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Neutrosophic Goal Programming Approach for the Dash Diet Model

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Abstract: This paper deals with the modelling and optimization of health care management with particular reference to the Dietary Approaches to Stop Hypertension (DASH) diet problem in a neutrosophic environment. We have considered the degree of acceptance, indeterminacy, and rejection of objectives to express the DASH diet problem's vulnerability in modelling. Further, neutrosophic goal programming (NGP) by considering three different types of membership functions have been used to minimize the sum of deviation from the set goal. A case study has been discussed to determine an appropriate DASH diet based on cost and user preferences. The results indicated that goal programming (GP) and fuzzy goal programming (FGP) approach failed to provide the value of all the concerned decision variables related to different types of food. However, we can get all the concerned decision variables valuable for diet problems through NGP. The application developed in this study is a problem of optimization that provides users with a daily diet that contains all the necessary amounts of supplements with less expense. The fundamental fact of the DASH diet is not only to shed blood pressure however to decrease the circulatory strain of the body, and so that it can likewise enable the individuals who need to get in shape, lessen Cholesterol, and counteract diabetes.

Keywords: Health care Management; DASH Diet; Neutrosophic Goal Programming.

1. Introduction

The heightened pressure (and boredom) will lead people to neglect their safe eating plans and binge on whatever is around. A substantial number of people globally have diabetes and other forms of infectious diseases, and a significant amount of money is spent on this chronic disease. It is essential to monitor the healthy plan with a suitable diet for patients suffering from lifestyle-related diseases. Carbohydrates usually involve foods like Bread, roti, rice, vegetable, and other food grains; throughout, consumption of these has been curtailed. Individuals work from home and might have neglected their regular schedule, so they have found that their dietary patterns go for a flip. His/Her may contribute to two primary factors– One, they might end up eating and drinking healthier foods during the day and having too much unhealthier food when they feel depressed or anxious. A nutritious and balanced diet and physical activity are the most common and effective means to maintain a healthier body. There are different diets with a broad array of targets. A diet may be used to promote weight loss, ensure the maintenance of muscle mass, reduce premature weight gain during breastfeeding or regulate many chronic diseases such as cardiovascular disease, hypertension and kidney disease. The "Diet Problem" (the quest for a low-cost diet that can satisfy a soldier's dietary needs) is distinguished by a lengthy background, while in 2000 or later, most approaches to similar diet problems were created, after which computers with massive computation capacities were readily accessible, and linear programming (L.P.) techniques were established.

Operations Research approaches provide an essential and efficient resource for grappling with many healthcare issues. Bailey [1] wrote an article related to a queuing methodology to examine waiting times and appointments in hospital emergency services, which is believed to be the first optimization research to be applied to health care management. One of Operations Research's most effective techniques is the L.P. technique that can be extended to many nutritional problems relevant to food relief, regional food services, and specific dietary recommendations. Most researchers have used dietary limitations and cost limitations to evaluate dietary challenges and alternatives, although these work revealed vulnerabilities in the circumstances with a limited number of food products and nutritional restrictions. Effective strategies were obtained for diet problems using L.P. techniques (Smith [2]; Dantzig [3]; Fletcher [4]). However, while this strategy gives the greatest solution to the problem (the cheapest diet), the resulting diet looks to be both distasteful (requiring the consumption of the same items every day) and impracticable (specifying excessive quantities of the food types chosen). Dantzig [5] utilized L.P. to simulate optimal meal patterns under a number of limitations. Khoshbakht [6] wanted to see how a DASH diet affected youngsters with attention deficit hyperactivity disorder (ages 6–12 years). Paidipati et al. [7] provided some dependable approaches for determining optimal menu planning utilizing GP and reduced the variations of over and under accomplishment for suitable meal menu selection with varied energy (calorie) levels. A neutrosophic logic set was invented by Smarandache [8]. Brouni and Smarandache [9] investigated interval neutrosophic set (N.S.) and proposed a new operation on interval neutrosophic numbers. In a real-world example, Abdel-Basset et al. [10] proposed a strategy for addressing the L.P. issue in which N.S. theory plays a critical role. Their parameters were represented by a trapezoidal neutrosophic number, and a neutrosophic L.P. model approach was proposed. To cope with multi-production planning difficulties, Khan et al. [11] suggested an unique multi-objective model operating in an intuitionistic and Neutrosophic context.

This research aims to develop a new mathematical model that generates hypocaloric diets with high protein content. The mathematical model has two goals: the one is to reduce the diet's calorie count, and the other is to minimize the diet's expense along with some restrictions in the form of constraints, *i.e.*, amount of the Fat, amount of the Sodium, amount of the Cholesterol, amount of the saturated Fat, amount of the Calcium, amount of the Magnesium, amount of the Fibre, amount of the Potassium in the food. The model has been formulated in an uncertain environment and solved using a NGP approach. The results have also been compared with the GP approach and FGP approach.

The following is how the rest of the paper is structured: Section 2 is an overview of the literature on health care administration, diet management, NGP; Section 3 deals with the model formulation of the concerned problem along with preliminaries related to N.S. theory; computational experiment is performed in Section 4; and finally, in the last segment closing remarks are made.

2. Literature Review

There is comprehensive literature available on management strategies for managing health care services. One of the most often discussed topics is hospital resource management, focusing on staff workforce planning and correct nutritional capital distribution. Healthcare management's complexity and significance cannot be overstated, and optimization techniques have become a commonly employed healthcare management technique. Guo et al. [12] proposed a bi-objective distribution model for Community-based health resources assessment. The model explores a cost-price trade-off, where the price is represented as the overall number of demand nodes providing service over a defined distance threshold. Harris [13] used a non-linear modelling model to assess resource distribution in a multi-site needle exchange network to accomplish the highest potential decrease at reduced risk of new HIV infections. Benneyan et al. [14] implemented a destination-allocation model for long-term decision-making in the Veterans Health Management market. The objective feature is a weighted total of competing factors, including travel time, unoccupied ability and obscured demands. Günes et al. [15] proposed an allocation based model for implementing a primary health network. Three parameters are listed individually as usability factors, including the maximization of reach, attendance, and overall travel distance. M'Hallah and Alkhabbaz [16] examine the usage of the operational techniques in scheduling a Kuwaiti hospital recognizing specific restrictions on ethnicity, class, and nationality. They proposed a mixed integer L.P. model to reduce the number of nurses outsourced. Turgay and Taskın [17] presented a FGP model using exponential membership function to solve the healthcare model for efficient management solution and explained with data produced by a medical facility in Turkey-Sakarya. Jafari and Salmasi [18] established a mathematical programming metaheuristic method to optimize nursing priorities by analyzing patient and local policies and nurses' roles in Iran government hospitals. Because of the fluctuation of demands, Singh and Goh [19] proposed a pharmaceutical supply chain model comprising several raw material manufacturers, producers, and service centres of multiple hospitals. The developed model combined supply chain planning approaches from raw material sourcing to optimal drugs to hospital-level delivery plans. Yazdani et al. [20] addressed the control of healthcare waste disposal, which can create severe healthcare staff, patients, and the general population and suggested a novel best-worst approach of approximate interval figures due to the shortage of accurate information.

The importance of diet planning is not hidden to anyone, and in the past author used optimization techniques to get the desired amount of diet required for a healthier body. Eghbali et al. [21] addressed the human diet concern in a fuzzy context by considering nutritional diet variables-including taste and size, the volume of nutrients and their dietary intake. Mamat et al. [22] built a Fuzzy L.P. model for balanced diet planning that carries various nutrients a few times a day for each person. Eghbali et al. [23] addressed the application of fuzzy L.P. in diet meal preparation for eating disorders and lifestyle linked with illness. The formula is used to measure the volume of nutrients in the day to day routine. Fourer et al. [24] created an L.P. model to serve a week of fixed nutritious material from the mix of economic foods such as meat, macaroni, spaghetti and others. Another approach was generalized to produce the problem formulation of fish feeds, which would improve fish productivity (Nath and Talukdar [25]). Ali et al. [26] developed a quantitative diet planning model that satisfies the high school student has required nutritional consumption and minimizes a budget. Using an optimization approach coupled with 0-1 Integer Programming, the problem was solved. Ducrot et al. [27] studied the relation between meal preparation and diet consistency, including adherence to dietary recommendations and various foods and weight status. Eghbali-Zarch et al. [28] built a novel multi-objective mixed integer L.P. model to structure the diet plans for patients who have diabetes. The model's goals are to reduce the overall volume of saturated Fat, caffeine, Cholesterol, and the overall diet plan costs. The model's restrictions satisfy the body's nutritional needs and the complex regulation of each individual's diet. Sheng and Sufahani [29] addressed using integer programming to construct the quantitative diet planning design for eczema patients to cut diet costs by achieving the required amounts of nutrients, preventing food allergens and bringing other items into the diet that relieve eczema. Ghorabi et al. [30] reported their findings on the relationship between adherence to the dietary methods to stop hypertension (DASH) diet and metabolic syndrome and its components. Rodriguez et al. [31] investigated the effects of a Transtheoretical model-based personalized behavioral intervention, a non-tailored intervention, and usual care on the DASH eating pattern. According to Farhadnejad et al. [32], following the DASH diet may be beneficial in reducing metabolic abnormalities in overweight and obese people. Pirozeh et al. [33] described the DASH diet, which contains several antioxidants and helps to reduce oxidative stress. Soltani et al. [34] conducted a comprehensive review and meta-analysis to investigate the linear and non-linear dose-response relationship between DASH diet adherence and the causes of particular mortality. Khan *et al.* [35] discussed a daily diet model and minimized the cost of diet, Saturated Fat and carbohydrate. The diet model was solved by fuzzy multi-objective GP to satisfy daily nutrients and compared different methods. Kim *et al.* [36] investigated the similarity of metabolic urine maker and Serum metabolomic markers of the Dietary Approaches to Stop Hypertension (DASH) diet was reported. Ahmed et al. [37] presented a bipolar single-valued neutrosophic issue and used the score function to convert the fuzzy set into a crisp L.P. problem. Ahmed [38] defined the ranking function for transforming LR-type single-valued neutrosophic numbers and proposed a method for solving the LR-type single-valued neutrosophic L.P. problem using the transformation methodology. Das et al. [39] proposed the notion of single-valued neutrosophic numbers and a computer approach for solving the trapezoidal neutrosophic L.P. problem using the ranking function. Das and Edalatpanah [40] examined the diet issue using the Pythagorean fuzzy idea and used the score function to convert proportionate crisp L.P. issues; and proposed a unique technique for addressing the L.P. problem using Pythagorean fuzzy numbers. Das et al. [41] presented a theoretical study of completely fuzzy L.P. and solved it using the lexicographic ordering approach.

3. Model Formulation

This paper has considered one of the essential healthcare management applications, *i.e.,* the balanced diet problem. A healthy or balanced diet gives the body essential nutrients to function adequately. We eat much of the daily calories in fresh fruits, fresh herbs, rice, legumes, nuts, and lean proteins to get the diet's best nutrients. The calorie count of a meal is a calculation of the amount of energy contained in that product. In walking, speaking, swallowing and other essential tasks, the body utilizes calories from food. To preserve well-being, the average individual requires to consume around 2,000 calories per day.

Nevertheless, the same daily intake of calories may differ based on age, gender and degree of physical activity. People require more calories than women in general, and people who work out need to get more calories than people who do not. It is necessary to have a healthy diet since our organs and tissues need proper nutrition to function effectively. The body is more vulnerable to illness, exhaustion and reduced results without adequate nutrition. Children with a low diet run the risk of rising and developing problems, poor academic results, and bad eating habits that last for the rest of their lives. Keeping this thing in mind, we have considered the DASH diet problem for our model formulation. The DASH diet demonstrates the appropriate portion sizes, food diversity and nutrients and finds out how to improve health and reduce blood pressure. The DASH diet emphasizes veggies, fruits and low-fat dairy products with reasonable amounts of whole grains, meats, poultry and nuts. The diet is influencing the body in many respects:

- With the help of the DASH diet, healthy people and high blood pressure can reduce blood pressure.
- People cut out lots of high-fat with the DASH diet aid and may notice that they effectively reduce calorie intake and assist in weight reduction.
- There is a reduced chance of certain tumours with the DASH diet, including colorectal.
- The DASH diet decreases cardiovascular disease risk by as much as 81%.
- The DASH diet helps in reducing type 2 diabetes.

The following decision variables and parameters are used for the model formulation:

Nomenclature

***Decision Variable*:**

x_j Optimal quantity of food items

Parameters:

C_{Dj} Diet Cost of the j^{th} Food Item

c_{lj} Calorie in the j^{th} Food Item

f_{tj} Content/amount of the Fat in the j^{th} Food Item

F_t Tolerable maximum input level of the Total Fat

s_{dj} Content/amount of the Sodium in the j^{th} Food Item

S_d Tolerable maximum input level of the Sodium

c_{hj} Content/amount of the Cholesterol in the j^{th} Food Item

C_h Tolerable maximum input level of the Cholesterol

s_{fj} Content/amount of the Saturated Fat in the j^{th} Food Item

S_f Tolerable maximum input level of the total Saturated Fat

c_{aj} Content/amount of the Calcium in the j^{th} Food Item

C_a Tolerable minimum input level of the Calcium

m_{gj} Content/amount of the Magnesium in the j^{th} Food Item

M_g Tolerable minimum input level of the Magnesium

f_{bj} Content/amount of the Fibre in the j^{th} Food Item

F_b Tolerable minimum input level of the Fibre

p_{tj} Content/amount of the Potassium in the j^{th} Food Item

P_t Tolerable minimum input level of the Potassium

w_{fj} Weight of the j^{th} Food Item

W_f Maximum amount of all food

S_{Ljc} Estimated minimum number of daily servings of the j^{th} food item for calorie level c

S_{Ujc} Estimated maximum number of daily servings of the j^{th} food item for calorie level

With all these above define parameters and decision variables, the problem has been formulated as follows:

In our considered DASH diet model, let $x_j\,(j=1,2,...,n)$ be the different types of food items required for the proper diet, and it works as a decision variable for us. The cost of serving and calories of each food item is $C_{Dj}, c_{lj}\,(j=1,2,...,n)$. Then the objective function will be formulated as:

$$Min\,Z_1 = \sum_{j=1}^{n} C_{Dj} x_j \quad \textbf{(1)}$$

$$Min\,Z_2 = \sum_{j=1}^{n} c_{lj} x_j \quad \textbf{(2)}$$

The non-negative constraints of the model satisfy the nutrients requirements of the diet. The left-hand side of the non-negative constraints is the food items' nutrient contents based on the DASH concerning nutrients. The DASH research suggested that Sodium, Saturated Fat, Total Fat and Cholesterol be taken less and Magnesium, Potassium, Calcium, and Fibre be taken more to reduce the human body's high blood pressure.

Then the non-negative constraints are as follow:

$$\sum_{j=1}^{n} f_{tj} x_j \le F_t, \text{ Constraint for Total Fat} \quad \textbf{(3)}$$

$$\sum_{j=1}^{n} s_{dj} x_j \le S_d, \text{ Constraint for Sodium} \quad \textbf{(4)}$$

$$\sum_{j=1}^{n} c_{hj} x_j \le C_h, \quad \text{Constraint for Cholesterol} \quad \textbf{(5)}$$

$$\sum_{j=1}^{n} s_{fj} x_j \le S_f, \quad \text{Constraint for Saturated Fat} \quad \textbf{(6)}$$

$$\sum_{j=1}^{n} c_{aj} x_j \ge C_a, \quad \text{Constraint for Calcium} \quad \textbf{(7)}$$

$$\sum_{j=1}^{n} m_{gj} x_j \ge M_g, \text{ Constraint for Magnesium} \quad \textbf{(8)}$$

$$\sum_{j=1}^{n} f_{bj} x_j \ge F_b, \quad \text{Constraint for Fibre} \quad \textbf{(9)}$$

$$\sum_{j=1}^{n} p_{tj} x_j \ge P_t, \text{ Constraint on Potassium} \quad \textbf{(10)}$$

$$\sum_{j=1}^{n} w_{fj} x_j \ge W_f, \quad \text{Constraint for Food Weight} \quad \textbf{(11)}$$

$$S_{Ljc} \le x_j \le S_{Hjc}, \text{ Upper and lower limit of the daily serving} \quad \textbf{(12)}$$

The conceptual frameworks for analyzing health care management difficulties are frequently used to examine various success measures, which may be further subdivided into economic performance metrics and quality of service metrics. The existence of contradictory objective functions necessitates an ideal universal method to considering a viable response. In contrast, in recent years, modifications or generalizations of fuzzy set and intuitionistic fuzzy set (IFS) have been confronted with the concept that there is a degree of determinism in real existence, and as a result, a set known as N.S. has emerged. Smarandache suggested the concept of N.S. [42]. The term "neutosophic" is a mixture of two words: the French word "Neutre" means "neutral," and the Greek word "Sophia" means "talent." The concept of indeterminacy in N.S. helps to the possible scope of study in this area. The NGP technique was created based on the N.S. principle to find the optimum compromise solution for the multi-objective optimization issue.

The NGP involves three membership characteristics: maximizing reality "belongingness," indeterminacy "belongingness to some extent," and eliminating falsehood "non-belongingness." Abdel-Basset et al. [10] proposed and developed an effective approach for solving completely neutrosophic L.P. in production planning. Liu and Teng [43] proposed certain standard neutrosophic operators based on particular neutrosophic numbers and constructed a multi-criteria decision-making model based on the generic weighted power mean neutrosophic number operator. Rizk-Allah et al. [44] posed the transportation issue in a neutrosophic setting and enhanced the results achieved with existing approaches by computing the classification degree with the TOPSIS method. For example, if 0.6 is the chance that the diet is healthy, 0.3 is the diet that is not healthy, and 0.1 is the diet about which we are unsure. In this scenario, this type of linguistic ambiguity or inaccuracy extends beyond the bounds of a fuzzy and IFS in order to make the correct judgment. As a result, the neutrosophic decision-based optimization strategy is more applicable to real-world optimization problems than other well-known approaches since it works with three membership functions, namely truth, indeterminacy, and a false membership function. The indeterminacy membership functionality, on the other hand, cannot be accepted by the fuzzy and intuitive fuzzy decision set. Some of the necessary preliminaries belong to N.S. has been taken from (Ali et al. [45]; Abdel-Baset et al. [46]; Haq et al. [47]; Gupta et al. [48]) and are given below:

Definition 1: A real fuzzy number $\tilde{x}$ is a continuous fuzzy subset from the real line $\Re$ whose triangular membership function $\alpha_{\tilde{x}}(x)$ is defined by a continuous mapping from $\Re$ in the closed interval [0,1], where

1. $\alpha_{\tilde{x}}(x) = 0 \; \forall \; x \in (-\infty, x_1]$,
2. $\alpha_{\tilde{x}}(x)$ to be strictly increasing on $x \in [x_1, m]$,
3. $\alpha_{\tilde{x}}(x) = 1$ for $x = m$,
4. $\alpha_{\tilde{x}}(x)$ to be strictly decreasing on $x \in [m, x_2]$,
5. $\alpha_{\tilde{x}}(x) = 0 \; \forall \; x \in (x_2, +\infty]$

It is elicited by:

$$\alpha_{\tilde{x}}(x)=\begin{cases}\dfrac{x-x_1}{m-x_1}, & x_1\le x\le m,\\ \dfrac{x_2-x}{x_2-m}, & m\le x\le x_2,\\ 0, & \text{otherwise}\end{cases}$$

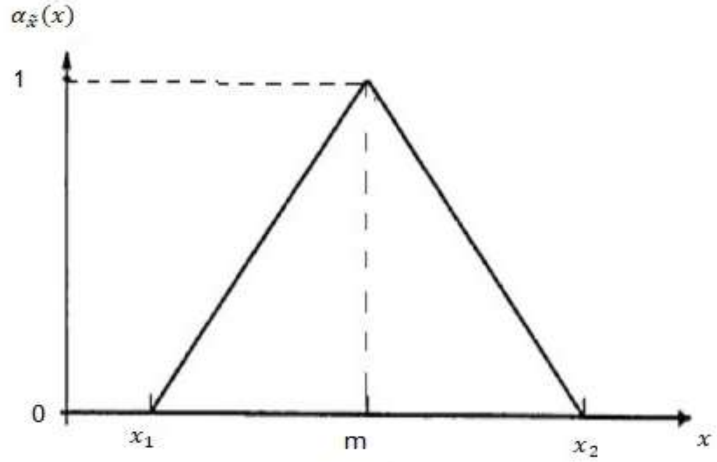

Fig. 1: Membership Function $\tilde{x}$

Where m is a targeted value and x_1 and x_2 denote the value of the lower and upper bound. In this case, we obtain

$$\alpha(x\,;x_1,m,x_2)=\text{Max}\left\{\text{Min}\left[\frac{x-x_1}{m-x_1},\frac{x_2-x}{x_2-m}\right],0\right\}$$

Definition 2: Let $T=\{t_1,t_2,\ldots,t_n\}$ is a fixed non-empty universe, an IFS X in T is defined as

$$X=\{\langle t,\alpha_X(t),\gamma_X(t)\rangle|t\in T\},$$

which is characterized by a membership function $\alpha_X:T\to[0,1]$ and a non-membership function $\gamma_X:T\to[0,1]$ with the condition $0\le\alpha_X(t)+\gamma_X(t)\le 1\,\forall\, t\in T$ where $\alpha_X(t)$ and $\gamma_X(t)$ represent, respectively, the degree of membership and non-membership of the element t to the set X. Also, for each IFS X in $T,\pi_X(t)=1-\alpha_X(t)+\gamma_X(t)\,\forall\, t\in T$ is called the degree of hesitation of the element t to the set X. Significantly if $\pi_X(t)=0$, then the IFS X is degraded to a fuzzy set.

Definition 3: The α-level set of the fuzzy parameters $\tilde{x}$ in definition (1) is defined as the ordinary set $L_\alpha(\tilde{x})$ for which the degree of membership function exceeds the level, $\alpha,\alpha\in[0,1]$, where

$$L_\alpha(\tilde{x})=\{x\in\Re|\alpha_{\tilde{x}}(x)\ge\alpha\},$$

for specific values α_x^* to be in the unit interval.

Definition 4: Let T is an object and $t\in T$. A N.S. X in T is defined by a truth membership function (t), an indeterminacy membership function (t) and a falsity membership function (t). It has shown in figure 2. Truth-membership function (t), indeterminacy membership function (t) and falsity-membership function (t) are real standard or real nonstandard subsets of $]0^-,1^+[$. That is $T_X(t):T \to]0^-,1^+[$, $I_X(t):T \to]0^-,1^+[$ and $F_X(t):T \to]0^-,1^+[$. There are no restrictions on the sum of truth-membership function (t), indeterminacy membership function (t) and falsity-membership function (t), $0^- \le \sup T_X(t) \le \sup I_X(t) \le F_X(t) \le 3^+$.

In the following, we adopt the notations $\alpha_X(x), \beta_X(x)$ and $\gamma_X(x)$ instead of $T_X(t),\ I_X(t)$ and $F_X(t)$ respectively.

Definition 5: Let T is a universe of discourse. A single-valued neutrosophic (SVN) set X over T is an object having the form

$$\mathrm{X} = \{\langle \alpha_X(t), \beta_X(t), \gamma_X(t)\rangle : t \in T\},$$

where $\alpha_X(t):T \to [0,1]$, $\beta_X(t):T \to [0,1]$ and $\gamma_X(t):T \to [0,1]$ with $0 \le \alpha_X(t) + \beta_X(t) + \gamma_X(t) \le 3 \,\forall\, t \in T$. The intervals $\alpha_X(t), \beta_X(t)$ and $\gamma_X(t)$ denote the truth membership degree, the indeterminacy-membership degree and the falsity membership degree of t to X, respect.

For convenience, an SVN number is denoted by $X = (a,b,c)$, where $a,b,c \in [0,1]$ and $a+b+c \le 3$.

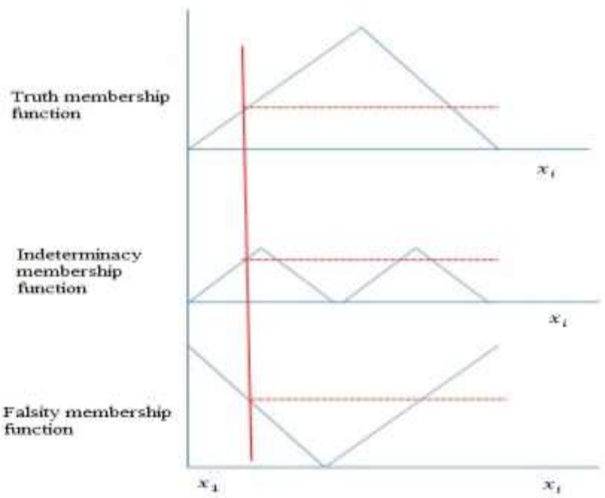

Fig. 2: Neutrosophication Process

Definition 6: Let $\tilde{x}$ is a neutrosophic number in the set of real numbers $\Re$, then its truth-membership function is

$$\alpha_{\tilde{x}}(x) = \begin{cases} \dfrac{x-a_1}{a_2-a_1}, & a_1 \le x \le a_2 \\ 1+\dfrac{a_2-x}{a_3-a_2}, & a_2 \le x \le a_3 \\ 0, & \text{otherwise} \end{cases}$$

its indeterminacy-membership function is

$$\beta_{\tilde{x}}(x)=\begin{cases}\dfrac{x-b_1}{b_2-b_1}, & b_1\le x\le b_2\\ 1+\dfrac{b_2-x}{b_3-b_2}, & b_2\le x\le b_3\\ 0, & \text{otherwise}\end{cases}$$

and its falsity-membership function is

$$\gamma_{\tilde{x}}(x)=\begin{cases}1-\dfrac{x-c_1}{c_2-c_1}, & c_1\le x\le c_2\\ 1-\dfrac{c_3-x}{c_3-c_2}, & c_2\le x\le c_3\\ 0, & \text{otherwise}\end{cases}$$

Let $Z_k, k=1,2$ be the objective function with the target value T_k, acceptance tolerance limit A_k, Indeterminacy tolerance limit I_k, rejection tolerance limit R_k. Then, the Truth Membership, Indeterminacy Membership and Falsity membership Functions will be defined as follows:

Truth membership function

$$\alpha_k^T(Z_k)=\begin{cases}1, & \text{if } Z_k\le T_k\\ 1-\dfrac{(Z_k-T_k)}{A_k}, & \text{if } T_k\le Z_k\le T_k+A_k\\ 0, & \text{if } Z_k\ge T_k+A_k\end{cases} \quad (13)$$

Indeterminacy membership function

$$\beta_k^I(Z_k)=\begin{cases}0, & \text{if } Z_k\le T_k\\ \dfrac{Z_k-T_k}{I_i}, & \text{if } T_k\le Z_k\le T_k+I_k\\ 1-\dfrac{(Z_k-(T_k+I_k))}{A_k-I_k}, & \text{if } T_k+I_k\le Z_k\le T_k+A_k\\ 0, & \text{if } Z_k\ge T_k+A_k\end{cases} \quad (14)$$

Falsity membership function

$$\gamma_k^F(Z_k)=\begin{cases}0, & \text{if } Z_k\le T_k\\ \dfrac{(Z_k-T_k)}{R_k}, & \text{if } T_k\le Z_k\le T_k+R_k\\ 1, & \text{if } Z_k\ge T_k+R_k\end{cases} \quad (15)$$

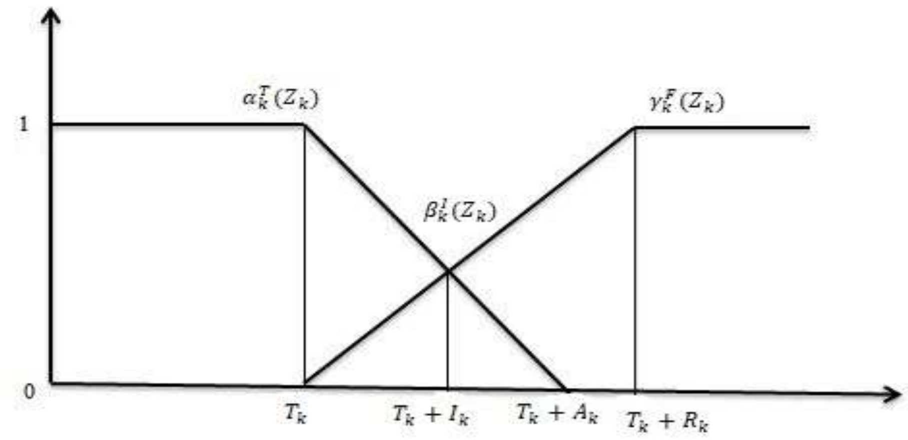

Fig. 3: Truth, Indeterminacy and Falsity Membership Functions for Z_k

To solve the above formulated multi-objective programming problem of the DASH diet, we have used the NGP approach by using the Truth, Indeterminacy and Falsity Membership Functions, and therefore further, the problem can be re-written as:

$$
\begin{aligned}
& Min(1-\alpha_k^T)(1-\beta_k^I).\gamma_k^F \\
& \alpha_k^T(Z_k) = \alpha_k, \quad k = 1,2,\ldots,K \\
& \beta_k^I(Z_k) = \beta_k, \quad k = 1,2,\ldots,K \\
& \gamma_k^F(Z_k) = \alpha_k, \quad k = 1,2,\ldots,K \\
& \sum_{j=1}^{n} f_{tj}x_j \le F_t, \quad \sum_{j=1}^{n} s_{dj}x_j \le S_d, \\
& \sum_{j=1}^{n} c_{hj}x_j \le C_h, \quad \sum_{j=1}^{n} s_{fj}x_j \le S_f, \\
& \sum_{j=1}^{n} c_{aj}x_j \ge C_a, \quad \sum_{j=1}^{n} m_{gj}x_j \ge M_g, \\
& \sum_{j=1}^{n} f_{bj}x_j \ge F_b, \quad \sum_{j=1}^{n} p_{tj}x_j \ge P_t, \\
& \sum_{j=1}^{n} w_{fj}x_j \ge W_f, \\
& x_j \ge S_{Ljc}, \quad j = 1,2,\ldots,n \\
& x_j \le S_{Hjc}, \quad j = 1,2,\ldots,n \\
& 0 \le \alpha_k + \beta_k + \gamma_k \le 3 \\
& \alpha_k, \gamma_k \ge 0, \beta_k \le 1, \quad \alpha_k, \beta_k, \gamma_k \in [0,1]
\end{aligned}
$$

where $Max\,\alpha_k^T, Max\,\beta_k^I$ are equivalent to $Min(1-\alpha_k^T), Min(1-\beta_k^I)$ respectively for all $0 \le \alpha_k^T, \beta_k^I \le 1$. If we take $(1-\alpha_k^T)(1-\beta_k^I)\gamma_k^F = v_k$ then the problem further reduces to:

$$Min\ \ v_k$$
$$(1-\alpha_k)(1-\beta_k)\gamma_k = v_k$$
$$\sum_{j=1}^{n} f_{tj}x_j \le F_t\ ,\quad \sum_{j=1}^{n} s_{dj}x_j \le S_d\ ,\quad \sum_{j=1}^{n} c_{hj}x_j \le C_h,\quad \sum_{j=1}^{n} s_{fj}x_j \le S_f\,,$$
$$\sum_{j=1}^{n} c_{aj}x_j \ge C_a,\quad \sum_{j=1}^{n} m_{gj}x_j \ge M_g,\quad \sum_{j=1}^{n} f_{bj}x_j \ge F_b\quad ,\quad \sum_{j=1}^{n} p_{tj}x_j \ge P_t,$$
$$\sum_{j=1}^{n} w_{fj}x_j \ge W_f\,,\quad x_j \ge S_{Ljc},\quad x_j \le S_{Hjc}\ ,\quad j = 1,2,...,n$$
$$\alpha_k^T(Z_k) = \alpha_k,\quad \beta_k^I(Z_k) = \beta_k,\quad \gamma_k^F(Z_k) = \alpha_k,\quad k = 1,2$$
$$0 \le \alpha_k + \beta_k + \gamma_k \le 3,\ \alpha_k,\gamma_k \ge 0, \beta_k \le 1,\ \ \alpha_k,\beta_k,\gamma_k \in [0,1]$$

4. Case Study

The developed diet model is explained using a collection of the real data set (Iwuji et al. [49]; Iwuji and Agwu [50]). Here we assessed the situation where a person wanted the best DASH Diet plan with 2000 calories. Table 1 indicates the required calories needed by male and female individuals in some age groups and activity rates. Here we offer a random set of 8 sample foods from the different food groups (i.e. wheat, beans, fruits, low-fat milk items, Fish and nuts) for the DASH diet and the maximum and minimum intake level of the nutrients. The foods packages with their nutrient composition, weight (in grams), requirements, availability and cost, are shown in Tables 2 and 3.

Table 1: DASH daily calorie chart for the different levels of activities

Gender	Age	Calorie needed for each activity level		
		Sedentary	Moderately Active	Active
Male	19-30	2400	2600-2800	3000
	31-50	2200	2400-2600	2800-3000
	51+	2000	2200-2400	2400-2800
Female	19-30	2000	2000-2200	2400
	31-50	1800	2000	2200
	51+	1600	1800	2000-2200

Table 2: Foods with their nutrient composition, weight (in grams), requirements

Nutrients	Foods								Max./Min. requirement
	Carrot	Ground Nut	Bread (Whole Wheat)	Sweet Potato (Boiled)	Milk (Low Fat)	Orange	Water Melon	Fish (Grilled)	
Total Fat	0.24	11.48	0.58	0.30	0.10	0.48	0.16	4.10	$\le$68
Sodium (mg)	33.60	1.50	124.80	15.00	8.10	3.20	2.40	73.00	$\le$1500
Cholesterol (mg)	0	0	0	0	3.00	0	0	0.29	$\le$129

Saturated Fat (g)	0	1.55	0.20	0	0.60	0	0	34.00	$\leq$16
Calcium (mg)	28	4.25	12.25	24	25	49.6	5.6	40	$\geq$1334
Magnesium (mg)	9.6	47.75	13.25	14	2.4	17.6	8	43	$\geq$542
Fiber (g)	2.48	2.33	1.55	3	0	2.72	0.29	0	$\geq$34
Potassium (mg)	212.8	181.75	56.5	264	31	262.6	87.2	397	$\geq$4721
Weight per serving of Foods (g)	80	25	25	100	2	160	80	100	$\leq$4000

Table 3: Minimum and maximum Availability of Foods with cost and Calorie

	Carrot	**Ground Nut**	**Bread (Whole Wheat)**	**Sweet Potato (Boiled)**	**Milk (Low Fat)**	**Orange**	**Water Melon**	**Fish (Grilled)**
Minimum Availability	4	0	3	4	6	4	4	0
Maximum Availability	20	1	8	6	9	8	9	6
Cost of per serving of Food ($)	15	20	15	15	30	15	15	50
Calorie	28	144.5	58.5	90	7	72	23.2	151

Cost per serving of the foods and their nutrient information with the maximum and minimum intake level; the estimated minimum and the maximum number of servings of foods into the above-formulated DASH diet model. The above-given table values, with the Target value (T_k), acceptance tolerance limit (A_k), Indeterminacy tolerance limit (I_k), Rejection tolerance limit (R_k), for k^{th} objectives are shown in Table 4.

Table 4: Target value, Acceptance, Indeterminacy and Rejection Tolerance Limit

k	**Target Value** T_k	**Acceptance Tolerance Limit** A_k	**Indeterminacy Tolerance Limit** I_k	**Rejection Tolerance Limit** R_k
1.	825	150	100	200
2.	2000	600	400	700

Using the table (3) value; Truth, Indeterminacy and Falsity membership Functions have been constructed as:

Truth Membership Function

$$\alpha_1^T(Z_1)=\begin{cases}1, & \text{if } Z_1 \le 825\\ 1-\dfrac{(Z_1-825)}{150}, & \text{if } 825 \le Z_1 \le 975\\ 0, & \text{if } Z_1 \ge 975\end{cases},\quad \alpha_2^T(Z_2)=\begin{cases}1, & \text{if } Z_2 \le 2000\\ 1-\dfrac{(Z_2-2000)}{600}, & \text{if } 2000 \le Z_2 \le 2600\\ 0, & \text{if } Z_2 \ge 2600\end{cases}$$

Indeterminacy Membership Function

$$\beta_1^i(Z_1)=\begin{cases}0, & \text{if } Z_1 \le 825\\ \dfrac{Z_1-825}{100}, & \text{if } 825 \le Z_1 \le 925\\ 1-\dfrac{(Z_1-925)}{50}, & \text{if } 925 \le Z_1 \le 975\\ 0, & \text{if } Z_1 \ge 975\end{cases},\quad \beta_2^i(Z_2)=\begin{cases}0, & \text{if } Z_2 \le 2000\\ \dfrac{Z_2-2000}{400}, & \text{if } 2000 \le Z_2 \le 2400\\ 1-\dfrac{(Z_2-2400)}{200}, & \text{if } 2400 \le Z_2 \le 2600\\ 0, & \text{if } Z_2 \ge 2600\end{cases}$$

Falsity Membership Function

$$\gamma_1^F(Z_1)=\begin{cases}0, & \text{if } Z_1 \le 825\\ \dfrac{(Z_1-825)}{200}, & \text{if } 825 \le Z_1 \le 1025\\ 1, & \text{if } Z_1 \ge 1025\end{cases}\quad \gamma_2^F(Z_2)=\begin{cases}0, & \text{if } Z_2 \le 2000\\ \dfrac{(Z_2-2000)}{700}, & \text{if } 2000 \le Z_2 \le 2700\\ 1, & \text{if } Z_2 \ge 2700\end{cases}$$

Using all the membership functions in the NCG model, finally, it has been solved using the optimizing software LINGO 16.0. The optimal compromise solution for the proposed model is summarized in Table 5.

Table 5: Optimal Compromise Daily Diet Plan

Foods	Daily Serving Sizes	Cost of Servings ($)	Calorie available in the foods
Carrot (cut up)	20	300.00	560.00
Groundnut (boiled, without salt)	0.7158484	14.31	103.44
Bread (whole wheat)	3	45.00	175.50
Sweet potato (boiled, without salt)	5.427117	81.40	488.44
Milk (low fat, skimmed) (' 00gm)	7	210.00	49.00
Orange	8	120.00	576.00
Watermelon	4	60.00	92.80
Fish (grilled, without salt)	0.2439209	12.20	36.83
Optimal daily diet cost		**842.91**	
Total calories			**2082.01**

The proposed healthy diet is composed of 20 servings of carrots, 0.7158484mg of Groundnut (boiled, without salt), three servings of Bread (whole wheat), around five servings of Sweet potato (boiled, without salt), around 700gm serving of Milk (low Fat, skimmed), around eight serving of Orange, around four serving of Watermelon, and around 0.2439209mg of Fish (grilled, without salt). The graphical representation of the compromise solution and the proposed model's membership values is shown in **Fig. 4** and **Fig. 5,** respectively.

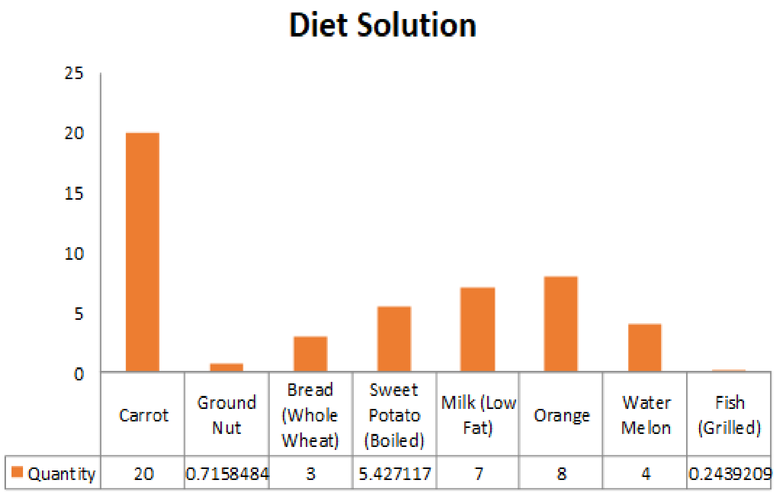

Fig. 4: The Optimal Compromise Solution

Fig. 5: Membership values of the proposed model

Table 6 compares the proposed approach with the famous GP approach and the FGP approach.

Table 6: Comparison of Results

Food	Carrot (cut up)	Groundnut (boiled, without salt)	Bread (whole wheat)	Sweet potato (boiled, without salt)	Milk (low Fat, skimmed)	Orange	Water melon	Fish (grilled, without salt)
Proposed Approach	20	0.7158484	3	5.427117	7	8	4	0.2439209
GP	0	2.8	11	0	3.9	0	39.7	0.02
FGP	0	1.8	7	0	4.7	0	34.1	0.02

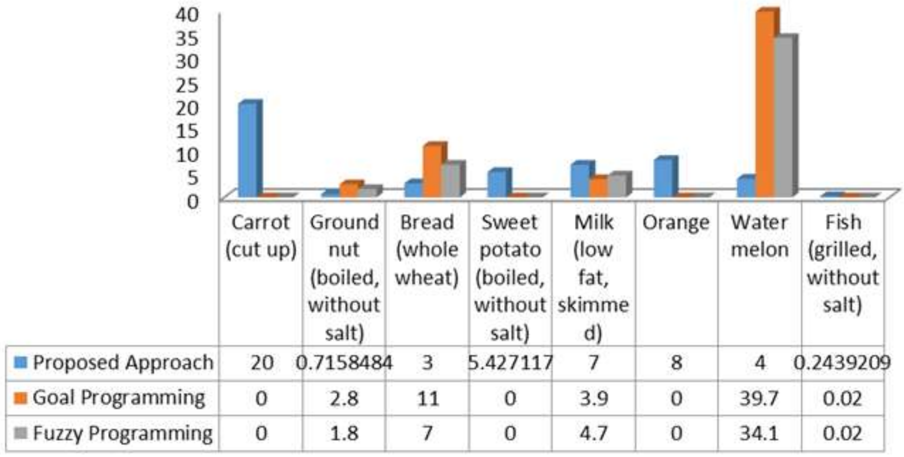

Fig. 6: Comparison of Result

Table 5 and Fig. 6 show our proposed method's supremacy over GP and FGP approach. The results indicated that GP and FGP approach failed to provide the value of all the concerned decision variables, but through the NGP, we can get all the concerned decision variables that are very important for diet problems. There are other behaviours that people can follow to improve their good well-being and the general standard of wellness. Making sure that one consumes a well-planned diet is essential. Nutrients, carbohydrates and minerals can be incorporated into a daily diet. They will also concentrate on including nuts, beans, fruits and vegetables in their diet, alongside garlic and garlic. It is therefore essential to take caution to reduce processed carbs and turn to foods containing natural carbs.

The right amount of nutrition is much more important in situations where the immune system may need to strike back to protect from infections. Eating a diverse, nutritious diet is the easiest way to achieve a full range of nutrients like micronutrients and vitamins. This will also reduce the chances of various severe health problems, including obesity, type 2 diabetes and cardiac failure. There is growing proof that vitamin D can have intestinal safety benefits. Recently, a report has suggested that vitamin d consumption are linked to higher death rates. Dietary Fibre lets you shed weight and reduce belly fat, lowering the chances of diabetes and cardiac failure. This encourages better gut microbes and leads to a balanced immune system. A tasty and healthy diet — comprising of lots of fresh fruits, leafy green vegetables — together with physical exercise can improve our immunity and keep us fit.

6. Motivation and Contribution

This work is prompted by a research topic in NGP that has the potential to capture decision-makers. The following are the study's contributions:

i. It contributes to the existing literature on the DASH Diet issue.

ii. ii. Solution strategies for multi-objective multi-product problem formulation are described in a case study.

iii. For the DASH Diet, a novel technique based on neutrosophic was used in this study.

The technique is compared to GP and FGP, with the conclusion demonstrating that the proposed work is superior.

6. Conclusion

The human body needs foods with low sodium content, saturated Fat, total Fat, and Cholesterol, although high in Potassium, Magnesium, Calcium, and Fibre. The DASH diet has difficulty making regular dietary schedules that fulfil the tolerable consumption rates of nutrients of the diets at a defined expenditure dependent on the required daily calorie and sodium amounts by the persons involved to minimize elevated blood pressure and other diseases. Here, to find out the optimum solution of the formulated multi-objective DASH diet optimization model, we implemented a neutrosophic optimization approach by combining three different types of membership functions, *i.e.,* Truth, Indeterminacy and Falsity. In the formulated model, our main aim is to concurrently optimize calorie consumption and diet cost by minimizing the deviation from the set goal. The formulated DASH diet NGP model has turned into a crisp type model by utilizing truth, indeterminacy, and falsity membership functions. The GP and FGP approach failed to provide the value of all the concerned decision variables, but through the NGP, we can get all the concerned decision variables that are very important for diet problems. The finding obtained in the neutrosophic optimization approach contrasts with the GP and FGP approaches. It demonstrates that the NGP approach gives a more transparent and accurate solution and is a useful optimization technique than the other current method.

References

1. Bailey, N. T. (1952). A study of queues and appointment systems in hospital out-patient departments, with special reference to waiting-times. *Journal of the Royal Statistical Society: Series B (Methodological)*, *14*(2), 185-199. https://doi.org/10.1111/j.2517-6161.1952.tb00112.x
2. Smith, V. E. (1959). Linear programming models for the determination of palatable human diets. *Journal of Farm Economics*, *41*(2), 272-283.
3. Dantzig, G. B. (1990). The diet problem. *Interfaces*, *20*(4), 43-47. https://doi.org/10.1287/inte.20.4.43
4. Fletcher, L. R., Soden, P. M., & Zinober, A. S. I. (1994). Linear programming techniques for the construction of palatable human diets. *Journal of the Operational Research Society*, *45*(5), 489-496. https://doi.org/10.1057/jors.1994.76
5. Dantzig, G. B. (1990). The diet problem. *Interfaces*, *20*(4), 43-47. https://doi.org/10.1287/inte.20.4.43
6. Khoshbakht, Y., Moghtaderi, F., Bidaki, R., Hosseinzadeh, M., & Salehi-Abargouei, A. (2021). The effect of dietary approaches to stop hypertension (DASH) diet on attention-deficit hyperactivity disorder (ADHD) symptoms: a randomized controlled clinical trial. *European Journal of Nutrition*, 1-12. https://doi.org/10.1007/s00394-021-02527-x
7. Paidipati, K. K., Komaragiri, H., & Chesneau, C. (2021). Pre-Emptive and Non-Pre-Emptive Goal Programming Problems for Optimal Menu Planning in Diet Management of Indian Diabetes Mellitus Patients. *International Journal of Environmental Research and Public Health*, *18*(15), 7842. https://doi.org/10.3390/ijerph18157842
8. Smarandache, F. (1999). A unifying field in Logics: Neutrosophic Logic. In *Philosophy* (pp. 1-141). American Research Press.
9. Broumi, S., & Smarandache, F. (2015). New operations on interval neutrosophic sets. *Journal of new theory*, (1), 24-37.

10. Abdel-Basset, M., Gunasekaran, M., Mohamed, M., & Smarandache, F. (2019). A novel method for solving the fully neutrosophic linear programming problems. *Neural computing and applications*, *31*(5), 1595-1605. https://doi. org/10.1007/s00521-018-3404-6.
11. Khan, M. F., Haq, A., Ahmed, A., & Ali, I. (2021). Multiobjective Multi-Product Production Planning Problem Using Intuitionistic and Neutrosophic Fuzzy Programming. *IEEE Access*, *9*, 37466-37486.. https://doi.org/10.1109/ACCESS.2021.3063725
12. Guo, S., Biegel, D. E., Johnsen, J. A., & Dyches, H. (2001). Assessing the impact of community-based mobile crisis services on preventing hospitalization. *Psychiatric Services*, *52*(2), 223-228. https://doi.org/10.1176/appi.ps.52.2.223
13. Harris, Z. K. (2006). Efficient allocation of resources to prevent HIV infection among injection drug users: the Prevention Point Philadelphia (PPP) needle exchange program. *Health economics*, *15*(2), 147-158. https://doi.org/10.1002/hec.1021
14. Benneyan, J. C., Musdal, H., Ceyhan, M. E., Shiner, B., & Watts, B. V. (2012). Specialty care single and multi-period location–allocation models within the Veterans Health Administration. *Socio-economic planning sciences*, *46*(2), 136-148. https://doi.org/10.1016/j.seps.2011.12.005
15. Güneş, E. D., Yaman, H., Çekyay, B., & Verter, V. (2014). Matching patient and physician preferences in designing a primary care facility network. *Journal of the Operational Research Society*, *65*(4), 483-496. https://doi.org/10.1057/jors.2012.71
16. M'Hallah, R., & Alkhabbaz, A. (2013). Scheduling of nurses: a case study of a Kuwaiti health care unit. *Operations Research for Health Care*, *2*(1-2), 1-19. https://doi.org/10.1016/j.orhc.2013.03.003
17. Turgay, S., & Taşkın, H. (2015). Fuzzy goal programming for healthcare organization. *Computers & Industrial Engineering*, *86*, 14-21. https://doi.org/10.1016/j.cie.2014.12.012
18. Jafari, H., & Salmasi, N. (2015). Maximizing the nurses' preferences in nurse scheduling problem: mathematical modeling and a meta-heuristic algorithm. *Journal of industrial engineering international*, *11*(3), 439-458. https://doi.org/10.1007/s40092-015-0111-0
19. Singh, S. K., & Goh, M. (2019). Multi-objective mixed integer programming and an application in a pharmaceutical supply chain. *International Journal of Production Research*, *57*(4), 1214-1237. https://doi.org/10.1080/00207543.2018.1504172
20. Yazdani, M., Tavana, M., Pamučar, D., & Chatterjee, P. (2020). A rough based multi-criteria evaluation method for healthcare waste disposal location decisions. *Computers & Industrial Engineering*, *143*, 106394. https://doi.org/10.1016/j.cie.2020.106394
21. Eghbali, H., Eghbali, M. A., & Kamyad, A. V. (2012). Optimizing human diet problem based on price and taste using multi-objective fuzzy linear programming approach. *An International Journal of Optimization and Control: Theories & Applications (IJOCTA)*, *2*(2), 139-151.
22. Mamat, M., Zulkifli, N. F., Deraman, S. K., & Noor, N. M. M. (2012). Fuzzy linear programming approach in balance diet planning for eating disorder and disease-related lifestyle. *Applied Mathematical Sciences*, *6*(103), 5109-5118.
23. Eghbali, H., Abdoos, E., Ashtiani, S., & Ahmadvand, M. (2013). Modeling the optimal diet problem for renal patients with fuzzy analysis of nutrients. *International Journal of Management and Fuzzy Systems*, *1*(1), 7-14. https://doi.org/10.11648/j.ijmfs.20150101.12
24. Fourer, R., Gay, D. M., & Kernighan, B. W. (2003). AMPL. A modeling language for mathematical programming.

25. Nath, T., & Talukdar, A. (2014). Linear programming technique in fish feed formulation. *International Journal of Engineering Trends and Technology (IJETT)*, *17*(3), 132-135.
26. Ali, M., Sufahani, S., & Ismail, Z. (2016). A new diet scheduling model for Malaysian school children using zero-one optimization approach. *Global Journal of Pure and Applied Mathematics*, *12*(1), 413-419.
27. Ducrot, P., Méjean, C., Aroumougame, V., Ibanez, G., Allès, B., Kesse-Guyot, E., ... & Péneau, S. (2017). Meal planning is associated with food variety, diet quality and body weight status in a large sample of French adults. *International journal of behavioral nutrition and physical activity*, *14*(1), 1-12. https://doi.org/10.1186/s12966-017-0461-7
28. Eghbali-Zarch, M., Tavakkoli-Moghaddam, R., Esfahanian, F., Azaron, A., & Sepehri, M. M. (2017). A New Multi-objective Optimization Model for Diet Planning of Diabetes Patients under Uncertainty. *Health Education and Health Promotion*, *5*(3), 37-55.
29. Sheng, L. Z., & Sufahani, S. (2018, April). Optimal Diet Planning for Eczema Patient Using Integer Programming. In *Journal of Physics: Conference Series* (Vol. 995, No. 1, p. 012049). IOP Publishing. https://doi.org/10.1088/1742-6596/995/1/012049
30. Ghorabi, S., Salari-Moghaddam, A., Daneshzad, E., Sadeghi, O., Azadbakht, L., & Djafarian, K. (2019). Association between the DASH diet and metabolic syndrome components in Iranian adults. *Diabetes & Metabolic Syndrome: Clinical Research & Reviews*, *13*(3), 1699-1704. https://doi.org/10.1016/j.dsx.2019.03.039
31. Rodriguez, M. A., Friedberg, J. P., DiGiovanni, A., Wang, B., Wylie-Rosett, J., Hyoung, S., & Natarajan, S. (2019). A tailored behavioral intervention to promote adherence to the DASH diet. *American journal of health behavior*, *43*(4), 659-670. https://doi.org/10.5993/AJHB.43.4.1
32. Farhadnejad, H., Darand, M., Teymoori, F., Asghari, G., Mirmiran, P., & Azizi, F. (2019). The association of Dietary Approach to Stop Hypertension (DASH) diet with metabolic healthy and metabolic unhealthy obesity phenotypes. *Scientific reports*, *9*(1), 1-7. https://doi.org/10.1038/s41598-019-55285-6
33. Pirozeh, R., Heidarzadeh-Esfahani, N., Morvaridzadeh, M., Izadi, A., Yosaee, S., Potter, E., ... & Heshmati, S. (2020). Effect of DASH diet on oxidative stress parameters: A systematic review and meta-analysis of randomized clinical trials. *Diabetes & Metabolic Syndrome: Clinical Research & Reviews*. https://doi.org/10.1016/j.dsx.2020.10.031
34. Soltani, S., Arablou, T., Jayedi, A., & Salehi-Abargouei, A. (2020). Adherence to the dietary approaches to stop hypertension (DASH) diet in relation to all-cause and cause-specific mortality: a systematic review and dose-response meta-analysis of prospective cohort studies. *Nutrition journal*, *19*(1), 1-13. https://doi.org/10.1186/s12937-020-00554-8
35. Khan, M. A., Haq, A., & Ahmed, A. (2021). Multi-objective Model for Daily Diet Planning. *Reliability: Theory & Applications*, *16*(1 (61)), 89-97. https://doi.org/10.24412/1932-2321-2021-161-89-97
36. Kim, H., Lichtenstein, A. H., Wong, K. E., Appel, L. J., Coresh, J., & Rebholz, C. M. (2021). Urine Metabolites Associated with the Dietary Approaches to Stop Hypertension (DASH) Diet: Results from the DASH-Sodium Trial. *Molecular Nutrition & Food Research*, *65*(3), 2000695. https://doi.org/10.1002/mnfr.202000695
37. Ahmed, J., Alharbi, M. G., Akram, M., & Bashir, S. (2021). A new method to evaluate linear programming problem in bipolar single-valued neutrosophic environment. *CMES-COMPUTER MODELING IN ENGINEERING & SCIENCES*, *129*(2), 881-906. https://doi.org/10.32604/cmes.2021.017222

38. Ahmed, J. (2021). LR-Type Fully Single-Valued Neutrosophic Linear Programming Problems. *Neutrosophic Sets and Systems*, *46*, 416-444.
39. Kumar Das, S., Edalatpanah, S. A., & Dash, J. K. (2021). A novel lexicographical-based method for trapezoidal neutrosophic linear programming problem. *Neutrosophic Sets and Systems*, *46*(1), 12.
40. Das, S. K., & Edalatpanah, S. A. (2021). Application of Linear Programming in Diet Problem Under Pythagorean Fuzzy Environment. In *Pythagorean Fuzzy Sets*, 315-327. Springer, Singapore. https://doi.org/10.1007/978-981-16-1989-2_13
41. Das, S. K., Mandal, T., & Edalatpanah, S. A. (2017). A mathematical model for solving fully fuzzy linear programming problem with trapezoidal fuzzy numbers. *Applied intelligence*, *46*(3), 509-519. https://doi.org/10.1007/s10489-016-0779-x
42. Smarandache, F. (1999). A unifying field in Logics: Neutrosophic Logic. In *Philosophy* (pp. 1-141). American Research Press.
43. Liu, P., & Teng, F. (2018). Multiple attribute decision making method based on normal neutrosophic generalized weighted power averaging operator. *International Journal of Machine Learning and Cybernetics*, *9*(2), 281-293. https://doi.org/10.1007/s13042-015-0385-y
44. Rizk-Allah, R. M., Hassanien, A. E., & Elhoseny, M. (2018). A multi-objective transportation model under neutrosophic environment. *Computers & Electrical Engineering*, *69*, 705-719. https://doi.org/10.1016/j.compeleceng.2018.02.024
45. Ali, I., Gupta, S., & Ahmed, A. (2019). Multi-objective linear fractional inventory problem under intuitionistic fuzzy environment. *International Journal of System Assurance Engineering and Management*, *10*(2), 173-189.
46. Abdel-Baset, M., Hezam, I. M., & Smarandache, F. (2016). Neutrosophic goal programming. *Neutrosophic Sets & Systems*, *11*(1), 1-9.
47. Haq, A., Gupta, S., & Ahmed, A. (2021). A multi-criteria fuzzy neutrosophic decision-making model for solving the supply chain network problem. *Neutrosophic Sets and Systems*, *46*, 50-66. https://doi.org/10.5281/zenodo.5553476
48. Gupta, S., Haq, A., Ali, I., & Sarkar, B. (2021). Significance of multi-objective optimization in logistics problem for multi-product supply chain network under the intuitionistic fuzzy environment. *Complex & Intelligent Systems*, 1-21. https://doi.org/10.1007/s40747-021-00326-9
49. Iwuji, A. C., Nnanna, M., & Ndulue, N. I. C. (2016). An optimal DASH diet model for people with hypertension using linear programming approach. *Open journal of optimization*, *5*(01), 14. https://doi.org 10.4236/ojop.2016.51002
50. Iwuji, A. C., & Agwu, E. U. (2017). A weighted goal programming model for the DASH diet problem: comparison with the linear programming DASH diet model. *American journal of operations research*, *7*(5), 307-322. https://doi.org10.4236/ajor.2017.75023

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