ACHIEVING FOOD SECURITY: AN EVALUATION OF FERTILIZER REQUIREMENTS FOR DIFFERENT CROPS USING VARIOUS OPTIMIZATION TECHNIQUES

Suganthi P[1], Ebenesar Anna Bagyam J[2*], Umamaheswari E[3], Divya Darshini S[4]

Article History: Received: 15.03.2023 **Revised:** 31.04.2023 **Accepted:** 14.06.2023

Abstract

Fertilizers are essential for crops in order to provide humans with food. Fertilizers provide plants with the nutrients potassium, phosphorus, and nitrogen, allowing them to grow more quickly and generate more food. Every living thing on Earth needs nutrients to develop, and nitrogen, in particular, is crucial. Almost 78% of the inhaled air comprises nitrogen, which is present all around us. By 2050, there will be 9 billion individuals due to population growth. We must produce 60 percent more food on the same land by then. Wherever people reside, there must be sufficient wholesome food accessible at reasonable costs at all times to attain food security. Food production and farm performance must be raised, especially in areas with excellent food insecurity. Furthermore, we must do so effectively to ensure future generations' access to food. Using fertilizers is vital for achieving food production, as they are the source of 50% of the food consumed today. Any product or material administered to the soil to encourage plant development is called a fertilizer. There are many different types of fertilizers, most of which include potash, phosphorus, and nitrogen. In reality, the package of fertilizer bought in supermarkets lists the N-P-K ratio. Fertilizers are used worldwide to maintain lush lawns and increase crop yields in agricultural areas. In this paper, we study the fertilizer requirements for different crops. We consider fuzzy triangular numbers and supply and demand as fuzzy quantities. We use Vogel's Approximation Method (VAM) to obtain the optimal solution. Additionally, we compare the solution obtained in VAM with five other methods: the Least Cost Method, Row Minima Method, Column Minima Method, Russell's Approximation Method, and Heuristic 1 Method.

Keywords: Triangular Fuzzy Number, Transportation Problem, Defuzzification, Ranking Method, Vogel's Approximation Method, Optimal Cost.

[1]Department of Mathematics, R.M.K. Engineering College, Tiruvallur, Tamil Nadu - 601 206
[2*]Department of Mathematics Karpagam Academy of Higher EducationCoimbatore, Tamil Nadu - 641021
[3]Department of Mathematics, R.M.K. Engineering College, Tiruvallur, Tamil Nadu - 601 206
[4]Department of Mathematics, Avinashilingam Institute for Home Science and Higher Education for Women, Coimbatore, Tamil Nadu – 641 043

Email: [1]suganthirajkannu@gmail.com, [3]eum.sh@rmkec.ac.in
Corresponding Email: [2*]ebenesar.j@gmail.com

DOI: 10.31838/ecb/2023.12.6.48

1. Introduction

In commercial settings, fertilizer is vital for the overall growth and productivity of vegetable crops. The soil in which we plant our veggies eventually serves as their habitat; therefore, it must have the necessary chemical and biological components to support healthy plant development. Like other living things, vegetable plants need nutrients and minerals to grow and produce fruit.

Three essential nutrients supplied by fertilizers are nitrogen (N), phosphorus (P), and potassium (K). Nitrogen supports veggie growth, while phosphorus enhances flowering and root development. Potassium improves resilience to environmental stresses, such as pest attacks and extremely high temperatures.

Ebrahimnejad reviewed some of the current solutions. Additionally, the inadequacies of several previous approaches are highlighted, and a novel method is proposed for determining the type of FTP in which transportation costs and values of supply and demand are represented by non-negative triangular fuzzy integers [4]. Shanmugasundari and Ganesan addressed the transportation problem with fuzzy parameters using a novel approach to fuzzy optimal solution. They created a fuzzy version of the Vogel's and MODI algorithms to provide a fundamental, practical, and fuzzy optimal solution to fuzzy transportation issues [13]. Chauhan and Joshi analyzed the goal of the current research as investigating a solution to the fuzzy transportation problem to determine the lowest possible transportation costs for goods. They proposed a ranking approach to locate the fuzzy ideal solution of a balanced fuzzy system. They solved a transportation problem using an improved Vogel's Approximation Technique [2]. Nareshkumar and Ghuru discussed the fuzzy transportation problem and suggested a method that uses symmetric triangular fuzzy numbers to represent the product's demand, availability, and transportation costs. They created a fuzzy version of Vogel's techniques to determine the fuzzy optimal solution to the fuzzy transportation problem. They provided a numerical example to demonstrate the effectiveness of the approach [10]. Kumar examined the type-2 and type-4 FTPs and converted them into a crisp form using Liou and Wang's existing ranking algorithm. They suggested a quick and effective procedure known as the PSK (P. Senthil Kumar) method to achieve the best result in terms of TrFNs [6]. Anuradha and Sobana studied a transportation problem with ambiguous numbers, which is considered uncertain. They presented a survey of the single-objective fuzzy transportation problem (SOFTP) and the multi-objective fuzzy transportation problem (MOFTP) along with their mathematical models [1].

Singh and Saxena analyzed and proposed a solution to the fuzzy transportation problem where the product's availability, demand, and transportation cost are represented as trapezoidal fuzzy numbers. They solved a numerical case to demonstrate the suggested method and compared the results to those of other methods [14]. Mishra described the best optimality condition and highlighted that minimizing the cost or time of transportation is the major goal of transportation problem-solving techniques. They used the North-West corner rule, the Minimum Cost Method, and Vogel's Approximation Method to arrive at an Initial Basic Feasible Solution (IBFS) for the transportation problem [9].

Kumar and Subramanian determined the least expensive method of transporting a set of commodities over a network with capacity, where the supply and demand of nodes, as well as the capacity and cost of edges, are represented by fuzzy integers

[5]. Rajkumari and Bhuvaneswari focused on fuzzy triangle numbers and fuzzy transportation costs. They utilized a fuzzy transportation algorithm and the least-cost method to find the optimal solution for FTP [11]. Vairal et al. highlighted the benefits of fuzzy logic for problem-solving in various domains and described its applications in areas such as business, politics, environment, chemistry, physics, statistics, medicine, computer science, engineering, agriculture, etc. [15].
Mathur and Srivastava aimed to offer a novel method for resolving transportation issues in a fuzzy environment using generalized trapezoidal numbers. Their key contribution is the creation of a novel approach to the generalized fuzzy trapezoidal transportation problem [8]. Sangeetha et al. discussed the dual simplex approach as the main strategy to address the fuzzy transportation problem. They employed a robust ranking technique for the iterative trapezoidal fuzzy number values within the fuzzy transportation problem. They transformed the fuzzy transportation problem into a crisp-valued transportation problem [12].
Das proposed a fully fuzzy triangular linear fractional programming (FFLFP) problem in this article, assuming that all the parameters and decision variables are represented by triangular fuzzy numbers. The FFLFP problem is transformed into a multi-objective function using triangular fuzzy number computation and Lexicographic order (LO) [3]. Kumari considered a fuzzy transportation problem and solved it using a variety of approaches, although some of the approaches did not produce the best results. They suggested selecting and applying the approach that yields the best result in daily life [7].

1 Fuzzy Transportation Model for Fertilizer and Nutrient Requirement

The considered fertilizers are urea, SSP, and MOP, and the nutrients considered are nitrogen, phosphorus, and potassium. We examine the fertilizer requirements for seven different vegetables: broccoli, carrots, cucumbers, potatoes, onions, tomatoes, and cauliflower. The optimum cost is obtained through a triangular fuzzy transportation model, and a comparative study of the optimum cost is conducted using various transportation models.

1.1 Interpretation of Fertilizer and Nutrient Requirement

The measurements of fertilizer content were obtained from various sources, including apnikheti.com. The fertilizer and nutrient requirements are represented as fuzzy triangular numbers, considering the minimum, standard, and maximum values. Both supply and demand are also represented as fuzzy triangular numbers. For instance, the minimum, standard, and maximum levels of urea in broccoli are (109.5, 110, and 110.5), and the levels of SSP in broccoli are (159.5, 160, and 160.5), as shown in Table 1.

The fuzzy transportation problem for the nutritional values of vegetables can be formulated in the following mathematical form:

Min z = R (109.5, 110, 110.5) a_{11}+ R (159.5, 160, 160.5) a_{12}+ R (39.5, 40, 40.5)a_{13} + R (54.5, 55, 55.5) a_{14} + R (24.5, 25, 25.5) a_{15} + R (24.5, 25, 25.5)a_{16} + R (54.5, 55, 55.5)a_{21} + R (74.5, 75, 75.5)a_{22} + R (54.5, 55, 55.5) a_{23} + R (24.4, 25, 25.5) a_{24} + R (12.5, 13, 13.5) a_{25} + R (28.5, 29, 29.5) a_{26}
+ R (89.5, 90, 90.5) a_{31} + R (119.5, 120, 120.5) a_{32} + R (35.5, 36, 36.5) a_{33} + R (39.5, 40, 40.5) a_{34} + R (19.5, 20, 20.5) a_{35} + R (19.5, 20, 20.5) a_{36}
+ R (164.5, 165, 165.5) a_{41}+R

(149.5, 150, 150.5) a_{42}+ R (44.5, 45, 45.5) a_{43} + R (69.5, 70, 70.5) a_{44} + R (24.5, 25, 25.5) a_{45} + R (24.5, 25, 25.5 a_{46} + R (89.5, 90, 90.5) a_{51} + R (124.5, 125, 125.5) a_{52} + R (29.5, 30, 30.5)a_{53} + R (39.5, 40, 40.5) a_{54} + R (18.5, 19, 19.5)a_{55} + R (18.5, 19, 19.5) a_{56} + R (134.5, 135, 135.5) a_{61}+ R (159.5, 160, 160.5) a_{62}+ R (44.5, 45, 45.5) a_{63} + R (59.5, 60, 60.5) a_{64} + R (24.5, 25, 25.5) a_{65} + R (24.5, 25, 25.5) a_{66} + R (109.5, 110, 110.5) a_{71}+ R (154.5, 155, 155.5) a_{72}+ R (39.5, 40, 40.5)a_{73} + R (49.5, 50, 50.5) a_{74} + R (24.5, 25, 25.5)a_{75} + R (24.5, 25, 25.5) a_{76}

Table 1.Fertilizer and Nutrient Requirement for Vegetable Crops

	Urea	**SSP**	**MOP**	**N**	**P**	**K**	**Supply**
Broccoli	(109.5, 110, 110.5)	(159.5, 160, 160.5)	(39.5, 40, 40.5)	(54.5, 55, 55.5)	(24.5, 25, 25.5)	(24.5, 25, 25.5)	(24.09, 24.59, 25.09)
Carrot	(54.5, 55, 55.5)	(74.5, 75, 75.5)	(54.5, 55, 55.5)	(24.4, 25, 25.5)	(12.5, 13, 13.5)	(28.5, 29, 29.5)	(7.39, 7.89, 8.39)
Cucumber	(89.5, 90, 90.5)	(119.5, 120, 120.5)	(35.5, 36, 36.5)	(39.5, 40, 40.5)	(19.5, 20, 20.5)	(19.5, 20, 20.5)	(6.289, 6.789, 7.289)
Potato	(164.5, 165, 165.5)	(149.5, 150, 150.5)	(44.5, 45, 45.5)	(69.5, 70, 70.5)	(24.5, 25, 25.5)	(24.5, 25, 25.5)	(4.894, 5.394, 5.894)
Onion	(89.5, 90, 90.5)	(124.5, 125, 125.5)	(29.5, 30, 30.5)	(39.5, 40, 40.5)	(18.5, 19, 19.5)	(18.5, 19, 19.5)	(3.994, 4.494, 4.994)
Tomato	(134.5, 135, 135.5)	(159.5, 160, 160.5)	(44.5, 45, 45.5)	(59.5, 60, 60.5)	(24.5, 25, 25.5)	(24.5, 25, 25.5)	(13.348, 13.848, 14.348)
Cauliflower	(109.5, 110, 110.5)	(154.5, 155, 155.5)	(39.5, 40, 40.5)	(49.5, 50, 50.5)	(24.5, 25, 25.5)	(24.5, 25, 25.5)	(9.38, 9.88, 10.38)
Demand	(5.022, 5.522, 6.022)	(6.74, 7.24, 7.74)	(17.5, 18, 18.5)	(5.5, 6, 6.5)	(22.12, 22.62, 23.12)	(39.5, 40, 40.5)	

The supply is considered as the cost of an edible portion of vegetables per 100 grams, and the demand is the cost of fertilizers and nutrients per 100 grams.

1.2 Ranking of Triangular Fuzzy Fertilizer Requirement

The Ranking for the fuzzy cost a_{ij} for the table is calculated as:
R (109.5, 110, 110.5) a_{11} = 110, R (159.5, 160, 160.5) a_{12} = 160, R (39.5, 40, 40.5)a_{13} = 40, R (54.5, 55, 55.5)a_{14} = 55, R (24.5, 25, 25.5)a_{15} = 25, R (24.5, 25, 25.5) a_{16} = 25, R (54.5, 55, 55.5)a_{21} = 55, R (74.5, 75, 75.5)a_{22} = 75, R (54.5, 55, 55.5)a_{23} = 55, R (24.2, 25, 25.5) a_{24} = 25, R (12.5, 13, 13.5) a_{25} = 13, R (28.5, 29, 29.5)a_{26} =29, R (89.5, 90, 90.5) a_{31} = 90, R (119.5, 120, 120.5)a_{32} = 120, R (35.5, 36, 36.5)a_{33} = 36, R (39.5, 40, 40.5) a_{34} = 40, R (19.5, 20, 20.5)a_{35} = 20, R (19.5, 20, 20.5)a_{36} = 20, R (164.5, 165, 165.5)a_{41} = 165, R (149.5, 150, 150.5) a_{42} = 150, R (44.5, 45, 45.5) a_{43} = 45, R (69.5, 70, 70.5) a_{44} = 70, R (24.5, 25, 25.5) a_{45} = 25, R (24.5, 25, 25.5)a_{46} = 25, R (89.5, 90, 90.5) a_{51} = 90, R (124.5, 125, 125.5)a_{52} = 125, R (29.5, 30, 30.5)a_{53} = 90, R (39.5, 40, 40.5) a_{54} = 40, R (18.5, 19, 19.5)a_{55} = 19, R (18.5, 19, 19.5)a_{56} = 19, R (134.5, 135, 135.5)a_{61} = 135, R (159.5, 160, 160.5) a_{62} = 160, R (44.5, 45, 45.5) a_{63} = 45, R (59.5, 60, 60.5) a_{64} = 60, R (24.5, 25, 25.5) a_{65} = 25, R (24.5, 25, 25.5)a_{66} = 25, R (109.5, 110, 110.5) a_{71} = 110, R (154.5, 155, 155.5)a_{72} = 155, R (39.5, 40, 40.5)a_{73} = 40, R (49.5, 50, 50.5) a_{74} = 50, R (24.5, 25, 25.5)a_{75} = 25, R (24.5, 25, 25.5)a_{76} = 25,

Supply
R (24.09, 24.59, 25.09) = 24.59, R(7.39, 7.89, 8.39) = 7.89 R (6.289, 6.789, 7.289) = 6.789, R (4.894, 5.394, 5.894) = 5.394, R(3.994, 4.494, 4.994) = 4.494, R (13.348, 13.848, 14.348)= 13.84 R (9.38, 9.88, 10.38) = 9.88

Demand
R (5.022, 5.522, 6.022) = 5.522, R (6.74, 7.24, 7.74) = 7.24, R (17.5, 18, 18.5) = 18, R (5.5, 6, 6.5) = 6, R (22.12, 22.62, 23.12) = 22.62, R(39.5, 40, 40.5) = 40

Table 2 Ranking Technique of the Fertilizer and Nutrient Requirement for Vegetable Crops

	Urea	**SSP**	**MOP**	**N**	**P**	**K**	**Supply**
Broccoli	110	160	40	55	25	25	24.59
Carrot	55	75	55	25	13	29	7.89
Cucumber	90	120	36	40	20	20	6.789
Potato	165	150	45	70	25	25	5.394
Onion	90	125	30	40	19	19	4.494
Tomato	135	160	45	60	25	25	13.848
Cauliflower	110	155	40	50	25	25	9.88
Demand	5.522	7.24	18	6	22.62	40	

The ranking value for the fertilizer and nutrient requirements of the vegetable crops is given in Table 2. For example, by applying the ranking technique to the urea requirement of broccoli, we obtain,
R (a) = (109.5, 110, 110.5)/3 = 110

The ranked values of the fertilizer and nutrient requirement of vegetables is given in figure 1.

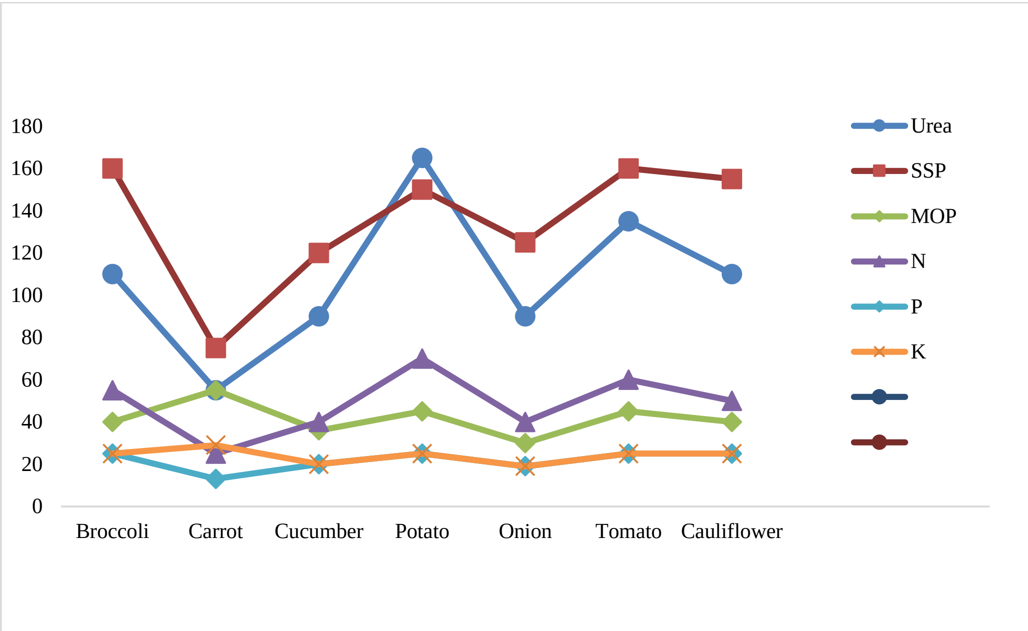

Figure 1 Fertilizer and Nutrient Requirement of Vegetables

1.3 Optimum Solution for Fertilizer Requirement by VAM

The initial basic feasible solution obtained using VAM is given in Table 3.

Table 3 Optimum Solution by VAM for Fertilizer and Nutrient Requirement

	Urea	**SSP**	**MOP**	**N**	**P**	**K**	**Supply**

Broccoli	110	160	40	55	25	24.59 25	24.59
Carrot	55	75	55	6 25	1.89 13	29	7.89
Cucumber	90	120	36	40	6.79 20	20	6.789
Potato	165	150	45	70	3.83 25	1.56 25	5.394
Onion	90	125	4.26 30	40	0.23 19	19	4.494
Tomato	135	160	45	60	25	13.85 25	13.848
Cauliflower	110	155	40	50	9.88 25	25	9.88
Demand	5.522	7.24	18	6	22.62	40	

Table 3 lists the optimum solution obtained by applying Vogel's approximation method (VAM) to the ranked value of fertilizer and nutrient requirement. The values in the top left corner of the table represent the allocated values obtained using VAM. For example, the allocated value for the potassium requirement of Broccoli is 24.59, and nitrogen requirement of carrot is 6.

Table 4 Defuzzification of the Fertilizer and Nutrient Requirement Values

	Urea	**SSP**	**MOP**	**N**	**P**	**K**	**Supply**

Broccoli	(109.5, 110, 110.5)	(159.5, 160, 160.5)	(39.5, 40, 40.5)	(54.5, 55, 55.5)	(24.5, 25, 25.5)	**(24.09, 24.59, 25.09)** (24.5, 25, 25.5)	(24.09, 24.59, 25.09)
Carrot	(54.5, 55, 55.5)	(74.5, 75, 75.5)	(54.5, 55, 55.5)	**(5.5, 6, 6.5)** (24.5, 25, 25.5)	**(1.39, 1.89, 2.39)** (12.5, 13, 13.5)	(28.5, 29, 29.5)	(7.39, 7.89, 8.39)
Cucumber	(89.5, 90, 90.5)	(119.5, 120, 120.5)	(35.5, 36, 36.5)	(39.5, 40, 40.5)	**(6.29, 6.79, 7.29)** (19.5, 20, 20.5)	(19.5, 20, 20.5)	(6.289, 6.789, 7.289)
Potato	(164.5, 165, 165.5)	(149.5, 150, 150.5)	(44.5, 45, 45.5)	(69.5, 70, 70.5)	**(3.33, 3.83, 4.33)** (24.5, 25, 25.5)	**(1.06, 1.56, 2.06)** (24.5, 25, 25.5)	(4.894, 5.394, 5.894)
Onion	(89.5, 90, 90.5)	(124.5, 125, 125.5)	**(3.76, 4.26, 4.76)** (29.5, 30, 30.5)	(39.5, 40, 40.5)	**(-0.27, 0.23, 0.73)** (18.5, 19, 19.5)	(18.5, 19, 19.5)	(3.994, 4.494, 4.994)
Tomato	(134.5, 135, 135.5)	(159.5, 160, 160.5)	(44.5, 45, 45.5)	(59.5, 60, 60.5)	(24.5, 25, 25.5)	**(13.35, 13.85, 14.35)** (24.5, 25,	(13.348, 13.848, 14.348)

						25.5)	
Cauliflower	(109.5, 110, 110.5)	(154.5, 155, 155.5)	(39.5, 40, 40.5)	(49.5, 50, 50.5)	**(9.38, 9.88, 10.38)** (24.5, 25, 25.5)	(24.5, 25, 25.5)	(9.38, 9.88, 10.38)
Demand	(5.022, 5.522, 6.022)	(6.74, 7.24, 7.74)	(17.5, 18, 18.5)	(5.5, 6, 6.5)	(22.12, 22.62, 23.12)	(39.5, 40, 40.5)	

Defuzzication values of the optimum solution are obtained in Table 4 by using the following procedure.

When only one allocated value is obtained:

- The defuzzification values are the same as that of the supply.

When two optimum solutions are obtained in the same row:

- The defuzzification values are obtained by considering the difference of the values in column 4 of row 2, i.e., 0.5. On subtracting and adding 6 with 0.5, we get values 5.5 and 6.5, respectively.

The total minimum cost for fertilizer and nutrient requirement is,

.

Min z = (25) (24.59) + (25) (6) + (13) (1.89) + (20) (6.79) + (25) (3.83) + (25)(1.56) + (30) (4.26) + (19) (0.23) + (25) (13.85) + (25)(9.88)

= 1785.29

The optimum cost obtained using VAM is 1785.29

1.4 Initial Basic Feasible Solution by Least Cost Method

On implementing Least Cost Method, we obtain Table 5.

Table 5 Optimum Solution by LCM for Fertilizer and Nutrient Requirement

	Urea	**SSP**	**MOP**	**N**	**P**	**K**	**Supply**
Broccoli	110	160	40	55	25	24.59 25	24.59
Carrot	55	75	55	25	7.89 13	29	7.89
Cucumber	90	120	36	40	6.79	20	6.789

					20		
Potato	165	150	1.95 45	70	3.45 25	25	5.394
Onion	90	125	30	40	4.49 19	19	4.494
Tomato	135	160	45	60	25	13.85 25	13.848
Cauliflower	110	155	8.32 40	50	25	1.56 25	9.88
Demand	5.522	7.24	18	6	22.62	40	

The total minimum cost for the fertilizer and nutrient requirement is,

Min z = (25) (24.59) + (13) (7.89) + (20) (6.79) + (45) (1.95) + (25) (3.45)
+ (19) (4.49) + (25) (13.85) + (40) (8.32) + (25) (1.56)
= 1830.48

The optimum cost obtained by LCM is 1830.48

1.5 Initial Basic Feasible Solution by Row Minima Method

On applying the Row Minima Method, we obtain Table 6.

Table 6 Optimum Solution by RMM for Fertilizer and Nutrient Requirement

	Urea	**SSP**	**MOP**	**N**	**P**	**K**	**Supply**
Broccoli	110	160	40	55	25	24.59 25	24.59
Carrot	55	75	55	25	7.89 13	29	7.89
Cucumber	90	120	36	40	6.79	20	6.789

					20		
Potato	165	150	45	70	5.39 25	25	5.394
Onion	90	125	30	40	19	4.49 19	4.494
Tomato	135	160	0.38 45	60	2.55 25	10.92 25	13.848
Cauliflower	110	155	9.88 40	50	25	25	9.88
Demand	5.522	7.24	18	6	22.62	40	

The total minimum cost for the fertilizer and nutrient requirement is,

Min z = (25) (24.59) + (13) (7.89) + (20) (6.79) + (25) (5.39) + (19) (4.49) + (45) (0.38) + (25) (2.55) + (25) (10.92) + (40) (9.88)

= 1822.23

The optimum cost obtained by RMM is □ 1822.23.

1.6 Initial Basic Feasible Solution by Column Minima Method

On employing the Column Minima method, we get Table 7.

Table 7 Optimum Solution by CMM for Fertilizer and Nutrient Requirement

	Urea	**SSP**	**MOP**	**N**	**P**	**K**	**Supply**
Broccoli	110	160	40	55	13.71 25	10.88 25	24.59
Carrot	55	75	55	6 25	1.89 13	29	7.89
Cucumber	90	120	36	40	6.79 20	20	6.789
Potato	165	150	45	70	25	5.39	5.394

						25	
Onion	90	125	4.26 30	40	0.23 19	19	4.494
Tomato	135	160	45	60	25	13.85 25	13.848
Cauliflower	110	155	40	50	25	9.88 25	9.88
Demand	5.522	7.24	18	6	22.62	40	

The total minimum cost for the fertilizer and nutrient requirement is,

Min z = (25) (13.71) + (25) (10.88) + (25) (6) + (13) (1.89) + (20) (6.79)

+ (25) (5.39 + (30) (4.26) + (19) (0.23) + (25) (13.85) + (25) (9.88)

= 1785.29

The optimum cost obtained by CMM is □ 1785.29.

1.7 Initial Basic Feasible Solution by Russell's Approximation Method

Russell's Approximation Method is administered in Table 8.

Table 8 Optimum Solution by Russell's Method for Fertilizer and Nutrient Requirement

	Urea	SSP	MOP	N	P	K	Supply
Broccoli	5.52 110	160	18 40	55	25	1.07 25	24.59
Carrot	55	75	55	25	7.89 13	29	7.89
Cucumber	90	120	36	40	20	6.79 20	6.789
Potato	165	150	45	70	25	5.39 25	5.394
Onion	90	125	30	40	19	4.49	4.494

						19	
Tomato	135	160	45	60	25	13.85 25	13.848
Cauliflower	110	155	40	6 50	25	3.88 25	9.88
Demand	5.522	7.24	18	6	22.62	40	

The total minimum cost for the fertilizer and nutrient requirement is,

Min z = (110) (5.52) + (40) (18) + (25) (1.07) + (13) (7.89) + (20) (6.79) + (25) (5.39)+ (19) (4.49) + (25) (13.85) + (50) (6) + (25) (3.88)
= 2555.63

The optimum cost obtained by Russell’s Method is □ 2555.63.

1.8 Initial Basic Feasible Solution by Heuristic Method

In Table 9 Heuristic Method is applied to the fertilizer and nutrient requirement for vegetables.

Table 9 Optimum Solution by Heuristic 1 Method for Fertilizer and Nutrient Requirement

	Urea	**SSP**	**MOP**	**N**	**P**	**K**	**Supply**
Broccoli	110	160	11.09 40	55	25	13.5 25	24.59
Carrot	55	75	55	25	7.89 13	29	7.89
Cucumber	90	120	36	40	6.79 20	20	6.789
Potato	165	1.95 150	45	70	3.45 25	25	5.394
Onion	90	125	30	40	4.49	19	4.494

					19		
Tomato	5.52 135	5.29 160	45	3.03 60	25	25	13.848
Cauliflower	110	155	6.91 40	2.97 50	25	25	9.88
Demand	5.522	7.24	18	6	22.62	40	

The total minimum cost for the fertilizer and nutrient requirement is,

Min z = (40) (11.09) + (25) (13.5) + (13) (7.89) + (20) (6.79) + (150) (1.95) + (25) (3.45) + (19) (4.49) + (135) (5.52) + (160) (5.29) + (60) (3.03)
+ (40) (6.91) + (50) (2.97)
= 3681.83

The optimum cost obtained by Heuristic Method is □ 3681.83.

2. Comparative Analysis

In this section, we compare different methods used to find the initial basic feasible solution; here, we have used six different methods: VAM (Vogel's Approximation Method), LCM (Least Cost Method), RMM (Row Minima Method), CMM (Column Minima Method), Russell's Approximation Method, and Heuristic 1 Method.

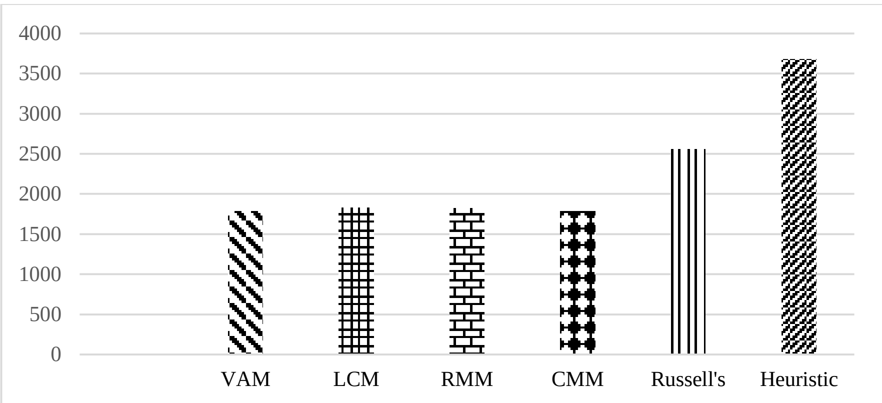

Figure 2 Comparison of Transportation Methods

Comparing the different transportation methods, we obtain the best initial basic feasible solution in VAM and CMM with the optimum cost of □ 1785.29.

Table 10 Maximum Weekly Fertilizer and Nutrient Requirement

Vegetables	**Weekly fertilizer requirement (in kg)**	**Cost of fertilizers in Rupees**

Broccoli	25	614.75
Carrot	38	174.57
Cucumber	20	135.8
Potato	50	134.75
Onion	49	132.17
Tomato	25	346.25
Cauliflower	25	247
Maximum weekly fertilizer cost	-	1785.29

Table 10 illustrates the requirements of fertilizers and nutrients, along with their costs, based on the maximum weekly requirements. The cost is calculated using both the allocated values of fertilizers and nutrients and the value of the specific cell, while the daily requirement for each vegetable is calculated using the values of the cell and the allocations.

2. Conclusion

A triangular fuzzy number in a transportation model helped us obtain the required fertilizers and nutrients for vegetable crops at the lowest possible cost. Additionally, we have analyzed six different transportation models. Through a comparative study of the optimum costs obtained by various methods, we determined that the solutions obtained by Vogel's Approximation Method and the Column Minima Method provide a better initial feasible solution compared to all other methods used here. Fuzzy logic can be successfully employed to simulate complex judgment-making in intricate environments. Furthermore, fuzzy logic accurately handles uncertainty. To delve deeper into our study, we will utilize improved versions of various transportation systems using current techniques. We may also incorporate multiple fuzzy numbers along with their ranking algorithms.

3. References

D. Anuradha, and V. E. Sobana. (2017). "A Survey on Fuzzy Transportation Problems". *In IOP Conference Series: Materials Science and Engineering*. 263 (4): 042105. doi:10.1088/1757-899X/263/4/042105.

S. S. Chauhan and N. Joshi. (2013). "Solution of Fuzzy Transportation Problem using Improved VAM with Robust Ranking Technique". *International Journal of Computer Applications*. 82 (15): 0975 – 8887. DOI:10.5120/14237-1165

S. K. Das. (2022). "An Approach to Optimize the Cost of Transportation Problem Based on Triangular Fuzzy Programming Problem". *Complex & intelligent systems*. *8* (1): 687-699. https://doi.org/10.1007/s40747-021-00535-2.

A. Ebrahimnejad. (2013). "On Solving Transportation Problems with Triangular Fuzzy Numbers: Review with Some Extensions". In *2013 13th Iranian Conference on Fuzzy Systems (IFSC)* (1-4).

IEEE. **DOI:** 10.1109/IFSC.2013.6675629

M. R. Kumar, and S. Subramanian. (2018). "Solution of Fuzzy Transportation Problems with Triangular Fuzzy Numbers using Ranking Function". *International Journal of Pure and Applied Mathematics*. 11(15): 2669-2682.

P.S. Kumar. (2016). "A Simple Method for Solving Type-2 and Type-4 Fuzzy Transportation Problems". *International Journal of Fuzzy Logic and Intelligent Systems*. 16 (4): 225-237. https://doi.org/10.5391/IJFIS.2016.16.4.225

P. Kumari. (2014). "A Comparative Study of Optimization Methods for Fuzzy Transportation Problems". *International Journal of Scientific & Engineering Research.* 5 (5): 76-80.

N. Mathur, and P.K. Srivastava. (2020). "An Inventive Approach to Optimize Fuzzy Transportation Problem". *International Journal of Mathematical, Engineering and Management Sciences*. 5(5): 985–994. DOI:10.33889/IJMEMS.2020.5.5.075

S. Mishra. (2017). "Solving Transportation Problem by Various Methods and their Comparison". *International Journal of Mathematics Trends and Technology*. 44 (4): 270-275.

S. Nareshkumar, and S. Ghuru. (2014). "Solving Fuzzy Transportation Problem Using Symmetric Triangular Fuzzy Number". *International Journal of Advanced Research in mathematics and applications*. 1(1): 74-83.

M. N. Rajakumari, and S. Bhuvaneswari. (2018). "Fuzzy Transportation Problem with Fuzzy Demand and Supply". *International Journal of Science, Humanities, Management and Technology*. 4 (3): 99–109.

V. Sangeetha, K. Thirisangu, and P. Elumalai. (2021). "Dual Simplex Method Based Solution for a Fuzzy Transportation Problem". *Journal of Physics: Conference Series.* 1947(1). **DOI** 10.1088/1742-6596/1947/1/012017012017.

M. Shanmugasundari, and K. Ganesan. (2013). "A Novel Approach for the Fuzzy Optimal Solution of Fuzzy Transportation Problem". *International Journal of Engineering Research and Applications (IJERA).* 3 (1): 1416-1424.

R. Singh, and V. Saxena. (2017). "A New Ranking Based Fuzzy Approach for Fuzzy Transportation Problem". *Computer modelling & new technologies*. 21 (4): 16-21.

K.L. Vairal, S. D Kulkarni, and V. Basotia. (2020). "Fuzzy Logic and its Applications in Some Area: a Mini Review". *Journal of Engineering Sciences*. 11(8): 85-96.