FUZZY MULTICHOICE MULTIOBJECTIVE MULTIMODAL TRANSPORTATION PROBLEM IN SOFT ENVIRONMENT

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Article History: Received: 02.03.2023 **Revised:** 08.04.2023 **Accepted:** 18.05.2023

ABSTRACT:

Supply chain management is the nucleus of every organization which keeps an eye on the life cycle of each product from the stage of planning to distribution. Effective transportation is one among the vital parts of a successful supply chain and has a strong effect on the global economic development. The factors like speed, shipment density, geographical location of the source and destination, vehicle capacity and many others develop a parametric ambiguity in the transportation of goods and services. The disregarding of the above parameters may prompt business failure to an entrepreneur. Such a complexity can be dealt with soft sets which lends a detectable vision on the transportation budgeting. In this paper, a fuzzy soft multichoice multi-objective transportation model generated from the modal choice possibilities arising out of the three basic modes of transport namely roadways, railways, airways are investigated. The binary variable and lagrange interpolating polynomial approach are utilised for picking out the optimum objective value between each source and destination in the four possible modal options. In the end, an example for the fuzzy multichoice multi-objective soft transportation problem is solved with the existing weighted sum method (in LINGO 19.0) and the results from the two multichoice reduction approaches are stated.

Keywords: soft set, multi-objective and multichoice transportation, binary variable approach, lagrange interpolating polynomial approach, weighted sum method.

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DOI: 10.31838/ecb/2023.12.s2.532

1. INTRODUCTION

In Operations Research, complex problems are formulated into a model to enhance profit despite the difficulties in real life. Transportation logistics is predominant since it permits trade among humankind thereby instituting a healthy supply chain. Transportation problem deals with the dispersal of a product from various sending localities to various receiving localities to acquire the finest value for the required objectives. Uncertainty has come out over the past decade as one of the key elements affecting the game plan of the global business ecosystem. Freight supply and demand, security and insurance, weight and density of shipments, mode of transport, continually switching seasons etc. have a wider impact on the budget management. The enlarging rivalry in the marketing world has aroused circumstances where the administrators are furnished with multiple choices to conclude on an exclusive chore. Multiple choice programming was initiated by Healy [6] which unfolded an approach for the linear programming problem with zero-one variables. Chang [4] proposed a method for resolving the problem with multi-choice aspiration levels for a goal using binary variables. Biswal and Acharya. S [2] initiated the transformation technique for multiple values with the aid of binary variables formulating a non-linear mixed integer programming problem. Biswal and Acharya [3] formulated the linear programming problems with multi-choice parameters using various interpolating polynomials. Kanan. K. Patro, M.M. Acharya, M.P. Biswal, S. Acharya [11] presented a model for the multi-choice goal programming problem by using Vandermonde’s interpolating polynomial, binary variables and least square approximation method. Roy. S.K and G. Maity [7] transfigured the multichoice multi-objective transportation problem into multi-objective transportation problem using the transformation technique namely the binary variable approach and solved the reformulated model by utility function approach. Roy. S.K[12] instigated a method for solving multichoice transportation problem by using Lagrange’s interpolating polynomial with the intention of choosing a suitable alternative from the multichoice coefficient in the objective function, supply and demand. Acharya and Biswal. M.P[1] used fuzzy programming approach to procure a compromise solution for the multi-objective transportation problem with multichoice demand values. Roy. S.K, G. Maity, G. W. Weber [13] had employed two varieties of greyness for the transportation parameters in the multi-objective two-stage transportation model and found its solution using RMCGP. J. Nayak, S. Nanda and S. Acharya [10] formulated an equivalent model for the multichoice transportation problem using binary variables and the solution obtained from this model is compared with the existing interpolating polynomial approach. Fuzzy set theory was initiated by L. A. Zadeh [15] to tackle the uncertainty in real life situations. The real world multi choice values are not always crisp and it aroused fuzzy multichoice values.The criteria based understanding is much needed and is favoured by soft sets [9] which aids in recognising the characteristic uncertainty and comes up with an efficient solution. This is widely used in reality decision making in the field of medicine, information system etc. Hedges and Quantifiers are utilised in fuzzy set theory by means of specialised membership functions which assures more accurate description of objects. Maji. P.K et al [8] launched the notion of fuzzy soft sets which is a merge of soft set and fuzzy set theory. Soft set based multichoice fuzzy numbers are still not under consideration in the transportation problem. Therefore, the objectives involving the multichoice fuzzy travelling cost, multichoice fuzzy travelling time and the multichoice fuzzy carbon emission cost relying on the preferred modal options are considered and resolved in this paper. Sharma, Gaurav, et al. [5] have already discussed the soft set based trans-modal as well as the combined mode transportation problems under crisp environment. Vinotha, J.M., Gladys, L.B, Ritha, W. and Vinoline, I.A., [14] elaborated the fuzzy soft set based trans-modal transportation problem which is used occasionally to ensure progression inside a single mode of transport. But the actuality in trade, demands intermodal or multimodal transportation which is believed to have a better efficiency than the trans-modal transportation. There may be times when the supplier or the consumer impose restriction on certain modes because of the ambiguous climatic conditions, pandemic situation and so on. All the possible optional combinations from three transportation modes are examined in which objectives are taken to be multichoice fuzzy parameters that are converted into crisp multichoice values. Then the defuzzified multichoice values for the four optional combinations namely $\{e_{l_1}, e_{l_2}\}, \{e_{l_1}, e_{l_3}\}, \{e_{l_2}, e_{l_3}\}$ and $\{e_{l_1}, e_{l_2}, e_{l_3}\}$ are transformed using two techniques namely the Lagrange interpolating polynomial approach and the binary variable approach. Finally, it is optimised using the weighted sum method for multiobjective transportation problem. The paper is organised as follows. In section 2, the mathematical formulation for the multichoice multiobjective soft transportation problem is provided. Section 3 comes up with the reduction techniques for the fuzzy multiobjective values. In section 4, an example along with the solutions are elaborated which is followed by conclusion in section 5.

2. MATHEMATICAL FORMULATION

Let m, n be the number of starting points and landing points. Then, the mathematical model of the fuzzy soft multi-objective transportation problem given by [14],

$$\text{Min } \widetilde{Z_k(e_l)} = \sum_{i=1}^{m}\sum_{j=1}^{n} \widetilde{Q_{ij}^{(k)}(e_l)} x_{ij}(e_l), l \in \mathbb{N} \quad (1)$$

s.t

$$\sum_{j=1}^{n} x_{ij}(e_l) \cong \widetilde{a_i}\ , i = 1,2,3, \dots m$$

$$\sum_{i=1}^{m} x_{ij}(e_l) \cong \widetilde{b_j}\ , j = 1,2,3, \dots n$$

Where $x_{ij} \geq 0\ \forall\ i, j$.

Here, $\widetilde{a_i}, \widetilde{b_j}$ and $\widetilde{Q_{ij}^{(k)}(e_l)}$ denotes the fuzzy number with respect to the parameter e_l in the transportation problem. One may completely neglect or strongly agree with specific transportation modes between the sources and various destinations depending upon the decision maker's favourable transportation characteristics. This kind of modal choice dilemma between the source and destination induces multi-choice fuzzy cost and multi-choice fuzzy time coefficient which creates a fuzzy soft multi-choice multi-objective transportation model which is given by,

$$\text{Min } Z_k\left(e_{l_1}, e_{l_2}, \dots, e_{l_p}\right) = \sum_{i=1}^{m}\sum_{j=1}^{n}\{\widetilde{Q_{ij}^{(1)}}, \widetilde{Q_{ij}^{(2)}}, \dots, \widetilde{Q_{ij}^{(p)}}\}^{(k)} x_{ij}\left(e_{l_1}, e_{l_2}, \dots, e_{l_p}\right) \quad (2)$$

s.t

$$\sum_{j=1}^{n} x_{ij} \cong \widetilde{a_i}, i = 1,2,3, \dots m$$

$$\sum_{i=1}^{m} x_{ij} \cong \widetilde{b_j}\ , j = 1,2,3, \dots n$$

Where

$Z_k(e_{l_1}, e_{l_2}, \dots, e_{l_p}) = \{Z_1(e_{l_1}, e_{l_2}, \dots, e_{l_p}), Z_2(e_{l_1}, e_{l_2}, \dots, e_{l_p}), \dots Z_k(e_{l_1}, e_{l_2}, \dots, e_{l_p})\}$. Here, $\{\widetilde{Q_{ij}^{(1)}}, \widetilde{Q_{ij}^{(2)}}, \dots, \widetilde{Q_{ij}^{(p)}}\}^{(k)}$ denotes the fuzzy multi-choice coefficients for the kth objective corresponding to 'p' number of transportation modes(or 'p' parameters), where we have assumed $4 > p \geq 2$ and $x_{ij} \geq 0\ \forall\ i, j$.

As the problem cannot be solved directly, we use an equivalent model where the multichoice values are replaced using the score function and some existing methods.

3. FUZZY MULTICHOICE TRANSFORMATION TECHNIQUES

3.1.1. BINARY VARIABLE APPROACH:

Every natural number can be expressed as sum of 2^g number of terms and each term is a power of 2, where $g \in \mathbb{N} \cup \{0\}$. The mathematical formulation using binary variable is given by,

$$\text{Min } Z\left(e_{l_1}, e_{l_2}, \dots, e_{l_p}\right) = \sum_{i=1}^{m}\sum_{j=1}^{n} \mathcal{P}(\theta^{ij^{(w)}}) x_{ij}$$

s.t

$$\sum_{j=1}^{n} x_{ij} \leq S(\widetilde{a_i})\ , i = 1,2,3, \dots m$$

$$\sum_{i=1}^{m} x_{ij} \geq S(\widetilde{b_j})\ , j = 1,2,3, \dots n \text{ where } x_{ij} \geq 0\ \forall\ i \ \& \ j \text{ and } \theta^{ij^{(w)}} \epsilon \{0,1\}\ \forall\ w.$$

$$\theta^{ij^{(1)}} + \theta^{ij^{(2)}} \leq 1 \text{ (or) } \theta^{ij^{(1)}} + \theta^{ij^{(2)}} \geq 1, \text{for } p = 3.$$

Here, $S(\tilde{\alpha}) = \frac{p+q+r+s}{4}(\mu^2 - \vartheta^2)$ where $(\mu^2 - \vartheta^2) \in [-1,1]$ is the score function used for the defuzzification of the Pythagorean trapezoidal fuzzy number.

3.1.2. LAGRANGE INTERPOLATING POLYNOMIAL APPROACH:

Interpolating polynomials are developed for replacing the multi-choice parameters having exactly one functional value at the nodal points. Let 0, 1, 2,…., p-1 be 'p' number of node points, where

$S\left(\widetilde{Q_{ij}^{(1)}}\right), S\left(\widetilde{Q_{ij}^{(2)}}\right), \dots S(\widetilde{Q_{ij}^{(p)}})$ are the respective functional values of the interpolating polynomial at 'p' different node points. The derivation of the Lagrange interpolating polynomial $P_{p-1}(\theta^{ij})$ of degree (p-1) is as follows:

$$P_{p-1}(s) = S\left(\widetilde{Q_{ij}^{(s+1)}}\right), s = 0, 1, 2, \dots\dots, (p-1), i = 1,2, \dots\dots m \text{ and } j = 1, 2, \dots\dots, n \qquad (3)$$

The formulation for the Lagrange interpolating polynomial for the p multi-choice parameters are given below,

$$P_{p-1}(\theta^{ij}) = \frac{(\theta^{ij}-1)(\theta^{ij}-2)\dots.(\theta^{ij}-p+1)}{(-1)^{(p-1)}(p-1)!} S(\widetilde{Q_{ij}^{(1)}}) + \frac{(\theta^{ij})(\theta^{ij}-2)\dots.(\theta^{ij}-p+1)}{(-1)^{(p-2)}(p-2)!} S(\widetilde{Q_{ij}^{(2)}}) + \frac{(\theta^{ij})(\theta^{ij}-1)(\theta^{ij}-3)\dots.(\theta^{ij}-p+1)}{(-1)^{(p-3)}(p-3)!\,2!} S(\widetilde{Q_{ij}^{(3)}}) + \cdots + \frac{(\theta^{ij})(\theta^{ij}-1)(\theta^{ij}-2)\dots.(\theta^{ij}-p+2)}{(p-1)!} S(\widetilde{Q_{ij}^{(p)}}) \forall \text{ i and j.} \qquad (4)$$

Now, the transformed multi choice linear programming problem is given by,

$$\text{Min } Z\left(e_{l_1}, e_{l_2}, \dots., e_{l_p}\right) = \sum_{i=1}^{m}\sum_{j=1}^{n}\left[\frac{(\theta^{ij}-1)(\theta^{ij}-2)\dots.(\theta^{ij}-p+1)}{(-1)^{(p-1)}(p-1)!} S(\widetilde{Q_{ij}^{(1)}}) + \frac{(\theta^{ij})(\theta^{ij}-2)\dots.(\theta^{ij}-p+1)}{(-1)^{(p-2)}(p-2)!} S(\widetilde{Q_{ij}^{(2)}}) + \frac{(\theta^{ij})(\theta^{ij}-1)(\theta^{ij}-3)\dots.(\theta^{ij}-p+1)}{(-1)^{(p-3)}(p-3)!\,2!} S(\widetilde{Q_{ij}^{(3)}}) + \cdots + \frac{(\theta^{ij})(\theta^{ij}-1)(\theta^{ij}-2)\dots.(\theta^{ij}-p+2)}{(p-1)!} S(\widetilde{Q_{ij}^{(p)}})\right] x_{ij} \qquad (5)$$

where $S\left(\widetilde{Q_{ij}^{(1)}}\right), S\left(\widetilde{Q_{ij}^{(2)}}\right), \dots S(\widetilde{Q_{ij}^{(p)}})$ are defuzzified values of the given fuzzy number $\widetilde{Q_{ij}^{(1)}}, \widetilde{Q_{ij}^{(2)}}, \dots., \widetilde{Q_{ij}^{(p)}}$ where $x_{ij} \geq 0 \ \forall$ i , j.

3.2. WEIGHTED SUM METHOD FOR THE MULTICHOICE MULTIOBJECTIVE TRANSPORTATION PROBLEM:

The weighted sum method redesigns the multi-objective transportation problem into a single objective transportation problem by allotting weights W_k to each objective function Z_k. The higher the weight W_k, the higher is the importance given to the objective function Z_k.

$$\text{Min} \sum_{k=1}^{3} W_k Z_k\left(e_{l_1}, e_{l_2}, \dots., e_{l_p}\right); \text{where} \sum_{k=1}^{3} W_k = 1$$

s.t

$$\sum_{j=1}^{n} x_{ij} \cong S(\widetilde{a_i}) \ , i = 1,2,3, \dots m$$

$$\sum_{i=1}^{m} x_{ij}(e_l) \cong S(\widetilde{b_j}) \ , j = 1,2,3, \dots n$$

ILLUSTRATIVE EXAMPLE: To elucidate the following model, example from [14] is considered.

Using **3.1.1**(***Binary Variable approach***)

The travelling cost, travelling time and emission cost w.r.t $e_{l_p}, p = 1,2$ are,

$$Min\ Z_1 = \left(2583.95z11 + 4170.06(1-z11)\right)x11 + \left(2746z12 + 3046(1-z12)\right)x12 + \left(1753.1z13 + 7263(1-z13)\right)x13 + (3389.04z14 + 5274.5(1-z14)x14 + \left(3063z21 + 4033.89(1-z21)\right)x21 + \left(3331.02z22 + 7038.54(1-z22)\right)x22 + \left(2289z23 + 3940.05(1-z23)\right)x23 + +\left(3925.08z24 + 8289(1-z24)\right)x24 + \left(3732.95z31 + 6994.1025(1-z31)\right)x31 + \left(3952.15z32 + 8865(1-z32)\right)x32 + \left(2958.92z33 + 3345(1-z33)\right)x33 + \left(4653z34 + 8849.88(1-z34)\right)x34)$$

$$Min\ Z_2 = \{max\ t_{ij} : x_{ij} > 0\}$$

DESTINATION / SOURCE		BHOPAL	LUCKNOW	HYDERABAD	PATNA	a_i
DELHI	T.C	{2583.95,2678.5,4170.06}	{2348.4,2746, 3046}	{1753.1,3561.6, 7263}	{3389.04,4043.5.5274.5,}	14
	T.T	{1.4,17.4,24.325}	{1.49,15.15,20.1}	{3.48,30.24, 36.2375}	{2.24, 21.36, 32.5876}	
	E.C	{2, 5.82, 241.76}	{1.44,1.44, 209.44}	{4.65,11.2, 312}	{2.76,7.875, 372.08}	
MUMBAI	T.C	{3063,3113.93, 4033.89}	{3331.02,4942.08, 7038.54}	{2289,2429.4, 3940.05}	{3925.08,6622.02, 8289}	13
	T.T	{3.15,20.16,22.16}	{5.22,28.6,36.2}	{3.6,20.25, 22.33}	{3.41,30.39, 38.5}	
	E.C	{2.31, 5.52, 281.4}	{3.41,10.395, 458.64}	{2.19,5.3325, 210.96}	{4.05,12.8, 620.64}	
CHENNAI	T.C	{3732.95,3099.6, 6994.1025}	{3952.15,6692.65, 8865}	{2414.16, 2958.92, 3345}	{4653,6622.02, 8849.88}	16
	T.T	{5.1,37.2,37.2125}	{4.13,33.48,49.2}	{2.03,21.18,24.3}	{5.18,33.24,55.26}	
	E.C	{4.23,10.395, 300.48}	{5.08,13.7,629}	{2.16,4.485, 210.50}	{6.35,14.63, 620.85}	
b_j		9	12	10	12	

$$\sum_{i=1}^{m}\sum_{j=1}^{n} t_{ij}x_{ij} = (17.4k11 + 24.325(1-k11))x11 + (15.15k12 + 20.1(1-k12))x12$$
$$+\big(30.24k13 + 36.2375(1-k13)\big)x13 + \big(21.36k14 + 32.5875(1-k14)\big)x14$$
$$+\big(20.16k21 + 22.16(1-k21)\big)x21 + (28.6k22 + 36.2(1-k22)x22$$
$$+\big(20.25k23 + 22.33(1-k23)\big)x23 + \big(30.39k24 + 38.5(1-k24)\big)x24$$
$$+\big(37.2k31 + 37.2125(1-k31)\big)x31 + \big(33.48k32 + 49.2(1-k32)\big)x32$$
$$+\big(21.18k33 + 24.3(1-k33)\big)x33 + \big(33.24k34 + 55.26(1-k34)\big)x34$$

$$Min\ Z_3 = \big(2s11 + 5.82(1 - s11)\big)x11 + \big(1.44s12 + 4.14(1 - s12)\big)x12 + \big(4.65s13 + 11.2(1 - s13)\big)x13 + \big(2.76s14 + 7.875(1 - s14)\big)x14 + \big(2.31s21 + 5.52(1 - s21)\big)x21 + \big(3.41s22 + 10.395(1 - s22)\big)x22 + \big(2.19s23 + 5.3325(1 - s23)\big)x23 + \big(4.05s24 + 12.8(1 - s24)\big)x24 + \big(4.23s31 + 10.395(1 - s31)\big)x31 + \big(5.08s32 + 13.07(1 - s32)\big)x32 + \big(2.16s33 + 4.485(1 - s33)\big)x33 + \big(6.35s34 + 14.63(1 - s34)\big)x34$$

s.t the demand and supply constraint where $x_{ij} \geq 0\ and\ z_{ij}, k_{ij}, s_{ij}\ \epsilon\ \{0,1\}\ \forall i, j$.
Using $\mathbf{3.1.2}(\boldsymbol{Interpolating\ Polynomial\ approach})$
The travelling cost, travelling time and emission cost w.r.t $e_{l_p}, p = 1,2$ are,

$$Min\ Z_1 = (1586.1z11 + 2583.95)x11 + (300z12 + 2746)x12 + (5509.9z13 + 1753.1)x13 + (1885.46z14 + 3389.04)x14 + (970.89z21 + 3063)x21 + (3707.52z22 + 3331.02)x22 + (1651.05z23 + 2289)x23 + (4363.92z24 + 3925.08)x24 + (3261.1525z31 + 3732.95)x31 + (4912.85z32 + 3952.15)x32 + (396.08z33 + 2958.92)x33 + (4196.88z34 + 4653)x34$$

$$Min\ Z_2 = \{max\ t_{ij}: x_{ij} > 0\}$$

$$\sum_{i=1}^{m}\sum_{j=1}^{n} t_{ij}x_{ij} = (6.925k11 + 17.4)x11 + (4.95k12 + 15.15)x12 + (5.9975k13 + 30.24)x13 + (11.2275k14 + 21.36)x14 + (2k21 + 20.16)x21 + (7.6k22 + 28.6)x22 + (2.08k23 + 20.25)x23 + (8.11k24 + 30.39)x24 + (0.0125k31 + 37.2)x31 + (15.72k32 + 33.48)x32 + (3.12k33 + 21.18)x33 + (22.02k34 + 33.24)x34$$

$$Min\ Z_3 = (3.82s11 + 2)x11 + (2.7s12 + 1.44)x12 + (6.55s13 + 4.65)x13 + (5.115s14 + 2.76)x14 + (3.21s21 + 2.31)x21 + (6.985s22 + 3.41)x22 + (3.1425s23 + 2.19)x23 + (8.15s24 + 4.05)x24 + (6.165s31 + 4.23)x31 + (8.62s32 + 5.08)x32 + (2.32s33 + 2.16)x33 + (8.28s34 + 6.35)x34$$

s.t the demand and supply constraint where $x_{ij} \geq 0\ and\ z_{ij}, k_{ij}, s_{ij} = 0,1\ for\ i = 1,2,3, j = 1,2,3,4$. Simultaneously, the objective functions of the other possible optional combinations are found and optimised using the weighted sum method for multiobjective transportation problem and the results are tabulated.
For **w = (0.2,0.1,0.7)** which represents a higher weightage to Emission cost,

MODAL COMBINATIONS	BINARY VARIABLE APPROACH	LAGRANGE INTERPOLATING POLYNOMAIL APPROACH
e_{l_1}, e_{l_2} **ie, Road, Rail**	$Z_1 = 140157.7$ $Z_2 = 33.48$ $Z_3 = 119.79$	$Z_1 = 140504.6$ $Z_2 = 33.24$ $Z_3 = 119.49$
e_{l_2}, e_{l_3} **ie, Rail, Air**	$Z_1 = 125872.2$ $Z_2 = 5.1$ $Z_3 = 123.06$	$Z_1 = 130338$ $Z_2 = 5.22$ $Z_3 = 129.86$
e_{l_1}, e_{l_3} **ie, Road, Air**	$Z_1 = 154714.1$ $Z_2 = 5.18$ $Z_3 = 298.94$	$Z_1 = 165312.9$ $Z_2 = 4.13$ $Z_3 = 315.77$
$e_{l_1}, e_{l_2}, e_{l_3}$ **ie, Road, Rail, Air**	$Z_1 = 125872.2$ $Z_2 = 5.1$ $Z_3 = 123.06$	$Z_1 = 125875.2$ $Z_2 = 5.1$ $Z_3 = 132.4875$

4. CONCLUSION

From the above tabulated results, we see that the binary variable approach furnishes a better solution compared with the interpolating polynomial approach. It also ensures the need for using combined transport in the global merchandise of products. The cost incurred by combined transportation is found to be relatively much lower than the trans-modal transport discussed in [14]. Analysing the objectives corresponding to optional combination of various transportation modes is significant due to the ambiguous reality. This may be beneficial during the times of crisis around the globe. It will enable the third-party transporters to have an efficient backup plan. Soft set plays a healthy role to concentrate on the parameters which has tremendous influence on the day today supply chain budgeting. Further, if all the parametric uncertainty associated with the transportation network are analysed keenly, the minute issues in and around transportation will be resolved and the financial impacts will be better.

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