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Application of Type-2 Defuzzification Method to Solve Profit Maximization Solid Transportation Problem Considering Carbon Emission

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Keywords

Transportation problem
Carbon emission
Critical value
Gaussion type-2 Fuzzy variables
Genetic algorithm
Reduction method

Abstract.

Transportation of incompatible items is a major problems for the logistic operators. Again today ceo-aware transportation is very much appreciated by the international bodies. In a transportation system, the realization of carbon-emission can be incorporated as an important part of optimization. Now, the infrastructure of surface transportation is developed through the world including third world countries (like India, South-africa, Bangladesh, etc). In the present study, we incorporated the above problems and developed profit maximization of solid transportation problem with carbon emission under type-2 Fuzzy environment. So, a new concept to solve profit maximization transportation problem including sales revenue, purchase cost, transportation cost, procurement cost and carbon-emission cost has been proposed while transporting some goods from sources to destinations. In this model, two transportation schemes with carbon emission (WCE) and with out carbon-emission (WOCE) have been designed. We consider maximization of the total profit in these two models. In the model few parameters are treated as Gaussion fuzzy type-2 variable i.e. purchase cost, selling price, transportation and procurement cost. Critical Value (CV) based reduction help us to transform fuzzy type-2 to type-1 variable. To solve the problem in deterministic way we have to utilized Genetic Algorithm (GA). Finally, numerical results presented to establish the originality of the investigation.

1. Introduction

Heley (1962) in the year 1962, first developed the concept of STP/3D- Transporta-

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tion problem. The STP is the method of supplies certain products from manufacturing points (sources) to the different demand points (destinations) using different conveyances keeping in mind the factor of different transportation capacities and transportation costs, fixed charge costs, etc so that total transportation cost is minimum. While dealing with real-life problems, vagueness appears in the transportation system due to insufficient information about the system or for some unforeseen troubles like strikes, natural disaster, festivals, etc. So consideration of above uncertain environment Jana (2022) in transportation problem is important for practical purposes. STP is nothing but an extension of traditional transportation problem (TP/2D-Transportation Problem) which considers source and demand constraints only. In STP Sifaoui and Aider (2022), Bera and Mondal (2022) conveyance capacity constraint is added with source and demand constraints shown in Figure 1. Also in the survey, there are many works in which TP/STPs are considered under the different uncertain environments. The TP was suggested by Hitchcock (1941) and then mentioned by Koopmans (1949) elaborately. Later Dantzig (1951) formulated the TP as a special class of linear programming problems and developed a special form of simplex technique. Based on Das et al. (1999), the interval number TPs were converted into deterministic multi-objective problems. Saad and Samir (2003) and Chanas and Kuchta (1996) suggested the solution algorithm for solving the TPs in a fuzzy environment. Yang and Liu (2007) investigated a fixed charge STP under the fuzzy environment with fuzzy direct costs, fuzzy supplies, fuzzy demands, and fuzzy conveyance capacities as an expected value scheme / chance-constrained programming scheme / dependent -chance programming model and solved using fuzzy simulation and a heuristic method- tabu search algorithm.

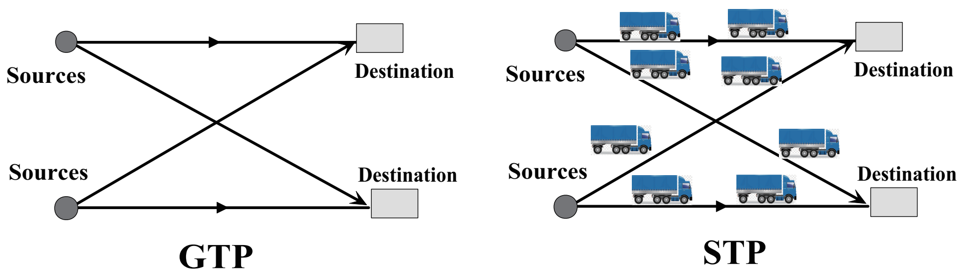

Figure 1: Illustration of GTP and STP.

Over the last few decades, global warming has received an urgent attention by the governments, industries, general public and academics. As a consequence, in the formulation and solution of decision making problems— such as supply chain problems, manufacturing problems, inventory control system, etc., effects of green house gases are considered. More over it is well known that carbon emission is one of the main causes of global warming. As per the estimation of ECOFYS (2010), 15% of global environmental pollution is due to the transportation. In a survey, it is found that road transportation causes $\frac{1}{5}^{th}$ of total carbon emission in the European Union. Thus transportation has negative effect on the environment. For this reason, Governments and other regulatory bodies has introduced several policies such as mandatory carbon emission capacity, cap and trade, cap, carbon emission tax, etc. to control the total carbon emission to the environment. However, very few operational research papers deals with the impact of carbon emission in the transportation system. To mention a few, Chen and Wang (2016) investigated the optimal ordering and transportation mode selection decision under different carbon emission reduction policies. Recently, Sengupta et al. (2018) presented a multi-objective solid transportation problem including the cost due to carbon emission in the other transportation costs and taken the transportation parameters as gamma type 2 fuzzy in nature. Guo et al. (2018) addressed a green transportation scheduling problem with pickup time and transport mode selections. They minimized the total carbon emission along with the sum of transportation related costs.

Type-2 fuzzy sets are used due to its flexibility and degrees of uncertainty and it is treated as three dimension. Thus, type-2 Jana et al. (2021) sets are more efficient for modelling uncertain problems Khalifa et al. (2021) accurately than the type-1 fuzzy variable. The logical operations of type-2 fuzzy were explored by Mizumoto and Tanaka (1981), and Prade and Dubois (1980). Later on, a significant number of theoretical research works on the property of type-2 fuzzy variables are Cheng (2004), Coupland (2007), Prade and Dubois (1980), etc. and its many applications have been presented Bit et al. (1993), Greenfield et al. (2012), Hasuike and Ishii (2009) etc..

Here, we have presented profit maximization of a multi-item STP with Gaussian type-2 fuzzy parameters. Several types of conveyances are used for transportation of goods from sources to destinations, and cost due to CO_2 emitted by these vehicles is taken into account. A transportation system is formulated with respect to a merchant who purchases the source amounts at different origins and sells the transported amount at different destinations as per the demands at destinations. Purchasing costs and selling prices at different origins and destinations respectively are different. Transportation costs, availabilities at sources, demands at the destinations, procurement costs and conveyance capacities are considered as Gaussian type-2 fuzzy variables. Total carbon emission due to road transports is evaluated and cost due to this emission is added with the other transportation-related costs.

In general, materials made in wealthy countries emit fewer carbon emissions but cost more to purchase. Emerging market products, on the other hand, have larger carbon emissions but lower procurement costs. The most relevant suppliers and order quantity should be assessed together to achieve lower procurement costs and fewer carbon emissions. Furthermore, because of economic conditions and electric energy mix, procurement costs and carbon emissions differ by country. As a result, if manufactures shift their production bases or switch suppliers to countries with lower carbon emission levels, overall carbon emissions could be lowered globally. this study presents a procurement choice for supplier selection and order amount in order to reduce carbon emissions and costs while taking into account various carbon levels in various nations. In real applications, the computing complexity of a Gaussian type-2 fuzzy number is extremely high due to the fuzzy membership function. Some defuzzification approaches have been offered in the literature to avoid this problem. We present Critical Value (CV) based reduction strategies for a Gaussian type-2 fuzzy variable. When we use the new methods to develop a mathematical model with Gaussian type-2 fuzzy coefficients, they are significantly easier to implement than the old approaches. The formulated green STP with Gaussian type-2 fuzzy parameters are transformed to a crisp using CV-based reduction method and credibility measures. Then it is solved using GA with Roulette wheel selection, arithmetic crossover and random mutation. Thus the present model mainly investigates the following:

- A multi-item green STP is considered in profit maximization form containing the sales revenue, purchasing cost, procurement cost, transportation cost and cost due to vehicle and road-related carbon emission.
- A computationally efficient defuzzification process of Gaussian type-2 fuzzy variables is presented.
- Transportation problems with Gaussian type-2 fuzzy variable are designed and solved.
- Chance-constrained type programming model with Gaussian type-2 fuzzy variables is formulated.

2. Preliminaries

2.1. Type-1 and type-2 fuzzy variable

Let U be a universal set. A fuzzy set (i.e. type-1 fuzzy set) $\tilde{F}$ is a set in which each element u of U has a membership value $\mu_{\tilde{F}}(u) \in [0,1]$. The fuzzy set $\tilde{F}$ is expressed as Kundu et al. (2014)

$$\tilde{F} = \{(u, \mu_{\tilde{F}}(u)) : \mu_{\tilde{F}}(u) \in [0,1], \forall u \in U\} \tag{2.1}$$

Now if the membership function $\mu_{\tilde{F}}(u)$ of $u \in U$ is again fuzzy (not a crisp value) then $\tilde{F}$ is called a type-2 fuzzy set. The type-2 fuzzy set $\tilde{F}$ is expressed as Mendel and John (2002)

$$\tilde{F} = \{((u,v), \mu_{\tilde{F}}(u,v)) : \forall u \in U, \forall v \in J_u \subseteq [0,1]\} \tag{2.2}$$

where J_u is called primary membership function of $u \in U$ and is the domain of $\mu_{\tilde{F}}(u,v)$, the secondary membership function of u so that $v \in J_u$ is the primary membership grade of u. Here $\mu_{\tilde{F}}(u,v) \in [0,1]$.

Let U be the universal set and Ω be the collection of subsets of U so that Ω is closed under arbitrary union, intersection and complements in U. Let a set function $Pos : \Omega \mapsto [0,1]$ be such that Liu and Liu (2007)

1) $Pos(\phi) = 0$ and $Pos(U) = 1$.
2) For any collection $\{A_i \mid i \in I\}$ of Ω (finite, countable or uncountable) $Pos(\bigcup_{i\in I} A_i) = \sum_{i\in I} Pos(A_i)$.

Then Pos is called the possibility measure and the triplet (U, Ω, Pos) is called the possibility space. Let $X : U \mapsto \Re$ be a function such that for any $t \in \Re$, the set $\{u \in U \mid X(u) \leq t\} \in \Omega$.

Then X is called a fuzzy variable. Now instead of $\Re$ if X be a measurable map from U to [0, 1] i.e. for any $t \in [0,1]$, the set$\{u \in U \mid X(u) \leq t\} \in \Omega$ then X is called regular fuzzy variable (RFV). The collection of all RFV on [0,1] is denoted by $\Re([0,1])$.

If a set function $\tilde{Pos} : \Omega \mapsto \Re([0,1])$ be such that $\{\tilde{Pos}(A) \mid \Omega \ni Aatom\}$ is a family of mutually independent RFVs and $\tilde{Pos}$ satisfies the condition Liu and Liu (2010).

Theorem 1 (See Qin et al., 2011). *Let by CV reduction method the type-2 triangular fuzzy variable* $\tilde{\xi}_i = (t_1^i, t_2^i, t_3^i, \theta_{l,i}, \theta_{r,i})$ *is reduced to* ξ_i *for* $i = 1, 2, \ldots, n$. *Let all the* ξ_i *are mutually independent and* $p_i \geq 0$ *for* $i = 1, 2, \ldots, n$. *Then for the generalized credibility level* $\alpha \in (0, 1)$, $\tilde{C}_r\{\sum_{i=1}^n p_i\xi_i \leq k\} \geq \alpha$ *is equivalent to*

$$\sum_{i=1}^{n} \frac{(1-2\alpha+(1-4\alpha)\theta_{r,i})p_i t_1^i + 2\alpha p_i t_2^i}{1+(1-4\alpha)\theta_{r,i}} \leq k \qquad \text{if } \alpha \in (0, 0.25]$$

$$\sum_{i=1}^{n} \frac{(1-2\alpha)p_i t_1^i + (2\alpha+(4\alpha-1)\theta_{l,i})p_i t_2^i}{1+(4\alpha-1)\theta_{l,i}} \leq k \qquad \text{if } \alpha \in (0.25, 0.5]$$

$$\sum_{i=1}^{n} \frac{(2\alpha-1)p_i t_3^i + (2(1-\alpha)+(3-4\alpha)\theta_{l,i})p_i t_2^i}{1+(3-4\alpha)\theta_{l,i}} \leq k \qquad \text{if } \alpha \in (0.5, 0.75]$$

$$\sum_{i=1}^{n} \frac{(2\alpha-1+(4\alpha-3)\theta_{r,i})p_i t_3^i + 2(1-\alpha)p_i t_2^i}{1+(4\alpha-3)\theta_{r,i}} \leq k \qquad \text{if } \alpha \in (0.75, 1].$$

Corollary 1. *From the above theorem, it is obvious that the expression* $\tilde{C}_r\{\sum_{i=1}^n p_i\xi_i \geq k\} \geq \alpha$ *is equivalent to*

$$\sum_{i=1}^{n} \frac{(1-2\alpha+(1-4\alpha)\theta_{l,i})p_i t_3^i + 2\alpha p_i t_2^i}{1+(1-4\alpha)\theta_{l,i}} \leq k \qquad \text{if } \alpha \in (0, 0.25]$$

$$\sum_{i=1}^{n} \frac{(1-2\alpha)p_i t_3^i + (2\alpha+(4\alpha-1)\theta_{r,i})p_i t_2^i}{1+(4\alpha-1)\theta_{r,i}} \leq k \qquad \text{if } \alpha \in (0.25, 0.5]$$

$$\sum_{i=1}^{n} \frac{(2\alpha-1)p_i t_1^i + (2(1-\alpha)+(3-4\alpha)\theta_{r,i})p_i t_2^i}{1+(3-4\alpha)\theta_{r,i}} \leq k \qquad \text{if } \alpha \in (0.5, 0.75]$$

$$\sum_{i=1}^{n} \frac{(2\alpha-1+(4\alpha-3)\theta_{l,i})p_i t_1^i + 2(1-\alpha)p_i t_2^i}{1+(4\alpha-3)\theta_{l,i}} \leq k \qquad \text{if } \alpha \in (0.75, 1].$$

Theorem 2 (See Qin et al., 2011). *Let by CV reduction method the type-2 Gaussian fuzzy variable* $\tilde{\xi}_i = (\mu_i, \sigma_i^2, \theta_{l,i}, \theta_{r,i})$ *is reduced to* ξ_i *for* $i = 1, 2, \ldots, n$. *Let all the* ξ_i *are mutually independent and* $p_i \geq 0$ *for* $i = 1, 2, \ldots, n$. *Then for the generalized credibility level* $\alpha \in (0, 1)$,$\tilde{C}_r\{\sum_{i=1}^n p_i\xi_i \leq k\} \geq \alpha$ *is equivalent to*

$$\sum_{i=1}^{n} p_i(\mu_i - \sigma_i\sqrt{2\ln(1+(1-4\alpha)\theta_{r,i}) - 2\ln 2\alpha} \leq k \qquad \text{if } \alpha \in (0, 0.25]$$

$$\sum_{i=1}^{n} p_i(\mu_i - \sigma_i\sqrt{2\ln(1+(4\alpha-1)\theta_{l,i}) - 2\ln(2\alpha+(4\alpha-1)\theta_{l,i}))} \leq k \qquad \text{if } \alpha \in (0.25, 0.5]$$

$$\sum_{i=1}^{n} p_i(\mu_i + \sigma_i\sqrt{2\ln(1+(3-4\alpha)\theta_{l,i}) - 2\ln(2(1-\alpha)+(3-4\alpha)\theta_{l,i}))} \leq k \qquad \text{if } \alpha \in (0.5, 0.75]$$

$$\sum_{i=1}^{n} p_i(\mu_i + \sigma_i\sqrt{2\ln(1+(4\alpha-3)\theta_{r,i}) - 2\ln(2(1-\alpha))} \leq k \qquad \text{if } \alpha \in (0.75, 1].$$

Corollary 2. *From the above theorem, it is obvious that the expression* $\tilde{C}_r\{\sum_{i=1}^{n} p_i\xi_i \geq k\} \geq \alpha$ *is equivalent to*

$$\sum_{i=1}^{n} p_i(\mu_i + \sigma_i\sqrt{2\ln(1+(1-4\alpha)\theta_{l,i}) - 2\ln 2\alpha} \leq k \qquad \text{if } \alpha \in (0, 0.25]$$

$$\sum_{i=1}^{n} p_i(\mu_i + \sigma_i\sqrt{2\ln(1+(4\alpha-1)\theta_{r,i}) - 2\ln(2\alpha+(4\alpha-1)\theta_{r,i}))} \leq k \qquad \text{if } \alpha \in (0.25, 0.5]$$

$$\sum_{i=1}^{n} p_i(\mu_i - \sigma_i\sqrt{2\ln(1+(3-4\alpha)\theta_{r,i}) - 2\ln(2(1-\alpha)+(3-4\alpha)\theta_{r,i}))} \leq k \qquad \text{if } \alpha \in (0.5, 0.75]$$

$$\sum_{i=1}^{n} p_i(\mu_i - \sigma_i\sqrt{2\ln(1+(4\alpha-3)\theta_{l,i}) - 2\ln(2(1-\alpha))} \leq k \qquad \text{if } \alpha \in (0.75, 1].$$

3. Notations and Assumptions

Following notations and assumptions are considered for this model.

3.1. Notations (For r-th item)

- M: number of sources ($i = 1, 2, \ldots, M$).
- N: number of destinations ($j = 1, 2, \ldots, N$).
- K: number of conveyances ($k = 1, 2, \ldots, K$).
- R: number of different items ($r = 1, 2, \ldots, R$).
- S_j^r: unit selling price (in \$) of the product at j-th destination.
- P_i^r: unit purchasing cost (in \$) of the product at i-th source.
- C_{ijk}^r: unit transportation cost (in \$) for transportation of the production from i-th source to $j-th$ destination by k-th conveyance.
- A_i^r: available quantity of the product at i-th source.
- B_i^r: necessary quantity of the product at j-th destination.
- E_k: capacity of k-th conveyance.
- x_{ijk}^r: a decision variable which represents the transported amount of the product from i-th source to j-th destination by k-th conveyance.
- BM_i^r: unit procurement cost for product at i-th source.
- CE_k: carbon emission by vehicle k from i-th source to j-th destination.
- ϕ_k: fuel emission factor of vehicle k
- α_{ij}: road specific constant from i-th source to j-th destination. α_{ij} ϵ (0.09,0.2)
- β_k: vehicle specific constant
- V_k: actual vehicle speed
- O_k: curb weight of conveyance k

– W_r: actual load carried by vehicle
– θ: conversion factor that is defined as liter of fuel consumed per joule of energy ($\theta = \frac{1}{(3.6.10^6.8.8)}$)
– ds_{ij}: distance of path which is constant in this case
– δ: cost per unit emission of carbon (δ=2 unit).
– WCE: with carbon emission.
– WOCE: without carbon emission.
– '$\sim$': denotes Gaussian type-2 fuzzy uncertainty.

3.2. Assumptions

– Problems are unbalanced in these models.
– The amount of carbon emission by the k-th conveyance is,

$$CE_k = \sum_{i=1}^{M}\sum_{j=1}^{N}\sum_{r=1}^{R} \phi_k \left[\alpha_{ij}(O_k + x^r_{ijk} \cdot W_r) + \beta_k V_k^2\right] \cdot \theta \cdot y(x^r_{ijk}).ds_{ij}; \quad k = 1, 2, \ldots, K$$
$$= \sum_{i=1}^{M}\sum_{j=1}^{N}\sum_{r=1}^{R} p_{ijk1} + \sum_{i=1}^{M}\sum_{j=1}^{N}\sum_{r=1}^{R} p_{ijk2} \cdot x^r_{ijk}$$

where

$$p_{ijk1} = \phi_k(\alpha_{ij}O_k + \beta_k V_k^2) \cdot \theta \cdot y(x^r_{ijk}) \cdot ds_{ij} \cdot p_{ijk2} = \phi_k \alpha_{ij} \cdot \theta \cdot W_r \cdot y(x^r_{ijk}) \cdot ds_{ij}.$$

It is clear that both p_{ijk1} and p_{ijk2} are vehicle and road-related constants containing the expressions of few constants (See Guo et al., 2018).
– $y(x^r_{ijk})$: a binary variable whose value is 1 if some amount is transported from i-th source to j-th destination by k-th conveyance and 0 otherwise, i.e.

$$y(x^r_{ijk}) = \begin{cases} 1, & \text{for } x^r_{ijk} > 0, \\ 0, & \text{otherwise.} \end{cases}$$

4. Mathematical Formulation

In this model, some number of items are transported from some origins to some destinations as per the demands at the destinations through some conveyances. Here, we try to formulate a green transportation problem addressing the cost of greenhouse gas (mainly carbon) emission due to 'intermodal transportation'–along with other transportation costs. The transportation from the origins to destinations is done by a group of homogeneous vehicles which are light, medium or heavy trucks (say). The carbon emission of each vehicle is assumed to depend on the curb weight O_k, fuel emission factor ϕ_k, road specific constant α_{ij}, vehicle specific constant β_k, actual vehicle speed of vehicle

V_k, actual load carried by the vehicle W_r, conversion factor θ, distance from origin to destination ds_{ij}. Following Guo et al. (2018), the cost due to carbon emission is taken as

$$\sum_{i=1}^{M}\sum_{j=1}^{N}\sum_{r=1}^{R} p_{ijk1} + \sum_{i=1}^{M}\sum_{j=1}^{N}\sum_{r=1}^{R} p_{ijk2} \cdot x_{ijk}^{r}$$

where

$$\begin{aligned} p_{ijk1} &= \phi_k(\alpha_{ij}O_k + \beta_k V_k^2) \cdot \theta \cdot y(x_{ijk}^r) \cdot ds_{ij}, \\ p_{ijk2} &= \phi_k \alpha_{ij} \cdot \theta \cdot W_r \cdot y(x_{ijk}^r) \cdot ds_{ij}. \end{aligned}$$

4.1. Proposed Model:

Price of selling, cost of purchase, unit transportation cost, unit procurement cost, availabilities origin, demands at destinations, and conveyance capabilities are considered as Gaussian fuzzy type-2 variables. Thus the problem is

$$\begin{aligned} \text{Max } f_1 = &\sum_{i=1}^{M}\sum_{j=1}^{N}\sum_{k=1}^{K}\sum_{r=1}^{R}\{\tilde{S}_j^r - \tilde{P}_i^r - \tilde{C}_{ijk}^r - \tilde{BM}_i^r\}x_{ijk}^r \\ &- \sum_{i=1}^{M}\sum_{j=1}^{N}\sum_{k=1}^{K}\sum_{r=1}^{R}(p_{ijk1} + p_{ijk2}x_{ijk}^r) \cdot \delta \end{aligned} \tag{4.1}$$

subject to

$$\left.\begin{aligned} &\sum_{j=1}^{N}\sum_{k=1}^{K} x_{ijk}^r \le \tilde{A}_i^r && i = 1,2,\ldots,M, r = 1,2,\ldots,R \\ &\sum_{i=1}^{M}\sum_{k=1}^{K} x_{ijk}^r \ge \tilde{B}_j^r && j = 1,2,\ldots,N, r = 1,2,\ldots,R \\ &\sum_{i=1}^{M}\sum_{j=1}^{N}\sum_{r=1}^{R} x_{ijk}^r \le \tilde{E}_k^r && k = 1,2,\ldots,K, \\ &x_{ijk}^r \ge 0, \forall\ i,j,k,r. \end{aligned}\right\} \tag{4.2}$$

where the binary variable $y(x_{ijk}^r)$ is defined by,

where $$y(x_{ijk}^r) = \begin{cases} 1, & \text{if } x_{ijk}^r > 0 \text{ for at least one } r \\ 0, & \text{if } x_{ijk}^r = 0 \text{ for all } r \end{cases}$$

and the cost due to carbon emission is given as

$$CCE = \sum_{i=1}^{M}\sum_{j=1}^{N}\sum_{k=1}^{K}\sum_{r=1}^{R}(p_{ijk1} + p_{ijk2}x_{ijk}^r) \cdot \delta.$$

4.2. Defuzzification of Gaussian type-2 fuzzy variables

Now to solve the above-mentioned problem, we construct a chance-constraint programming model with the reduced fuzzy parameters. So, using generalized credibility measure, the following chance-constraint programming model is constructed:

$$\left.\begin{array}{l}
\text{Max } \bar{f} \\
\text{s.t} \quad Cr\Big\{ \sum_{i=1}^{M}\sum_{j=1}^{N}\sum_{k=1}^{K}\sum_{r=1}^{R}\{\tilde{S}_j^r - \tilde{P}_i^r - \tilde{C}_{ijk}^r - \tilde{BM}_i^r\}x_{ijk}^r \\
-\sum_{i=1}^{M}\sum_{j=1}^{N}\sum_{k=1}^{K}\sum_{r=1}^{R}(p_{ijk1} + p_{ijk2}x_{ijk}^r).\delta_k \geq \bar{f}\Big\} \geq \alpha \\
Cr\Big\{ \sum_{j=1}^{N}\sum_{k=1}^{K} x_{ijk}^r \leq \tilde{A}_i^r \Big\} \geq \alpha_i \qquad i = 1,2,\ldots,M, r = 1,2,\ldots,R \\
Cr\Big\{ \sum_{j=1}^{N}\sum_{k=1}^{K} x_{ijk}^r \geq \tilde{B}_j^r \Big\} \geq \beta_j \qquad j = 1,2,\ldots,N, r = 1,2,\ldots,R \\
Cr\Big\{ \sum_{i=1}^{M}\sum_{j=1}^{N}\sum_{r=1}^{R} x_{ijk}^r \leq \tilde{E}_k \Big\} \geq \gamma_k, k = 1,2,\ldots,K, x_{ijk}^r \geq 0, \forall i,j,k,r.
\end{array}\right\} \quad (4.3)$$

$$\text{where} \qquad y(x_{ijk}^r) = \begin{cases} 1, \text{ if } x_{ijk}^r > 0 \text{ for at least one } r, \\ 0, \text{ if } x_{ijk}^r = 0, \text{for all } r, \end{cases}$$

Here Max$\bar{f}$ indicates the maximum value and the objective function accomplishes with generalized credibility $\alpha(0 < \alpha \leq 1)$. $\alpha_i, \beta_j, \gamma_k (0 < \alpha_i, \beta_j, \gamma_k \leq 1)$ which are the present generalized credibility satisfaction levels at the origin and end point restriction respectively for all i, j, k, r.

Case i: When $\alpha\epsilon(0,0.25]$, then the equivalent parametric programming problem for the model given by (4.1) is:

$$\left.\begin{array}{l}
\text{Max } \bar{f} \\
\text{s.t} \sum_{i=1}^{M}\sum_{j=1}^{N}\sum_{k=1}^{K}\sum_{r=1}^{R}\bigg[\bigg((\mu_{\tilde{s}_j^r} - \sigma_{\tilde{s}_j^r}\sqrt{2\ln(1+(1-4\alpha)\theta_{r,\tilde{s}_j^r}) - 2\ln 2\alpha})x_{ijk}^r \\
-(\mu_{\tilde{p}_i^r} - \sigma_{\tilde{p}_i^r}\sqrt{2\ln(1+(1-4\alpha)\theta_{r,\tilde{p}_i^r}) - 2\ln 2\alpha})x_{ijk}^r - (\mu_{\tilde{c}_{ijk}^r} \\
-\sigma_{\tilde{c}_{ijk}^r}\sqrt{2\ln(1+(1-4\alpha)\theta_{r,\tilde{c}_{ijk}^r}) - 2\ln 2\alpha})x_{ijk}^r \\
-(\mu_{\tilde{BM}_i^r} - \sigma_{\tilde{BM}_i^r}\sqrt{2\ln(1+(1-4\alpha)\theta_{r,\tilde{BM}_i^r}) - 2\ln 2\alpha})x_{ijk}^r\bigg) \\
-\sum_{i=1}^{M}\sum_{j=1}^{N}\sum_{k=1}^{K}\sum_{r=1}^{R}(p_{ijk1} + p_{ijk2}x_{ijk}^r).\delta_k\bigg] \geq \bar{f} \\
\text{and} \sum_{j=1}^{N}\sum_{k=1}^{K} x_{ijk}^r \leq (\mu_{\tilde{a}_i^r} - \sigma_{\tilde{a}_i^r}\sqrt{2\ln(1+(1-4\alpha_i)\theta_{r,\tilde{a}_i^r}) - 2\ln 2\alpha_i}), \\
i = 1,2,\ldots,M; r = 1,2,\ldots,R \\
\sum_{i=1}^{M}\sum_{k=1}^{K} x_{ijk}^r \geq (\mu_{\tilde{b}_j^r} - \sigma_{\tilde{b}_j^r}\sqrt{2\ln(1+(1-4\beta_j)\theta_{r,\tilde{b}_j^r}) - 2\ln 2\beta_j}), \\
j = 1,2,\ldots,N; r = 1,2,\ldots,R \\
\sum_{i=1}^{M}\sum_{j=1}^{N}\sum_{r=1}^{R} x_{ijk}^r \leq (\mu_{\tilde{e}_k} - \sigma_{\tilde{e}_k}\sqrt{2\ln(1+(1-4\gamma_k)\theta_{r,\tilde{e}_k}) - 2\ln 2\gamma_k}), \ k = 1,2,\ldots,K
\end{array}\right\}$$

Case ii: When $\alpha\epsilon(2.5,0.5]$, then the equivalent parametric programming problem for the model given by (4.1) is:

$$\left.\begin{array}{l}
\text{Max } \bar{f} \\
\text{s.t} \sum_{i=1}^{M}\sum_{j=1}^{N}\sum_{k=1}^{K}\sum_{r=1}^{R}\Bigg[\Bigg((\mu_{\tilde{s}_j^r}-\sigma_{\tilde{s}_j^r}\sqrt{2\ln(1+(4\alpha-1)\theta_{r,\tilde{s}_j^r})-2\ln(2\alpha+(4\alpha-1)\theta_{1,s_j^r})})x_{ijk}^r \\
-(\mu_{\tilde{p}_i^r}-\sigma_{\tilde{p}_i^r}\sqrt{2\ln(1+(4\alpha-1)\theta_{r,\tilde{p}_i^r})-2\ln(2\alpha+(4\alpha-1)\theta_{1,p_i^r})})x_{ijk}^r \\
-(\mu_{\tilde{c}_{ijk}^r}-\sigma_{\tilde{c}_{ijk}^r}\sqrt{2\ln(1+(4\alpha-1)\theta_{r,\tilde{c}_{ijk}^r})-2\ln(2\alpha+(4\alpha-1)\theta_{1,c_{ijk}^r})})x_{ijk}^r \\
-(\mu_{\tilde{BM}_i^r}-\sigma_{\tilde{BM}_i^r}\sqrt{2\ln(1+(4\alpha-1)\theta_{r,\tilde{BM}_i^r})-2\ln(2\alpha+4\alpha-1)\theta_{1,BM_i^r})})x_{ijk}^r\Bigg) \\
-\sum_{i=1}^{M}\sum_{j=1}^{N}\sum_{k=1}^{K}\sum_{r=1}^{R}(p_{ijk1}+p_{ijk2}x_{ijk}^r).\delta_k\Bigg] \geq \bar{f} \\
\text{and} \\
\sum_{j=1}^{N}\sum_{k=1}^{K}x_{ijk}^r \leq (\mu_{\tilde{a}_i^r}-\sigma_{\tilde{a}_i^r}\sqrt{2\ln(1+(4\alpha_i-1)\theta_{r,\tilde{a}_i^r})-2\ln(2\alpha_i+(4\alpha_i-1)\theta_{1,a_i^r})}), \\
i=1,2,\ldots,M; r=1,2,\ldots,R \\
\sum_{i=1}^{M}\sum_{k=1}^{K}x_{ijk}^r \geq (\mu_{\tilde{b}_j^r}-\sigma_{\tilde{b}_j^r}\sqrt{2\ln(1+(4\beta_j-1)\theta_{r,\tilde{b}_j^r})-2\ln(2\beta_j+(4\beta_j-1)\theta_{r,b_j^r})}), \\
j=1,2,\ldots,N; r=1,2,\ldots,R \\
\sum_{i=1}^{M}\sum_{j=1}^{N}\sum_{r=1}^{R}x_{ijk}^r \leq (\mu_{\tilde{e}_k}-\sigma_{\tilde{e}_k}\sqrt{2\ln(1+(4\gamma_k-1)\theta_{r,\tilde{e}_k})-2\ln(2\gamma_k+(4\gamma_k-1)\theta_{1,e_k})}), \\
k=1,2,\ldots,K
\end{array}\right\}$$

Case iii:
When $\alpha\epsilon(0.5,7.5]$, then the equivalent parametric programming problem for the model given by (4.1) is:

$$\left.\begin{array}{l}
\text{Max } \bar{f} \\
\text{s.t} \sum_{i=1}^{M}\sum_{j=1}^{N}\sum_{k=1}^{K}\sum_{r=1}^{R}\Bigg[\Bigg((\mu_{\tilde{s}_j^r}+\sigma_{\tilde{s}_j^r}\sqrt{2\ln(1+(3-4\alpha)\theta_{r,\tilde{s}_j^r})-2\ln(2(1-\alpha)+(3-4\alpha)\theta_{1,\tilde{s}_j^r})})x_{ijk}^r \\
-(\mu_{\tilde{p}_i^r}+\sigma_{\tilde{p}_i^r}\sqrt{2\ln(1+(3-4\alpha)\theta_{r,\tilde{p}_i^r})-2\ln(2(1-\alpha)+(3-4\alpha)\theta_{1,\tilde{p}_i^r})})x_{ijk}^r \\
-(\mu_{\tilde{c}_{ijk}}+\sigma_{\tilde{c}_{ijk}^r}\sqrt{2\ln(1+(3-4\alpha)\theta_{r,\tilde{c}_{ijk}^r})-2\ln(2(1-\alpha)+(3-4\alpha)\theta_{1,\tilde{c}_{ijk}^r})})x_{ijk}^r \\
-(\mu_{\tilde{BM}_i^r}+\sigma_{\tilde{BM}_i^r}\sqrt{2\ln(1+(3-4\alpha)\theta_{r,\tilde{BM}_i^r})-2\ln(2(1-\alpha)+(3-4\alpha)\theta_{1,\tilde{BM}_i^r})})x_{ijk}^r\Bigg) \\
-\sum_{i=1}^{M}\sum_{j=1}^{N}\sum_{k=1}^{K}\sum_{r=1}^{R}(p_{ijk1}+p_{ijk2}x_{ijk}^r).\delta_k\Bigg] \geq \bar{f} \\
\text{and} \\
\sum_{j=1}^{N}\sum_{k=1}^{K}x_{ijk}^r \leq (\mu_{\tilde{a}_i^r}+\sigma_{\tilde{a}_i^r}\sqrt{2\ln(1+(3-4\alpha_i)\theta_{r,\tilde{s}_j^r})-2\ln(2(1-\alpha_i)+(3-4\alpha_i)\theta_{1,\tilde{s}_j^r})}), \\
i=1,2,\ldots,M; r=1,2,\ldots,R \\
\sum_{i=1}^{M}\sum_{k=1}^{K}x_{ijk}^r \geq (\mu_{\tilde{b}_j^r}+\sigma_{\tilde{b}_j^r}\sqrt{2\ln(1+(3-4\beta_j)\theta_{r,\tilde{s}_j^r})-2\ln(2(1-\beta_j)+(3-4\alpha)\theta_{1,\tilde{s}_j^r})}), \\
j=1,2,\ldots,N; r=1,2,\ldots,R \\
\sum_{i=1}^{M}\sum_{j=1}^{N}\sum_{r=1}^{R}x_{ijk}^r \leq (\mu_{\tilde{e}_k}+\sigma_{\tilde{e}_k}\sqrt{2\ln(1+(3-4\gamma_k)\theta_{r,\tilde{s}_j^r})-2\ln(2(1-\gamma_k)+(3-4\gamma_k)\theta_{1,\tilde{s}_j^r})}), \\
k=1,2,\ldots,K
\end{array}\right\}$$

Case iv: When $\alpha\epsilon(0.75,1]$, then the equivalent parametric programming problem for the model given by (4.1) is (cf. section 1.2.4):

$$\left.\begin{array}{l}
\text{Max } \bar{f} \\
\text{s.t} \sum_{i=1}^{M}\sum_{j=1}^{N}\sum_{k=1}^{K}\sum_{r=1}^{R}\Bigg[\Bigg((\mu_{\tilde{s}_j^r}+\sigma_{\tilde{s}_j^r}\sqrt{2\ln(1+(4\alpha-3)\theta_{r,\tilde{s}_j^r})-2\ln(2(\alpha-1))}x_{ijk}^r \\
-(\mu_{\tilde{p}_i^r}+\sigma_{\tilde{p}_i^r}\sqrt{2\ln(1+(4\alpha-3)\theta_{r,\tilde{p}_i^r})-2\ln(2(1-\alpha))}x_{ijk}^r \\
-(\mu_{\tilde{c}_{ijk}^r}+\sigma_{\tilde{c}_{ijk}^r}\sqrt{2\ln(1+(4\alpha-3)\theta_{r,\tilde{c}_{ijk}^r})-2\ln(2(1-\alpha))}x_{ijk}^r \\
-(\mu_{\tilde{BM}_i^r}+\sigma_{\tilde{BM}_i^r}\sqrt{2\ln(1+(4\alpha-3)\theta_{r,\tilde{BM}_i^r})-2\ln(2(1-\alpha))}x_{ijk}^r\Bigg) \\
-\sum_{i=1}^{M}\sum_{j=1}^{N}\sum_{k=1}^{K}\sum_{r=1}^{R}(p_{ijk1}+p_{ijk2}x_{ijk}^r).\delta_k\Bigg] \geq \bar{f} \\
\quad \text{and} \\
\sum_{j=1}^{N}\sum_{k=1}^{K}x_{ijk}^r \leq (\mu_{\tilde{a}_i^r}+\sigma_{\tilde{a}_i^r}\sqrt{2\ln(1+(4\alpha_i-3)\theta_{r,\tilde{a}_i^r})-2\ln(2(\alpha_i-1))}, \\
i=1,2,\ldots,M; r=1,2,\ldots,R \\
\sum_{i=1}^{M}\sum_{k=1}^{K}x_{ijk}^r \geq (\mu_{\tilde{b}_j^r}+\sigma_{\tilde{b}_j^r}\sqrt{2\ln(1+(4\beta_j-3)\theta_{r,\tilde{b}_j^r})-2\ln(2(1-\beta_j))}, \\
j=1,2,.N; r=1,2,\ldots,R \\
\sum_{i=1}^{M}\sum_{j=1}^{N}\sum_{r=1}^{R}x_{ijk}^r \leq (\mu_{\tilde{e}_k}+\sigma_{\tilde{e}_k}\sqrt{2\ln(1+(4\gamma_k-3)\theta_{r,\tilde{e}_k})-2\ln(2(\gamma_k-1))}, \\
k=1,2,\ldots,K
\end{array}\right\}$$

5. Solution Procedure

Real coded GA with Roulette wheel, arithmetic crossover, and random mulation has been used to solve the reduced problem of Model. Here population is a set of feasible solutions of proposed problem. The proposed model is solved with and without the emitted carbon emission.

5.1. Parameters:

The different parameters are considered to solve the problem through GA as follows.

$(MAXGEN)$-number of generation (set 5000)

$(POPSIZE)$-size of population (set 100)

$(PXOVER)$- probability of crossover (set 0.6)

(PMU)-probability of mutation (set 0.2).

5.2. Representation of Chromosome :

The variables in this proposed models are non-linear. So, a real - number is used to represent the chromosome to solve the proposed model. Many non-linear real problems used binary vectors but those were not effective .

5.3. Reproduction:

To evaluate the chromosome, Parents are randomly selected. The boundaries, dependent variables, independent variables are determined from all (here 16) variables to initialize the population.

5.4. Crossover:

The main operator of GA is Crossover. It is used to exchange the parent's characteristics and communicate to the children. It may happen in two steps:

(i) Selection for crossover: A random number r is generated for each solution of $P^1(T)$ from the range [0..1]. The solution is considered for crossover, If $r < p_c$, where p_c is crossover probability.

(ii) Crossover process: After selection some solution, Crossover has been applied. The random number c has been taken from the range [0..1] for the pair of solutions Y_1, Y_2. Y_{11} and Y_{21} are calculated using Y_1, Y_2 as follows :
where Y_{11}=cY_1+$(1-c)Y_2$, Y_{21}=$c\,Y_2$+$(1-c)Y_1$, where Y_{11}, Y_{21} must meet the problem constraints .

5.5. Mutation:

To recover any loss of some important characteristics, we need to perform mutation operation. It also used for maintain population diversity. It is done in two steps:

(i) Mutation Selection : A random number r is generated for each solution of $P^1(T)$ from the range [0..1]. The solution is considered for mutation, If $r <$p$_m$, where $p\ _m$ is the mutation probability.

(ii) Mutation process: A random number r is selected with in the range $[1..K]$. Then by replacement of x_r within r^{th} component of X they are random number. We get a solution $X = (x_1, x_2, \dots x_k)$. Which is a solution through mutation.

5.6. Evaluation:

The evaluation function is used to solve this problem is

$$\text{eval}(V_i) = \text{objective function value.}$$

Through Roulette wheel selection chromosome. Here better chromosome has been chosen from the population to create the new chromosomes. Presently, new enhanced better chromosomes are produced through arithmetic crossover and mutation. The steps of the proposed algorithm is given below:

Step-1: Begin
t=0; Where t is considered as number of iteration.
Step-2: Population(t) is initialized.
Step-3: Population(t) is evaluated.
Step-4: while(condition is true)
{
Population (t) is selected from Population $(t-1)$.
Perform crossover on Population (t)
Perform mutation on Population (t)
evaluate Population (t)
}
Step-5:Optimization Result Printed
Step-6: end.

6. Numerical Experiments with Discussion and Practical Implication

To present the relevancy and utility of the proposed model, a numerical illustration with two sources, two destinations and three convenances are considered. The model described above are coded in GA to solve the profit maximization solid transportation problem with and without carbon emission.

Input Data: Here, $M = 2$, $N = 2$, $K = 3$ and $R = 5$. Unit Transportation cost $(((c^r_{ijk}, k = 1,2,3; r = 1,\ldots,5), j = 1,2), i = 1,2)$, (availabilities, demands and conveyance capacities), (selling prices and purchase costs) and procurement costs are presented in Tables 1, 2, 3, 4 and 5 respectively.

Input of vehicle related constant p_{ijk1} and road related constant p_{ijk2} are presented in Table 6

Table 1: Gaussian T2 fuzzy unit transportation costs (c^r_{ijk}) for both models.

	r	1		2		3		4		5	
k	i/j	1	2	1	2	1	2	1	2	1	2
1	1	(2.4, 0.05, 0.5,0.6)	(2.2,.04, 0.3,0.5)	(2.1,.05, 0.7,0.8)	(1.9,.03, 0.5,0.4)	(2.2,.04, 0.6,0.8)	(2.6,.07, 0.4,0.3)	(2.3,.06, 0.5,0.7)	(2.4, .05, 0.5,0.6)	(2.4, .05, 0.5,0.6)	(2.4, .05, 0.5,0.6)
	2	(1.6,0.03, 0.4,0.5)	(2.2,.04, 0.6,0.8)	(1.5,.02, 0.6,0.4)	(1.6,.02, 0.5,0.3)	(2.4,.06, 0.5,0.7)	(2.6,.07, 0.5,0.6)	(2,.04, 0.3,0.4)	(2.8,.08, 0.4,0.8)	(2.8,.08, 0.4,0.8)	(2.8,.08, 0.4,0.8)
2	1	(1.9,0.04, 0.5,0.7)	(1.2,.01, 0.2,0.5)	(1.2,.01, 0.7,0.4)	(1.5,.02, 0.4,0.3)	(1.7,.03, 0.4,0.3)	(1.8,.03, 0.4,0.3)	(1.4,.02, 0.5,0.7)	(2.1,.04, 0.7,0.6)	(2.1,.04, 0.7,0.6)	(2.1,.04, 0.7,0.6)
	2	(1.9,0.04, 0.5,0.7)	(1.2,.01, 0.2,0.5)	(1.2,.01, 0.7,0.4)	(1.5,.02, 0.4,0.3)	(1.7,.03, 0.4,0.3)	(1.8,.03, 0.4,0.3)	(1.4,.02, 0.5,0.7)	(2.1,.04, 0.7,0.6)	(2.1,.04, 0.7,0.6)	(2.1,.04, 0.7,0.6)
3	1	(1.9,0.04, 0.5,0.7)	(1.2,.01, 0.2,0.5)	(1.2,.01, 0.7,0.4)	(1.5,.02, 0.4,0.3)	(1.7,.03, 0.4,0.3)	(1.8,.03, 0.4,0.3)	(1.4,.02, 0.5,0.7)	(2.1,.04, 0.7,0.6)	(2.1,.04, 0.7,0.6)	(2.1,.04, 0.7,0.6)
	2	(1.9,0.04, 0.5,0.7)	(1.2,.01, 0.2,0.5)	(1.2,.01, 0.7,0.4)	(1.5,.02, 0.4,0.3)	(1.7,.03, 0.4,0.3)	(1.8,.03, 0.4,0.3)	(1.4,.02, 0.5,0.7)	(2.1,.04, 0.7,0.6)	(2.1,.04, 0.7,0.6)	(2.1,.04, 0.7,0.6)

Table 2: Solid transportation problem Parameters $(\mu, \sigma^2; \theta_l, \theta_r)$ for model.

Source $(A_{11}, A_{12}, A_{13}, A_{14}, A_{15}, A_{21}, A_{22}, A_{23}, A_{24}, A_{25})$	Demand $(B_{11}, B_{12}, B_{13}, B_{14}, B_{15}, B_{21}, B_{22}, B_{23}, B_{24}, B_{25},)$
((72,.04,0.5,0.7)	((60,.04,0.5,0.7),
(68,.04,0.5,0.7),	(55,.04,0.5,0.7),
(71,.04,0.5,0.7),	(52,.04,0.5,0.7),
(64,.04,0.5,0.7),	(58,.04,0.5,0.7),
(75,.04,0.5,0.7),	(60,.04,0.5,0.7),
(75,.04,0.5,0.7),	(53,.04,0.5,0.7),
(80,.04,0.5,0.7),	(60,.04,0.5,0.7),
(62,.04,0.5,0.7),	(58,.04,0.5,0.7),
(65,.04,0.5,0.7),	(52,.04,0.5,0.7),
(72,.04,0.5,0.7))	(57,.04,0.5,0.7))

Table 3: Capacity of Conveyance $(\mu, \sigma^2; \theta_l, \theta_r)$ at sources for both models

E_1	E_2	E_3
(260, 1.0;0.8,1.8)	(215,1.2;0.9,1.5)	(225,1.0;1.1,1.5)

Table 4: Selling Prices and Purchase costs $(\mu, \sigma^2; \theta_l, \theta_r)$ for both models

Selling Price	Purchase costs
(45,1.0;0.8,1.8)	(7,1.2;0.9,1.5)
(58,1.0;0.8,1.8)	(9,1.2;0.9,1.5)
(35,1.0;0.8,1.8)	(6,1.2;0.9,1.5)
(40,1.0;0.8,1.8)	(10,1.2;0.9,1.5)
(50,1.0;0.8,1.8)	(8,1.2;0.9,1.5)

Table 5: Procurement costs $(\mu, \sigma^2; \theta_l, \theta_r)$ at sources for model

Item	1	2	3	4	5
BM_i^r	(4.5,1.0;0.8,1.8)	(3.1,1.2;0.9,1.5)	(2.23,1.0;1.1,1.5)	(4.53,1.0;1.1,1.2)	(3.13,1.0;1.1,1.3)

Table 6: Input of vehicle related constant p_{ijk1} and road related constant p_{ijk2}

From/To	k	Destination-1	Destination-2
Source-1	1	(72.6, 0.013)	(85.9, 0.013)
	2	(80.8, 0.013)	(95.2, 0.014)
	3	(85.8, 0.013)	(100.2, 0.014)
Source-2	1	(102.1, 0.013)	(104.5, 0.014)
	2	(116.3, 0.013)	(110.12, 0.014)
	3	(106.3, 0.013)	(108.12, 0.014)

Table 7: Optimal solutions of the model without carbon emission

	x_{ijk}^r	Profit
α=0.20	x_{112}^1=67.75, x_{111}^2=72.78, x_{111}^3=70.27, x_{112}^4=65.12, x_{113}^4=42.72, x_{113}^5=92.15, x_{121}^2=11.21, x_{121}^5=10.42, x_{223}^2=38.45, x_{222}^4=55.02	12812.72
α=0.45	x_{111}^3=72.16, x_{113}^5=64.02, x_{122}^1=108, x_{121}^2=14.19, x_{123}^2=73.09, x_{121}^3=32.05, x_{123}^4=63.95, x_{123}^5=40.47, x_{212}^1=68.22, x_{211}^2=27.16	15128.05
α=0.70	x_{111}^3=72.18, x_{113}^5=99.25, x_{122}^1=112.05, x_{122}^2=66.13, x_{123}^2=21.17, x_{121}^3=3012, x_{123}^4=72.01, x_{212}^1=68.07, x_{213}^2=76.23, x_{211}^4=78.06	18270.79
α=0.95	x_{111}^1=75, x_{111}^2=72.78,x_{112}^3=73.02, x_{112}^4=2.72, x_{113}^5=92.57, x_{121}^4=105.37, x_{211}^3=11.04, x_{213}^4=103.15, x_{223}^1=80.52, x_{222}^5=103.41	21390.62

Discussion:

After solving the problem with the above mentioned data using the proposed GA,

Table 8: Optimal solutions of the model with carbon emission

	x^r_{ijk}	CCE	Profit
α=0.20	x^1_{112}=65.05, x^2_{111}=72.78, x^3_{113}=79.12, x^4_{112}=105.72, x^5_{113}=74.12, x^5_{121}=54.05, x^4_{211}=7.01, x^4_{212}=10.52, x^5_{211}=17.75, x^3_{223}=15.92	825.0063	10628.43
α=0.45	x^1_{112}=67.05, x^2_{113}=74.12, x^3_{112}=66.32, x^3_{113}=4.53, $x112^4$=53.15, x^5_{113}=92.43, x^1_{121}=40.84, x^1_{122}=13.75, x^4_{121}=54.72, x^5_{121}=36.51	841.06	10812.18
α=0.70	x^2_{111}=12.98, x^3_{111}=74.65, x^1_{121}=109.15, x^2_{123}=76.05, x^3_{121}=3.97, x^4_{123}=71.02, x^5_{123}=106.91, x^1_{212}=68.07, x^2_{211}=69.03, x^2_{211}=4.26	865.12	16270.79
α=0.95	x^3_{111}=72.98, x^5_{113}=64.95, x^1_{122}=108.05, x^2_{121}=14.95, x^2_{123}=73.17, x^3_{121}=31.92, x^4_{123}=62.51, x^5_{123}=39.27, x^1_{212}=67.93, x^2_{211}=80.06	893.06	19390.62

the compromise optimal solutions for the Model with and without carbon emission are shown in Table 7 and Table 8. Here for different level of credibility, we get different sets of optimal schedule. From these two tables, it is seen that, ignoring the effect of carbon emission, a transportation system yields more profit. This is as per our expectation. As expected, if the emission has no penalty for carbon emission, then management transports more amount of item. The limits of amounts for WCE system is $[10,628.43, 19,390.62]$, where as this limit for WOCE is $[12,812.72, 21,390.62]$. For both the systems, the increasing of credibility level (α) means increasing of flexibility of constraints. For these reasons, increasing of (α) helps the system to enhance the amount of transportation and finally increases the profit amount.

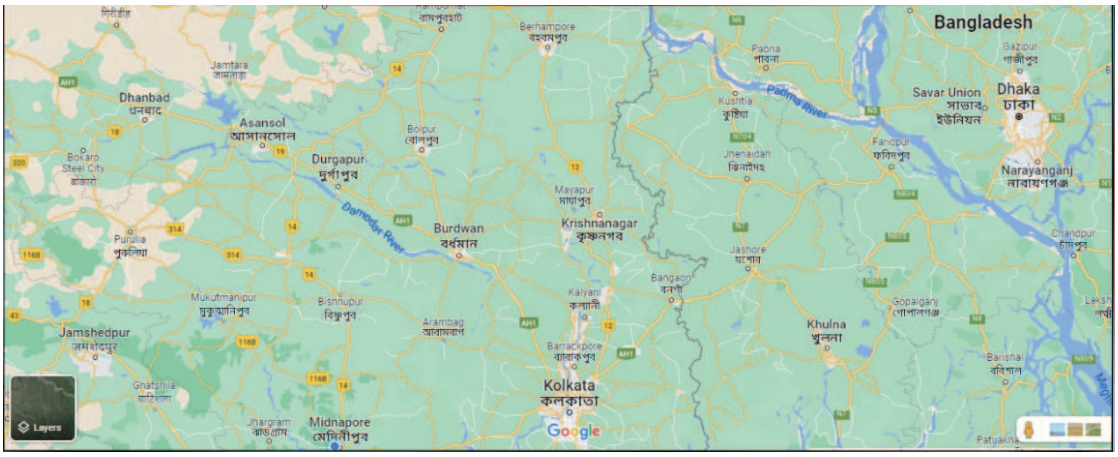

Figure 2: Rice supply business of a rice merchant.

Practical Implication:

The main aim of the proposed model is to maximize the profit against the market prices at different markets including the cost of transportation and the cost due to carbon emission. So indirectly, we want to minimize the effect of pollution to have a green transportation schedule. Due to the fluctuation of fuel price, road tax for different routes, political issues, different types of procurement costs in each market, etc., are not fixed. The transportation cost of carrying one unit (1000 kg) say of rice from sources to destinations by conveyances and the other transport parameters are treated as Gaussian type-2 fuzzy to represent the uncertainty in data. The business of a rice merchant in Bangladesh is described as Figure 2. Here, a food supplier company of Bangladesh supply one type of food product namely rice from three source points namely Faridpur, Gopalganj and Jashore from Bangladesh by difference conveyances (lorry, truck, train) to three destinations Kolkata, Midnapore and Burdwan of India. The suppliers use google road map as their route. For this type of problems, the presented model can be applied to determine optimum profit with uncertain data.

Comparison:

In 2016, Sinha et al. (2016) proposed Profit Maximization Solid Transportation Problem with Trapezoidal Interval Type-2 Fuzzy Numbers. They considered profit maximization and time minimization transportation problem. Again they have taken the unit purchase cost, unit selling price, unit transportation cost and transportation time as trapezoidal interval type-2 fuzzy number. In comparison with this model, we have considered a new concept to solve profit maximization and minimum carbon emission problem including sales revenue, purchase cost, transportation cost,and procurement cost which has been proposed while transporting some goods from sources to destinations. Our approach considered carbon emmission with procurement cost which may vary depending of the nations.

5. Conclusions

Transportation has significantly negative impacts on the environment due to the emission of greenhouse gas or Co_2. The model addresses a green transportation scheduling problem by reducing the emission of Co_2. The parameters i.e., supply, demand, capacity of conveyance, selling price, purchase cost, cost of transportation and unit procurement cost are Gaussian type-2 fuzzy parameters. The real coded GA has been used to solve the proposed model and optimum results are obtained. The main contributions are mentioned below:

- This is an attempt on STP where profit has been maximized including the effect of carbon emission.
- Gaussian type-2 fuzzy has been used to introduce more uncertainty than type-1 fuzzy in the transportation parameters.

Here, cost/tax (imposed by the Government) against carbon emission due to road transportation has been added with the other costs of transportation. In some countries, carbon cap and trade policy is followed. The present model can be directly implemented to include the carbon cap and trade policy. Moreover, the carbon emission may be separately minimized as an objective and the present problem can be formulated as a multi-objective problem with the minimization of transportation and carbon costs.

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