A Comparative Case Study on Neutrosophic Linear Programming Approach and ε-Constraint Method for Fuzzy Multiobjective Solid Cold Transportation Problem with an Improved Preservation Technology

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Abstract

Cold transportation is one among the unquenching needs of people around the globe. Although cost sensitive, refrigerated transportation is preferred globally as it ensures the quality of perishable items in pharmaceutical, food and beverages, chemicals and certain other industries during transportation. However, many refrigerated vehicles fail in offering consistent preservation as most of their cooling units depend on the vehicle's engine. It is also important to acknowledge that operating a vehicle unceasingly to maintain temperature is impossible in real life. This set up of poor cold logistics and supply chain leads to an increased deterioration of sensitive items. The paper overcomes this complication by adjoining an extra power source that supports freezing during the shutdown time of the vehicle engine by proposing improved mathematical models on Multi-Objective Cold Fuzzy Solid Transportation Problem (MOCFSTP) with an extra time parameter relating to the static and delay condition of the vehicles during various preservation modes (zero, semi, full) and defends them with comparable scrutinizing. The objectives contemplated in the problem are minimizing the cost, time and rate of deterioration. Numerical examples are discussed in detail and solved using reknown methods in LINGO (19.0) to stress on the effectiveness of the models.

Keywords: Fuzzy multiobjective; Cold solid transportation problem; Preservation technology; Freezing; Delay proportion; Direct belt drive; Auxiliary power source

1. Introduction

Wastage of perishable items starts from production (or) harvest and pursue until the edge of the supply chain. Decaying goods have a restricted shelf-life period and demand a precise temperature throughout their storage and distribution. The broken and disorganized supply chain of many countries including India has a greater impact on the food distribution system in spite of their massive food production. Crops worth billions are wasted each year leading to reduction in the country's GDP. As it is a significant matter, some of the notable circumstances that result in wastage of perishable item are identified and the practical understanding to improve them are furnished in [1]. Many operations are put forth and practiced by experts to ascertain perishability. Hsueh, Che-Fu, and Mei-Shiang Chang [5] proposed a model to detect the quality of perishable items during transportation by employing RFID with wireless sensors. Other techniques that provide insight to product quality are intelligent packing with time-temperature indicators [10] [11], freshness indicators [16] etc. Apart from economic losses, the perished items are hazardous to environment due to the unnecessary use of land resources for dumping and managing them.

To rectify and prevent these issues, preservation technologies have become a mandatory need for perishables. Seervi, Pradeep, et al [15] investigated and reported on some of the traditional food preservation methods like canning, drying, fermentation, pickling, salting availed by the village residents of Himachal Pradesh. Some other methods used for

DOI: https://doi.org/10.54216/IJNS.250416

preserving fruits and vegetables are high pressure preservation, microwave preservation, essential oil preservation, edible film coatings and are elaborated in [2], [19], [12]. Vamza. I, Valters K, Dzalbs A, Kudurs E, Blumberga D [18] performed a multi criteria analysis on pharmaceutical and chemical industries and concluded that price is the most considered factor while opting for thermal packings. The choice of preservation technique varies depending upon the perishable item's sustainability rate and the decision maker.

Among the practiced preservation techniques, refrigeration is found to be quite popular in diminishing the spoilage of perishable goods. In the initial days, home based cold storage techniques were explored and it led to the invention of first vapor-compression refrigeration system. Makule E, Dimoso N, Tassou SA makul [9] discussed about the various cooling system technologies that reduce post-harvest deprivation of fruits and vegetables. Non-vegan foods like poultry, meat, fish, and others are also vastly susceptible to spoilage with temperature changes and needs chilled or frozen treatment. ICAR bestowed an overview on numerous fish processing and preservation technologies in their training manual that adds value to seafood [7]. Until now, no other techniques have become an outstanding remedy for lifting and stocking perishable goods other than cold storage.

Earlier, there was a strong need for cold transportation as perishables without proper transit temperature led to food wastage. So, in the late 1930's, portable air-cooling units were designed and implemented in transportation system. This evolution enabled millions of individuals in different parts of the Earth to avail such products and uplifted cold logistics around the world. They also helped the companies to earn profit in the end by preventing product loss. Cold transportation problem is the transit of temperature-sensitive products from sources to destinations alongside the given constraints with specialized conveyances that ensure good quality of the products. Many forms of refrigerated transport systems are being developed every day. Choosing a reliable logistics partner with good freezing technology is highly essential to reduce the rate of deterioration of products. Cold transportation is the growing economical dream that aspires to reassure the standard of perishable items. Some problems on perishable item transportation with or without deterioration rate have been studied by researchers such as Roy SK & Maity G [13] [14], Kaur D, Mukherjee S, Basu K [8], Chhibber D, Bisht DC, Srivastava PK [3].

Refrigerated preservation technology is recently introduced for Multiobjective Solid Transportation Problem (MOSTP) by Ghosh S, Roy SK, Fügenschuh A [4] in Pythagorean fuzzy environment. This study analyzed the effectiveness of refrigerated preservation rendered by the direct belt drive compressors that offer preservation using the vehicle engine's energy. However, this sustains preservation only during the operating and idle time of transport. It excluded preservation failure due to unavoidable engine shutdown scenarios like condition of the driver, the vehicle, the road etc. Perishables are more prone to spoilage with temperature fluctuations and so an extension for this model is proposed to emphasize the necessity to retain the correct temperature throughout the entire time of transportation including vehicle off conditions in the case of direct drive belt cooling. The drawback is tackled by fitting an efficient alternate power source (freezing parameter) for the non-operating vehicle condition (resting time) along with the corresponding constraint changes.

The paper is organized as follows. In Section 2, the basic definitions are laid out. Section 3 is about the detailed mathematical formulations with the notations and description of the three models. Section 4 chew over the optimization approaches prevailing for multi-objective problems. In Section 5, the models are given a justification and concluded with references.

2. Basic Definitions

2.1. Pythagorean Fuzzy Set [21]

Let X be the universe of discourse. Then, a Pythagorean fuzzy set is $\tilde{A} = \{(x, \mu_{\tilde{A}}(x), \vartheta_{\tilde{A}}(x)) : x \in X\}$ and $\mu_A(x), \vartheta_A(x)) : X \to [0,1]$ are functions of membership and non-membership satisfying the relation $0 \le \mu^2{}_{\tilde{A}}(x) + \vartheta^2{}_{\tilde{A}}(x)) \le 1, \forall x \in X$. This relation makes it stand out from intuitionistic fuzzy set (IFS) as IFS satisfy the same relation but with the negletion of squaring on $\mu_{\tilde{A}}(x), \vartheta_{\tilde{A}}(x)$.

2.2. Triangular Pythagorean Fuzzy Number (TPFN)

Triangular Pythagorean fuzzy number is defined by $\tilde{A} = \{(x, \mu_{\tilde{A}}(x), \vartheta_{\tilde{A}}(x)) : x \in X\}$. Here, x being a triangular fuzzy number (p, q, r) ∍ $0 \le p \le q \le r$ and has membership and non-membership functions defined with the condition $0 \le \mu^2{}_{\tilde{A}}(x) + \vartheta^2{}_{\tilde{A}}(x) \le 1$ as

DOI: https://doi.org/10.54216/IJNS.250416

$$\mu_{\tilde{A}}(x)=\begin{cases}\frac{x-p}{q-p} & if\ p\le x\le q\\ \frac{r-x}{r-q} & if\ q<x\le r\\ 0 & else\end{cases},\ \vartheta_{\tilde{A}}(x)=\begin{cases}\sqrt{1-\left(\frac{x-p}{q-p}\right)^2} & if\ p\le x\le q\\ \sqrt{1-\left(\frac{r-x}{r-q}\right)^2} & if\ q<x\le r\\ 1 & else\end{cases}$$

2.3. Ranking function

For a fixed parameter $\lambda\in(0,1)$, the ranking index defined for triangular Pythagorean fuzzy number $\tilde{A}$ is

$$\Re(\tilde{A})=\frac{\lambda\int_p^r x\mu^2_{\tilde{A}}dx+(1-\lambda)\int_p^r x\vartheta^2_{\tilde{A}}dx}{\lambda\int_p^r \mu^2_{\tilde{A}}dx+(1-\lambda)\int_p^r \vartheta^2_{\tilde{A}}dx}$$

$$=\frac{\lambda(p+2q+r)+(1-\lambda)(5p-2q+5r)}{4(2-\lambda)}$$

2.4. Arithmetic Operations on TPFN

Let $\tilde{A}_1=\{((p_1,q_1,r_1);\mu_{\tilde{A}_1}(x),\vartheta_{\tilde{A}_1}(x)):x\in X\}\ and\ \tilde{A}_2=\{((p_2,q_2,r_2);\mu_{\tilde{A}_2}(x),\vartheta_{\tilde{A}_2}(x)):x\in X\}$ be two TPFNs. Then,

2.4.1. Sum

$$\tilde{A}_1\oplus\tilde{A}_2=\left\{\left((p_1+p_2,q_1+q_2,r_1+r_2);\sqrt{\mu^2_{\tilde{A}_1}(x)+\mu^2_{\tilde{A}_2}(x)-\mu^2_{\tilde{A}_1}(x)\mu^2_{\tilde{A}_2}(x)},\vartheta_{\tilde{A}_1}(x)\vartheta_{\tilde{A}_2}(x)\right):x\in X\right\}$$

2.4.2. Inner Product

$$\tilde{A}_1\otimes\tilde{A}_2=\left\{\left((p_1p_2,q_1q_2,r_1r_2);\mu_{\tilde{A}_1}(x)\mu_{\tilde{A}_2}(x),\sqrt{\vartheta^2_{\tilde{A}_1}(x)+\vartheta^2_{\tilde{A}_2}(x)-\vartheta^2_{\tilde{A}_1}(x)\vartheta^2_{\tilde{A}_2}(x)}\right):x\in X\right\}$$

2.4.3. Scalar Product

$$k.\tilde{A}_1=\left\{\left((kp_1,kq_1,kr_1);\sqrt{1-(1-\mu^2_{\tilde{A}_1}(x))^k},(\vartheta_{\tilde{A}_1}(x))^k\right):x\in X\right\}$$

2.5. Neutrosophic Fuzzy set [17]

For a universal set Y, a neutrosophic fuzzy set is $\tilde{B}=\{y,T_{\tilde{B}}(y),I_{\tilde{B}}(y),F_{\tilde{B}}(y)\},y\in Y$ where $T_{\tilde{B}}(y),I_{\tilde{B}}(y),F_{\tilde{B}}(y)$ are the membership functions for truth, indeterminacy and falsity defined from Y to a non-standard unit interval, $]0^-,1+[$ with no restriction imposed on their sum.

2.6. Operations on Neutrosophic set [20]

2.6.1. Complement

The complement $\tilde{B}^c=\{y,T_{\tilde{B}^c}(y),I_{\tilde{B}^c}(y),F_{\tilde{B}^c}(y)\}$ of a neutrosophic set $\tilde{B}$ is defined by,

$$T_{\tilde{B}}(y)=\{1^+\}-T_{\tilde{B}}(y);I_{\tilde{B}}(y)=\{1^+\}-I_{\tilde{B}}(y);F_{\tilde{B}}(y)=\{1^+\}-F_{\tilde{B}}(y)$$

2.6.2. Union

The union of two neutrosophic sets $\tilde{B}_1\ and\ \tilde{B}_2$ is defined by $\tilde{B}_1\cup\tilde{B}_2=\{y,T_{\tilde{B}_1\cup\tilde{B}_2}(y),I_{\tilde{B}_1\cup\tilde{B}_2}(y),F_{\tilde{B}_1\cup\tilde{B}_2}(y)\}$ in which truth, indeterminacy and falsity memberships are given by,

$$T_{\tilde{B}_1\cup\tilde{B}_2}(y)=T_{\tilde{B}_1}(y)+T_{\tilde{B}_2}(y)-T_{\tilde{B}_1}(y)*T_{\tilde{B}_2}(y);$$

$$I_{\tilde{B}_1\cup\tilde{B}_2}(y)=I_{\tilde{B}_1}(y)+I_{\tilde{B}_2}(y)-I_{\tilde{B}_1}(y)*I_{\tilde{B}_2}(y);$$

$$F_{\tilde{B}_1\cup\tilde{B}_2}(y)=F_{\tilde{B}_1}(y)+F_{\tilde{B}_2}(y)-F_{\tilde{B}_1}(y)*F_{\tilde{B}_2}(y);\forall y\in Y$$

DOI: https://doi.org/10.54216/IJNS.250416

2.6.3. Intersection

The intersection of two neutrosophic sets $\tilde{B}_1$ *and* $\tilde{B}_2$ is defined by $\tilde{B}_1 \cap \tilde{B}_2 = \{y, T_{\tilde{B}_1 \cap \tilde{B}_2}(y), I_{\tilde{B}_1 \cap \tilde{B}_2}(y), F_{\tilde{B}_1 \cap \tilde{B}_2}(y)\}$ in which truth, indeterminacy and falsity memberships are given by,

$$T_{\tilde{B}_1 \cap \tilde{B}_2}(y) = T_{\tilde{B}_1}(y) * T_{\tilde{B}_2}(y); I_{\tilde{B}_1 \cap \tilde{B}_2}(y) = I_{\tilde{B}_1}(y) * I_{\tilde{B}_2}(y); F_{\tilde{B}_1 \cap \tilde{B}_2}(y) = F_{\tilde{B}_1}(y) * F_{\tilde{B}_2}(y); \forall y \in Y$$

2.7. Single-valued Neutrosophic Fuzzy set [4]

A set $\tilde{B} = \{y, T_{\tilde{B}}(y), I_{\tilde{B}}(y), F_{\tilde{B}}(y) : y \in Y\}$ over the universe Y is called single-valued neutrosophic set if the sum of truth, indeterminacy and falsity membership function is restricted from 0 to 3 for $T_{\tilde{B}}(y), I_{\tilde{B}}(y), F_{\tilde{B}}(y) : Y \rightarrow$ [0,1]

3. Mathematical Formulation for the Multiobjective Cold Triangular Pythagorean Fuzzy Solid Transportation Problem (MOCTPFSTP)

3.1. Notations

I*: Set of sources indexed by i*
J*: Set of destinations indexed by j*
K*: Set of conveyances indexed by k*
$\tilde{C}_{i^* j^* k^*}$: Triangular Pythagorean fuzzy transportation cost from i*th source to j*th destination through k*th conveyance
$\tilde{T}_{i^* j^* k^*}$: Triangular Pythagorean fuzzy operating and idle time of k*th conveyance from i*th source to j*th destination
$\tilde{P}_{i^* j^* k^*}$: Triangular Pythagorean fuzzy preservation cost from i*th source to j*th destination through k*th conveyance
$\tilde{D}_{i^* j^* k^*}$: Triangular Pythagorean fuzzy deterioration rate from i*th source to j*th destination through k*th conveyance
θ_c : Cooling function $\in [0,1]$ during the transportation of perishable item
$\tilde{e}_{k^*}$: Triangular Pythagorean fuzzy conveyance capacity of the k*th conveyance
$y_{i^* j^* k^*}$: binary variable taking value 1 whenever $x_{i^* j^* k^*} > 0$
$x_{i^* j^* k^*}$: quantity of items transported from i*th source to j*th destination through k*th conveyance
$\tilde{R}_r$: Triangular Pythagorean fuzzy average proportion of rest during the transportation.
$\tilde{a}_{i^*}$: Triangular Pythagorean fuzzy availability of items at the i*th source
$\tilde{b}_{j^*}$: Triangular Pythagorean fuzzy demand of items at the the j*th destination

3.2. Description of the models

Here, three solid transportation models with multiple objectives are investigated under the various states of preservation namely zero, semi and full in order to magnify the significance of preservation technologies and their impact in supply chain management. The motto of the formulations is to minimize the cost, the duration, and the decay rate during the transportation of perishable items. In all the three models, it is assumed that the vehicles are in perfect operating condition before the beginning of distribution.

3.2.1. Model-I

Many distributors have not yet inherited cold transportation completely. Model I (zero preservation) is all about optimising the transportation problem under negletion of preservation technology namely refrigeration in the overall transportation time.

$$Min\, \tilde{Z}_1(x) = \sum_{i^*=1}^{I^*} \sum_{j^*=1}^{J^*} \sum_{k^*=1}^{K^*} \tilde{C}_{i^* j^* k^*} x_{i^* j^* k^*} \quad (1)$$

$$Min\, \tilde{Z}_2(x) = (1 + \tilde{R}_r) \sum_{i^*=1}^{I^*} \sum_{j^*=1}^{J^*} \sum_{k^*=1}^{K^*} \tilde{T}_{i^* j^* k^*} y_{i^* j^* k^*} \quad (2)$$

$$Min\, \tilde{Z}_3(x) = (1 + \tilde{R}_r) \sum_{i^*=1}^{I^*} \sum_{j^*=1}^{J^*} \sum_{k^*=1}^{K^*} \tilde{D}_{i^* j^* k^*} x_{i^* j^* k^*} \quad (3)$$

DOI: https://doi.org/10.54216/IJNS.250416

Subject to

$$\sum_{i^*=1}^{I^*}\sum_{k^*=1}^{K^*}(1-(1+\tilde{R}_r)\tilde{D}_{i^*j^*k^*})x_{i^*j^*k^*} \geq \tilde{b}_{j^*} \;\; for \;\; j^*=1,2,...,J^* \tag{4}$$

$$\sum_{j^*=1}^{J^*}\sum_{k^*=1}^{K^*}x_{i^*j^*k^*} \leq \tilde{a}_{i^*}, \; for \;\; i^*=1,2,...,I^* \tag{5}$$

$$\sum_{i^*=1}^{I^*}\sum_{j^*=1}^{J^*}x_{i^*j^*k^*} \leq \tilde{e}_{k^*}, \; for \;\; k^*=1,2,...,K^* \tag{6}$$

$$x_{i^*j^*k^*} \geq 0, \forall \, i^*, j^*, k^* \tag{7}$$

$$y_{i^*j^*k^*} = \begin{cases} 1 \;\; if \;\; x_{i^*j^*k^*} > 0 \\ 0 \;\; else \end{cases} \tag{8}$$

The model is feasible if

$$\sum_{i^*=1}^{I^*}\tilde{a}_{i^*} \geq \sum_{j^*=1}^{J^*}\tilde{b}_{j^*} \;\; \& \;\; \sum_{k^*=1}^{K^*}\tilde{e}_{k^*} \geq \sum_{j^*=1}^{J^*}\tilde{b}_{j^*} \tag{9}$$

3.2.2. Model-II

Model II (semi preservation) accommodates a cooling function only during the run time of the vehicle which erases the rate of deterioration of the products to a certain extend. In other words, the model does not offer preservation during the uncertain resting situations.

$$Min\,\tilde{Z}_1(x) = \sum_{i^*=1}^{I^*}\sum_{j^*=1}^{J^*}\sum_{k^*=1}^{K^*}\tilde{C}_{i^*j^*k^*}x_{i^*j^*k^*} + \theta_c\sum_{i^*=1}^{I^*}\sum_{j^*=1}^{J^*}\sum_{k^*=1}^{K^*}\tilde{T}_{i^*j^*k^*}\tilde{P}_{i^*j^*k^*}x_{i^*j^*k^*} \tag{10}$$

$$Min\;\tilde{Z}_2(x) = (1+\tilde{R}_r)\sum_{i^*=1}^{I^*}\sum_{j^*=1}^{J^*}\sum_{k^*=1}^{K^*}\tilde{T}_{i^*j^*k^*}y_{i^*j^*k^*} \tag{11}$$

$$Min\,\tilde{Z}_3(x) = (\theta_c+\tilde{R}_r)\sum_{i^*=1}^{I^*}\sum_{j^*=1}^{J^*}\sum_{k^*=1}^{K^*}\tilde{D}_{i^*j^*k^*}x_{i^*j^*k^*} \tag{12}$$

Subject to

$$\sum_{i^*=1}^{I^*}\sum_{k^*=1}^{K^*}(1-(\theta_c+\tilde{R}_r)\tilde{D}_{i^*j^*k^*})x_{i^*j^*k^*} \geq \tilde{b}_{j^*} \;\; for \;\; j^*=1,2,...,J^* \tag{13}$$

And constraints (5)-(9)

3.2.3. Model-III

The temperature of a cooling unit increases rapidly if the steady cooling is disturbed often and this leads to increased decay or decrease in the shelf life of the perishable items. This limitation is overcomed by Model III (full preservation) which controls the temperature of the truck by practicing complete freezing throughout the transportation period including the resting time by using an auxiliary power source.

$$Min\,\tilde{Z}_1(x) = \sum_{i^*=1}^{I^*}\sum_{j^*=1}^{J^*}\sum_{k^*=1}^{K^*}\tilde{C}_{i^*j^*k^*}x_{i^*j^*k^*} + \theta_c\sum_{i^*=1}^{I^*}\sum_{j^*=1}^{J^*}\sum_{k^*=1}^{K^*}\tilde{T}_{i^*j^*k^*}(1+\tilde{R}_r)\tilde{P}_{i^*j^*k^*}x_{i^*j^*k^*} \tag{14}$$

$$Min\;\tilde{Z}_2(x) = (1+\tilde{R}_r)\sum_{i^*=1}^{I^*}\sum_{j^*=1}^{J^*}\sum_{k^*=1}^{K^*}\tilde{T}_{i^*j^*k^*}y_{i^*j^*k^*} \tag{15}$$

$$Min\,\tilde{Z}_3(x) = \theta_c(1+\tilde{R}_r)\sum_{i^*=1}^{I^*}\sum_{j^*=1}^{J^*}\sum_{k^*=1}^{K^*}\tilde{D}_{i^*j^*k^*}x_{i^*j^*k^*} \tag{16}$$

Subject to

$$\sum_{i^*=1}^{I^*}\sum_{k^*=1}^{K^*}(1-\theta_c(1+\tilde{R}_r)\tilde{D}_{i^*j^*k^*})x_{i^*j^*k^*} \geq \tilde{b}_{j^*} \;\; for \;\; j^*=1,2,...,J^* \tag{17}$$

And constraints (5)-(9)

DOI: https://doi.org/10.54216/IJNS.250416

3.3. Corresponding Deterministic Model for CTFFSTP

3.3.1. Zero Preservation Model (I)

$$Min\,\Re(\tilde{Z}_1(x)) = \sum_{i^*=1}^{I^*}\sum_{j^*=1}^{J^*}\sum_{k^*=1}^{K^*}\Re(\tilde{C}_{i^*j^*k^*})x_{i^*j^*k^*} \quad (1a)$$

$$Min\,\Re(\tilde{Z}_2(x)) = (1+\Re(\tilde{R}_r))\sum_{i^*=1}^{I^*}\sum_{j^*=1}^{J^*}\sum_{k^*=1}^{K^*}\Re(\tilde{T}_{i^*j^*k^*})y_{i^*j^*k^*} \quad (2a)$$

$$Min\,\Re(\tilde{Z}_3(x)) = (1+\Re(\tilde{R}_r))\sum_{i^*=1}^{I^*}\sum_{j^*=1}^{J^*}\sum_{k^*=1}^{K^*}\Re(\tilde{D}_{i^*j^*k^*})x_{i^*j^*k^*} \quad (3a)$$

Subject to

$$\sum_{i^*=1}^{I^*}\sum_{k^*=1}^{K^*}(1-(1+\Re(\tilde{R}_r))\Re(\tilde{D}_{i^*j^*k^*}))x_{i^*j^*k^*} \ge \Re(\tilde{b}_{j^*}) \; for \; j^*=1,2,\ldots,J^* \quad (4a)$$

$$\sum_{j^*=1}^{J^*}\sum_{k^*=1}^{K^*}x_{i^*j^*k^*} \le \Re(\tilde{a}_{i^*}), \; for \; i^*=1,2,\ldots,I^* \quad (5a)$$

$$\sum_{i^*=1}^{I^*}\sum_{j^*=1}^{J^*}x_{i^*j^*k^*} \le \Re(\tilde{e}_{k^*}), \; for \; k^*=1,2,\ldots,K^* \quad (6a)$$

$$x_{i^*j^*k^*} \ge 0, \forall\, i^*, j^*, k^* \quad (7a)$$

$$y_{i^*j^*k^*} = \begin{cases} 1 & if \; x_{i^*j^*k^*} > 0 \\ 0 & else \end{cases} \quad (8a)$$

The model is feasible if

$$\sum_{i^*=1}^{I^*}\Re(\tilde{a}_{i^*}) \ge \sum_{j^*=1}^{J^*}\Re(\tilde{b}_{j^*}) \;\&\; \sum_{k^*=1}^{K^*}\Re(\tilde{e}_{k^*}) \ge \sum_{j^*=1}^{J^*}\Re(\tilde{b}_{j^*}) \quad (9a)$$

3.3.2. Semi Preservation Model (II)

$$Min\,\Re(\tilde{Z}_1(x)) = \sum_{i^*=1}^{I^*}\sum_{j^*=1}^{J^*}\sum_{k^*=1}^{K^*}\Re(\tilde{C}_{i^*j^*k^*})x_{i^*j^*k^*} + \theta_c\sum_{i^*=1}^{I^*}\sum_{j^*=1}^{J^*}\sum_{k^*=1}^{K^*}\Re(\tilde{T}_{i^*j^*k^*})\Re(\tilde{P}_{i^*j^*k^*})x_{i^*j^*k^*} \quad (10a)$$

$$Min\,\Re(\tilde{Z}_2(x)) = (1+\Re(\tilde{R}_r))\sum_{i^*=1}^{I^*}\sum_{j^*=1}^{J^*}\sum_{k^*=1}^{K^*}\Re(\tilde{T}_{i^*j^*k^*})y_{i^*j^*k^*} \quad (11a)$$

$$Min\,\Re(\tilde{Z}_3(x)) = (\theta_c+\Re(\tilde{R}_r))\sum_{i^*=1}^{I^*}\sum_{j^*=1}^{J^*}\sum_{k^*=1}^{K^*}\Re(\tilde{D}_{i^*j^*k^*})x_{i^*j^*k^*} \quad (12a)$$

Subject to

$$\sum_{i^*=1}^{I^*}\sum_{k^*=1}^{K^*}(1-(\theta_c+\Re(\tilde{R}_r)\Re(\tilde{D}_{i^*j^*k^*}))x_{i^*j^*k^*} \ge \Re(\tilde{b}_{j^*}) \; for \; j^*=1,2,\ldots,J^* \quad (13a)$$

And constraints (5a) -(9a)

3.3.3. Full Preservation Model (III)

$$Min\,\Re(\tilde{Z}_1(x)) = \sum_{i^*=1}^{I^*}\sum_{j^*=1}^{J^*}\sum_{k^*=1}^{K^*}\Re(\tilde{C}_{i^*j^*k^*})x_{i^*j^*k^*} + \theta_c\sum_{i^*=1}^{I^*}\sum_{j^*=1}^{J^*}\sum_{k^*=1}^{K^*}\Re(\tilde{T}_{i^*j^*k^*})(1+\Re(\tilde{R}_r))\Re(\tilde{P}_{i^*j^*k^*})x_{i^*j^*k^*} \quad (14a)$$

$$Min\,\Re(\tilde{Z}_2(x)) = (1+\Re(\tilde{R}_r))\sum_{i^*=1}^{I^*}\sum_{j^*=1}^{J^*}\sum_{k^*=1}^{K^*}\Re(\tilde{T}_{i^*j^*k^*})y_{i^*j^*k^*} \quad (15a)$$

$$Min\,\Re(\tilde{Z}_3(x)) = \theta_c(1+\Re(\tilde{R}_r))\sum_{i^*=1}^{I^*}\sum_{j^*=1}^{J^*}\sum_{k^*=1}^{K^*}\Re(\tilde{D}_{i^*j^*k^*})x_{i^*j^*k^*} \quad (16a)$$

DOI: https://doi.org/10.54216/IJNS.250416

Subject to

$$\sum_{i^*=1}^{I^*}\sum_{k^*=1}^{K^*}(1-\theta_c(1+\Re(\tilde{R}_r))\Re(\tilde{D}_{i^*j^*k^*}))x_{i^*j^*k^*} \geq \Re(\tilde{b}_{j^*})\ for\ j^*=1,2,...,J^* \qquad (17a)$$

And constraints (5a) -(9a)

4. Solution Methodology

4.1. ε -Constraint Method

This method was first devised by Haimes et. Al [22]. It involves the acquisition of pareto-optimal solutions by wavering the ε values to every objective function by picking up only one objective function for optimization and treating the others as constraints by delimiting their aspiration values.

Steps

- Find the solution for each objective in the deterministic models separately with respect to the constraints.
- Evaluate the maximum and minimum value of each objective function from the solutions found.
- Choose any one objection function Z_c from Z_{c^*} and rebuff the remaining Z_{c^*} objective functions as constraints and resolve the following.

$$Minimize\ Z_c \qquad (18)$$

Subject to $Z_{c^*} \leq \varepsilon_{c^*}\ for\ c \neq c^*$, either (4a) or (13a) or (17a), (5a) -(9a) (19)

4.2. Neutrosophic Linear Programming Approach (NLP)

The possibility of a statement being true or false craved the path for intuitionistic sets while reality has a degree in which he/ she is unsure about the case developed the Neutrosophic sets. Neutrosophic linear programming problem [6] defines truth, indeterminacy, and falsity membership functions for all the 'n' objective functions. While truth is maximized, falsity is minimized; indeterminacy either can be maximized or minimized depending upon the decision's maker's choice to obtain an efficient pareto-optimal solution.

Steps

- Find the solution for each objective in their corresponding deterministic model with respect to the constraints.
- Insert the solution of each objective to every other objective and gather the best and worst value of each objective function.
- Assign higher tolerance level to truth and indeterminacy and lower level to falsity and constitute the problem as below.

$$Maximize\ \mu+\nu-\gamma \qquad (18a)$$

Subject to

$$\mu \leq T_n(Z_n(x)) \qquad (19a)$$

$$\nu \leq I_n(Z_n(x)) \qquad (20a)$$

$$\gamma \geq F_n(Z_n(x)) \qquad (21a)$$

$$where\ T_n(Z_n(x)) = \begin{cases} 1 & if\ Z_n(x) < L_n^T \\ 1-\dfrac{Z_n(x)-L_n^T}{U_n^T-L_n^T} & if\ L_n^T \leq Z_n(x) \leq U_n^T \\ 0 & if\ Z_n(x) > U_n^T \end{cases}$$

$$I_n(Z_n(x)) = \begin{cases} 1 & if\ Z_n(x) < L_n^I \\ 1-\dfrac{U_n^I-Z_n(x)}{U_n^I-L_n^I} & if\ L_n^I \leq Z_n(x) \leq U_n^I \\ 0 & if\ Z_n(x) > U_n^I \end{cases}$$

DOI: https://doi.org/10.54216/IJNS.250416

$$F_n(Z_n(x)) = \begin{cases} 0 & if\ Z_n(x) < L_n^{\ F} \\ 1 - \dfrac{U_n^{\ F} - Z_n(x)}{U_n^{\ F} - L_n^{\ F}} & if\ L_n^{\ F} \le Z_n(x) \le U_n^{\ F} \\ 1 & if\ Z_n(x) > U_n^{\ F} \end{cases}$$

$$\mu + \nu + \gamma \le 3 \qquad (22a)$$

$$\mu \ge \gamma, \mu \ge \nu, \mu, \nu, \gamma \in [0,1], n = 1,2,3,... \qquad (23a)$$

Here, $U_n^{\ T} = U_n, L_n^{\ T} = L_n; U_n^{\ F} = U_n^{\ T}, L_n^{\ F} = L_n^{\ T} + t_1(U_n^{\ T} - L_n^{\ T}),$

$L_n^{\ I} = L_n^{\ T}, U_n^{\ I} = L_n^{\ T} + s_1(U_n^{\ T} - L_n^{\ T})\ for\ t_1, s_1 \in (0,1)$

And either (4a) or (13a) or (17a), (5a) -(9a) (24a)

5. Numerical Example

The distribution data of a reputed company, which supplies sea fishes from [4] and the resting proportion gathered from the statistics, is considered to explain the efficiency of the models. The results are tabulated in table-1,2 & 3.

Resting Time Proportion

Some of the major parameters like resting hours of a truck driver, necessity break hours like food and nature calls, sleep, fueling, traffic; repairs are assembled roughly to find average resting proportion of vehicle engine. $\tilde{R}_r = (0.09, 0.1278, 0.1315)\ per\ hour$.

Table 1: Objective Value for the Transportation Problem without Preservation

METHODS	MODEL-I (ZERO PRESERVATION)		
	Z_1	**Z_2**	**Z_3**
ε-CONSTRAINT	Rs. 8207.548	43.3329 hrs	22.5386
NLP	Rs. 7167.541	97.7768 hrs	31.48957

Table 2: Objective Value for Transportation Problem without Preservation on the Resting Time

METHODS	MODEL-II (SEMI PRESERVATION)		
	Z_1	**Z_2**	**Z_3**
ε-CONSTRAINT	Rs. 12157.06	43.31 hrs	3.1243
NLP	Rs. 11346.97	124.4432 hrs	4.18

Table 3: Solutions for the Transportation Problem with Complete Preservation

METHODS	MODEL-III (FULL PRESERVATION)		
	Z_1	**Z_2**	**Z_3**
ε-CONSTRAINT	Rs. 12575.44	42.9923 hrs	1.0730
NLP	Rs. 12575.44	43.3329 hrs	1.0730

DOI: https://doi.org/10.54216/IJNS.250416

6. Conclusion and scope to further research

From the tables, it is observed that the ε **-Constraint Method** renders a low rate of deterioration and **Model-III (Full Preservation),** a better efficiency than the other two. This type of break free freezing technologies is already practiced in some developed countries. However, majority of the developing countries are unaware and careless in implementation of such freezing technologies due to their high investment or procurement cost. Though these preservation technologies create an impulsive hike in cost, decrease in deterioration rate will throw a nice outcome on the number of quality items transported thereby overcoming the economic and social expenses. They also prevent pollution caused by dumping of perished items in the landfill contributing to environmental sustainability. Many numbers of auxiliary power sources are existing and are still under discovery and this paper does not pinpoint any specific source but rather offers a layout on the importance of such sources. The time parameters can be still studied deeply based on external or internal factors that affect vehicle flow like precooling, engine heating or cooling, dwelling at fuel station, off-route delays & ambient temperature etc. that are left as future scopes. Preservation with refrigeration have a notable impact on the environment and so technology and mechanisms that prohibit or lessen harmful vehicular emissions due to cold transport can be an idea for additional studies and extensions.

Funding: "This research received no external funding"

Conflicts of Interest: "The authors declare no conflict of interest."

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