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Environmentally Sustainable Multi-Stage Multi-Objective Multi-Item Fixed-Charge Solid Fractional Hesitant Fuzzy Transportation Problem

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Abstract: This paper presents the creative study on environmentally sustainable multi-stage multi-objective multi-item fixed-charge solid fractional hesitant fuzzy transportation problem (MSMOMISFHFTP). Emission of greenhouse gas from the vehicle plays vital role in environmental pollution and global warming. This study helps to control such pollution and gives the optimal solution to lead the green supply chain. The objective of the problem is to minimise the ratio of cost and profit, deterioration rate and emission. This paper provides the proper plan of distribution of multi items from production plants to the customers in three stages. Here all the parameters of multi-stage multi-objective multi-item fixed-charge solid fractional transportation problem are treated as trapezoidal hesitant fuzzy numbers. Hesitant TOPSIS method is introduced to solve MSMOMISFHFTP which provides the better solution than the other existing methods. Finally numerical problem is solved using proposed methodology with the help of LINGO package.

Keywords: Multi-stage Transportation Problem , multi-objective Transportation Problem , multi-item Transportation Problem , fixed-charge solid fractional Transportation Problem , hesitant fuzzy transportation problem.

1. INTRODUCTION

The traditional transportation model determines transportation network for a homogenous commodity from origins to destinations at the minimum transportation cost in which all the parameters of transportation problem (TP) are deterministic. In many situations, the parameters of TP are ambivalent. Due to this the parameters of TP become fuzzy.

The classical transportation provides the network planning from the sources to destinations. When the fixed cost is taken into consideration, transportation problem turns into the fixed transportation problem. Fixed cost is introduced whenever a non-zero quantity is transported through that particular root.

Haley(1962) first person who studied the solid transportation problem (STP) by introducing the constraints on conveyances. In STP, the goods are transported through different types of modes. Zhang(2016) proposed the algorithm for finding the solution of STP.

The transportation problems can be characterized as multi-objective transportation problems (MOTP) by considering more than one objective at a time. Objectives of MOTP may be of minimizing the transportation time, transportation cost and deterioration of products during transportation etc. Bhatia et al have described procedure of the MOTP. A many researchers have developed the mathematical model of MOTP. In many situations, multi objectives are used in fixed solid transportation problem. Many authors Chen(2017), Roy(2019) have developed the mathematical model of multi objective fixed solid transportation under uncertain environment.

In real life problems, transportation system is delivering the goods from production plants to customers in multi stages. Therefore, in this study multi objective multi item multi stage problem has been considered.

Global carbon emissions have been increasing owing to continued incredible economic growth and consumption of fossil-fuel in recent years. This significant development of carbon emissions may create climate change, raising of sea level and global temperature increases which bring impacts environment. Transportation problem plays the major role in carbon emission. This study helps to control emission of greenhouse gas pollution from the transportation to develop the green environment.

Torra (2009) was introduced the concept of a Hesitant Fuzzy Set (HFS) and the proper definition of HFS has developed by Torra (2010). Dual-Hesitant Fuzzy Sets (DHFS) is the extension of HFS which was initiated by Zhu (2012). This DHFS includes the concepts of fuzzy sets, intuitionistic fuzzy set, hesitant fuzzy set and multi fuzzy sets. Torra(2010) and Zhu(2012) have introduced the basic properties and operations of DHFSs. Thereafter, they presented the concept of DHFSs in a group forecasting problem.

Several existing methods are available to solve multi objective transportation problem. But the solution obtained by TOPSIS method gives the efficient optimal compromise solution for multi objective problems. TOPSIS was studied by Hwang and Yoon (1981) for Pareto-optimal solutions to multi-attribute decision making. Traditional TOPSIS has been described for solving multi-attribute problems or ranking problem. Abo-Sinna (2008) and Li(2010) developed a TOPSIS method for non-linear programming. Roy(2017) has introduced the TOPSIS with intuitionistic fuzzy environment. Here we extended the TOPSIS in hesitant fuzzy numbers by introducing possible membership values to solve MSMOMISFHFTP for the first time in this paper.

Section 2 presents preliminaries which have used in paper. The mathematical model of environmentally sustainable multi-stage multi-objective multi-item fixed-charge solid fractional hesitant fuzzy transportation problem (MSMOMISFHFTP) and solution procedure for solving that problem are described in section 3. This study helps to control Emission of greenhouse gas pollution and gives the optimal solution to lead the green supply chain. Hesitant TOPSIS method is introduced to solve MSMOMISFHFTP which provides the best solution. The numerical problem is solved using proposed methodology with the help of LINGO package in section 4. Conclusion and references are provided in section 5 and 6 respectively.

2. PRELIMINARIES

2.1 Hesitant Fuzzy Set : Torra (2009)
A hesitant fuzzy set HF on Y is defined in terms of a function h(y) from Y to the subset of values in the interval [0, 1].
If $\rho([0,1])$ is the power set of [0,1] then h is the function from Y to $\rho([0,1])$.
h: Y → $\rho([0,1])$
Mathematically it can be stated that $HF = \{ (y_i, h(y_i)) : y_i \in Y \}$ where $h(y_i)$ is a set of several values in [0,1].In general each member of $h(y_i)$ is called a hesitant fuzzy element denoted by h_i .

2.2 Generalized Hesitant Fuzzy Set
Let HF be a fixed set, , $h(y_i) \in [0, 1]$ $i \in I = \{1, 2, \ldots, n\}$ and ai , bi , ci , $di \in$ R such that $ai \leq bi \leq ci \leq di$ $(i \in I)$. Then a generalized hesitant fuzzy set is defined as follows:

$GT = \{x, \{(ai, bi, ci, di); h(y_i) : i \in I\}, x \in X\}$
where $\{(ai, bi, ci, di); h(y_i)\_ : i \in I\}$ is a set of some different generalized trapezoidal fuzzy numbers in the set of real numbers R, representing the possible membership functions of the element $x \in X$.

If $a = ai$, $b = bi$, $c = ci$, $d = di$ for all $i \in I$, then a generalized trapezoidal fuzzy number (GTHF-numbers) is reduced to single valued generalized hesitant trapezoidal fuzzy number $GT = ((a, b, c, d); h(y_i)) : i \in I$ is a set of some values in [0,1] is a special hesitant fuzzy set on the real number set R, whose membership functions are defined as

$$\mu i = \begin{cases} \dfrac{(x-a)h(y_i)}{b-a} & a \leq x \leq b \\ h(y_i) & \mathrm{b} \leq \mathrm{x} \leq \mathrm{c} \\ \dfrac{(d-x)h(y_i)}{\mathrm{d}-\mathrm{c}} & \mathrm{c} \leq \mathrm{x} \leq \mathrm{d} \\ 0 & otherwise \end{cases}$$

2.4 Score Function
Let $GT = ((a, b, c, d); h(y_i))$ be a GTHF-number and l_h is the number of the elements in GT. Then score of GT, is denoted by $S(GT)$, is defined as

$$GT = \frac{c^2 + d^2 - a^2 - b^2}{2l_h} \sum_i h(y_i)$$

3. MATHEMATICAL MODEL

Consider the problem has m production plants, n distribution centres, p retailors and q customers with demands. First shipment is from production plants to distribution centres then from distribution centres to retailors finally retailors to customers. The objective of the problem is to predict the number of items to be shipped so as to minimise the cost-profit ration, deterioration rate and emission.

3.1. Model 1

Minimise $Q_1 = \sum_{i=1}^{m}\sum_{j=1}^{n}\sum_{k=1}^{l}\sum_{o=1}^{q}\frac{(c_{ijko}(x_{ijko})+f_{ijko}\gamma^1(x_{ijko}))}{P_{ijko}(x_{ijko})} +$
$\sum_{j=1}^{n}\sum_{r=1}^{p}\sum_{k=1}^{l}\sum_{o=1}^{q}\frac{(c_{jrko}(y_{jrko})+f_{jrko}\gamma^2(y_{jrko}))}{P_{jrko}(y_{jrko})} +$
$\sum_{r=1}^{p}\sum_{s=1}^{q}\sum_{k=1}^{l}\sum_{o=1}^{q}\frac{(c_{rsko}(z_{rsko})+f_{rsko}\gamma^3(z_{rsko}))}{P_{rsko}(z_{rsko})}$ (1)

Minimise $Q_2 = \sum_{i=1}^{m}\sum_{j=1}^{n}\sum_{k=1}^{l}\sum_{o=1}^{q}\frac{t_{ijko}\gamma^1(x_{ijko})}{w_{ijko}(x_{ijko})} +$
$\sum_{j=1}^{n}\sum_{r=1}^{p}\sum_{k=1}^{l}\sum_{o=1}^{q}\frac{t_{jrko}\gamma^2(y_{jrko})}{w_{jrko}(y_{jrko})} +$
$\sum_{r=1}^{p}\sum_{s=1}^{q}\sum_{k=1}^{l}\sum_{o=1}^{q}\frac{t_{rsko}\gamma^3(z_{rsko})}{w_{rsko}(z_{rsko})}$ (2)

Minimise $Q_3 = \sum_{i=1}^{m}\sum_{j=1}^{n}\sum_{k=1}^{l}\sum_{o=1}^{q} ce_{ijko}(x_{ijko}) +$
$\sum_{j=1}^{n}\sum_{r=1}^{p}\sum_{k=1}^{l}\sum_{o=1}^{q} ce_{jrko}\left(y_{jrko}\right) +$
$\sum_{r=1}^{p}\sum_{s=1}^{q}\sum_{k=1}^{l}\sum_{o=1}^{q} ce_{rsko}(z_{rsko})$ (3)

Subject to

$\sum_{j=1}^{n}\sum_{k=1}^{l}\sum_{o=1}^{q} x_{ijko} \le \widetilde{a_{io}}$ (i=1,2,…,m) (4)

$\sum_{r=1}^{p}\sum_{k=1}^{l}\sum_{o=1}^{q} z_{ijko} \ge \widetilde{b_{so}}$ (s=1,2,….,u) (5)

$\sum_{i=1}^{n}\sum_{k=1}^{l}\sum_{o=1}^{q} x_{ijko} \le \widetilde{e_{ko}^{1}}$ (k=1,2,…,l) (6)

$\sum_{j=1}^{m}\sum_{k=1}^{l}\sum_{o=1}^{q} y_{jrko} \le \widetilde{e_{ko}^{2}}$ (k=1,2,…,l) (7)

$\sum_{s=1}^{u}\sum_{k=1}^{l}\sum_{o=1}^{q} z_{rsko} \le \widetilde{e_{ko}^{3}}$ (k=1, 2,…,l) (8)

$\sum_{i=1}^{m}\sum_{k=1}^{l}\sum_{o=1}^{q} x_{ijko} = \sum_{r=1}^{p}\sum_{k=1}^{l}\sum_{o=1}^{q} y_{jrko}$ (j= 1,2,…,n) (9)

$\sum_{r=1}^{p}\sum_{k=1}^{l}\sum_{o=1}^{q} y_{jrko} = \sum_{s=1}^{u}\sum_{k=1}^{l}\sum_{o=1}^{q} z_{rsko}$ (r=1,2,…,p) (10)

$\gamma^1\left(x_{ijko}\right) = \begin{cases} 0 & if\ x_{ijko} = 0 \\ 1 & if\ x_{ijko} > 0 \end{cases}$ (11)

$\gamma^2\left(y_{jrko}\right) = \begin{cases} 0 & if\ y_{jrko} = 0 \\ 1 & if\ y_{jrko} > 0 \end{cases}$ (12)

$\gamma^3(z_{rsko}) = \begin{cases} 0 & if\ z_{rsko} = 0 \\ 1 & if\ z_{rsko} > 0 \end{cases}$ (13)

$x_{ijko} \ge 0$, $y_{jrko} \ge 0$ & $z_{rsko} \ge 0$ for all (i=1,2,…,m) , (j= 1,2,…,n) , (r=1,2,…,p) , (s=1,2,….,u) & o = (1,2,…,q) (14)

Proposed model has feasible solution if

$\sum_{i=0}^{m}\widetilde{a_{io}} = \sum_{s=1}^{q}\widetilde{b_{so}}$ (o = 1,2,…,q) (15)

$\sum_{k=1}^{l}\sum_{o=1}^{q}\widetilde{e_{ko}^{1}} = \sum_{k=1}^{l}\sum_{o=1}^{q}\widetilde{e_{ko}^{2}} = \sum_{k=1}^{l}\sum_{o=1}^{q}\widetilde{e_{ko}^{3}} \ge \sum_{k=1}^{l}\sum_{o=1}^{q}\widetilde{b_{so}}$ (16)

In above model first objective determines the ratio of transportation cost and profit, second objectives determines deterioration rate of time and wastage and third objective represents emission from the transportation. Constraints (4)&(5) represent supply and demand of the production plants and customers. Constraints (6) , (7) & (8) describe the conveyance capacities at stage 1 ,2 and 3 . Constraints (9) & (10) determine flow conversation and (11),(12)&(13) represent characteristic function of fixed charge. Last constraint (14) represents the non-negativity.

3.2. Solution Procedure for MSMOMISFHFTP using Hesitant TOPSIS

In order to obtain the optimal solution of multi-objective hesitant problem, TOPSIS method is used. Here extended TOPSIS programming to hesitant fuzzy environment. The steps of developed hesitant TOPSIS as follows:

Step 1: Convert the given hesitant MSMOMISFHFTP into crisp MSMOMISFTP using the score function described in section 2.

Step 2: Evaluate the individual lower and upper values of all the objective functions.

Step 3: Calculate PIS and NIS as described below:

$$Q^{+} = (Q_1^{+}, Q_2^{+}, Q_3^{+})$$
$$Q^{-} = (Q_1^{-}, Q_2^{-}, Q_3^{-})$$

where Q_b^{+} and Q_b^{-} as

$Q_b^{+} = \min Q_b$ subject to the constraints from (4) to (10)

$Q_b^{-} = \max Q_b$ subject to the constraints from (4) to (10)

Step 4: Determine PIS and NIS and find the distance function from PIS and NIS as follows:

$$dh_v^{PIS}(x) = \left[\sum_{b=1}^{3}\left[W_k \frac{Q_b(x) - Q_b^{+}(x)}{Q_b^{-} - Q_b^{+}}\right]^{v}\right]^{1/v}$$
$$dh_v^{NIS}(x) = \left[\sum_{b=1}^{3}\left[W_k \frac{Q_b^{-}(x) - Q_b(x)}{Q_b^{-} - Q_b^{+}}\right]^{v}\right]^{1/v}$$

The variables W_1 , W_2 and W_3 are the weightage for the objectives. Here the weightages are taken as

$W_1 = 0.3$, $W_2 = 0.3$ and $W_3 = 0.4$. The parameter v presents the control of Pareto-optimal solution of hesitant TOPSIS. In general v takes any positive integer.

Step 5: Assume that v = 2 and then formulate following model which has two objectives

$$\min dh_2^{PIS}(x)$$
$$\max dh_2^{NIS}(x)$$

Subject to (9) to (14)

Step 6: Determine the objective values of $\min dh_2^{PIS}(x)$ and $\max dh_2^{NIS}(x)$ and frame the payoff matrix as:

Table: 1 Payoff Matrix

	$dh_2^{PIS}(x)$	$dh_2^{NIS}(x)$
x^{PIS}	$dh_2^{PIS}(x)^{*}$	$dh_2^{NIS}(x)'$
x^{NIS}	$dh_2^{PIS}(x)'$	$dh_2^{NIS}(x)^{*}$

Step 7: Formulate the possible membership functions $\vartheta_1(x)$ and $\vartheta_2(x)$ for $dh_2^{PIS}(x)$ and $dh_2^{NIS}(x)$ as shown below:

$$\vartheta_1(x) = \begin{cases} 1 & if\ dh_2^{PIS}(x) \le dh_2^{PIS}(x)^{*} \\ \alpha_g \dfrac{dh_2^{PIS}(x)' - dh_2^{PIS}(x)}{dh_2^{PIS}(x)' - dh_2^{PIS}(x)^{*}} & if\ dh_2^{PIS}(x)^{*} \le dh_2^{PIS}(x) \le dh_2^{PIS}(x)' \\ 0 & if\ dh_2^{PIS}(x)' \le dh_2^{PIS}(x) \end{cases}$$

$$\vartheta_2(x) = \begin{cases} 1 & if\ dh_2^{NIS}(x)^* \leq dh_2^{PIS}(x) \\ \alpha_g \dfrac{dh_2^{NIS}(x) \quad - dh_2^{NIS}(x)'}{dh_2^{NIS}(x)^* - dh_2^{NIS}(x)'} & if\ \ dh_2^{NIS'} \leq dh_2^{NIS}(x) \leq dh_2^{NIS}(x)^* \\ 0 & if\ \ dh_2^{NIS}(x) \quad \leq \ dh_2^{NIS}(x)' \end{cases}$$

α_g are the possible membership values.
Step 8 : Finally determine the following model
Model 2

$$\max \delta$$

Subject to

$$\vartheta_1(x) \geq \ \delta$$
$$\vartheta_2(x) \geq \ \delta$$
$$0 \leq \delta \leq 1$$

constraints from (4) to (10)
model 2 provides the optimal solution of the problem.

4. NUMERICAL EXAMPLE

Consider the company with two production plants (I , II), three distribution centres (A,B,C), three retailors (1,2,3) and three customers (L,M,N). The company wishes to distribute two different items from production plants to the customers through two different type of vehicles. Aim of the company is to minimise the ratio of cost and profit, deterioration rate and emission.

Table: 2 Transportation cost, Fixed cost and Profit from Production Plants to Distribution Centres

From-To		Conveyance – 1		Conveyance – 2	
		Item – 1	Item – 2	Item – 1	Item – 2
I - A	Transportation cost	(6,8,9,10 ; 0.3,0.2,0.1)	(5,8,9,10 ; 0.3,0.2)	(3,4,5,6; 0.3,0.2,0.25)	(3,5,6,7; 0.3,0.2,0.1)
	Fixed cost	(16,18,20,21 ; 0.1,0.2)	(15,18,20,22 ; 0.1,0.12)	(12,14,16,17 ; 0.1,0.2)	(11,14,16,18; 0.1,0.14)
	Profit per unit	(5,7,8,9 ; 0.1,0.2,0.3)	(4,7,9,10 ; 0.12,0.14)	(3,4,5,7 ; 0.19,0.2,0.21)	(1,4,6,8 ; 0.08,0.12)
I – B	Transportation cost	(4,6,7,8 ; 0.1,0.2)	(5,6,7,9 ; 0.2,0.25)	(4,6,7,9 ; 0.1,0.2,0.3)	(5,6,7,9; 0.3,0.2,0.1)
	Fixed cost	(18,19,20,21 ; 0.2,0.3)	(17,18,20,21 ; 0.1,0.22)	(14,15,16,17 ; 0.22, 0.24)	(13,14,16,18 ; 0.14,0.16)
	Profit per unit	(3,5,7,8 ; 0.1,0.3)	(4,6,7,10 ; 0.11,0.15)	(6,8,9,10 ; 0.1,0.2,0.3)	(5,7,8,10 ; 0.12, 0.2)
I – C	Transportation cost	(4,5,6,7 ; 0.2,0.3)	(3,5,7,9 ; 0.1,0.11)	(2,3,4,5 ; 0.2,0.3)	(1,3,4,6 ; 0.2,0.1)
	Fixed cost	(20,21,22,23 ; 0.2,0.3)	(19,21,22,24 ; 0.1, 0.24)	(16,17,18,19 ; 0.2,0.3)	(16,17,18,20 ; 0.1,0.2,0.3)
	Profit per unit	(4,5,6,7 ; 0.1,0.3,0.5)	(4,5,6,9 ; 0.15,0.18,0.27)	(2,3,4,7 ; 0.1,0.2)	(2,3,4,6 ; 0.1,0.2,0.3)
II – A	Transportation	(5,6,8,9 ;	(4,6,8,10 ;	(3,4,6,7 ;	(2,4,6,8 ;

	cost	0.12,0.14)	0.1,0.14)	0.1,0.2)	0.1,0.2)
	Fixed cost	(15,17,19,20 ; 0.15,0.16)	(14,17,18,21 ; 0.2,0.24)	(11,13,15,16 ; 0.1,0.15,0.18)	(10,13,15,17 ; 0.1, 0.4)
	Profit per unit	(6,8,9,10; 0.2,0.22)	(5,6,8,10 ; 0.1,0.2)	(4,5,6,7 ; 0.1,0.4)	(3,4,5,7 ; 0.1,0.2,0.3)
II – B	Transportation cost	(5,6,7,8 ; 0.2,0.3)	(4,6,7,8 ; 0.3,0.2,0.1)	(3,4,5,6 ; 0.4,0.3,0.2)	(2,4,5,7 ; 0.1,0.26)
	Fixed cost	(16,18,19,20 ; 0.1,0.2,0.3)	(15,18,20,21 ; 0.12,0.14)	(12,14,15,16; 0.1,0.2,0.3)	(11,13,15,19 ; 0.12,0.14)
	Profit per unit	(6,8,10,12 ; 0.1,0.2)	(6,8,11,13 ; 0.1,0.12)	(4,5,8,10 ; 0.1,0.12)	(5,7,8,10; 1)
II – C	Transportation cost	(5,7,9,10 ; 0.1,0.18)	(4,7,9,11 ; 0.1,0.12)	(3,5,7,8 ; 0.3,0.2,0.1)	(2,5,7,4 ; 0.1,0.2)
	Fixed cost	(18,20,22,23 ; 0.1,0.2,0.3)	(16,21,22,24; 0.11,0.13,0.15)	(14,16,18,19; 0.1,0.2)	(12,16,19,20 ; 0.02,0.18)
	Profit per unit	(5,7,9,11; 0.13,0.11)	(4,6,8,10 ; 0.1,0.2)	(3,5,7,9 ; 0.13,0.15)	(8,9,10,11 ; 0.2,0.3)

Table: 3 Transportation cost, Fixed cost and Profit from Distribution Centres to Retailers

From-To	Cost	Conveyance – 1		Conveyance – 2	
		Item – 1	Item – 2	Item – 1	Item – 2
A-1	Transportation cost	(5,6,7,8 ; 0.2,0.3,0.5)	(4,6,7,9 ; 0.14,0.2)	(3,5,6,7 ; 0.1,0.2,0.3)	(2,5,6,8 ; 0.12,0.2)
	Fixed cost	(20,22,24,25 ; 0.1,0.2)	(19,22,23,25 ; 0.16,0.12)	(16,18,20,21 ; 0.15,0.17)	(15,18,20,22; 0.1,0.12)
	Profit per unit	(8,9,10,11 ; 0.2,0.3)	(6,7,8,10 ; 0.1,0.2,0.3)	(4,5,6,7 ; 0.1,0.3,0.5)	(6,7,8,10 ; 0.1,0.2,0.3)
A-2	Transportation cost	(5,7,8,9 ; 0.2,0.24)	(4,7,8,10 ; 0.12,0.2)	(5,7,8,9 ; 0.2,0.22)	(4,7,8,10 ; 0.15,0.19)
	Fixed cost	(22,23,24,25 ; 0.2,0.3)	(21,22,24,25 ; 0.11,0.13)	(18,19,20,21 ; 0.2,0.3)	(17,20,21,23 ; 0.1,0.2)
	Profit per unit	(5,8,10,11 ; 0.1,0.2)	(6,7,8,10 ; 0.2,0.22)	(5,7,8,9 ; 0.2,0.24)	(4,9,10,11 ; 0.12,0.14)
A-3	Transportation cost	(7,9,10,11 ; 0.1,0.2,0.3)	(6,9,10,12 ; 0.25,0.11)	(3,4,5,6 ; 0.2,0.3,0.4)	(2,4,5,7 ; 0.1,0.14,0.11)
	Fixed cost	(24,25,26,27 ; 0.2,0.3)	(23,25,26,27 ; 0.1,0.2,0.3)	(20,21,22,23 ; 0.1,0.18,0.22)	(19,20,22,24 ; 0.1,0.18)
	Profit per unit	(9,10,11,12; 0.25,0.27)	(10,12,13,15 ; 0.1,0.22)	(8,9,10,11 ; 0.23, 0.29)	(7,8,9,10; 0.17,0.19)
B-1	Transportation cost	(6,8,10,11; 0.1,0.18)	(6,8,11,12 ; 0.07,0.13)	(4,5,7,8 ; 0.1,0.2,0.3)	(3,5,6,9 ; 0.1,0.3,0.5)
	Fixed cost	(19,21,23,24 ; 0.1,0.2)	(18,21,23,25 ; 0.1,0.12)	(15,17,19,20 ; 0.1,0.2)	(14,17,19,21 ; 0.1,0.4)
	Profit per unit	(7,8,9,10; 0.22,0.29,0.3)	(11,12,13,14 ; 0.2,0.3)	(9,10,1,12 ; 0.2,0.3)	(10,11,12,13 ; 0.23, 0.29)
B-2	Transportation	(6,7,8,9 ;	(5,7,9,10 ;	(4,5.6,7 ;	(3,4,7,8 ;

	cost	0.1,0.2,0.3)	0.1,0.2)	0.2,0.3,0.4)	0.13,0.15)
	Fixed cost	(20,22,23,24 ; 0.1,0.2,0.3)	(19,22,23,26 ; 0.1,0.14)	(16,18,19,20 ; 0.1,0.2,0.3)	(15,17,19,22 ; 0.1,0.12)
	Profit per unit	(8,9,11,12 ; 0.1,0.2)	(9,10,12,13 ; 0.11,0.18,0.19)	(14,15,16,17 ; 0.2,0.3)	(15,16,17,18 ; 0.2,0.3)
B-3	Transportation cost	(6,7,9,10 ; 0.2,0.14)	(5,7,9,11 ; 0.12,0.14)	(4,6,8,9 ; 0.14,0.18)	(3,5,7,11 ; 0.1,0.12)
	Fixed cost	(22,24,26,27 ; 0.1,0.2)	(20,24,26,28 ; 0.08,0.12)	(18,20,22,23 ; 0.1,0.2)	(18,19,22,24 ; 0.1,0.12)
	Profit per unit	(9,10,11,12 ; 0.23,0.29)	(12,14,15,17 ; 0.14,0.2)	(13,15,16,17 ; 0.1,0.2,0.3)	(15,16,17,18 ; 0.2,0.3)
C-1	Transportation cost	(8,9,10,12 ; 0.1,0.2,0.3)	(7,9,10,14 ; 0.1,0.14)	(5,7,8,9 ; 0.1,0.3)	(4,5,6,7 ; 0.2,0.3,0.4)
	Fixed cost	(21,23,25,26 ; 0.1,0.2)	(20,23,25,27 ; 0.1,0.12)	(17,19,21,22 ; 0.1,0.2)	(16,19,20,24 ; 0.1,0.12)
	Profit per unit	(10,11,12,14; 0.1,0.2,0.3)	(13,14,15,18 ; 0.1,0.18,0.2)	(12,14,16,18; 0.11,0.13)	(13,14,15,16 ; 0.2,0.3)
C-2	Transportation cost	(7,9,10,11 ; 0.1,0.2,0.3)	(6,9,11,12 ; 0.1,0.2)	(6,7,8,10 ; 0.1,0.2,0.3)	(5,7,9,11 ; 0.1,0.14)
	Fixed cost	(22,24,26,27 ; 0.1,0.2)	(21,23,25,28 ; 0.1,0.12)	(18,20,22,23 ; 0.1,0.2)	(17,20,22,24 ; 0.1,0.12)
	Profit per unit	(11,12,13,14 ; 0.2,0.3)	(14,15,16,17; 0.2,0.3)	(13,14,15,16; 0.2,0.26,0.29)	(7,18,19,20 ; 0.23,0.29)
C-3	Transportation cost	(4,5,6,7 ; 0.2,0.3,0.4)	(3,5,6,9 ; 0.12,0.16)	(2,3,4,5 ; 0.2,0.3)	(1,2,6,7 ; 0.11,0.15)
	Fixed cost	(19,21,23,25 ; 0.1,0.14)	(18,21,23,26 ; 0.08,0.14)	(15,17,19,21 ; 0.12,0.14)	(14,17,20,22 ; 0.08,0.12)
	Profit per unit	(14,15,16,17; 0.2,0.25,0.3)	(13,14,15,16 ; 0.19,0.26,0.3)	(12,14,16,18 ; 0.12,0.14)	(13,14,15,16 ; 0.2,0.3)

Table: 4 Transportation cost , Fixed cost and Profit from Retailers to Customers

From-To	Cost	Conveyance – 1		Conveyance – 2	
		Item – 1	Item – 2	Item – 1	Item – 2
1-L	Transportation cost	(4,7,8,9 ; 0.1,0.2,0.3)	(3,7,8,10 ; 0.1,0.2)	(4,6,7,8 ; 0.1,0.2,0.3)	(3,6,7,9 ; 0.15,0.17)
	Fixed cost	(21,23,25,26; 0.12,0.18)	(20,22,25,27 ; 0.1,0.12)	(19,21,23,24 ; 0.13,0.15)	(18,21,23,26 ; 0.08,0.12)
	Profit per unit	(6,7,8,10 ; 0.1,0.2,0.3)	(9,10,11,12 ; 0.2,0.3)	(13,14,15,17; 0.1,0.2,0.3)	(14,15,16,17 ; 0.2,0.3)
1-M	Transportation cost	(5,6,7,8 ; 0.1,0.4)	(4,5,7,9 ; 0.1,0.2)	(4,5,6,7 ; 0.1,0.3,0.5)	(3,5,7,8 ; 0.1,0.2)
	Fixed cost	(23,24,25,26 ; 0.2,0.3)	(22,23,25,27 ; 0.12,0.16)	(21,22,23,24 ; 0.2,0.25,0.3)	(20,21,23,25 ; 0.13, 0.15)
	Profit per unit	(9,10,11,12 ; 0.2,0.25,0.3)	(10,11,13,15; 0.1,0.2)	(12,14,16,18 ; 0.1,0.14)	(15,17,18,19 ; 0.1,0.3)
1-N	Transportation	(6,8,10,11 ;	(5,7,8,10 ;	(5,7,9,10 ;	(4,6,10,12 ;

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	cost	0.2,0.12)	0.1,0.2)	0.1,0.22)	0.08,0.12)
	Fixed cost	(25,26,27,28 ; 0.2,0.3)	(24,26,27,29 ; 0.1,0.24)	(25,27,28,29 ; 0.1,0.2,0.3)	(22,24,25,27 ; 0.08,0.12)
	Profit per unit	(13,14,15,16 ; 0.2,0.3)	(13,14,15,16 ; 0.2,0.3)	(15,16,17,18 ; 0.2,0.3)	(18,19,20,21 ; 0.1,0.4)
2-L	Transportation cost	(6,7,9,11 ; 0.1,0.2)	(5,7,9,13 ; 0.1)	(5,6,8,9 ; 0.1,0.3)	(4,6,8,10 ; 0.13,0.15)
	Fixed cost	(20,22,24,25 ; 0.1,0.2)	(19,22,24,26 ; 0.1,0.12)	(18,20,22,23 ; 0.2,0.25,0.3)	(17,20,22,24 ; 0.1,0.12)
	Profit per unit	(12,13,14,15; 0.27,0.28)	(14,15,16,18 ; 0.1,0.2,0.3)	(14,17,18,20 ; 0.1,0.2)	(21,22,23,24 ; 0.2,0.3)
2-M	Transportation cost	(5,7,9,11 ; 0.11,0.13)	(4,7,10,12 ; 0.1)	(4,6,8,10 ; 0.1)	(3,5,9,12 ; 0.1)
	Fixed cost	(21,23,24,25 ; 0.1,0.2,0.3)	(20,22,25,27 ; 0.03,0.17)	(19,21,22,23; 0.1,.2,0.3)	(18,21,22,25 ; 0.11,0.13)
	Profit per unit	(16,17,18,19 ; 0.2,0.3)	(14,16,17,18 ; 0.2,0.3)	(13,14,16,19; 0.2,0.3)	(17,18,20,22; 0.8,1)
2-N	Transportation cost	(6,7,8,9 ; 0.2,0.3)	(5,7,8,10 ; 0.1,0.2,0.3)	(5,6,7,8 ; 0.1,0.3,0.5)	(4,6,7,9 ; 0.1,0.2,0.3)
	Fixed cost	(23,25,27,28; 0.1,0.2)	(21,25,27,29; 0.12,0.18)	(21,23,25,26 ; 0.1,0.2)	(19,21,22,25 ; 0.14,0.6)
	Profit per unit	(17,18,19,20; 0.2,0.3)	(15,17,18,19; 0.4,0.5)	(17,18,19,20 ; 0.1,0.14)	(19,20,21,22; 0.2,0.3)
3-L	Transportation cost	(7,9,10,12 ; 0.16,0.18)	(6,9,10,14 ; 0.1,0.12)	(6,8,9,10 ; 0.1,0.2,0.3)	(5,8,9,11 ; 0.17)
	Fixed cost	(22,24,26,27 ; 0.1,0.2)	(21, 24,26,28; 0.1,0.12)	(20,22,24,25 ; 0.1,0.2)	(19,22,24,26 ; 0.1,0.12,0.14)
	Profit per unit	(12,13,14,15; 0.4,0.5)	(17,18,19,20; 0.7,0.8)	(13,14,15,16; 0.9,1)	(19,20,21,22 ; 0.8,0.9)
3-M	Transportation cost	(8,9,10,11 ; 0.2,0.3)	(7,10,11,13 ; 0.2,0.3)	(7,8,9,10 ; 0.2,0.3)	(6,8,9,11 ; 0.07)
	Fixed cost	(23,25,27,28 ; 0.1,0.2)	(22,25,27,29 ; 0.1,0.12)	(21,23,25,26 ; 0.1,0.2)	(21,23,28,29 ; 0.1,0.2)
	Profit per unit	(15,16,18,20; 0.4,0.5)	(18,19,20,21; 0.2,0.3)	(19,20,21,22; 0.4,0.6,0.7)	(20,22,24,26; 0.1,0.11)
3-N	Transportation cost	(7,9,11,12 ; 0.1,0.2)	(6,8,9,12 ; 0.1,0.2)	(6,8,10,11 ; 0.1,0.2)	(5,8,10,12 ; 0.12)
	Fixed cost	(20,22,24,26; 0.12,0.14)	(19,20,21,26 ; 0.11,0.13)	(19,21,23,24 ; 0.1,0.2)	(18,21,22,25 ; 0.12,0.14)
	Profit per unit	(17,18,20,21; 0.15,0.17)	(20,21,22,23 ; 0.2,0.3)	(17,18,19,20 ; 0.7,0.9)	(21,22,23,25; 0.6,0.7)

Table: 5 Transportation Time and Wastage Cost from Production Plants to Distribution Centres

From-To		Conveyance – 1		Conveyance – 2	
		Item – 1	Item – 2	Item – 1	Item – 2
I - A	Time	(25,27,28,29; 0.1,0.2,0.3)	(24,27,29,30; 0.12,0.14)	(31,32,33,34; 0.2,0.3)	(31,32,33,36; 0.16,0.8)
	Wastage cost	(1,2,3,4; 0.4,0.5)	(2,3,4,5; 0.3,0.6)	(1,2,2.5,3; 0.4,0.5,0.6)	(1,2,5,6; 0.1,0.2)
I – B	Time	(23,24,25,26; 0.1,0.2,0.3)	(22,24,25,27; 0.15,0.17)	(34,36,37,38; 0.2,0.3)	(33,35,37,39; 0.1,0.14)
	Wastage cost	(2,3,4,5; 0.2,0.3)	(3,5,6,7; 0.1,0.2,0.3)	(4,5,5.5,6; 0.3,0.4,0.5)	(5,6,7,8; 0.2,0.3)
I – C	Time	(21,22,25,26; 0.12,0.14)	(20,22,23,24; 0.1,0.2,0.3)	(33,34,36,38; 0.12,0.16)	(31,33,35,38; 0.1,0.12)
	Wastage cost	(1,1.5,2,2.5; 0.49,0.5,0.51)	(2,2.5,3,3.5; 0.45,0.5,0.55)	(4,5,6,7; 0.2,0.5)	(5,7,9,10; 0.1,0.2)
II – A	Time	(21,22,23,25; 0.1,0.2,0.3)	(20,22,24,25; 0.1,0.2)	(15,16,17,18; 0.2,0.3)	(14,16,18,20; 0.12,0.14)
	Wastage cost	(2,3,4,4.5; 0.25,0.3,0.35)	(2,3,4,5; 0.2,0.25,0.3)	(3,3.5,4,4.5; 0.45,0.5,0.55)	(2,2.5,2.6,3; 0.5,0.6,0.7)
II – B	Time	(11,12,13,14; 0.2,0.3)	(10,12,14,16; 0.1,0.14)	(10,12,14,16; 0.12,0.13)	(9,10,1,12; 0.2,0.25)
	Wastage cost	(1,1.5,2,2.5; 0.25,0.5,0.75)	(2,3,4,5; 0.2,0.3)	(2,3,4,5; 0.2,0.3)	(4,5,6,7; 0.2,0.25,0.3)
II – C	Time	(22,23,24,25; 0.3,0.5,0.6)	(21,23,24,26; 0.14,0.2)	(20,21,22,23; 0.2,0.3)	(30,32,34,36; 0.12,0.14)
	Wastage cost	(2,3,4,5; 0.2,0.3)	(4,5,7,9; 0.1,0.2)	(4,5,7,9; 0.1,0.2)	(7,8,10,11; 0.14,0.2)

Table: 6 Transportation Time and Wastage Cost from Distribution Centres to Retailers

From-To		Conveyance – 1		Conveyance – 2	
		Item – 1	Item – 2	Item – 1	Item – 2
A-1	Time	(1,3,5,6; 0.1,0.2)	(1,2,4,7; 0.02,0.8)	(2,4,5,7; 0.1,0.2,0.3)	(4,5,6,7; 0.2,0.3)
	Wastage cost	(2,4,6,8; 0.1,0.14)	(3,4,5,6; 0.2,0.3)	(6,7,9,10; 0.16,0.2)	(5,7,10,12; 0.1,0.12)
A-2	Time	(4,5,6,7; 0.2,0.5)	(3,5,6,8; 0.12,0.2)	(10,11,12,13; 0.2,0.3)	(9,12,13,14; 0.17,0.19)
	Wastage cost	(3,5,6,7; 0.2,0.24)	(9,10,11,12; 0.2,0.3)	(5,6,7,8; 0.2,0.3)	(13,14,15,16; 0.2,0.3)
A-3	Time	(6,7,8,9; 0.2,0.3)	(5,7,8,10; 0.15,0.19)	(6,7,8,9; 0.1,0.2,0.3)	(5,7,8,10; 0.14,0.2)
	Wastage cost	(4,5,7,9; 0.1,0.15,0.2)	(6,7,9,10; 0.16,0.18)	(11,12,13,14; 0.1,0.2,0.3)	(10,11,12,13; 0.2,0.33)
B-1	Time	(8,9,10,11; 0.2,0.3)	(7,9,10,12; 0.14,0.18)	(4,6,7,8; 0.2,0.22)	(3,7,9,11; 0.1,0.14)
	Wastage cost	(6,7,8,9;	(7,8,9,10;	(4,5,6,7;	(12,13,14,15;

		0.2,0.3)	0.2,0.4)	0.4,0.5)	0.4,0.5)
B-2	Time	(2,3,4,5; 0.2,0.3)	(4,5,6,7; 0.2,0.25,0.3)	(4,8,10,12; 0.1,0.12)	(7,9,10,11; 0.2,0.21,0.22)
	Wastage cost	(7,9,10,11; 0.2,0.22)	(10,11,13,14; 0.16,0.18)	(13,16,17,18; 0.15,0.17)	(11,13,14,16; 0.15,0.19)
B-3	Time	(5,6,7,8; 0.2,0.25,0.3)	(7,8,10,12; 0.1,0.2)	(13,15,17,19; 0.1,0.14)	(11,13,15,16; 0.1,0.15,0.2)
	Wastage cost	(7,8,9,11; 0.17,0.19)	(13,14,15,16; 0.6,0.8)	(13,15,16,17; 0.1,0.2,0.3)	(15,17,19,20; 0.1,0.15,0.2)
C-1	Time	(10,11,12,13; ,0.2,0.3)	(9,10,13,15; 0.06,0.14)	(16,17,18,19; 0.2,0.3)	(12,13,14,15; 0.2,0.3)
	Wastage cost	(7,8,12,14; 0.09,0.11)	(11,12,13,14; 0.15,0.2 0.250)	(12,13,14,15; 0.2,0.3)	(17,18,19,20; 0.2,0.3)
C-2	Time	(10,13,14,15; 0.17,0.19)	(9,12,14,16; 0.11,0.13)	(18,19,20,21; 0.2,0.3)	(14,15,16,18; 0.08,0.14)
	Wastage cost	(5,7,9,11; 0.12,0.14)	(11,12,14,15; 0.1,0.22)	(15,16,17,18; 0.4,0.6,0.8)	(14,17,18,19; 0.16,0.18)
C-3	Time	(12,13,14,15; 0.2,0.3)	(17,18,19,20; 0.2,0.3)	(20,21,22,23; 0.2,0.3)	(24,25,26,27; 0.2,0.3,0.4S)
	Wastage cost	(14,16,17,19; 0.15,0.17)	(13,14,17,19; 0.13,0.07)	(17,18,19,20; 0.2,0.3)	(20,22,23,24; 0.15,0.2,0.25)

Table: 7 Transportation Time and Wastage Cost from Retailers to Customers

From-To		Conveyance – 1		Conveyance – 2	
		Item – 1	Item – 2	Item – 1	Item – 2
1-L	Time	(1,2,3,5; 0.1,0.3)	(2,5,6,7; 0.1,0.2,0.3)	(2,3,4,6; 0.16,0.2,0.24)	(1,3,5,6; 0.14,0.2,0.26)
	Wastage cost	(1,1.5,2,3; 0.3,0.4,0.5)	(2,3,3.5,4; 0.2,0.4,0.6)	(3,4,5,6; 0.2,0.3)	(2,3,3.5,4; 0.2,0.4,0.6)
1-M	Time	(1,2,3,6; 0.12,0.16)	(1,2,3,7; 0.1,0.12)	(3,5,7,8; 0.1,0.2)	(2,3,5,6; 0.1,0.2,0.3)
	Wastage cost	(1,2,3,5; 0.1,0.2,0.3)	(1,1.5,2,2.5; 0.1,0.5,0.9)	(2,3,3.5,4; 0.2,0.4,0.6)	(2,3,4,5; 0.2,0.3)
1-N	Time	(4,5,6,7; 0.1,0.3,0.5)	(4,6,7,9; 0.1,0.2,0.3)	(4,5,6,7; 0.2,0.3)	(3,5,6,8; 0.16,0.2)
	Wastage cost	(0.5,1,2,3; 0.2,0.3,0.4)	(2,3,3.5,4; 0.1,0.4,0.7)	(2,2.5,3,3.5; 0.45,0.5,0.55)	(2,3,4,5; 0.5,0.7)
2-L	Time	(4,5,6,8; 0.14,0.2,0.26)	(3,5,8,9; 0.09,0.11)	(5,6,7,8; 0.2,0.3)	(9,10,11,12; 0.4,0.5)
	Wastage cost	(2,2.5,3,3.5; 0.49,0.5,0.51)	(2,2.8,3,3.5; 0.5,0.6,0.7)	(3,3.5,4,5; 0.2,0.3)	(1,2,3,4; 0.2,0.3)
2-M	Time	(6,7,9,11; 0.1,0.2)	(3,5,6,8; 0.11,0.21)	(4,5,6,7; 0.2,0.3)	(3,5,6,8; 0.1,0.22)
	Wastage cost	(1,2,3,4; 0.2,0.3)	(1,2,3,4; 0.2,0.3)	(2,3,4,5; 0.5,0.6)	(2,3,4,5; 0.9,1)
2-N	Time	(1,2,4,5;	(1,2,3,5;	(5,7,9,10;	(7,8,9,10;

		0.1,0.2,0.3)	0.17,0.19)	0.1,0.2)	0.22,0.25,0.28)
	Wastage cost	(1,2,3,4; 0.2,0.25,0.3)	(0.5,1,2,3; 0.2,0.3)	(2,2.5,3,3.5; 0.45,0.5,0.55)	(3,3.5,4,4.5; 0.4,0.5,0.6)
3-L	Time	(2,4,6,8; 0.13,0.15)	(11,12,13,14; 0.2,0.3)	(16,17,18,19; 0.24,0.26,0.25)	(7,8,9,11; 0.18,0.2,0.22)
	Wastage cost	(2,2.5,3,3.5; 0.1,0.3,0.5)	(2,2.5,3,3.5; 0.4,0.5,0.6)	(1,2,3,4; 0.7,0.8,)	(2,2.5,3,3.5; 0.4,0.5)
3-M	Time	(5,6,7,8; 0.2,0.25,0.3)	(7,9,10,11; 0.2,0.22)	(10,12,13,14; 0.2,0.22)	(11,12,13,14; 0.2,0.3)
	Wastage cost	(3,3.5,4,4.5; 0.3,0.5)	(3,4,5,6; 0.7,0.8)	(4,5,6,7; 0.1,0.3)	(3,4,5,6; 0.3,0.5)
3-N	Time	(7,8,9,10; 0.2,0.4)	(7,9,11,12; 0.1,0.2)	(13,14,15,16; 0.2,0.3)	(17,18,19,20; 0.2,0.3)
	Wastage cost	(2,3,3.5,4; 0.3,0.4,0.5)	(1,2,3,4; 0.2,0.3)	(2,3,3.5,4; 0.3,0.4,0.5)	(1,2,3,4; 0.2,0.3)

Table: 8 Emission from Production Plants to Distribution Centres

From-to	Conveyance – 1		Conveyance – 2	
	Item – 1	Item – 2	Item – 1	Item – 2
I – A	(541,542,543,544; 0.2,0.3)	(540,542,544,546; 0.2,0.25,0.3)	(122,123,124,125; 0.24,0.25,0.26)	(123,124,125,126; 0.24,0.25,0.26)
I – B	(491,492,493,494; 0.2,0.25,0.3)	(494,495,496,497; 0.2,0.3)	(123,124,125,126; 0.2,0.3)	(125,126,127,128; 0.2,0.25,0.3)
I – C	(461,462,463,464; 0.2,0.3)	(464,465,466,467; 0.2,0.3)	(110,111,112,113; 0.24,0.25,0.26)	(111,112,113,114; 0.2,0.3)
II – A	(421,422,423,424; 0.2,0.25,0.3)	(422,423,424,425; 0.24,0.25,0.26)	(65,66,67,68; 0.2,0.3)	(67,68,69,70; 0.2,0.3)
II – B	(201,202,203,204; 0.24,0.25,0.26)	(202,203,204,205; 0.2,0.25,0.3)	(31,32,33,34; 0.2,0.3)	(32,33,34,35; 0.2,0.25,0.3)
II – C	(431,432,433,434; 0.2,0.3)	(432,433,434,435; 0.2,0.3)	(71,72,73,74; 0.2,0.3)	(74,75,76,77; 0.24,0.25,0.26)

Table: 9 Emission from Distribution Centres to Retailers

From-to	Conveyance – 1		Conveyance – 2	
	Item – 1	Item – 2	Item – 1	Item – 2
A-1	(65,66,67,68; 0.2,0.25,0.3)	(67,68,69,70; 0.2,0.3)	(5,6,7,8; 0.2,0.25,0.3)	(6,7,8,9; 0.22,0.25,0.28)
A-2	(134,135,136,137; 0.2,0.3)	(135,136,137,138; 0.2,0.25,0.3)	(26,27,28,29; 0.24,0.25,0.26)	(27,28,29,30; 0.24,0.25,0.26)
A-3	(157,158,159,160; 0.2,0.3)	(159,160,161,162; 0.22,0.25,0.28)	(32,33,34,35; 0.2,0.25,0.3)	(33,34,35,36; 0.2,0.25,0.3)
B-1	(155,156,157,158; 0.22,0.25,0.28)	(157,158,159,160; 0.24,0.25,0.26)	(17,18,19,20; 0.24,0.25,0.26)	(18,19,20,21; 0.24,0.25,0.26)
B-2	(86,87,88,89; 0.24,0.25,0.26)	(87,88,89,90; 0.2,0.25,0.3)	(16,17,18,19; 0.24,0.25,0.26)	(17,18,19,20; 0.2,0.3)
B-3	(175,176,177,178; 0.22,0.25,0.28)	(177,178,179,180; 0.24,0.25,0.26)	(23,24,25,26; 0.2,0.25,0.3)	(24,25,26,27; 0.24,0.25,0.26)

C-1	(221,222,223,224; 0.2,0.25,0.3)	(222,223,224,225; 0.24,0.25,0.26)	(19,20,21,22; 0.2,0.3)	(29,30,31,32; 0.24,0.25,0.26)
C-2	(251,252,253,254; 0.24,0.25,0.26)	(253,254,255,256; 0.2,0.25,0.3)	(19,20,21,22; 0.22,0.25,0.28)	(21,22,23,24; 0.2,0.3)
C-3	(132,133,134,135; 0.2,0.25,0.3)	(133,134,135,136; 0.22,0.25,0.28)	(14,15,16,17; 0.22,0.25,0.28)	(15,16,17,18; 0.2,0.25,0.3)

Table:10 Emission from Retailers to Customers

From-to	Conveyance – 1		Conveyance – 2	
	Item – 1	Item – 2	Item – 1	Item – 2
A-1	(6,62,63,64; 0.2,0.25,0.3)	(662,63,64,65; 0.2,0.3)	(57,58,59,60; 0.2,0.25,0.3)	(58,59,60,61; 0.22,0.25,0.28)
A-2	(61,62,63,64; 0.2,0.3)	(63,64,65,66; 0.2,0.25,0.3)	(26,27,28,29; 0.24,0.25,0.26)	(27,28,29,30; 0.24,0.25,0.26)
A-3	(131,132,133,135; 0.2,0.3)	(132,133,134,135; 0.22,0.25,0.28)	(126,127,128,129; 0.2,0.25,0.3)	(127,128,129,130; 0.2,0.25,0.3)
B-1	(241,242,243,244; 0.22,0.25,0.28)	(242,243,244,245; 0.24,0.25,0.26)	(235,236,237,238; 0.24,0.25,0.26)	(236,237,238,239; 0.24,0.25,0.26)
B-2	(135,136,137,138; 0.24,0.25,0.26)	(137,138,139,140; 0.2,0.25,0.3)	(131,132,133,134; 0.24,0.25,0.26)	(132,133,134,135; 0.2,0.3)
B-3	(135,136,137,138; 0.22,0.25,0.28)	(136,137,138,139; 0.24,0.25,0.26)	(131,132,133,134; 0.2,0.25,0.3)	(132,133,134,135; 0.24,0.25,0.26)
C-1	(121,122,123,124; 0.2,0.25,0.3)	(122,123,124,125; 0.24,0.25,0.26)	(126,127,128,129; 0.2,0.3)	(127,128,129,130; 0.24,0.25,0.26)
C-2	(135,136,137,138; 0.24,0.25,0.26)	(136,137,138,139; 0.2,0.25,0.3)	(131,132,133,134; 0.22,0.25,0.28)	(132,133,134,135; 0.2,0.3)
C-3	(204,205,206,207; 0.2,0.25,0.3)	(205,206,207,208; 0.22,0.25,0.28)	(190,191,192,193; 0.22,0.25,0.28)	(189,190,191,192; 0.2,0.25,0.3)

Table : 11 Availability

	Item -1	Item – 2
Plant 1	(47,48,49,50; 0.2,0.25,0.3)	(44,45,46,47; 0.2,0.3)
Plant 2	(43,44,45,46; 0.24,0.25,0.26)	(42,44,46,48 ; 0.2,0.25,0.3)

Table : 12 Demand

	Item - 1	Item – 2
Customer centre – 1	(25,26,27,28; 0.2,0.3)	(26,27,28,29; 0.24,0.25,0.26)
Customer centre – 2	(27,28,29,30; 0.24,0.25,0.26)	(21,22,23,24; 0.2,0.25,0.3)
Customer centre – 3	(19,20,21,22; 0.2,0.25,0.3)	(27,28,29,30; 0.2,0.3)

Table: 13 Vehicle Capacity

Vehicle – 1	(79,80,81,82; 0.2,0.25,0.3)
Vehicle – 2	(83,84,85,86; 0.2,0.3)

Table:14 Score values Transportation cost, Fixed cost and Profit from Production Plants to Distribution Centres

From-To		Conveyance – 1		Conveyance – 2	
		Item – 1	Item – 2	Item – 1	Item – 2
I - A	Transportation cost	8.1	9.375	4.5	5.1
	Fixed cost	19.58	18.43	15.38	16.13
	Profit per unit	7.1	7.54	4.9	4.15
I – B	Transportation cost	4.58	7.76	7.8	6.9
	Fixed cost	19.5	18.24	14.26	16.13
	Profit per unit	7.9	6.31	8.1	7.2
I – C	Transportation cost	5.05	5.04	3.5	3.15
	Fixed cost	21.5	21.93	17.5	17.9
	Profit per unit	6.6	7.6	3.9	3.9
II – A	Transportation cost	6.11	6.72	4.5	6
	Fixed cost	18.53	16.8	13.37	14.7
	Profit per unit	8.51	7.73	6.6	4.9
II – B	Transportation cost	6.5	6.1	5.4	4.86
	Fixed cost	18.1	18.98	14.1	16.28
	Profit per unit	10.8	10.45	6.77	9
II – C	Transportation cost	7.49	7.53	7.9	7.579
	Fixed cost	21.68	23.6	17.48	18.05
	Profit per unit	7.68	8.4	6.72	9.5

Table: 15 Score Values of Transportation cost, Fixed cost and Profit from Distribution Centres to Retailers

From-To	Cost	Conveyance – 1		Conveyance – 2	
		Item – 1	Item – 2	Item – 1	Item – 2
A-1	Transportation cost	8	7.95	6.1	6.8
	Fixed cost	23.78	21.63	20.88	18.43
	Profit per unit	9.5	7.9	6.6	7.9
A-2	Transportation cost	6.5	6.675	6.6	5.93
	Fixed cost	23.5	22.56	19.5	21.08
	Profit per unit	9.9	8.2	7.81	9.56
A-3	Transportation cost	9.68	9.75	8.56	9.6
	Fixed cost	25.5	25.1	21.5	20.93
	Profit per unit	10.92	12	9.88	8.82
B-1	Transportation cost	8.775	8.8	8.4	7.84

	Fixed cost	22.73	21.4	18.53	17.28
	Profit per unit	9.06	12.5	10.5	11.93
B-2	Transportation cost	7.68	8.95	7.28	9.55
	Fixed cost	21.1	21.6	18.1	18.21
	Profit per unit	9	10.56	15.5	16.5
B-3	Transportation cost	7.5	9	7.8	9.55
	Fixed cost	25.88	24.2	21.68	20.63
	Profit per unit	10.92	14.79	15.1	16.5
C-1	Transportation cost	9.69	9.85	8.1	8.67
	Fixed cost	24.83	25.5	20.63	19.75
	Profit per unit	11.9	14.72	14.4	14.5
C-2	Transportation cost	9.5	10.58	8.5	9.18
	Fixed cost	25.88	24.15	21.68	20.41
	Profit per unit	12.5	15.5	14.5	19.29
C-3	Transportation cost	10.125	9.375	9.075	9.3
	Fixed cost	21.12	22	18.72	19.95
	Profit per unit	15.5	14.5	15.6	14.5

Table: 16 Score Values of Transportation cost , Fixed cost and Profit from Retailers to Customers

From-To	Cost	Conveyance – 1		Conveyance – 2	
		Item – 1	Item – 2	Item – 1	Item – 2
1-L	Transportation cost	8	7.95	6.1	6.8
	Fixed cost	24.83	25.85	21.21	22
	Profit per unit	7.9	10.5	14.9	15.5
1-M	Transportation cost	6.5	6.675	6.6	5.93
	Fixed cost	24.5	23.87	22.5	21.91
	Profit per unit	10.5	12.98	14.4	17.1
1-N	Transportation cost	9.68	9.75	8.56	9.6
	Fixed cost	26.5	27.05	27.1	24.99
	Profit per unit	14.5	14.5	15.5	19.5
2-L	Transportation cost	8.775	8.8	8.4	7.84
	Fixed cost	23.78	22.39	21.68	20.41
	Profit per unit	13.5	15.9	17.93	22.5
2-M	Transportation cost	7.68	8.95	7.28	9.55
	Fixed cost	23.1	23.5	21.1	20.64

	Profit per unit	17.5	16.5	15.12	20.5
2-N	Transportation cost	7.5	9	7.8	9.55
	Fixed cost	26.93	25.2	24.83	23.2
	Profit per unit	18.5	17.5	18.5	20.5
3-L	Transportation cost	9.64	9.85	8.1	8.67
	Fixed cost	25.88	24.37	23.78	24.42
	Profit per unit	13.5	18.5	14.5	20.5
3-M	Transportation cost	9.5	10.58	8.5	9.18
	Fixed cost	26.93	25.36	24.83	24.83
	Profit per unit	17.01	19.5	20.5	22.08
3-N	Transportation cost	10.125	9.375	9.075	9.3
	Fixed cost	23.92	21.36	22.73	22.36
	Profit per unit	18.24	21.5	18.5	22.5

Table: 17 Score value of Transportation Time and Wastage Cost from Production Plants to Distribution Centres

From-To		Conveyance – 1		Conveyance – 2	
		Item – 1	Item – 2	Item – 1	Item – 2
I - A	Time	27.1	28.34	32.5	34
	Wastage cost	2.5	3.5	2.27	4.2
I – B	Time	24.5	23.52	36.5	34.56
	Wastage cost	3.5	5.1	5.05	6.5
I – C	Time	24.44	22.1	34.65	34.05
	Wastage cost	1.75	2.75	5.5	7.28
II – A	Time	22.9	23.78	16.5	17.68
	Wastage cost	3.49	3.5	4.75	2.25
II – B	Time	12.5	12.48	12.48	10.5
	Wastage cost	1.75	3.5	3.5	5.5
II – C	Time	22.5	23.97	21.5	34.32
	Wastage cost	3.5	6.68	6.68	9.18

Table: 18Transportation Time and Wastage Cost from Distribution Centres to Retailers

From-To		Conveyance – 1		Conveyance – 2	
		Item – 1	Item – 2	Item – 1	Item – 2
A-1	Time	3.83	3	4.9	5.5
	Wastage cost	4.8	4.5	8.64	9.35
A-2	Time	5.5	5.28	11.5	12.6
	Wastage cost	5.61	10.5	6.5	14.5
A-3	Time	7.5	7.65	7.9	7.65
	Wastage cost	6.68	8.16	12.5	11.5
B-1	Time	9.5	9.12	7.9	8.64
	Wastage cost	7.5	8.5	5.5	13.5

B-2	Time	3.5	4.5	9.02	9.56
	Wastage cost	9.56	12.24	17.04	13.77
B-3	Time	6.5	9.83	15.36	14.33
	Wastage cost	9.72	14.5	15.1	18.53
C-1	Time	11.5	10.65	17.5	13.5
	Wastage cost	11.35	12.5	13.5	18.5
C-2	Time	13.68	13.62	19.5	13.35
	Wastage cost	8.32	12.48	16.5	17
C-3	Time	13.5	18.5	21.5	25.5
	Wastage cost	15.84	14.25	18.5	22.5

Table: 19 Transportation Time and Wastage Cost from Retailers to Customers

From-To		Conveyance – 1		Conveyance – 2	
		Item – 1	Item – 2	Item – 1	Item – 2
1-L	Time	2.9	5.6	3.9	5.1
	Wastage cost	1.95	3.05	4.5	3.05
1-M	Time	2.8	2.65	5.93	4.8
	Wastage cost	2.9	1.75	3.05	3.5
1-N	Time	6.6	7.8	5.5	5.94
	Wastage cost	1.61	3.05	2.75	3.5
2-L	Time	5.9	5.55	6.5	10.5
	Wastage cost	2.75	2.82	3.72	2.5
2-M	Time	8.78	5.28	5.5	5.28
	Wastage cost	2.5	2.5	3.5	3.5
2-N	Time	3.6	2.61	8.03	8.5
	Wastage cost	2.5	1.47	2.75	3.75
3-L	Time	5.6	12.5	17.5	8.9
	Wastage cost	2.75	2.75	2.5	2.75
3-M	Time	6.5	9.56	12.76	12.5
	Wastage cost	3.75	4.5	5.5	4.5
3-N	Time	8.5	10.130	14.5	18.5
	Wastage cost	3.05	2.5	3.05	2.5

Table: 20 Score Values of Emission from Production Plants to Distribution Centres

From-to	Conveyance – 1		Conveyance – 2	
	Item – 1	Item – 2	Item – 1	Item – 2
I – A	542.5	542.5	123.5	124.5
I – B	492.5	495.5	124.5	126.5
I – C	462.5	465.5	111.5	112.5
II – A	422.5	423.5	66.5	68.5
II – B	202.5	203.5	32.5	33.5
II – C	432.5	433.5	72.5	75.5

Table: 21 Score values of Emission from Distribution Centres to Retailers

From-to	Conveyance – 1		Conveyance – 2	
	Item – 1	Item – 2	Item – 1	Item – 2

A-1	66.5	68.5	6.5	7.5
A-2	135.5	136.5	27.5	28.5
A-3	158.5	160.5	33.5	34.5
B-1	156.5	158.5	18.5	19.5
B-2	87.5	88.5	17.5	18.5
B-3	176.5	178.5	24.5	25.5
C-1	222.5	223.5	29.5	30.5
C-2	252.5	253.5	20.5	22.5
C-3	133.5	134.5	15.5	16.5

Table: 22 Score values of Emission from Retailers to Customers

From-to	Conveyance – 1		Conveyance – 2	
	Item – 1	Item – 2	Item – 1	Item – 2
A-1	62.5	63.5	58.5	59.5
A-2	62.5	64.5	27.5	28.5
A-3	132.5	133.5	127.5	128.5
B-1	242.5	243.5	236.5	237.5
B-2	136.5	138.5	132.5	133.5
B-3	136.5	137.5	132.5	133.5
C-1	122.5	123.5	127.5	128.5
C-2	136.5	137.5	132.5	133.5
C-3	205.5	206.5	191.5	190

Table: 23 Score values of Availability

	Item -1	Item – 2
Plant 1	48.5	45.5
Plant 2	44.5	44.5

Table: 24 Demand

	Item – 1	Item – 2
Customer centre – 1	26.5	27.5
Customer centre – 2	28.5	22.5
Customer centre – 3	20.5	28.5

Table: 25 Score value of vehicle Capacity

Vehicle – 1	80.5
Vehicle – 2	84.5

Solving each objectives and maximum and minimum values of the objectives are as :

Table: 26

	Q_1	Q_2	Q_3
Q_1	0.8708	72.3229	1052025
Q_2	1.0858	51.6577	1050269
Q_3	1.1228	92.4657	1029403

And $Q_1^+ = 0.8708$; $Q_2^+ = 51.6577$; $Q_3^+ = 1029403$
$Q_1^- = 1.1228$; $Q_2^- = 92.4657$; $Q_3^- = 1052025$

$$dh_2^{PIS}(x) = \left[\left[0.3\frac{Q_1(x)-0.8708}{1.1228-0.8708}\right]^2 + \left[0.3\frac{Q_2(x)-51.6577}{92.4657-51.6577}\right]^2 + \left[0.4\frac{Q_3(x)-1029403}{1052025-1029403}\right]^2\right]^{1/2}$$

$$dh_2^{NIS}(x) = \left[\left[0.3\frac{1.1228-Q_1(x)}{1.1228-0.8708}\right]^2 + \left[0.3\frac{92.4657-Q_2(x)}{92.4657-51.6577}\right]^2 + \left[0.4\frac{1052025-Q_3(x)}{1052025-1029403}\right]^2\right]^{1/2}$$

Solve the above functions with respect to the constraints, obtained results are as follows:

$dh_2^{PIS}(x) = 0.001076\ and\ dh_2^{NIS}(x) = 38.52290$

Now payoff matrix of $dh_2^{PIS}(x)$ & $dh_2^{NIS}(x)$

	$dh_2^{PIS}(x)$	$dh_2^{NIS}(x)$
x^{PIS}	0.00107	37.0514
x^{NIS}	0.1047	38.5229

Formulate the possible membership functions $\vartheta_1(x)$ and $\vartheta_2(x)$ for $dh_2^{PIS}(x)$ and $dh_2^{NIS}(x)$ as shown below:

$$\vartheta_1(x) = \begin{cases} 1 & if\ dh_2^{PIS}(x) \leq 0.00107 \\ \alpha_g \dfrac{0.1047 - dh_2^{PIS}(x)}{0.1047 - 0.00107} & if\ \ 0.00107 \leq dh_2^{PIS}(x) \leq 0.1047 \\ 0 & if\ \ 0.1047 \leq\ dh_2^{PIS}(x) \end{cases}$$

$$\vartheta_2(x) = \begin{cases} 1 & if\ 38.5229 \leq dh_2^{PIS}(x) \\ \alpha_g \dfrac{dh_2^{NIS}(x) \quad - 37.0514}{38.5229 - 37.0514} & if\ \ 37.0514 \leq dh_2^{NIS}(x) \leq 38.5229 \\ 0 & if\ \ dh_2^{NIS}(x) \quad \leq\ 37.0514 \end{cases}$$

α_g are the possible membership values. Finally determine the following model by assuming $\alpha_1 = 1$.

Model: 3

$$\max \delta$$

Subject to

$$\frac{0.1047 - dh_2^{PIS}(x)}{0.1047 - 0.00107} \geq\ \delta$$

$$\frac{dh_2^{NIS}(x) \quad -37.0514}{38.5229 - 37.0514} \geq\ \delta$$

$$0 \leq \delta \leq 1$$

constraints from (20) to (24), (9) to (14)

Finally, the optimal values of the variables are

$Q_1 = 0.805; Q_2 = 98.99\ ; Q_3 = 1094536$

$x_{1311} = 43.2882$; $x_{1312} = 44.69174$; $x_{2112} = 26.77595$; $x_{1321} = 3.296303$; $x_{1322} = 0.8082601$; $x_{2222} = 1.640926$; $x_{2321} = 44.5$; $y_{2222} = 1.640926$; $y_{3312} = 80.5$; $y_{3321} = 56.08313$; $y_{1221} = 26.77595$; $z_{2311} = 28.41687$; $z_{3111} = 12.51421$; $z_{3121} = 13.98579$;

$z_{3122} = 22.5$; $z_{3221} = 27.5$; $z_{3222} = 20.5$; $z_{3312} = 0.06891$; $z_{3312} = 39.5$;

5. CONCLUSION

Emission of greenhouse gas from the vehicle plays vital role in environmental pollution and global warming. This study helps to control such pollution and gives the optimal solution to lead the green supply chain. This paper focused on environmentally sustainable multi-stage multi-objective multi-item fixed-charge solid fractional hesitant fuzzy transportation problem (MSMOMISFHFTP). The objective of the problem is to minimise the ratio of cost and profit, deterioration rate and emission. This paper provides the proper plan of distribution of multi items from production plants to the customers in three stages. The three stages are from production plants to distribution centres, from distribution centres to retailers, from retailers to customers. Here all the parameters of multi-stage multi-objective multi-item fixed-charge solid fractional transportation problem are treated as trapezoidal hesitant fuzzy numbers. Hesitant TOPSIS method is introduced to solve MSMOMISFHFTP which provides the best solution. The optimal solution obtained from the proposed method is more efficient than other methods. The proposed method can be extended further to soft fuzzy sets. Finally numerical problem is solved using proposed methodology with the help of LINGO package.

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