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RESEARCH ARTICLE

Neutrosophic Profit-based Multi-objective Fixed-charge Emission and Budget Constrained Solid Transportation Problem with Mobile Carbon Capture and Storage Technology

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Abstract

Objectives: To introduce and justify the advantages of profit-based mobile carbon capture and storage technology in multi-objective emission and budget constrained fixed-charge solid transportation problem under neutrosophic environment. **Methods:** A mathematical model with an alternating cost objective related to mobile carbon capture and storage is introduced and compared with an existing multi-objective fixed-charge emission and budget constrained solid transportation problem with carbon taxation policy. The remodeled formulation is broken into bunch of sub-models, and each broken model is solved using interactive Pythagorean hesitant fuzzy programming approach in LINGO (19.0) and the results are compared. **Findings:** Alike carbon taxation and stationary carbon capture, mobile carbon capturing and storage is also a carbon neutralization technology that enhances environmental sustainability in supply chain management and logistics. Though expensive, it makes sense due to the consistent higher inflation of carbon pricing percentage across countries. The results obtained by solving the reformulated neutrosophic mathematical model with mobile carbon capture and storage technology show that the operational efficiency of mobile carbon capture and storage is vibrant than carbon cost policy with an average profit around 1400 hundred dollars. **Novelty:** A profit-based mathematical model for multi-objective fixed-charge emission and budget constrained solid transportation problem with mobile carbon capture and storage technology is not yet investigated in literature.

Mathematics Subject Classification (2020): 90B06, 90C08

Keywords: Neutrosophic; Multi-objective; Fixed-charge; Solid transportation problem; Mobile carbon capture and storage

1 Introduction

1.1 Literature Review

Optimization of freight transportation problem with multiple conflicting objectives is still a necessity due to the global desire of amelioration on money making, sustainability, technology, product reliability etc. From the beginning, researchers are amalgamating various conditions which influence the overall stages of transport notably the vehicle capacity, fixed charges, budget, safety and so on. Gupta, Shivani and Rani defined a multi-objective neutrosophic parameter-based transportation problem with fixed charges and justified the model using an example[1]. S. Sandhiya and A. Dhanapal untangled a neutrosophic multi-dimensional transportation problem with fixed charge for breakable commodities[2]. Haque S, Bhurjee AK, Kumar P used closed interval-based formulation for multi-objective solid transportation problem with fixed charge and budget constraints[3]. As transportation acts as a main contributor of hazardous emission, several researchers even kicked around vehicle emission constraints in such optimization problem. Environmental experts and mathematicians have already suggested numerous climate policies and models to handle transport emission which include change of fuels, pollution monitors or trackers, route and cargo optimization, direct carbon tax, cap and trade etc. Mardanya and SK Roy talked through a profit maximization just in time transportation problem with constraints imposed on supply, demand, conveyance and emission capacity, destination budget which are indispensable for the optimistic performance of freight distribution[4]. Javanpour, Saba, et al. propounded a multi-modal transportation problem that minimized transport expenses with restriction on vehicle availability and requirement at various time periods, budget and emission cap policy[5]. Revathi and Mohanaselvi solved an uncertain fixed charge transportation problem with emission-based budget constraint to stress on the importance of carbon cap and trade[6]. Yu, Vincent F., et al investigated a green two-stage solid transportation problem with carbon cap and trade policy and a case study to justify it[7]. Revathi and Mohanaselvi addressed a four-dimensional budget, emission and vehicle speed constrained transportation problem to maximize profit and minimize time under neutrosophic environment for multiple items[8].

Some environmental scientists and climate analyst recommend carbon capturing as a systematic strategy that master climatic change. Nagireddi, S., Agarwal, J.R. and Vedapuri, D did a review on carbon capture technology and rendered the challenges and opportunities linked with it[9]. Saxena, Aryan, et al. elaborated the financial aspects associated with carbon capture, storage and utilization with the inclusion of artificial intelligence[10]. Carrascal-Hernández, Domingo Cesar, et al. navigated through the advancements, strengths and weakness in carbon capture technology and the need for Government funding programs in making them come into reality[11]. In general, carbon capture technology is possible only at stationary sources of carbon emission like industry and plants and doesn't benefit transportation sector, a major contributor of the worldly emission. So, scientists have developed mobile carbon capture system which means the on-board capture of carbon from the transport conveyances. Reynolds, C. performed an economical evaluation of mobile carbon capture with stationary capture and electrification and found that mobile carbon capture is competitive over the other two[12]. Voice and Hamad suggested mobile carbon capture technology as a possible remedy for reducing the transport sector emission by designing and building a mobile capturing system on a semi-truck[13]. Saafi and Hamad did a techno-economic analysis of mobile carbon capture system for heavy duty vehicles in different regions of the world and highlighted its potential[14]. Mobile carbon capture and storage don't require outdated policies like cap and trade, carbon offset and direct taxing of carbon emission with which some companies earn windfall profits rather than investing in green transportation[15].

1.2 Limitations

Almost all the prevailing multi-objective budget constrained transportation problems have either ignored sustainability or have defined taxes, cap and trade policies on carbon and portrayed them as efficient climate changer options for unsustainability, but its actual drawbacks are not profoundly observed. Rosenbloom, Daniel, et al have mentioned the shortcomings of carbon pricing policies and suggests that they can be used only as a part but not as a whole to overcome global warming[16]. Li and Wang studied a decision-making problem in two-level supply chain of manufacturer and retailer to reduce the loss of social welfare with carbon policies[17]. Literature reviews on carbon pricing strategies, carbon cap and trade schemes state that these schemes shield only a little of the overall emissions which just demoralize the concept of emission rather than reducing them. Ardliana, Nyoman and Nurhadi observed that higher value of carbon cap and carbon tax increase the total supply chain and emission cost and affects the social inequities in supply chain management which is moreover passed to the customers[18]. Increase in logistic expenses due to high imposed carbon tax is neglected almost in all existing multi-objective transportation problems with carbon policies. No work has been done yet to evaluate the consistent hikes of carbon tax and the effectiveness of the paid carbon taxes or cap and trade policies towards environmental sustainability in multi-objective transportation models which is clearly a limitation. Switching onto renewable fuel is another breath-taking task which needs complete infrastructure alteration in fuel hoses, vehicle engine etc. Also, decarbonizing with renewable energy sources is a long-term process and is production deficit. So, there still exists needs for modifications or technologies that contribute to intense neutralization of carbon thus simultaneously minimizing extra expenses incurred in transportation sector which can be lighted by implementing mobile carbon capture and storage technology.

1.3 Our Contributions

Heavy carbon penalties are levied on transport emissions when logistic partners exceed the allowance level and also excess money payments are done to trade carbon from other companies as per norms. Though carbon tax is a zero-investment policy, its pricing is gradually increasing each day which is reduced by the implementation of mobile carbon capture and storage technology. It helps logistics and supply chain by capturing transit carbon directly and hence stands out as an alternative theme towards sustainability. Mobile carbon capture and storage model overcomes the issue of spending more money on carbon tax which is certainly discussed on an existing neutrosophic fixed charge solid transportation problem with emission and budget constraints that priced every ton of carbon emitted during transport [(19)]. The existing and the proposed models are solved using Pythagorean hesitant fuzzy programming approach which considers multiple expert views and Pythagorean hesitant values in a way providing keen idea on the state of the problem [(20)]. Neutrosophic sets are developed by Smarandache to help real life problems with indeterminacy which is why the extended model and its respective changes subject to addition of mobile carbon capture and storage are analyzed in the same ambiguous environment [(21)]. No model has been yet formulated to avoid the excess expense incurred by carbon tax policies that prices carbon massively with each growing day with the help of mobile carbon capture and storage technology. Comparative analysis between carbon tax policy and mobile carbon capture and storage is not performed in multi-objective transportation models especially with fixed charge, budget and emission constraints under neutrosophic environment and is a go to mathematical investigation choice.

2 Methodology

2.1 Preliminaries

2.1.1. Single-valued neutrosophic set

Let Ω be the universal set. A structure $B_n = \{< u, \mu_B(u), \nu_B(u), \gamma_B(u) >: u \in \Omega\}$ is called single-valued neutrosophic set where$\mu, \nu, \gamma : \Omega \to [0,1]$ and $\mu_{\widetilde{B}}(u) + \nu_{\widetilde{B}}(u) + \gamma_{\widetilde{B}}(u) \in [0,3], \forall u \in \Omega$.

At this place, μ, ν, γ represent the truth, falsity and indeterminacy degrees.

2.1.2. Interval valued neutrosophic number

An element of form $\tilde{b}_n = l + mI$ with l, m being real numbers and $I \subseteq [0,1]$ is called an interval valued neutrosophic number where I refer indeterminacy. If $I = [I_1, I_2] \ni I_1 < I_2$then $\tilde{b}_n = [l + mI_1, l + mI_2]$.

2.1.3. Basic properties of interval valued neutrosophic number

Let $\tilde{b}_n^1 = l^1 + m^1 I^1 and \tilde{b}_n^2 = l^2 + m^2 I^2$be two neutrosophic numbers where $I^1 = [I_1^1, I_2^1]$ and $I^2 = [I_1^2, I_2^2]$ with $I_1^1 < I_2^1 and I_1^2 < I_2^2$. Then, their interval forms are $\tilde{b}_n^1 = [l^1 + m^1 I_1^1, l^1 + m^1 I_2^1] = [\tilde{b}_1^1, \tilde{b}_2^1]$ and $\tilde{b}_n^2 = [l^2 + m^2 I_1^2, l^2 + m^2 I_2^2] = [\tilde{b}_1^2, \tilde{b}_2^2]$.

Addition: $\tilde{b}_n^1 + \tilde{b}_n^2 = [\tilde{b}_1^1 + \tilde{b}_1^2, \tilde{b}_2^1 + \tilde{b}_2^2]$

Subtraction: $\tilde{b}_n^1 - \tilde{b}_n^2 = [\tilde{b}_1^1 - \tilde{b}_1^2, \tilde{b}_2^1 - \tilde{b}_2^2]$

Multiplication: $\tilde{b}_n^1 * \tilde{b}_n^2 = \begin{cases} [\min(\tilde{b}_1^1 * \tilde{b}_1^2, \tilde{b}_1^1 * \tilde{b}_2^2, \tilde{b}_2^1 * \tilde{b}_1^2, \tilde{b}_2^1 * \tilde{b}_2^2), \\ \max(\tilde{b}_1^1 * \tilde{b}_1^2, \tilde{b}_1^1 * \tilde{b}_2^2, \tilde{b}_2^1 * \tilde{b}_1^2, \tilde{b}_2^1 * \tilde{b}_2^2)] \end{cases}$

Division: $\tilde{b}_n^1 / \tilde{b}_n^2 = \begin{cases} [\min(\tilde{b}_1^1 / \tilde{b}_1^2, \tilde{b}_1^1 / \tilde{b}_2^2, \tilde{b}_2^1 / \tilde{b}_1^2, \tilde{b}_2^1 / \tilde{b}_2^2), \\ \max(\tilde{b}_1^1 / \tilde{b}_1^2, \tilde{b}_1^1 / \tilde{b}_2^2, \tilde{b}_2^1 / \tilde{b}_1^2, \tilde{b}_2^1 / \tilde{b}_2^2)] \end{cases}$

Scalar multiplication: $k * \tilde{b}_n^1 = \begin{cases} [k\tilde{b}_1^1, k\tilde{b}_2^1] if k \geq 0 \\ [k\tilde{b}_2^1, k\tilde{b}_1^1] if k < 0 \end{cases}$

2.1.4. Constrained Neutrosophic Optimization

When the indeterminacy I in the optimization problem is an interval, the problem is broken down into two sub-problems that furnishes the best and worst solution which combine to give a neutrosophic number. The generalization for $I=[0,1]$ and real numbers $a,b,...,p$ is provided below.

$$MaximizeG(x,I)=(a+bI)x_1+(c+dI)x_2=[ax_1+cx_2,(a+b)x_1+(c+d)x_2]$$

$$subjectto(e+fI)x_1+(g+hI)x_2\le(i+jI)=[ex_1+gx_2,(e+f)x_1+(g+h)x_2]\le[i,(i+j)]$$

$$(k+lI)x_1+(m+nI)x_2\le(o+pI)=[kx_1+mx_2,(k+l)x_1+(m+n)x_2]\le[o,(o+p)]$$

This optimization problem is converted into two crisp sub-problems as follows to get the worst and best solution.

Sub-problem 1:

$$Maximize(ax_1+cx_2)$$

$$subjecttoex_1+gx_2\le i$$

$$kx_1+mx_2\le o$$

Sub-problem 2:

$$Maximize(a+b)x_1+(c+d)x_2$$

$$subjecttoex_1+gx_2\le i$$

$$kx_1+mx_2\le o$$

The coefficients of decision variable may vary depending upon the optimization choice of the decision maker. Here, the objective is maximized under the condition of satisfying the minimal availability.

2.2 Mathematical Model

2.2.1. Assumptions

- Only vehicles with mobile carbon capturing units are used for product transportation.
- Regeneration of captured carbon happens only with renewable energy sources.
- Pipelines are established for transport of captured carbon at the regeneration hub.
- Transportation time and amount of emission don't vary with implementation of carbon capture units in the vehicles

2.2.2. Limitations

- Only the operational and maintenance costs of mobile carbon capture and storage technology are considered meanwhile the capital costs are disregarded.
- The excess time incurred for replacing or evacuating the capturing unit when reaching full capacity and regeneration time of the captured carbon and its respective changes in deterioration rate are neglected in the model.

2.2.3. Indices, Parameters and Decision Variables

I - set of sources indexed by i,
J - set of destination indexed by j,
K - set of vehicles indexed by k,
$\tilde{s}_n^j$ - neutrosophic selling price per unit product at destination j,
$\tilde{c}_n^{ijk}$ - neutrosophic transportation cost of the product from i to j using k,
$\tilde{\delta}_n^1$ - neutrosophic capturing cost per unit of carbon,
$\tilde{\delta}_n^2$ - neutrosophic regenerating cost per unit of carbon,
$\tilde{\delta}_n^3$ - neutrosophic pipeline transportation cost per unit of carbon,
$\tilde{\delta}_n^4$ - neutrosophic storage cost per unit of carbon,
$\tilde{\delta}_n^5$- neutrosophic contingency cost per unit of carbon,
$\tilde{e}_n^{ijk}$- neutrosophic carbon emission per unit from i to j in k,
$\tilde{p}_n^i$- neutrosophic procurement cost of the product at i,
$\tilde{f}_n^{ijk}$- neurosophic fixed-charge from i to j for k,
$\tilde{d}_n^{ijk}$- neutrosophic deterioration rate of the product from i to j in k,
$\tilde{\tau}_n^{ijk}$ - neutosophic transportation time from i to j using k,
$\tilde{a}_n^i$ - neutrosophic supply at i,
$\tilde{b}_n^j$ - neutrosophic demand at j,
$\tilde{e}_n^k$ - neutrosophic storage capacity of vehicle k,
$\widetilde{B}_n^j$- neutrosophic budget limit at j,
$\tilde{c}_n^k$ - neutrosophic carbon emission capacity of vehicle k,
$\psi(x_{ijk})$ - binary variable depending on product transportation from i to j via k,
x_{ijk}- quantity of products to be transported from i to j using k.

2.2.4. Mathematical Formulation of Neutrosophic Multi-objective Budget Constrained Fixed-charge Solid Transportation Problem with Mobile Carbon Capture and Storage Technology

$$Maximize Z_n^1 = \sum_i \sum_j \sum_k [(\tilde{s}_n^j - \tilde{c}_n^{ijk} - (\tilde{\delta}_n^1 + \tilde{\delta}_n^2 + \tilde{\delta}_n^3 + \tilde{\delta}_n^4 + \tilde{\delta}_n^5)\tilde{e}_n^{ijk} - \tilde{p}_n^i)x_{ijk} - \tilde{f}_n^{ijk}\psi(x_{ijk})] \tag{1}$$

$$Minimize \widetilde{Z}_n^2 = \sum_i \sum_j \sum_k \tilde{d}_n^{ijk} x_{ijk} \tag{2}$$

$$Minimize \widetilde{Z}_n^3 = \sum_i \sum_j \sum_k \tilde{\tau}_n^{ijk} \psi(x_{ijk}) \tag{3}$$

$$\text{Subject to } \sum_j \sum_k x_{ijk} \le \tilde{a}_n^i, i = 1, 2, ..., m, \tag{4}$$

$$\sum_i \sum_k x_{ijk} \ge \tilde{b}_n^j, j = 1, 2, ..., n, \tag{5}$$

$$\sum_i \sum_j x_{ijk} \le \tilde{e}_n^k, k = 1, 2, ..., o, \tag{6}$$

$$\sum_i \sum_k \left(\tilde{c}_n^{ijk} + (\tilde{\delta}_n^1 + \tilde{\delta}_n^2 + \tilde{\delta}_n^3 + \tilde{\delta}_n^4 + \tilde{\delta}_n^5)\tilde{e}_n^{ijk} + \tilde{p}_n^i\right) x_{ijk} \le \widetilde{B}_n^j, j = 1, 2, ..., n, \tag{7}$$

$$\sum_i \sum_j \tilde{e}_n^{ijk} x_{ijk} \le \tilde{c}_n^k, k = 1, 2, ..., o, \tag{8}$$

$$\psi(x_{ijk}) = \begin{cases} 1 if x_{ijk} > 0 \\ 0 else \end{cases} \tag{9}$$

$$x_{ijk} \geq 0, \forall i, j, k. \tag{10}$$

The feasibility condition of the above model is as follows:

$\sum\limits_i \tilde{a}_n^i \geq \sum\limits_j \tilde{b}_n^j; \sum_k \tilde{e}_n^k \geq \sum_j \tilde{b}_n^j.$

Here all the parameters are of form $\tilde{a}_n = p + qI$. They turn into an interval number when indeterminacy $I = [I_1, I_2] \ni I_1 < I_2$. Equations (1)-(3) are the objective functions corresponding to profit maximization, deterioration rate and time minimization. Equations (4)-(6) are the supply, availability and vehicle capacity constraints while Equations (7) and (8) are the budget and carbon capacity constraints.

2.2.5. *Equivalent Deterministic form of Neutrosophic Multi-objective Budget Constrained Fixed-charge Solid Transportation Problem with Mobile Carbon Capture and Storage Technology*

To obtain the compromise solution of the model, the relation $Minimize(-Z_n^1) = MaximizeZ_n^1$ is utilized in the first objective function. The above model breaks into two sub-problems as indeterminacy I is an interval.

Model-I:

$$Minimize\ Z_1^1 = \sum_i \sum_j \sum_k [(\tilde{c}_2^{ijk} + (\tilde{\delta}_2^1 + \tilde{\delta}_2^2 + \tilde{\delta}_2^3 + \tilde{\delta}_2^4 + \tilde{\delta}_2^5)\tilde{e}_n^{ijk} + \tilde{p}_2^i - \tilde{s}_1^j)x_{ijk} - \tilde{f}_2^{ijk}\psi(x_{ijk})] \tag{1a}$$

$$Minimize\ \widetilde{Z}_1^2 = \sum_i \sum_j \sum_k \tilde{d}_1^{ijk} x_{ijk} \tag{2a}$$

$$Minimize\ \widetilde{Z}_1^3 = \sum_i \sum_j \sum_k \tilde{\tau}_1^{ijk} \psi(x_{ijk}) \tag{3a}$$

Subject to

$$\sum_j \sum_k x_{ijk} \leq \tilde{a}_2^i, i = 1, 2, ..., m, \tag{4a}$$

$$\sum_i \sum_k x_{ijk} \geq \tilde{b}_1^j, j = 1, 2, ..., n, \tag{5a}$$

$$\sum_i \sum_j x_{ijk} \leq \tilde{e}_2^k, k = 1, 2, ..., o, \tag{6a}$$

$$\sum_i \sum_k \left(\tilde{c}_1^{ijk} + (\tilde{\delta}_1^1 + \tilde{\delta}_1^2 + \tilde{\delta}_1^3 + \tilde{\delta}_1^4 + \tilde{\delta}_1^5)\tilde{e}_1^{ijk} + \tilde{p}_1^i\right) x_{ijk} \leq \widetilde{B}_1^j, j = 1, 2, ..., n, \tag{7a}$$

$$\sum_i \sum_k \left(\tilde{c}_2^{ijk} + (\tilde{\delta}_2^1 + \tilde{\delta}_2^2 + \tilde{\delta}_2^3 + \tilde{\delta}_2^4 + \tilde{\delta}_2^5)\tilde{e}_2^{ijk} + \tilde{p}_2^i\right) x_{ijk} \leq \widetilde{B}_2^j, j = 1, 2, ..., n, \tag{7b}$$

$$\sum_i \sum_j \tilde{e}_1^{ijk} x_{ijk} \leq \tilde{c}_1^k, k = 1, 2, ..., o, \tag{8a}$$

$$\sum_i \sum_j \tilde{e}_2^{ijk} x_{ijk} \leq \tilde{c}_2^k, k = 1, 2, ..., o, \tag{8b}$$

And Equations (9)-(10).

Model-II:

$$Minimize\ Z_2^1 = \sum_i \sum_j \sum_k [(\tilde{c}_1^{ijk} + (\tilde{\delta}_1^1 + \tilde{\delta}_1^2 + \tilde{\delta}_1^3 + \tilde{\delta}_1^4 + \tilde{\delta}_1^5)\tilde{e}_1^{ijk} + \tilde{p}_1^i - \tilde{s}_2^j)x_{ijk} - \tilde{f}_1^{ijk}\psi(x_{ijk})] \tag{1b}$$

$$Minimize\ \widetilde{Z}_2^2 = \sum_i \sum_j \sum_k \tilde{d}_2^{ijk} x_{ijk} \tag{2b}$$

$$Minimize\ \widetilde{Z}_2^3 = \sum_i \sum_j \sum_k \tilde{\tau}_2^{ijk} \psi(x_{ijk}) \tag{3b}$$

Subject to Equations (4a) - (8a), (7b), (8b) and (9)-(10).

2.3 Pythagorean Hesitant Fuzzy Programming Multi-objective Optimization Method

Pythagorean Hesitant Fuzzy Programming optimization technique aims to establish a higher degree of satisfaction by considering both Pythagorean hesitant membership and non-membership degrees thrown by multiple decision experts. The steps for solving 'f' objective transportation problem using this method are given below.

Step-1: Solve each objective function in Model-I individually using LINGO GLOBAL (19.0) with respect to their constraints and get 'f' solutions $(X_1^1, X_1^2, ..., X_1^f)$.

Step-2: Evaluate each solution in 'f' objectives $(Z_1^1, Z_1^2, ..., Z_1^f)$ of Model-I to gather the $f \times f$pay-off matrix.

Step-3: Acquire the best (L_1^f) and worst bounds (U_1^f) for the 'f' minimization objective functions.

Step-4: Bestow Pythagorean hesitant membership functions $(\mu_{E_h}^f)$ and non-membership functions $(\nu_{E_h}^f)$ for 'f' objectives in Model-I using $\mu_{E_h}^f(Z_1^f(x)) = \begin{cases} 1 if Z_1^f < L_1^f \\ \phi_h \dfrac{U_1^f - Z_1^f(x)}{U_1^f - L_1^f} if L_1^f \leq Z_1^f(x) \leq U_1^f \\ 0 else \end{cases}$

and $\nu_{E_h}^f(Z_n^f(x)) = \begin{cases} 0 if Z_1^f < L_1^f \\ \chi_h \dfrac{Z_1^f(x) - L_1^f}{U_1^f - L_1^f} if L_1^f \leq Z_1^f(x) \leq U_1^f \\ 1 else \end{cases}$. Here, $\phi_h, \chi_h \in (0,1)$ are hesitant membership and non-membership values rendered by 'h' experts for each objective function in the transportation problem.

Step-5: Define satisfaction and dissatisfaction degrees $(\lambda_h and \sigma_h)$ for 'h' experts to formulate and solve the following model using LINGO GLOBAL (19.0).

$Maximize\left[\frac{\sum_1^h(\lambda_h)^2 - \sum_1^h(\sigma_h)^2}{h}\right]$ subject to $(\mu_{E_h}^f(Z_1^f(x)))^2 \geq \lambda_h^2$, $(\nu_{E_h}^f(Z_1^f(x)))^2 \leq \sigma_h^2 \forall f and h$,

where $\lambda_h^2, \sigma_h^2, \lambda_h^2 + \sigma_h^2 \in [0,1]$ and $\lambda_h^2 \geq \sigma_h^2 \forall h$ and the constraints (4a) - (8a), (7b), (8b) and (9)-(10).

Step-6: Repeat step-1 to 5 for Model-II and combine the solutions to get an interval valued neutrosophic compromise solution for the transportation problem.

3 Results and Discussion

The numerical data for justifying the proposed model is taken from the case study of sea fishes [19]. Additional cost parameters related to mobile carbon capture and storage that are furnished are as follows [12].

$\tilde{\delta}_n^1 = (0.05 + 0.07I)$, $\tilde{\delta}_n^2 = (0.02 + I)$, $\tilde{\delta}_n^3 = (0.01 + 0.015I)$, $\tilde{\delta}_n^4 = (0.07 + 0.06I)$, $\tilde{\delta}_n^5 = (0.18 + 0.1I)$.

The deterministic objectives functions and constraints and Pay-off of Model-I and II are elaborated below.

$$\text{Minimize } Z_1 = -30.55x111 + 18y111 - 29.55x112 + 16y112 - 34.125x121 + 27y121 - 47.275x122 + 9y122$$

$$-33.125x211 + 8y211 - 26.275x212 + 23y212 - 45.7x221 + 9y221 - 42.125x222 + 17y222,$$

$$\text{Minimize } Z_1 = -43.34x111+10y111-41.01x112+9y112-44.01x121+25y121-55.34x122+7y122$$

$$-44.34x211+6y211-38.34x212+13y212-55.34x221+7y221-53.01x222+15y222,$$

$$\text{Minimize } Z_2 = 4x111+5x112+5x121+3x122+3x211+4x212+2x221+2x222,$$

$$\text{Minimize } Z_2 = 6x111+7x112+6x121+5x122+4x211+6x212+3x221+3x222,$$

$$\text{Minimize } Z_3 = 12y111+15y112+8y121+11y122+6y211+9y212+10y221+14y222,$$

$$\text{Minimize } Z_3 = 15y111+20y112+10y121+15y122+10y211+14y212+15y221+20y222,$$

$$x111+x112+x121+x122 \leq 235,$$

$$x211+x212+x221+x222 \leq 250,$$

$$x111+x112+x211+x212 \geq 100,$$

$$x121+x122+x221+x222 \geq 120,$$

$$x111+x121+x211+x221 \leq 275,$$

$$x112+x122+x212+x222 \leq 300,$$

$$11.66x111+13.99x112+10.66x211+16.66x212 \leq 3900,$$

$$19.45x111+20.45x112+16.875x211+23.725x212 \leq 4000,$$

$$20.99x121+9.66x122+9.66x221+11.99x222 \leq 3500,$$

$$25.875x121 + 12.725x122 + 14.3x221 + 17.875x222 \leq 3600,$$

$$2x111 + 3x121 + 2x211 + 2x221 \leq 360, 6x111 + 5x121 + 5x211 + 4x221 \leq 400,$$

$$3x112 + 2x122 + 2x212 + 3x222 \leq 420, 6x112 + 3x122 + 3x212 + 5x222 \leq 460,$$

$x_{ijk} \geq 0 \forall i, jandk.$

The solution obtained from the existing model-I and proposed model-II using LINGO (19.0) are bestowed in [Table 1,Table 2]. From the [Figure 1], it is easy to notice that, for the proposed model, profit is maximum around an average of 1400 hundred dollars with respect to every expert membership and non-membership values while deterioration rate and time vary slightest within the same neighborhood from that of the existing carbon taxation model from [Figure 2, Figure 3].

Table 1. Compromise solution of existing model using Pythagorean Hesitant Fuzzy Programming Approach

S.no	Membership & non-membership degrees		Objectives		
	Expert 1	Expert 2	Profit	Det. rate	Time
1	0.4,0.5,0.2 & 0.3,0.1,0.5	0.3,0.5,0.5 & 0.3,0.2,0.4	[7105.576, 10621.6584]	[701.4182, 1081.121]	[26,39]
2	0.5,0.4,0.5 & 0.2,0.6,0.4	0.7,0.7,0.3 & 0.2,0.5,0.3	[6603, 10005.8454]	[660, 971.2596]	[40,64]
3	0.6,0.5,0.5 & 0.1,0.6,0.5	0.5,0.6,0.6 & 0.2,0.6,0.4	[6786.1525, 9964.9137]	[674.985, 965.9059]	[40,64]

Table 2. Compromise solution of proposed model using Pythagorean Hesitant Fuzzy Programming Approach

S.no	Membership & non-membership degrees		Objectives		
	Expert 1	Expert 2	Profit	Det. rate	Time
1	0.4,0.5,0.2 & 0.3,0.1,0.5	0.3,0.5,0.5 & 0.3,0.2,0.4	[9115.2107, 11427.1256]	[699.4634, 1085.024]	[26,39]
2	0.5,0.4,0.5 & 0.2,0.6,0.4	0.7,0.7,0.3 & 0.2,0.5,0.3	[8688.5, 10937.4212]	[660.985, 985.5771]	[40,59]
3	0.6,0.5,0.5 & 0.1,0.6,0.5	0.5,0.6,0.6 & 0.2,0.6,0.4	[8871.6526, 10937.4254]	[674.985, 985.1841]	[40,59]

4 Conclusion

Mobile carbon capture and storage is an ongoing carbon reduction policy that needs to reach more heights to enhance green environment alongside economic development. Technology based sustainable solutions are often presumed as expensive options, but their operational expenses are lower than null investment plans like carbon tax due to the gradual price hike behavior of taxes. The model for proving its potentiality is legitimized in this work using Pythagorean hesitant fuzzy programming approach which includes exceptional membership and non-membership thoughts of various decision experts. From the results of the numerical example, it is found that the compromise solution of model with mobile carbon capture and storage is quite efficient than the existing carbon taxation policy especially with expenses on carbon emission. They also confirm that income can be generated even after the amount invested for mobile carbon capture and storage by neglecting carbon tax. Mobile carbon capture and storage keep up with the existing fuel types and ensure the removal of carbon to a greater extent unlike carbon tax or trading policies which is just an economic activity to reduce emission. On-board captured carbon is thoroughly measurable and reusable which assures environmental credibility directly unlike other carbon policies where credits are manipulated and unseen. The proposed model is solved using Pythagorean hesitant fuzzy programming approach

Fig 1. Comparison of profit range from existing and proposed model for various set of experts

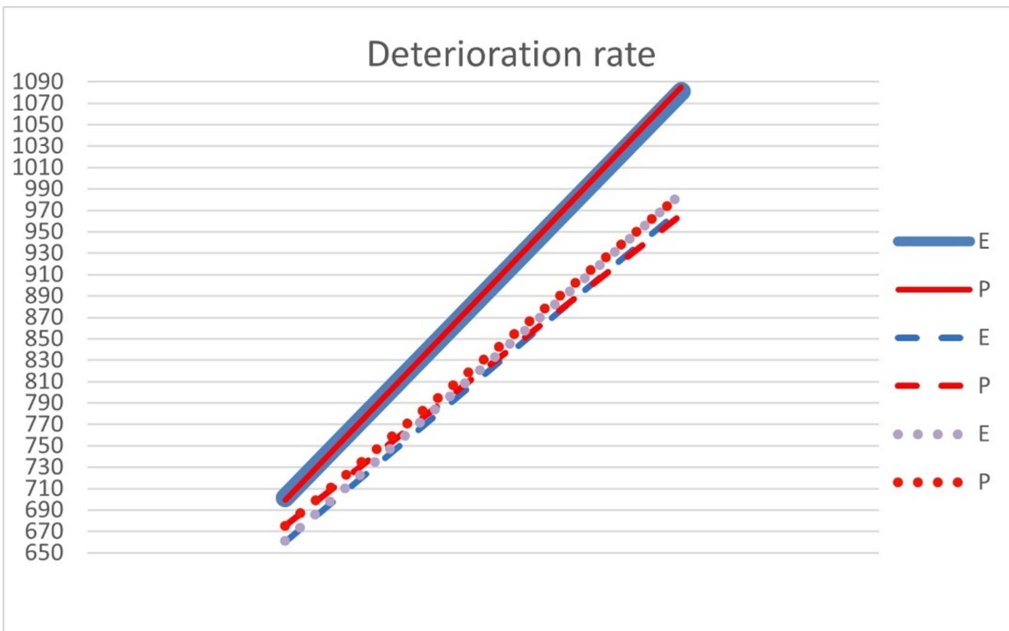

Fig 2. Comparison of deterioration rate from existing and proposed model for various set of experts

which is an existing method and thus the model's performance may be evaluated using some different methods of multi-objective optimization. Also, safety constraints due to mobile carbon capture can be taken into account as an extension, with carbon capture incentives which could increase the profit to the next level. Capturing efficiency along different routes and road parameters, integration with carbon markets, location problems based on capacity of the capturing units can also be accessed as futuristic research. Queuing and vehicle routing problems with mobile carbon capture technology could be an impressive new pick of investigation. Further extensions can also be discussed on the reuse of captured carbon and other innovative strategies to overcome the assumptions and limitations of the proposed model. Failure risks and space constraints during long-term storage of carbon are left unsettled. The overall process of onboard capturing and storing demands infrastructure change alike electrification which is vulnerable at present and definitely needs more awareness and investigation.

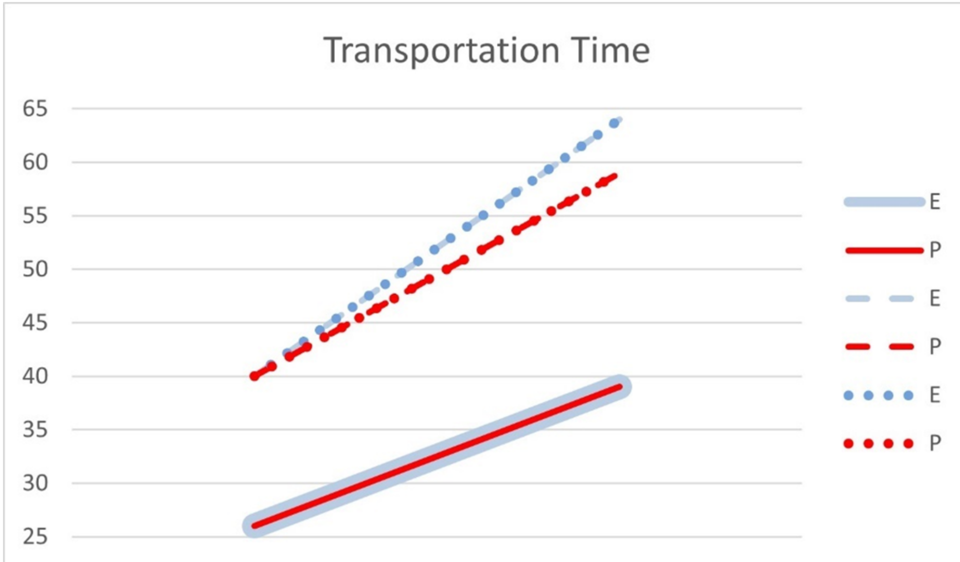

Fig 3. Comparison of transportation time from existing and proposed model for various set of experts

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