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Research paper

An Empirical Study on Multi-objective Transportation Problem in Fuzzy Environment

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Abstract

For both in economical and social development of country transportation system plays a vital role. As it is directly involved with financial growth of the country, for that a complete well planned transportation infrastructure is necessary. Most of the transportation models are formulated with minimization of transportation cost as the basic objective. But consideration of transportation system with a single objective is not able to meet the various requirements of transportation industry for which it may not lead to the practical optimal solution. It bounds the decision makers (DMs) to consider several objectives at a time instead of single objective. To handle a multi-objective transportation problem with fixed parameters is a challenging issue; rather it is easy to consider all parameters in terms of linguistic variables. In this paper, a multi criteria multi-objective transportation models is formulated based on fuzzy relations under the fuzzy logic with several objectives like (i) minimization of total transportation cost and (ii) minimization of total transportation time. Another objective, maximization of the transported amount from a source to a destination is determined on the basis of previous two objectives. All the objectives are associated with multiple numbers of criteria like breakable items, shipping distance, service charge, mode of transportation etc. These relations are imprecise in nature and represented in terms of verbal words such as low, medium, high and very high. The fuzzy rule based multi-objective transportation problem is formulated and result is discussed.

Keywords: *Multi-objective transportation problem, Multi-criteria decision making, Fuzzy inference systems*

1.Introduction

The basic objective of decision making process is, to identify and choose the best alternative as per the requirement of decision maker. In complex organizational environment, a decision based on single criteria is not sufficient to meet the actual requirements. In this case, one must acknowledge the necessity of consideration of different criteria which leads to development and necessity of multi-criteria decision making. A specified set of constraints are considered to optimize a problem whether it is a single objective or multi-objective transportation problem which are either equality or inequality type. Problems which often arise as a result of mathematical modeling of many real life situations are called optimization problems. Transportation problem is one such type of problem.

Now days, transportation has a vital role in our daily life. In our day to day activities, it is not possible for an individual to avoid transportation related problems. To meet the daily requirement, it is not possible for anybody to produce everything in his home. Goods can be produced more efficiently in factories, large farms, etc. but this necessitates the movement of both the goods and the people to meet the requirements. The whole structure of society involves a trade-off between the economies of scale and focusing activities or groups of activities and the cost of transporting people from home to work places and goods from factories to customers. The whole system of transportation process generates a problem known as Transportation Problem.The transportation problem is a special case of Linear programming problem, in which all the constraints are of equality type. It allows the decision maker to regulate the optimum shipping patterns between different supply and demand points. The solution of the problem will empower the decision maker to determine the number of entities to be transported from a particular supply point to a particular demand point with minimum transportation cost or deliver the products with less time. In both the cases, it maximizes the total profit. In traditional transportation problem, products are transported from different supply points to the demand points so as to minimize the total transportation costs with fixed parameters.

1.1. Multi-Objective Transportation Problem

Shifting of product from manufacturing point to customer is called "Transportation Problem" (TP) which first developed by F. L. Hitchcock since (1941). The primary objective of the transportation models is to minimize the total transportation cost satisfying supply-demand conditions. In the present era due to complex organizational structure the single objective transportation problem is fails to satisfy the managerial decision making requirements. To fulfill that requirement, it is necessary for decision maker to focus on several objectives at a time, which is the main characteristic of a multi-objective transportation problem. Besides minimization of transportation cost, the

parameters like quantity of goods delivered, underused capacity, energy consumption, total delivery time etc. are also considered as different objectives for a multi- objective transportation problem.
The multi-objective transportation problem is a particular type of vector minimum problem with all equality type constraints with different conflicting objectives. For example in a transportation system, the amount of transported products is inversely depends on the level of unit transportation cost. Because the decision maker (DM) tries to transport the maximum possible amount of products through the route for which the unit transportation cost is comparatively low among all possible routes , i.e., it increases the transported amount. In the reverse way, the high unit transportation cost minimizes the number of transported products. Similarly, the unit transportation cost is inversely proportional to delivery time.
In this study, a multi-objective transportation problem is considered with two different objectives minimizing total transportation cost and minimizing total transportation time. Another objective, maximize the quantity of transported amount is considered with the combination of previous two objectives. By using traditional fuzzy tool, a set of rules are manually framed with all related factors. These relations are imprecise in nature and expressed by verbal words and these are called fuzzy inferences. Till now, a very few multi-objective transportation problem has been formulated and solved using fuzzy inferences.

1.2. Mathematical Formulation

Consider the m-supply points S1, S2…Sm and n-demand points D1, D2 …Dn with k-objectives Z1, Z2 …Zk. Without any loss of generality it is assume that, all the objectives are of minimization type. Suppose the supply point Si has an availability ai (i = 1, 2 …m) and the demand point Dj has the requirement bj (j = 1, 2 ….n). Let for each objective Zk, the penalty $Cij^{(k)}$ associated with transporting a single unit from supply point Si to demand point Dj. Let the variable x_{ij} represents the unknown quantity transported from supply point Si to destination Dj.

$$\text{Min } Z_k = \sum_{i=1}^{m}\sum_{j=1}^{n} C_{ij}{}^{k}\, x_{ij} \quad k= 1, 2….K \tag{1.1}$$

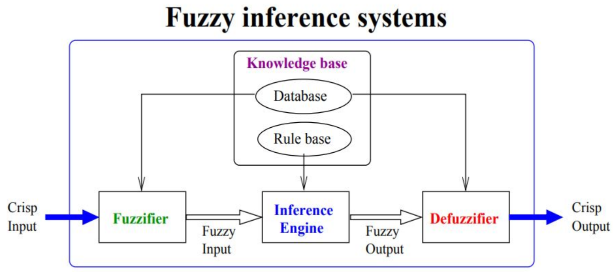
Subject to

$\sum_{j=1}^{n} x_{ij} = a_i$ for i = 1, 2 …m (1.2) $\sum_{j=1}^{n} x_{ij} = b_j$ for j= 1, 2 …n (1.3)

$$x_{ij} \geq 0 \tag{1.4}$$

1.3. Fuzzy Inference System

Human knowledge is often represented in terms of imprecise data. In real life problems some vague terms such as very low, low, medium, high and very high etc. are used. To express these terms in form of natural language expressions is the key role of fuzzy inference system. The expression is of the type, IF premise (antecedent) THEN conclusion (consequent).This process is commonly referred to as an IF–THEN rule-based form. Fuzzy inference is the process of formulating the mapping from a given imprecise input to an imprecise output using fuzzy logic. The whole process of fuzzy inference system involves membership functions, fuzzy logic operators, and if-then rules. In Fuzzy Logic Toolbox, two types of fuzzy inference systems Mamdani-type and Sugeno-type can be implemented.
In different areas such as automatic control, data classification, decision analysis, expert systems, computer vision etc. fuzzy inference systems have been successfully applied. Fuzzy inference systems are associated with a number of names, such as fuzzy-rule-based systems, fuzzy expert systems, fuzzy modeling, fuzzy associative memory, fuzzy logic controllers, and fuzzy systems etc. because of its multi-disciplinary nature. The most commonly seen fuzzy methodology is Mamdani's fuzzy inference method. It was among the first control systems built using fuzzy set theory and was proposed in 1975 by Ebrahim Mamdani, as an attempt to control a steam engine and boiler combination by synthesizing a set of linguistic control rules obtained from experienced human operators. Mamdani-type inference, as we have defined it for the Fuzzy Logic Toolbox, expects the output membership functions to be fuzzy sets. After the aggregation process, there is a fuzzy set for each output variable that needs defuzzification. According to Mamdani, fuzzy inference process has three basic parts (i) Fuzzification of input variables. (ii) Rule-strength and fuzzy output calculation. (iii) Defuzzification of the fuzzy output. The basic structure of a fuzzy inference system consists of three conceptual components: a rule base, which contains a selection of fuzzy rules, a database (or dictionary) which defines the membership functions used in the fuzzy rules and a reasoning mechanism, which performs the inference procedure upon the rules and given facts to derive a reasonable output or conclusion. The structural view of an fuzzy inference systems is shown as below



2. Related Work

When all the terms associated with a transportation model like transportation expenditures, supply and demand quantities are expressed in terms of fuzzy quantities then it is called as fuzzy transportation problem. Zadeh first introduced the concepts of fuzzy sets. To solve multi objective linear programming problems by fuzzy set theory concept with some suitable membership function was first applied by Zimmermann (1978) where he consider [0,1] as the range of the membership function. Degree of the membership function for each objective represents its satisfaction level. If the membership function of an objective is one or zero then objective is fully achieved or not at all achieved, respectively. If the membership function of the objective lies in (0, 1) then the objective is partially achieved. A variety of approaches has been developed by many authors Diaz (1978, 1979), Aneja and Nair (1979), Isermann (1979), Lee and Moore (1973) for the multi-objective transportation problem. Ringuest and Rinks (1987) have mentioned about the existing solution procedures for multi-objective transportation problem. Current and Min (1986) have done a review work of multi-objective design of transportation network. To find solution of multi-objective transportation problem, Michalewicz et al applied GA. (Genetic Algorithm). L Li and K. K. Lai et al applied fuzzy approach and Mistuo Gen et al used spanning tree concept for it. But in all these cases whatever the solution obtained, is based on the accuracy of past data gathered. So if provided data is accurate then solution of multi-objective transportation problemis accurate, and hence sometimes due to data error, it does not possible to get an appropriate solution of transportation problem. For example, suppose the multi-objective transportation problem involves two parameters transportation time and transportation cost and the objective is to optimize both the parameters simultaneously, whereas these two parameters depend on several other parameters like vehicle type, road condition, climatic conditions, energy consumption, safe and secure delivery , traffic volume and so on. The related data on which solution of multi-objective transportation problem depends may not always correct due to some of the above factors and hence it is difficult to find the optimal solution. It is necessary to use knowledge based system to avoid such situations which will provide accurate data with its tools and techniques.

Wahed and Lee (2006) proposed an interactive fuzzy goal programming approach to determine the preferred compromise solution for the multi-objective transportation problem. They consider the imprecise nature of the input data with the assumption of fuzzy goal for each objective. Their approach mainly focuses on minimizing the worst upper bound to obtain an efficient solution which is close to the best lower bound of each objective function. Zangiabadi and Maleki (2007) presented a fuzzy goal programming approach to determine an optimal compromise solution for the multi-objective transportation problem with the same assumption. They assign a special type of non-linear (hyperbolic) membership function to each objective function to describe each fuzzy goal. Their approach focuses on minimizing the negative deviation variables from one to obtain a compromise solution of the multi-objective transportation problem. Surapati and Roy (2008) used another approach, fuzzy goal programming for solving a multi-objective transportation problem with fuzzy coefficients. Firstly, they defined the membership functions for the fuzzy goals. Subsequently, they transformed the membership functions into membership goals, by assigning the highest degree (unity) of a membership function as the aspiration level and introducing deviational variables to each of them. In the solution process, negative deviational variables are minimized to obtain the most satisfying solution. Osuji et al (2013) carried out a research on the paradox algorithm application of linear transportation problem. Lau et al. (2009) presented an algorithm called the fuzzy logic guided non-dominated sorting genetic algorithm to solve the multi-objective transportation problem. It mainly deals with the optimization of the vehicle routing in which he considers multiple sources from where several types of products to be transported to multiple destinations. Since the total traveling time is not always restrictive as a time constraint, the objective considered compromises not only the total traveling distance, but also the traveling time.

3. Proposed Model

In this study, we consider a multi-objective transportation problem with three different objectives like minimization of transportation cost (Z_1), minimization of transportation time (Z_2) and maximization of quantity of transported amount (Z_3) with four different criteria such as breakable item (BI), shipping distance (SD), service charge (SC) and mode of transportation (MT). All the parameters involved with this model are assumed as fuzzy in nature and expressed in terms of linguistic terms. Mamdani fuzzy inference system is used to find solution of the above problem considering only a singly objective at a time.

The input parameter breakable item (BI) is represented in terms of two linguistic variables Max and Min. Similarly, the input parameters shipping distance (SD) and service charge (SC)are represented in terms of linguistic variables like Low (L), Medium (M), High(H) and Very High (VH) whereas modes of transportation (MT) is represented as Road (R), Train (T), Ship (S) and Flight(F). Each of the input parameters are represented in linguistic terms with their ranges is shown as below.

Table 1: Linguistic term and their range for the input parameters X_1= {breakable item}

Linguistic terms	Membership function	Parameter Range
Min	Trimf	[0.0 , 0.5]
Max	Trimf	[0.5 , 1.0]

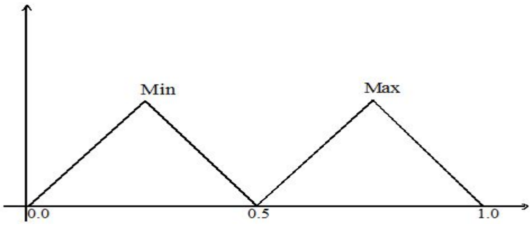


Fig 1: Membership functions of input parameter X_1= {breakable item}

Table 2: Linguistic term and their range for the input parameter X_2= {shipping distance}, X_3= {service charge}

Linguistic terms	Membership function	Parameter range
Low (L)	Trimf	[0.0 , 0.4]
Medium (M)	Trimf	[0.2 , 0.6]
High (H)	Trimf	[0.4 , 0.8]
Very high(VH)	Trimf	[0.6 , 1.0]

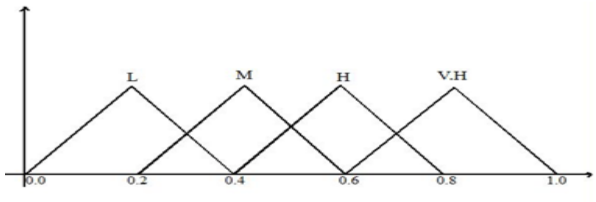


Fig 2: Membership functions of input parameters X_2= {shipping distance}, X_3= {service charge}

Table 3: Linguistic term and their range for the input parameter X_4= {mode of transportation}

Linguistic terms	Membership function	Parameter range
Road(R)	Trimf	[0.0 , 0.4]
Train (T)	Trimf	[0.2 , 0.6]
Ship(S)	Trimf	[0.4 , 0.8]
Flight(F)	Trimf	[0.6 , 1.0]

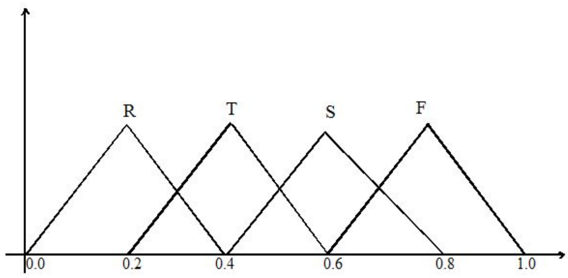


Fig.3: Membership functions of input parameter X_4= {mode of transportation}

Four linguistic variables Low (L), Medium (M), High (H) and Very High (VH) are also used to represent the output parameters, transportation cost, transportation time and quantity of transported amount. The Mamdani min-operator is used for aggregation and defuzzification is made using the Centre of the Sums (COS) method (Pratihar, 2008). Membership function distribution for output fuzzy parameter is shown in Figure 4.

Table 4: Linguistic term and their range for the output parameter Z_1= {Transportation Cost}, Z_2= {Transportation Time} and Z_3= {Transported Amount}

Linguistic terms	Membership function	Parameter range
Low (L)	Trimf	[0.0 , 0.4]
Medium (M)	Trimf	[0.2 , 0.6]
High (H)	Trimf	[0.4 , 0.8]
Very high(VH)	Trimf	[0.6 , 1.0]

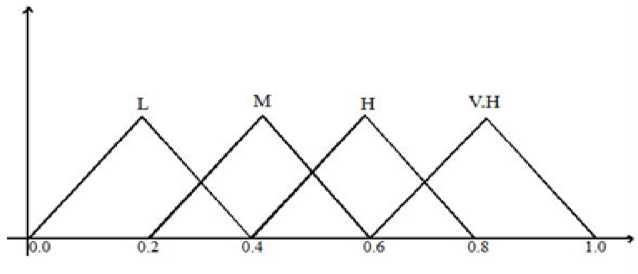


Fig 4: Membership functions of output parameters Z_1= {Transportation Cost}, Z_2= {Transportation Time} and Z_3= {Transported Amount}

3.1 Mathematical Formulation of Present Model

The present multi-objective transportation problem is mathematically formulated as:

$$\text{Minimize } Z_1 = \sum_{i=1}^{m}\sum_{j=1}^{n} \widehat{c_{ij}}\, \widehat{x_{ij}} \tag{2.1}$$

$$\text{Minimize } Z_2 = \sum_{i=1}^{m}\sum_{j=1}^{n} \widehat{t_{ij}}\, f\left(\widehat{x_{ij}}\right) \tag{2.2}$$

$$\text{Maximize } Z_3 = \sum_{i=1}^{m}\sum_{j=1}^{n} \widehat{x_{ij}} \tag{2.3}$$

$$\text{Subject to } \sum_{j=1}^{n} \widehat{x_{ij}} = a_i \text{ for i = 1, 2 …m} \tag{2.4}$$

$$\sum_{i=1}^{m} \widehat{x_{ij}} = b_j \text{ for j= 1, 2 …n} \tag{2.5}$$

$$\sum_{i=1}^{m} a_i = \sum_{j=1}^{n} b_j \tag{2.6}$$

$$\widehat{x_{ij}} \geq 0 \tag{2.7}$$

and

$$f\left(\widehat{x_{ij}}\right) = \begin{cases} 1 & \widehat{x_{ij}} > 0 \\ 0 & \widehat{x_{ij}} = 0 \end{cases} \tag{2.8}$$

Where

a_i = the number of units of a product available at origin i

b_j = the number of units of the product required at destination j

$\widehat{C_{ij}}$= the cost of transporting one unit from origin i to destination j

$\widehat{x_{ij}}$ = the amount of quantity carried or shipped from origin i to destination j

$\widehat{d_{ij}}$ = the distance from source i to destination j and

$\widehat{t_{ij}}$ = the time required for transport the product from source i to destination j.

3.2 Determining Fuzzy Rule Base from Input and Output Parameters

A traditional fuzzy reasoning tool is developed with the objective is to maximize the quantity of transported goods (Z_3) along with another two objectives minimization of both transportation cost(Z_1) and transportation time (Z_2). The objectives transportation cost and transportation time are associated with four input variables such as breakable item (X_1), shipping distance (X_2), service charge (X_3) and mode of transportation (X_4).Whereas the objective quantity of transported goods is depends on previous two objectives.

In the first part, a set of 128 rules are designed manually by considering the simultaneous effect of input parameters on two objectives transportation cost and transportation time (shown in Appendix A) as follows.

Rule 1: if breakable item (X_1) is **Max**, shipping distance (X_2) is **Low**, service charge (X_3) is **Low** and mode of transportation(X4)is **Road** then the transportation cost is **Low** and transportation time is **Low.**

Rule 2:if breakable item (X_1) is **Max**, shipping distance (X_2) is **Low**, service charge (X_3) is **Low** and mode of transportation(X4) is **Train** then the transportation cost is **Low** and transportation time is **Low.**

Rule 3:if breakable item (X_1) is **Max**, shipping distance (X_2) is **Low**, service charge (X_3) is **Low** and mode of transportation(X4) is **Ship** then the transportation cost is **High** and transportation time is **Low.**

Rule 128:if breakable item (X_1) is **Min**, shipping distance (X_2) is **Very High**, service charge (X_3) is **Very High** and mode of transportation(X4) is **Flight** then the transportation cost is **Very High**, and transportation time is **Medium**.

3.3 Result Discussion

Using Mamdani approach, both the transportation cost and transportation time is obtained by considering above rules and their corresponding membership functions. All possible combinations of input parameters are considered separately and their effect on the output parameters transportation cost and transportation time are observed. From the analysis it is observed that the input parameter breakable item has less impact on both the outputs transportation cost and transportation time whereas there is an increase in transportation cost in case of more shipping distance and maximum breakable items (See Fig 5a). The transportation cost is more depends on all other three factors whereas transportation time is particularly depends on both shipping distance and Mode of transportation. There is an increase in transportation cost, if shipping distance increases with high service charge (See Fig 5b). Similarly flight mode of transportation is another reason of expensive transportation cost with high service charge but it minimizes transportation time (See Fig 5c & Fig 5d). It is also observed that both for minimum transportation cost and transportation time, the input parameters shipping distance and service charge should be less. It is observed that less shipping distance with road mode of transportation minimizes transportation cost but it increases transportation time (See Fig 5e & Fig 5f).

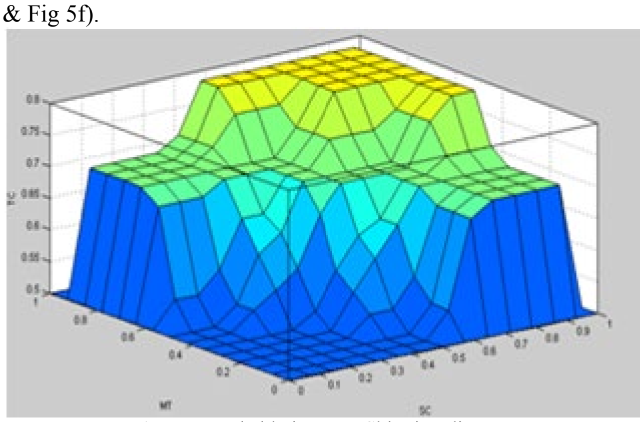


Fig 5a: Breakable item vs. Shipping distance

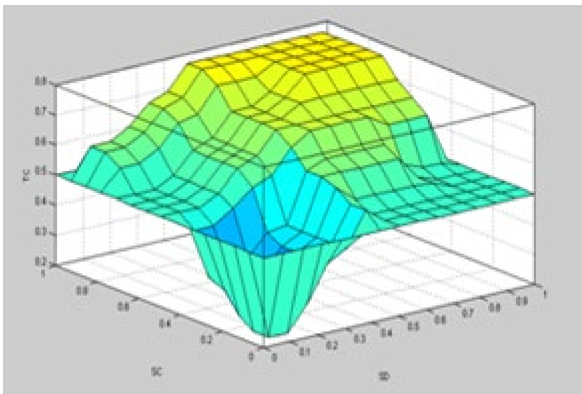


Fig 5b: Service Charge vs. Shipping distance

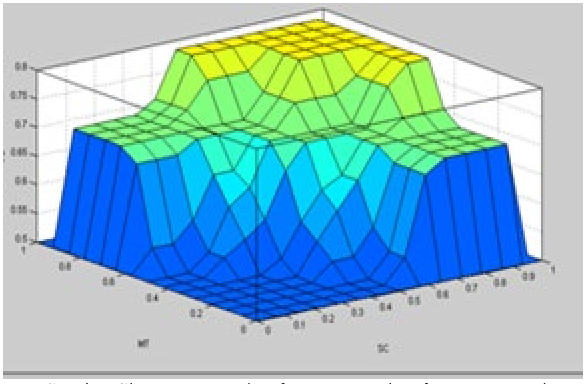


Fig 5c: Service Charge vs. Mode of Transportation for transportation cost

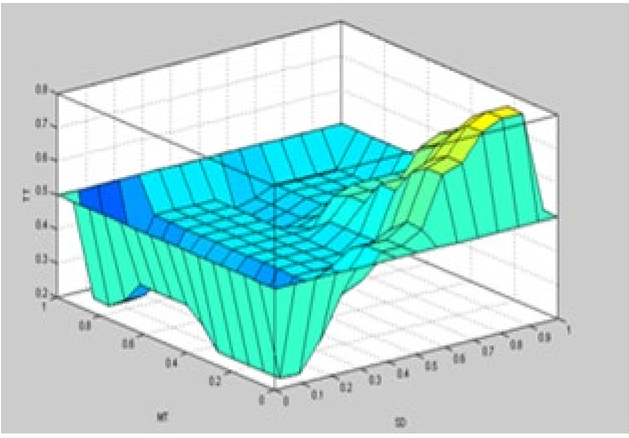


Fig 5d: Service Charge vs. Mode of Transportation for Transportation Time

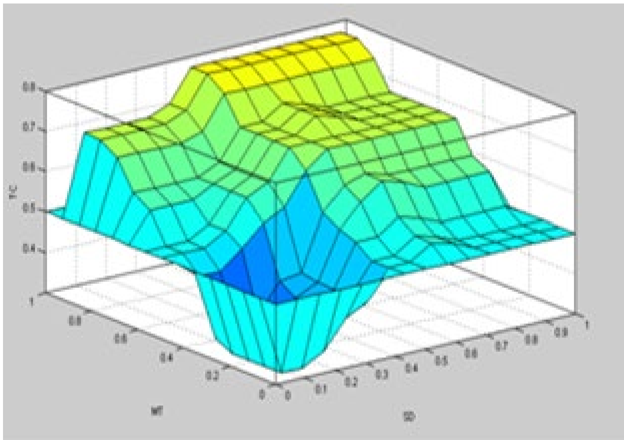


Fig 5e: Shipping distance vs. Mode of Transportation for transportation cost

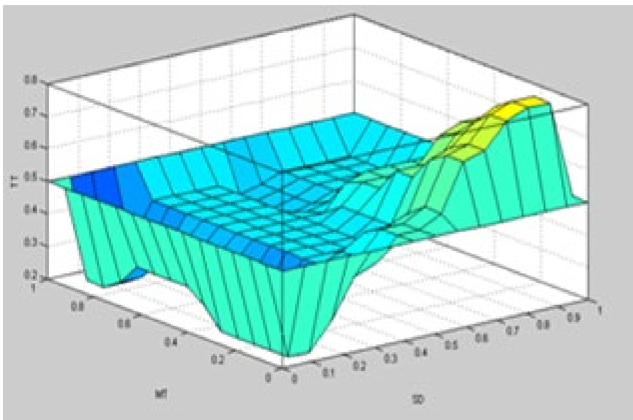


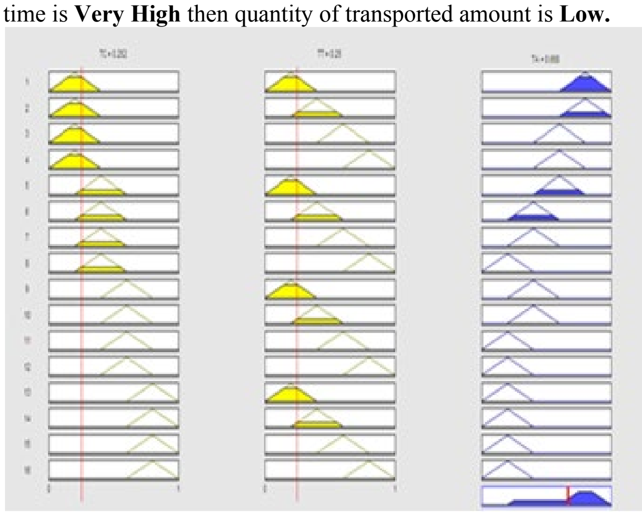
Fig 5f: Shipping distance vs. Mode of Transportation for transportation time

In next part, another set of 16 rules are framed manually by In next part, another set of 16 rules are framed manually by considering impact of both transportation cost and transportation time on quantity of transported amount (shown in Appendix B) as follows.

Rule 1: if transportation cost is **Low** and transportation time is **Low** then quantity of transported amount is **Very High.**

Rule 2: if transportation cost is **Low** and transportation time is **Medium** then quantity of transported amount is **Very High.**

Rule 16: if transportation cost is **Very High** and transportation time is **Very High** then quantity of transported amount is **Low.**



Analyzing the impact of first two objectives transportation cost and transportation time on third objective, quantity of transported amount it is observed that, there is an increase in quantity of transported amount with minimum transportation cost and less transportation time. The result is also revealed that high transportation cost and more transportation time, decreases the quantity of transported amount (See Fig 8). Hence, the quantity of transported amount is inversely proportional to both transportation cost and transportation time.

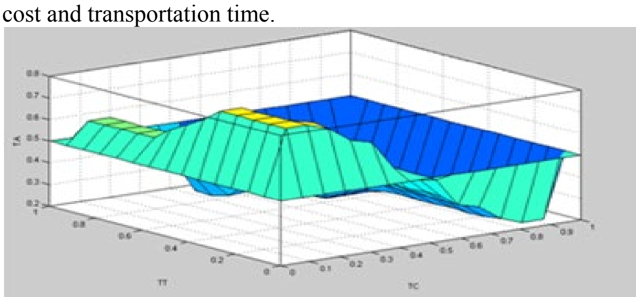


Fig 8: Transportation Cost vs. Transportation Time

4. Conclusion

In this study, a fuzzy rule based multi-objective transportation problem is formulated with multiple numbers of criteria. Initially different criteria like breakable items, shipping distance, service charge, mode of transportation etc are considered to analyze their effects on two objectives transportation cost and transportation time. In next phase, the impact of first two objectives on another objective, quantity of transported amount is analyzed and the result is discussed by using fuzzy inference systems.

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Appendix A

Rule base used for predicting outputs transportation cost and transportation time

Sl No.	BI	SD	SC	MT	TC	TT
1	Max	L	L	R	L	L
2	Max	L	L	T	L	L
3	Max	L	L	S	H	L
4	Max	L	L	F	H	L
5	Max	L	M	R	L	L
6	Max	L	M	T	M	L
7	Max	L	M	S	M	L
8	Max	L	M	F	H	L
9	Max	L	H	R	M	L
10	Max	L	H	T	M	L
11	Max	L	H	S	H	M
12	Max	L	H	F	VH	L
13	Max	L	VH	R	H	L
14	Max	L	VH	T	H	L
15	Max	L	VH	S	H	L
16	Max	L	VH	F	VH	L
17	Max	M	L	R	H	M
18	Max	M	L	T	H	L
19	Max	M	L	S	H	L
20	Max	M	L	F	H	L
21	Max	M	M	R	M	M
22	Max	M	M	T	H	L
23	Max	M	M	S	H	L
24	Max	M	M	F	VH	L
25	Max	M	H	R	H	H
26	Max	M	H	T	H	H
27	Max	M	H	S	VH	H
28	Max	M	H	F	VH	H
29	Max	M	VH	R	H	H
30	Max	M	VH	T	VH	L
31	Max	M	VH	S	VH	L
32	Max	M	VH	F	VH	L
33	Max	H	L	R	M	H
34	Max	H	L	T	M	M
35	Max	H	L	S	H	L
36	Max	H	L	F	VH	L
37	Max	H	M	R	H	H
38	Max	H	M	T	H	H
39	Max	H	M	S	VH	M
40	Max	H	M	F	VH	L
41	Max	H	H	R	H	H
42	Max	H	H	T	VH	M
43	Max	H	H	S	VH	M
44	Max	H	H	F	VH	M
45	Max	H	VH	R	VH	H

Appendix A

Rule base used for predicting outputs transportation cost and transportation time

Sl No.	BI	SD	SC	MT	TC	TT
46	Max	H	VH	T	VH	M
47	Max	H	VH	S	VH	M
48	Max	H	VH	F	VH	M
49	Max	VH	L	R	M	VH
50	Max	VH	L	T	M	H
51	Max	VH	L	S	H	M
52	Max	VH	L	F	H	L
53	Max	VH	M	R	M	VH
54	Max	VH	M	T	H	H
55	Max	VH	M	S	H	M
56	Max	VH	M	F	VH	L
57	Max	VH	H	R	H	VH
58	Max	VH	H	T	VH	H
59	Max	VH	H	S	VH	H
60	Max	VH	H	F	VH	H
61	Max	VH	VH	R	VH	VH
62	Max	VH	VH	T	VH	H
63	Max	VH	VH	S	VH	H
64	Max	VH	VH	F	VH	H
65	Min	L	L	R	L	L
66	Min	L	L	T	L	L
67	Min	L	L	S	M	L
68	Min	L	L	F	M	L
69	Min	L	M	R	L	L
70	Min	L	M	T	M	L
71	Min	L	M	S	M	L
72	Min	L	M	F	M	L
73	Min	L	H	R	M	L
74	Min	L	H	T	M	L
75	Min	L	H	S	H	L
76	Min	L	H	F	H	L
77	Min	L	VH	R	H	L
78	Min	L	VH	T	VH	L
79	Min	L	VH	S	VH	L
80	Min	L	VH	F	VH	L
81	Min	M	L	R	L	M
82	Min	M	L	T	L	M
83	Min	M	L	S	M	L
84	Min	M	L	F	M	L
85	Min	M	M	R	M	L
86	Min	M	M	T	M	L
87	Min	M	M	S	M	L
88	Min	M	M	F	H	L
89	Min	M	H	R	M	M
90	Min	M	H	T	H	M

Appendix A

Rule base used for predicting outputs transportation cost and transportation time

Sl No.	BI	SD	SC	MT	TC	TT
91	Min	M	H	S	H	L
92	Min	M	H	F	H	L
93	Min	M	VH	R	H	M
94	Min	M	VH	T	H	M
95	Min	M	VH	S	VH	L
96	Min	M	VH	F	VH	L
97	Min	H	L	R	M	H
98	Min	H	L	T	M	M
99	Min	H	L	S	H	M
100	Min	H	L	F	H	L
101	Min	H	M	R	M	H
102	Min	H	M	T	H	M
103	Min	H	M	S	H	M
104	Min	H	M	F	H	L
105	Min	H	H	R	H	H
106	Min	H	H	T	H	M
107	Min	H	H	S	VH	M
108	Min	H	H	F	VH	L
109	Min	H	VH	R	H	H
110	Min	H	VH	T	H	M
111	Min	H	VH	S	VH	M
112	Min	H	VH	F	VH	L
113	Min	VH	L	R	H	VH
114	Min	VH	L	T	H	H
115	Min	VH	L	S	VH	H
116	Min	VH	L	F	VH	M
117	Min	VH	M	R	H	VH
118	Min	VH	M	T	H	H
119	Min	VH	M	S	VH	H
120	Min	VH	M	F	VH	M
121	Min	VH	H	R	H	VH
122	Min	VH	H	T	VH	H
123	Min	VH	H	S	VH	H
124	Min	VH	H	F	VH	M
125	Min	VH	VH	R	VH	VH
126	Min	VH	VH	T	VH	H
127	Min	VH	VH	S	VH	H
128	Min	VH	VH	F	VH	M

Appendix B

Rule base for predicting the output parameter, transportated amount

Sl No.	TC	TT	TA
1	L	L	VH
2	L	M	VH
3	L	H	H
4	L	VH	H
5	M	L	H
6	M	M	M
7	M	H	M
8	M	VH	L
9	H	L	M
10	H	M	M
11	H	H	L
12	H	VH	L
13	VH	L	L
14	VH	M	L
15	VH	H	L
16	VH	VH	L