} respectively. Since we assume that the cost and dosage functions are linear, the total treatment cost and dosage of medicines are calculated as $c_{ij}x_{ij}$ and $d_{ij}x_{ij}$ respectively. Finally, the overall treatment cost and dosage of medicines for all disease-treatment combination is calculated by summing all i and j. This is formulated as objective functions of the proposed problem. Mathematically, it is noted as follows:

Minimize $\tilde{Z} = \sum_{i=1}^{m}\sum_{j=1}^{n} \tilde{c}_{ij}x_{ij}$

Minimize $\tilde{Z} = \sum_{i=1}^{m}\sum_{j=1}^{n} \tilde{d}_{ij}x_{ij}$.

Then it will become single objective function as per the objective of the problem based on the weights of the objectives cost and dosage. The objective function with bi-objectives is given as follows.

Minimize $\tilde{Z} = w_1 \sum_{i=1}^{m}\sum_{j=1}^{n} \tilde{c}_{ij}x_{ij} + w_2 \sum_{i=1}^{m}\sum_{j=1}^{n} \tilde{d}_{ij}x_{ij}$.

Subsequently, the constrain equations for the above objective function is formulated as follows: The total affordability of the specific treatment i for curing the various diseases spreading in a certain region is the sum of the decision variables $x_{i1}, x_{i2}, \ldots, x_{in}$. The affordability cannot exceed the availability of this treatment a_i in that region.

(i.e.) $\sum_{j=1}^{n} x_{ij} \leqslant a_i$ for $i = 1,2,\ldots,m$

The total affordability of the various treatments ($i = 1,2, \ldots, n$) for the specific disease j in a certain region is the sum of the decision variables $x_{1j}, x_{2j}, \ldots, x_{mj}$. The affordability should not be less than the total size of the patients b_j affected by such disease.

(i.e.) $\sum_{i=1}^{m} x_{ij} \geqslant b_j$ for $j = 1,2,\ldots,n$

where $x_{ij} \geqslant 0$ for all i and j.

From the above constraint equations, the total availability of various treatments is greater than or equal to the size of the patients affected by the various diseases in the certain region.

(i.e.) $\sum_{i=1}^{m} a_i \geqslant \sum_{j=1}^{n} b_j$.

This problem is called an unbalanced problem. It will become a balanced one if the above inequality is the equality.

(i.e.) $\sum_{i=1}^{m} a_i = \sum_{j=1}^{n} b_j$.

Table 4.1. Fuzzy Model for Optimization of Cost and dosage of Treatment of Diseases.

Treatments/ Diseases	D_1	D_2	$\dots$	D_j	$\dots$	D_n	Supply (availability of treatment T_j)
T_1	$\tilde{c}_{11};\tilde{d}_{11}$	$\tilde{c}_{12};\tilde{d}_{12}$	$\dots$	$\tilde{c}_{1j};\tilde{d}_{1j}$	$\dots$	$\tilde{c}_{1n};\tilde{d}_{1n}$	$\tilde{a}_1$
T_2	$\tilde{c}_{21};\tilde{d}_{21}$	$\tilde{c}_{22};\tilde{d}_{22}$	$\dots$	$\tilde{c}_{2j};\tilde{d}_{2j}$	$\dots$	$\tilde{c}_{2n};\tilde{d}_{2n}$	$\tilde{a}_2$
$\vdots$			$\ddots$		$\ddots$		$\vdots$
T_i	$\tilde{c}_{i1};\tilde{d}_{i1}$	$\tilde{c}_{i2};\tilde{d}_{i2}$	$\dots$	$\tilde{c}_{ij};\tilde{d}_{ij}$	$\dots$	$\tilde{c}_{in};\tilde{d}_{in}$	$\tilde{a}_i$
$\vdots$			$\ddots$		$\ddots$		$\vdots$
T_m	$\tilde{c}_{m1};\tilde{d}_{m1}$	$\tilde{c}_{m2};\tilde{d}_{m2}$	$\dots$	$\tilde{c}_{mj};\tilde{d}_{mj}$	$\dots$	$\tilde{c}_{mn};\tilde{d}_{mn}$	$\tilde{a}_m$
Demand (no. of patients affected by disease D_i to be taken for treatment)	$\tilde{b}_1$	$\tilde{b}_2$	$\dots$	$\tilde{b}_j$	$\dots$	$\tilde{b}_n$	

In a balanced problem, each constraint equations are as follows:

$\sum_{j=1}^{n} x_{ij} = a_i$ for $i = 1,2,\dots,m$.

$\sum_{i=1}^{m} x_{ij} = b_j$ for $j = 1,2,\dots,n$.

It is always possible to convert the unbalanced problem into a balanced one by introducing dummy row(s) or column(s).

Explicitly, the problem is represented in Table 4.1.

5. Case Study

In many countries, the communicable diseases are major causes of illness that are as a result of causative organism spreading from one person to another. Most probably, children are affected by such type of diseases. However, the people of all ages are also affected by the same. So that Health Department has a greater responsibility to control these type of diseases by its effective management system.

In Nagapattinam Region, the availability of various treatments like Allopathy (T_1), Ayurvedic (T_2), Homeopathy (T_3) and Unani (T_4), Yoga (T_5), Naturopathy (T_6) for all type of diseases are (52000, 54000, 57000), (33000, 35000, 37000), (11200, 13700, 15300), (6400, 8700, 10800), (2500, 3200, 4100) and (1540, 1630, 1750) respectively. Moreover, the size of patients affected by the communicable diseases in winter season like Synflu (D_1), Ebola (D_2), Dengue (D_3), Malaria (D_4) and Tuberculosis (D_5) are (22700, 23400, 26500), (15250, 17500, 19250). (11350, 13550, 16550), (6340, 7520, 8450) and (4230, 5420, 6320). respectively. Treatment cost and dosage of medicines for all above said treatment-disease combination per patient are given in Table 5.1.

Table 5.1. Fuzzy Treatment Cost and Fuzzy Dosage per Patient

Treatment	Disease	Treatment Cost per Patient (in Rupees)	Dosage per Patient (in gms) (per course)
Allopathy	Synflu	(2500, 3400, 3700)	(4, 5.5, 7)
	Ebola	(2000, 2700, 3200)	(7, 11, 13)
	Dengue	(8000, 8600, 9000)	(425, 510, 560)
	Malaria	(10000, 12000, 14000)	(250, 275, 300)
	Tuberculosis	(28000, 30000, 32000)	(550, 650, 750)
Ayurvedic	Synflu	(1500, 2200, 2500)	(90, 250, 425)
	Ebola	(2400, 3100, 3500)	(450, 520, 580)
	Dengue	(4200, 4500, 5000)	(1200, 1450, 1850)
	Malaria	(5400, 6500, 7200)	(1300, 1750, 1920)
	Tuberculosis	(22000, 24000, 26500)	(850, 950, 1050)
Homeopathy	Synflu	(3500, 4100, 4600)	(0.6, 0.85, 1.2)
	Ebola	(4000, 4500, 5000)	(1.2, 1.8, 2.3)
	Dengue	(3200, 4300, 4600)	(36, 48, 54)
	Malaria	(18000, 20000, 24000)	(55, 68, 80)
	Tuberculosis	(32000, 43000, 45000)	(90, 120, 175)
Unani	Synflu	(3200, 3600, 4300)	(190, 280, 390)
	Ebola	(3500, 4200, 4500)	(420, 480, 520)
	Dengue	(5000, 5400, 5800)	(1200, 1450, 1520)
	Malaria	(12000, 17000, 21000)	(725, 845, 950)
	Tuberculosis	(29000, 31000, 33000)	(1290, 1320, 1475)
Yoga	Synflu	(950, 1200, 1500)	(10, 25, 42)
	Ebola	(1000, 1200, 1400)	(14, 21, 24)
	Dengue	(2100, 2500, 2700)	(1300, 1700, 2050)
	Malaria	(3200, 4700, 5200)	(545, 625, 850)
	Tuberculosis	(17000, 19500, 21400)	(48, 57, 74)
Naturopathy	Synflu	(4200, 4800, 5200)	(8, 11, 14)
	Ebola	(4000, 5400, 6500)	(19, 21, 23)
	Dengue	(6200, 7400, 8200)	(950, 1200, 1450)
	Malaria	(12000, 17000, 21000)	(325, 420, 540)
	Tuberculosis	(29000, 31000, 33000)	(37, 42, 53)

The data collected from the Department of Medical and Rural Health Services at Nagapattinam District.

Let us consider a optimization problem given in Table 5.2 with rows representing treatments Allopathy (T_1), Ayurvedic (T_2), Homeopathy (T_3) Unani (T_4), Yoga (T_5) and Naturopathy (T_6) and column representing communicable diseases Synflu (D_1), Ebola (D_2), Dengue (D_3) and Malaria (D_4) and Tuberculosis (D_5) which are affected in the winter season at Nagapattinam Region.

Using the ranking function in equation (3.3), the values of $R(\tilde{c}_{ij})$, $R(\tilde{t}_{ij})$, $R(\tilde{a}_i)$ and $R(\tilde{b}_j)$ for all i and j are calculated and given in Table 5.3.

Table 5.2. Unbalanced Table with Fuzzy Treatment Cost and Fuzzy Dosage

Treatments/ Diseases	Synflu (D_1)	Ebola (D_2)	Dengue (D_3)	Malaria (D_4)	Tuberculosis (D_5)	Supply (availability of treatment T_j)
Allopathy (T_1)	(2500, 3400, 3700) (4, 5.5, 7)	(2000, 2700, 3200) (7, 11, 13)	(8000, 8600, 9000) (425, 510, 560)	(10000, 12000, 14000) (250, 275, 300)	(28000, 30000, 32000) (550, 650, 750)	(52000, 54000, 57000)
Ayurvedic (T_2)	(1500, 2200, 2500) (90, 250, 425)	(2400, 3100, 3500) (450, 520, 580)	(4200, 4500, 5000) (1200, 1450, 1850)	(5400, 6500, 7200) (1300, 1750, 1920)	(22000, 24000, 26500) (850, 950, 1050)	(33000, 35000, 37000)
Homeopathy (T_3)	(3500, 4100, 4600) (0.6, 0.85, 1.2)	(4000, 4500, 5000) (1.2, 1.8, 2.3)	(3200, 4300, 4600) (36, 48, 54)	(18000, 20000, 24000) (55, 68, 80)	(32000, 43000, 45000) (90, 120, 175)	(11200, 13700, 15300)
Unani (T_4)	(3200, 3600, 4300) (190, 280, 390)	(3500, 4200, 4500) (420, 480, 520)	(5000, 5400, 5800) (1200, 1450, 1520)	(12000, 17000, 21000) (725, 845, 950)	(29000, 31000, 33000) (1290, 1320, 1475)	(6400, 8700, 10800)
Yoga (T_5)	(950, 1200, 1500) (10, 25, 42)	(1000, 1200, 1400) (14, 21, 24)	(2100, 2500, 2700) (1300, 1700, 2050)	(3200, 4700, 5200) (545, 625, 850)	(17000, 19500, 21400) (48, 57, 74)	(2500, 3200, 4100)
Naturopathy (T_6)	(4200, 4800, 5200) (8, 11, 14)	(4000, 5400, 6500) (19, 21, 23)	(6200, 7400, 8200) (950, 1200, 1450)	(12000, 17000, 21000) (325, 420, 540)	(29000, 31000, 33000) (37, 42, 53)	(1540, 1630, 1750)
Demand (no. of patients affected by the disease D_i to be taken for the treatment)	(22700, 23400, 26500)	(15250, 17500, 19250)	(11350, 13550, 16550)	(6340, 7520, 8450)	(4230, 5420, 6320)	

Table 5.3. Unbalanced Table with Treatment Cost and Dosage

Treatments/ Diseases	Synflu (D_1)	Ebola (D_2)	Dengue (D_3)	Malaria (D_4)	Tuberculosis (D_5)	(D_6)	Supply (availability of treatment T_j)
Allopathy (T_1)	3166.67 5.35	2577.78 10.12	8488.89 492.78	11777.78 272.22	29777.78 638.89	0 0	54000.00
Ayurvedic (T_2)	2033.33 235.56	2955.56 510.00	4511.11 1455.56	6288.89 1637.78	23888.89 938.89	0 0	34777.78
Homeopathy (T_3)	4011.11 0.95	4444.44 1.77	4000.00 45.34	20222.22 66.33	39777.78 122.22	0 0	13222.22
Unani (T_4)	3622.22 274.44	4033.33 468.89	5355.56 1382.22	16222.22 828.33	30777.78 1344.44	0 0	8400.00
Yoga (T_5)	1183.33 23.78	1177.78 19.34	2411.11 1644.44	4311.11 648.33	19088.89 57.78	0 0	3166.67
Naturopathy (T_6)	4688.89 10.68	5177.78 20.78	7177.78 1172.22	16222.22 415.00	30777.78 42.78	0 0	1626.67
Demand (no. of patients affected by the disease D_i to be taken for treatment)	23855.56	17138.89	13483.33	7333.33	5223.33	0	

The problem shown in Table 5.3 is unbalanced. For make it as a balanced one, the dummy column is introduced as shown in Table 5.4. The crisp multi-objective transportation problem shown in Table 5.4 is converted into the following crisp linear programming problem by using step 6.

Table 5.4. Balanced Table with Treatment Cost and Dosage

Treatments/ Diseases	Synflu (D_1)	Ebola (D_2)	Dengue (D_3)	Malaria (D_4)	Tuberculosis (D_5)	(D_6)	Supply (availability of treatment T_j)
Allopathy (T_1)	1586.01	1293.95	4490.83	6025.00	15208.33	0	54000.00
Ayurvedic (T_2)	1134.44	1732.78	2983.33	3963.33	12413.89	0	34777.78
Homeopathy (T_3)	2006.03	2223.11	2022.67	10144.28	19950.00	0	13222.22
Unani (T_4)	1948.33	2251.11	3368.89	8525.28	16061.11	0	8400.00
Yoga (T_5)	603.56	598.56	2027.78	2479.72	9573.33	0	3166.67
Naturopathy (T_6)	2349.78	2599.28	4175.00	8318.61	15410.28	0	1626.67
Demand (no. of patients affected by the disease D_i to be taken for treatment)	23855.56	17138.89	13483.33	7333.33	5223.33	0	

Minimize
$(1586.01)x_{11}+(1293.95)x_{12}+(4490.83)x_{13}+(6025.00)x_{14}$
$+(15208.33)x_{15}+(0)x_{16}+(1134.44)x_{21}+(1732.78)x_{22}$
$+(2983.33)x_{23}+(3963.33)x_{24}+(12413.89)x_{25}+(0)x_{26}$
$+(2006.03)x_{31}+(2223.11)x_{32}+(2022.67)x_{33}$
$+(10144.28)x_{34}+(19950.00)x_{35}+(0)x_{36}+(1948.33)x_{41}$
$+(2251.11)x_{42}+(3368.89)x_{43}+(8525.28)x_{44}$
$+(16061.11)x_{45}+(0)x_{46}+(603.56)x_{51}+(598.56)x_{52}$
$+(2027.78)x_{53}+(2479.72)x_{54}+(9573.33)x_{55}+(0)x_{56}$
$+(2349.78)x_{61}+(2599.28)x_{62}+(4175.00)x_{63}$
$+(8318.61)x_{64}+(15410.28)x_{65}+(0)x_{66}$
Subject to
$x_{11}+x_{21}+x_{31}+x_{41}+x_{51}+x_{61}=23855.56$
$x_{12}+x_{22}+x_{32}+x_{42}+x_{52}+x_{62}=17138.89$
$x_{13}+x_{23}+x_{33}+x_{43}+x_{53}+x_{63}=13483.33$
$x_{14}+x_{24}+x_{34}+x_{44}+x_{54}+x_{64}=7333.33$
$x_{11}+x_{12}+x_{13}+x_{14}+x_{15}+x_{16}=54000.00$
$x_{21}+x_{22}+x_{23}+x_{24}+x_{25}+x_{26}=34777.78$
$x_{31}+x_{32}+x_{33}+x_{34}+x_{35}+x_{36}=13222.22$
$x_{41}+x_{42}+x_{43}+x_{44}+x_{45}+x_{46}=8400.00$
$x_{51}+x_{52}+x_{53}+x_{54}+x_{55}+x_{56}=3166.67$
$x_{61}+x_{62}+x_{63}+x_{64}+x_{65}+x_{66}=1626.67$

Using LINGO software, the crisp linear programming problem is solved to find the optimum solution which is as follows:
$x_{12}=17138.89$, $x_{16}=36861.11$,
$x_{21}=23855.56$, $x_{23}=261.11$, $x_{24}=4166.66$,
$x_{26}=6494.45$, $x_{33}=13222.22$, $x_{46}=8400.00$,
$x_{54}=3166.67$, $x_{66}=1626.67$

The overall minimum treatment cost and dosage respectively are Rs. 186,608,861.6 and 15,649,398.09 mg.

6. Conclusion

In this paper we have made an attempt to analyze the health care system in order to minimize the human productivity loss by the effective distribution of available medicines to disease population in a particular region. In order to analyze the healthcare system, bi-objective Fuzzy Mathematical Model based on fuzzy linear programming problem has been proposed for the effective distribution of medicines to the disease population in a certain region. The proposed method also minimizes the total treatment cost and dosage of medicines by its effective distribution. Moreover, an effective case study has been made in Nagapattinam District to demonstrate the proposed methodology. This study might be handy to the health department in the near future.

Acknowledgement

I acknowledge the University Grant Commission for supporting this research work by funding under the scheme Minor Research Project wide Reference No. MRP-6738/16 (SERO/UGC) dated June 2017.

References

[1] Ahmet F. Ozok, Fuzzy modelling and efficiency in health care systems, IOS Press, 41(2012) 1797–1800.
[2] Gü rsel, G., Healthcare, uncertainty, and fuzzy logic, *Digit Med*, 2(2016), 101–12.
[3] Mayilvaganan, M. and Rajeswari, K. Health Care Analysis Based On Fuzzy Logic Control System, *International Journal of Computer Science Trends and Technology (IJCST)*, 2(4)(2014).
[4] Sivakumar, G. and Hari Ganesh, A., Application of Fuzzy Multi Objective Linear Programming in the Efficient Treatment of Communicable Diseases, *Global Journal of Pure and Applied Mathematics*, 11(3)(2015), 1363–1377.
[5] Suman Sankar Bhunia, Sourav Kumar Dhar and Nandini Mukherjee, iHealth: A Fuzzy approach for provisioning Intelligent Health-care system in Smart City, *IEEE*, (2014) 187–193.

[6] Thanh Nguyen, Abbas Khosravi, Douglas Creighton, Saeid Nahavandi, Classification of healthcare data using genetic fuzzy logic system and wavelets, *Expert Systems with Applications*, 42(4)(2015), 2184–2197.

[7] Venkatesh, A. and Sivakumar, G., On Fuzzy Optimization Modeling in Healthcare Analysis Based on Linear Programming Problem, *International Journal of Current Research and Modern Education*, 2(1)(2017), 124–131.

[8] Venkatesh, A. and Sivakumar, G., On Single Objective Linear Model in Controlling Communicable Diseases Based on Fuzzy Linear Programming Problem, *International Journal of Applied and Advanced Scientific Research*, 2(2)(2017), 211–218.

[9] Venkatesh, A. and Sivakumar, G. and Rameshbabu, S., Fuzzy Optimization Modeling in the Analysis of Human Health Care Based on Linear Programming Problem, *International Journal of Applied and Advanced Scientific Research*, 2(2)(2017), 82–90.

⋆⋆⋆⋆⋆⋆⋆⋆⋆
ISSN(P):2319 − 3786
Malaya Journal of Matematik
ISSN(O):2321 − 5666
⋆⋆⋆⋆⋆⋆⋆⋆⋆