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A compromise method for solving fuzzy multi objective fixed charge transportation problem

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Abstract

The fixed charge transportation problem is a special case of the traditional fixed charge problem wherein other than the direct costs, a fixed charge is associated when a transportation activity takes place between a source and destination pair-which does not depend on the level of activity. This paper studies a particular form of this problem where there are multiple and conflicting objectives, and when the information provided by the decision maker regarding these fixed charges and the direct cost coefficients in the objective functions is imprecise.

Introduction

In a traditional transportation problem, products are to be transported from a given set of sources to a given set of destinations such that the demand at each destination is satisfied without exceeding the supply at any source. The decision on the amount of products to be transported is based on the objective of minimizing the total cost of transportation. The fixed charge transportation problem (FCTP) is a special case of the transportation problem wherein other than the variable cost which is proportional to the number of products transported, there is a fixed charge which is associated when a transportation activity takes place between a source and destination pair. The fixed charge problem was first formulated by Hirsch and Dantzig (1968), who observed that its optimal solution occurs at an extreme point of the constraint set. Balinski (1961) showed the FCTP to be a special class of the fixed charge problem and presented an approximate solution procedure.

In the real world transportation scenario, there may be multiple and conflicting objectives which need to be addressed simultaneously and are difficult to combine in one overall utility function. This leads us to formulate a multi objective fixed charge transportation problem, having different direct costs and fixed charges corresponding to each objective function of the problem. The optimal compromise solution of such a problem may be defined as the solution which is considered by the decision maker to be the closest to the ideal solution. Due to its compensatory nature and being a strongly monotonically increasing function, a modified form of the "fuzzy and" operator introduced by Werners (1988) is employed in our fuzzy programming approach. In practice, the parameters in the objective functions of the FCTP - namely the direct cost and the fixed cost - are supplied according to the decision makers' requirements. In most cases he/she is unable to provide this information precisely, and to deal with this imprecision we formulate these parameters as fuzzy numbers, in particular as triangular fuzzy numbers hence a leverage is provided to the decision maker to operate. In an earlier work, the general fuzzy multi objective fixed charge problem has been studied by the authors and they have recently developed a procedure for obtaining a compromise solution.

In this paper we intend to provide the required algorithm and a compromise solution for solving the multi objective fixed charge transportation problem with objective functions having fuzzy parameters.

Preliminaries

In this section, some fundamentals and basic notions of fuzzy numbers are reviewed. It is to be noted here that we are assuming both the fuzzy fixed cost coefficients and the fuzzy fixed charges to be triangular fuzzy numbers.

Definition 1. A fuzzy number $\tilde{A} = (a^o, a^m, a^p)$ is said to be a triangular fuzzy number if its membership function is defined as

$$\mu_{\tilde{A}}(x) = \begin{cases} 0 & ,x \le a^o \\ \dfrac{x - a^o}{a^m - a^o} & ,a^o \le x < a^m \\ \dfrac{a^p - x}{a^p - a^m} & ,a^m \le x < a^p \\ 0 & ,x \ge a^p \end{cases}$$

where a^m is the most possible value that definitely belongs to the set of most available values (possibility = 1, if normalized), and a^p (the most pessimistic value) and a^o (the most optimistic value) are the least possible values which have a very low likelihood of belonging to the set of available values.

Let us denote the set of fuzzy numbers by F(ℝ). Some basic arithmetic operations on triangular fuzzy numbers are as follows as given by Zimmermann (1978).

Let $\tilde{A} = (a, b, c),\ \tilde{B} = (x, y, z) \in F(\mathbb{R})$, then

i. Addition: $(\tilde{A} \oplus \tilde{B}) = (a + x, b + y, c + z)$
ii. Scalar Multiplication: $(k \otimes \tilde{A}) = \begin{cases} (ka, kb, kc), \text{if } k > 0 \\ (kc, kb, ka), \text{if } k < 0 \end{cases}$
iii. Multiplication: $(\tilde{A} \otimes \tilde{B}) = (\min\{ax, az, cx, cz\}, by, \max\{ax, az, cx, cz\})$
iv. Division: $(\tilde{A} \oslash \tilde{B}) = (\min\left\{\frac{a}{x}, \frac{a}{z}, \frac{c}{x}, \frac{c}{z}\right\}, b/y, \max\left\{\frac{a}{x}, \frac{a}{z}, \frac{c}{x}, \frac{c}{z}\right\})$
v. Non negativity: $\tilde{A}$ is said to be a non negative triangular fuzzy number if and only if $a \ge 0$.

Unlike the set of real numbers, F(ℝ) does not have any linear ordering defined on it; and as a result no two fuzzy numbers can be compared. To enable such a comparison, we introduce the concept of ranking functions.

Definition 2. A ranking function is a mapping $R: F(\mathbb{R}) \to \mathbb{R}$ which maps each fuzzy number into a point on the real line where a natural order exists. This ordering is defined as

$$\tilde{A} \succcurlyeq \tilde{B} \text{ if and only if } R(\tilde{A}) \ge R(\tilde{B}),$$
$$\tilde{A} \succ \tilde{B} \text{ if and only if } R(\tilde{A}) > R(\tilde{B}),$$
$$\tilde{A} \approx \tilde{B} \text{ if and only if } R(\tilde{A}) = R(\tilde{B}),$$

where $\tilde{A}, \tilde{B} \in F(\mathbb{R})$. Also we write $\tilde{A} \preccurlyeq \tilde{B}$ if and only if $\tilde{B} \succcurlyeq \tilde{A}$, and $\tilde{A} \prec \tilde{B}$ if and only if $\tilde{B} \succ \tilde{A}$. Note For computational purposes, we have used the linear ranking function

$$R(\tilde{A}) = 1/3(a + b + c), \text{for } \tilde{A} = (a, b, c) \in F(\mathbb{R}) \quad (1)$$

Problem formulation

We now develop the problem under consideration and define some related efficiency concepts.

Fuzzy multi objective FCTP

The FCTP can be seen as a distribution problem in which there are *m* suppliers (factories or warehouses) and *n* customers (demand points or destinations). Each of the suppliers can ship to any customer at a shipping cost c_{ij} per unit (this is the unit cost for shipping from supplier i to customer j) plus a fixed cost of f_{ij}, assumed for opening this route. Each supplier i has a_i units of supply and each customer j demands b_j units. The objective is to determine which routes are to be opened and the size of the shipment on these routes, so that the total cost of meeting demand - given the supply constraints - is minimized.

In the real world, there may exist cases when this problem has multiple objectives of conflicting nature which are to be optimized along with the cost. Our aim is to find the solution which is closest to the ideal solution of this multi objective program. Also, the shipping costs c_{ij} and the fixed costs f_{ij} are provided by the decision maker and due to technical and/or natural reasons he/she may be unable to provide this information precisely. To deal with this imprecision, we formulate these parameters in the form of triangular fuzzy numbers. Keeping these factors in mind, consider the multi objective fixed cost transportation problem with fuzzy cost coefficients and fuzzy fixed charges (F-MFTP) as follows

(F-MFTP) $\quad$ Min $\tilde{Z} = (\tilde{Z}_1, \tilde{Z}_2, \dots, \tilde{Z}_p)$

subject to $\quad \sum_{j=1}^{n} x_{ij} = a_i \,,\ i \in I = \{1,2,\dots,m\}$ (2)

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

$x_{ij} \geq 0$, for all $i \in I,\ j \in J$ (4)

where, $\tilde{Z}_k = \sum_{i=1}^{m} \sum_{j=1}^{n} (\tilde{c}_{ijk} x_{ij} + \tilde{f}_{ijk} y_{ij}),\ k \in K = \{1,2,\dots,p\}$ (5)

Here p is the number of objectives, $\tilde{c}_{ijk}$ is the kth fuzzy direct cost per unit and $\tilde{f}_{ijk}$ is the kth fuzzy fixed charge for transporting the goods from supply point i to demand point j for the objective k ($k \in K$), and

$$y_{ij} = \begin{cases} 0 & , \text{if } x_{ij} = 0 \\ 1 & , \text{if } x_{ij} > 0 \end{cases}$$

Without loss of generality, we assume that it is a balanced transportation problem. It is further assumed that the direct costs, fixed charges, supplies and demands are all non negative; i.e.$\tilde{c}_{ijk} \succcurlyeq 0$, $\tilde{f}_{ijk} \succcurlyeq 0$, $a_i \geq 0$, $b_j \geq 0$ ($i \in I$, $j \in J$, $k \in K$). Let us define the set of feasible solutions of F-MFTP as

$$S = \left\{ x = \{x_{ij}\} : \sum_{j=1}^{n} x_{ij} = a_i \,, \sum_{i=1}^{m} x_{ij} = b_j \,, x_{ij} \geq 0, i \in I, j \in J \right\}.$$

With the help of ranking functions and by extending the ordinary Pareto optimality definition, we define the concept of Pareto optimal solutions for the fuzzy F-MFTP.

Definition 3. A feasible solution $x^* = \{x_{ij}^*\} \in S$ is said to be an R-efficient (or Pareto optimal or non-dominated) solution of F-MFTP if and only if there exists no other $x \in S$ such that

$\tilde{Z}_k(x) \preccurlyeq \tilde{Z}_k(x^*)$ for all $k = 1,2,\dots,p$
and $\tilde{Z}_k(x) \prec \tilde{Z}_k(x^*)$ for at least one $k \in \{1,2,\dots,p\}$

i.e, x∗ is said to be an R-efficient solution of F-MFTP if and only if there exists no other x ∈ S such that

$R(\tilde{Z}_k(x)) \leq R(\tilde{Z}_k(x^*))$ for all $k = 1,2,\dots,p$
and $R(\tilde{Z}_k(x)) < R(\tilde{Z}_k(x^*))$ for at least one $k \in \{1,2,\dots,p\}$

where R is a linear ranking function.

The set of all Pareto optimal solutions E is called the complete solution of the problem. By our assumption, the fuzzy direct costs and the fuzzy fixed charges are defined in the form of triangular fuzzy numbers as

$\tilde{c}_{ijk} = (c_{ijk}^o, c_{ijk}^m, c_{ijk}^p)$ and $\tilde{f}_{ijk} = \left(f_{ijk}^o, f_{ijk}^m, f_{ijk}^p\right)$ for $i \in I, j \in J, k \in K$.

Then the fuzzy objectives $\tilde{Z}_k$ will also be defined as triangular fuzzy numbers for each $k \in K$ as follows

$$\tilde{Z}_k = \sum_i \sum_j \left(\left(c_{ijk}^o, c_{ijk}^m, c_{ijk}^p\right) x_{ij} + \left(f_{ijk}^o, f_{ijk}^m, f_{ijk}^p\right) y_{ij} \right)$$
$$= \left(\sum_i \sum_j \left(c_{ijk}^o x_{ij} + f_{ijk}^o y_{ij}\right), \sum_i \sum_j \left(c_{ijk}^m x_{ij} + f_{ijk}^m y_{ij}\right), \sum_i \sum_j \left(c_{ijk}^p x_{ij} + f_{ijk}^p\right) \right) = \left(Z_k^o, Z_k^m, Z_k^p\right)$$

By the nature of the chosen ranking function, where $R(\tilde{Z}_k) = \frac{1}{3}(Z_{k^o} + Z_k^m + Z_k^p)$, it is seen that in order to minimize $\tilde{Z}_k$ we must find the minimum value of $R(\tilde{Z}_k)$; which in turn can be obtained by minimizing each of the three components of the fuzzy number $\tilde{Z}_k$ simultaneously. It is easy to see that the smaller the values of the three components, the smaller will be the value of $R(\tilde{Z}_k)$ and the more preferred that solution will be. So based on the above discussion, we define the minimum of the fuzzy valued objective function $\tilde{Z}_k$ as

$$\text{Min } \tilde{Z}_k = \text{Min } (Z_k^o, Z_k^m, Z_k^p), \quad k \in K$$

An equivalent multicriteria fixed charge transportation problem (MFTP) is formulated below with three objectives corresponding to each $k \in K$.

(MFTP)

$$\min Z_{k1} = \min Z_k^o = \min \sum_i \sum_j \left(c_{ijk}^o x_{ij} + f_{ijk}^o y_{ij}\right) \quad (6)$$

$$\min Z_{k2} = \min Z_k^m = \min \sum_i \sum_j \left(c_{ijk}^m x_{ij} + f_{ijk}^m y_{ij}\right) \quad (7)$$

$$\min Z_{k3} = \min Z_k^p = \min \sum_i \sum_j \left(c_{ijk}^p x_{ij} + f_{ijk}^p y_{ij}\right) \quad (8)$$

subject to $x \in S$

This crisp MFTP and the original fuzzy F-MFTP are equivalent in the sense that there is a direct correspondence between the sets of Pareto optimal solutions of both these problems.

Fuzzy aggregation operators

Consider the multi objective problem

$$\min_{x \in X} z_k(x) \text{ for } k = 1,2,\ldots,p$$

An ideal solution of this problem is said to be obtained if by solving each objective function in isolation, the same optimal solution is attained. Due to the conflicting nature of the objective functions, this is a rare occurrence. So instead of trying to find an ideal solution, we try to find a compromise solution at which the degree of satisfaction of each objective function is maximum. We propose an interactive method to determine the preferred compromise solution of the multi objective problem.

In this paper, we make use of Werners' (1988) "fuzzy and" operator which has the properties of being strictly monotonic increasing in each component, is continuous and compensatory. Zimmermann (1980) indicts that this operator is a convex combination of the minimum operator and the arithmetic mean which in turn leads to very good results with respect to empirical data and allows compensation between the membership values of the aggregated sets. Werners' defined the "fuzzy and" operator as

$$\mu_{and}(x) = \gamma \ \min_i \mu_i(x) + (1-\gamma)\frac{1}{p}\sum_{i=1}^{p} \mu_i(x), \quad \text{with } \gamma \in [0,1]$$

where p is the total number of fuzzy objectives, $\mu_i(x)$ is the membership function of the fuzzy goal i, and γ is the coefficient of compensation defined within the interval [0,1]. It can also be seen that for $\gamma = 0$ and $\gamma = 1$, the "fuzzy and" operator reduces to the arithmetic mean and the "min" operator respectively. Thus, Werners' "fuzzy and" operator is used here to aggregate the multiple objectives of MFTP.

Fuzzy compromise programming

Consider the crisp multi objective MFTP

$$\min_{x \in S} Z_{kl}(x) \quad \text{for } k = 1,2,\ldots,p, l = 1,2,3$$

The membership functions for the 3p objectives of MFTP are defined as

$$\mu_{kl}(Z_{kl}) = \begin{cases} 1, & \text{if } Z_{kl} \le L_k \\ \dfrac{U_{kl} - Z_{kl}}{U_{kl} - L_{kl}}, & \text{if } L_{kl} < Z_{kl} < U_{kl} \\ 0, & \text{if } Z_{kl} \ge U_{kl} \end{cases}$$

where $U_{kl}$and L_{kl} can be viewed as the highest acceptable level and the aspired level of achievement for the objective Z_{kl} respectively. Aggregating all the fuzzy sets using Werners' "fuzzy and" operator, we obtain

$$\max_{x\in S} \quad \mu_{and} = \gamma \min_{k,l} \mu_{kl} + \frac{1-\gamma}{3p} \sum_{k,l} \mu_{kl}.$$

By adopting the "min" operator into the above equation, we obtain the following auxiliary problem as suggested by Kocken and Ahlatcioglu (2011):

$\max_{x\in S} \quad \lambda + \frac{1-\gamma}{3p} \sum_{k,l} \lambda_{kl}$
subject to
$\mu_{kl}(Z_{kl}) \ge \lambda + \lambda_{kl} \quad \forall k,l$
$\lambda, \lambda_{kl}, \gamma \in [0,1]$.

where $\lambda = \min_{k,l} \mu_{kl}(Z_{kl})$ denotes the minimum satisfaction degree of the objectives; λ_{kl} denotes the difference between the satisfaction degree of each objective and the minimum satisfaction degree of the objectives and γ is the coefficient of compensation.

To reflect the relative importance of each objective function Z_{kl}, positive weights w_{kl} are determined by the decision maker based on his/her preference such that $\sum_{k,l} w_{kl} = 1$.

On introducing these weights proposed by Selim and Ozkarahan (2008), the problem reduces to

(MLP) $\quad \max_{x\in S} \quad \lambda + (1-\gamma) \sum_{k=1}^{p} \sum_{l=1}^{3} w_{kl} \lambda_{kl}$
subject to $\mu_{kl}(Z_{kl}) \ge \lambda + \lambda_{kl} \quad \forall k,l$
$\lambda + \lambda_{kl} \le 1 \quad \forall k,l$
$\lambda, \lambda_{kl}, \gamma \in [0,1]$

Solving a fixed charge transportation problem

Consider a fixed charge transportation problem of the form

(TP) $\quad \min Z = \sum_{i=1}^{m} \sum_{j=1}^{n} (c_{ij} x_{ij} + f_{ij} y_{ij})$
subject to
$\sum_{j=1}^{n} x_{ij} = a_i$, $i \in I = \{1,2,\dots,m\}$
$\sum_{i=1}^{m} x_{ij} = b_j$, $j \in J = \{1,2,\dots,n\}$
$x_{ij} \ge 0$, for all $i \in I,\ j \in J$
$y_{ij} = \begin{cases} 0, & \text{if } x_{ij} = 0 \\ 1, & \text{if } x_{ij} > 0 \end{cases}$

It was observed by Balinski (1961) that this problem will always have integer solutions. Now consider the relaxed version of TP formed by ignoring the integral restrictions on y_{ij}.

(**$\overline{\text{TP}}$**) $\quad \min Z = \sum_{i=1}^{m} \sum_{j=1}^{n} (c_{ij} x_{ij} + f_{ij} y_{ij})$

subject to $\sum_{j=1}^{n} x_{ij} = a_i$, $i \in I = \{1,2, \dots , m\}$
$\sum_{i=1}^{m} x_{ij} = b_j$, $j \in J = \{1,2, \dots , n\}$
$0 \leq x_{ij} \leq m_{ij}y_{ij}$, for all $i \in I,\ j \in J$
$0 \leq y_{ij} \leq 1$, for all $i \in I,\ j \in J$
where $m_{ij} = \min(a_i, b_j)$

It has further been shown that there exists an optimal solution to $\overline{\text{TP}}$ with the property that $x_{ij} = m_{ij}y_{ij}$. Then, on substituting x_{ij}/m_{ij} for y_{ij} in $\overline{\text{TP}}$, an equivalent program TP' is formulated as

(**TP′**) $\min Z = \sum_{i=1}^{m}\sum_{j=1}^{n}(c_{ij} + f_{ij}/m_{ij})\, x_{ij}$
subject to $\sum_{j=1}^{n} x_{ij} = a_i$, $i \in I = \{1,2, \dots , m\}$
$\sum_{i=1}^{m} x_{ij} = b_j$, $j \in J = \{1,2, \dots , n\}$
$x_{ij} \geq 0$, for all $i \in I,\ j \in J$

which is a standard transportation problem. An integer solution $x_{ij}{}'$ to TP' in turn results in a feasible solution (x_{ij}^*, y_{ij}^*) to TP where,

$x_{ij}^* = y_{ij}^* = 0$, if $x_{ij}{}' = 0$
and $x_{ij}^* = x_{ij}{}', y_{ij}^* = 1$, if $x_{ij}{}' > 0$

Now let (x_{ij}^o, y_{ij}^o) be an optimal solution to TP, $(\bar{x}_{ij}, \bar{y}_{ij})$ be optimal for $\overline{\text{TP}}$ and $x_{ij}{}'$ be optimal for TP', then we can derive an upper bound and lower bound on the optimal value of TP as

$$Z(x') = Z(\bar{x}, \bar{y}) \leq Z(x^0, y^0) \leq Z(x^*, y^*).$$

Balinski (1961) claimed that under fairly general conditions, one might expect (x_{ij}^*, y_{ij}^*) to be a reasonably good estimate and possibly an optimal solution to TP. This approximate solution (x_{ij}^*, y_{ij}^*) is used to compute the bounds on each objective function Z_{kl} of MFTP.

Solution procedure

Step 1. Consider the given multi objective fuzzy fixed charge transportation problem F-MFTP. Using the linear ranking function corresponding to each fuzzy objective function $\tilde{Z}_k$, transform this problem into a crisp multi objective fixed charge transportation problem MFTP, which is then solved by the fuzzy programming technique.
Step 2. In order to compute the bounds U_{kl} and L_{kl} of each crisp objective function Z_{kl}, solve the single objective fixed charge problems taking one objective at a time according to Balinski's algorithm. Formulate the equivalent program TP' obtained by substituting x_{ij}/m_{ij} for y_{ij} subject to the constraints $x \in S$.
Step 3. Let X_{kl} be the optimal solution corresponding to the single objective problem with objective function Z_{kl}. If the decision maker selects one of them as a preferred compromise solution, go to Step 6. Else, the bounds
$U_{kl} = \max\{Z_{kl}(X_{11}), Z_{kl}(X_{12}), Z_{kl}(X_{13}), \dots , Z_{kl}(X_{p3})\}$, and
$L_{kl} = \min\{Z_{kl}(X_{11}), Z_{kl}(X_{12}), Z_{kl}(X_{13}), \dots , Z_{kl}(X_{p3})\}, k = 1, \dots , p,\ \ l = 1,2,3$
define the membership function of each objective.
Step 4. Fix the value of the coefficient of compensation initially as $\gamma = 0.1$, and based on the weights provided by the decision maker, formulate the auxiliary mixed integer problem MLP.
Step 5. Using LINGO9, obtain the optimal solution (x^*, λ^*) and the corresponding compromise solution x^* of F-MFTP and present it to the decision maker. If the decision maker accepts it, go to Step 6. Otherwise, modify the coefficient of compensation γ according to his/her preferences and go to Step 4.
Step 6. The preferred compromise solution of MFTP and hence of the original fuzzy problem F-MFTP is given by x^*.

Numerical Illustration

Consider the multi objective fuzzy fixed charge transportation problem F-MFTP

(F-MFTP) Min $\tilde{Z} = (\tilde{Z}_1, \tilde{Z}_2)$

subject to

$$x_{11} + x_{12} + x_{13} = 80 \quad (9)$$
$$x_{21} + x_{22} + x_{23} = 30 \quad (10)$$
$$x_{11} + x_{21} = 40 \quad (11)$$
$$x_{12} + x_{22} = 50 \quad (12)$$
$$x_{13} + x_{23} = 20 \quad (13)$$
$$x_{ij} \geq 0 \text{ , } i = 1,2, \; j = 1,2,3 \quad (14)$$
$$y_{ij} = \begin{cases} 0 & \text{, if } x_{ij} = 0 \\ 1 & \text{, if } x_{ij} > 0 \end{cases} \quad (15)$$

where, $\tilde{Z}_k = \sum_{i=1}^{2}\sum_{j=1}^{3}(\tilde{c}_{ijk}x_{ij} + \tilde{f}_{ijk}y_{ij}), \; k \in K = \{1,2\}$.

The direct costs $\tilde{c}_{ijk}$ and the fixed charges $\tilde{f}_{ijk}$ for the two objectives $\tilde{Z}_1$ and $\tilde{Z}_2$ are given below

$$\tilde{c}_{ij1} = \begin{bmatrix} (7,8,9) & (1,5,11) & (1,3,5) \\ (3,6,7) & (4,8,15) & (1,4,9) \end{bmatrix}$$
$$\tilde{c}_{ij2} = \begin{bmatrix} (2,4,6) & (3,7,10) & (7,9,12) \\ (3,7,8) & (6,9,14) & (6,9,11) \end{bmatrix}$$
$$\tilde{f}_{ij1} = \begin{bmatrix} (20,22,27) & (24,25,26) & (21,23,25) \\ (19,21,28) & (20,27,29) & (25,26,27) \end{bmatrix}$$
$$\tilde{f}_{ij2} = \begin{bmatrix} (20,22,28) & (23,25,26) & (18,20,22) \\ (16,18,25) & (15,15,18) & (20,21,24) \end{bmatrix}$$

Using LINGO9, the optimal solution is $\lambda^* = 0.29$, $X^* = (30, 50, 0, 10, 0, 20)$ and $Z_{11}^* = 373$, $Z_{12}^* = 724$, $Z_{13}^* = 1178$, $Z_{21}^* = 439$, $Z_{22}^* = 746$, $Z_{23}^* = 1083$. The fuzzy objective function value of F-MFTP corresponding to the compromise solution X^* is $Z_1^* = (373, 724, 1178)$ and $Z_2^* = (439, 746, 1083)$. If the decision maker does not accept this compromise solution, modify the coefficient of compensation γ according to his preference.

Conclusion

In this paper we have obtained an interactive solution procedure for solving the multi objective fixed charge transportation problem with objective functions having fuzzy parameters. Instead of providing the decision maker with a set of efficient solutions; based on his preferences, we have provided an optimal compromise solution which is closest to the ideal solution. A modified form of Werners' "fuzzy and" operator developed here ensures that this solution maximizes the level of satisfaction of the decision maker. In future, we intend to look into the complexity and performance of this algorithm in terms of the processing time. Also, by making use of other ranking functions we wish to compare their subsequent effect on the R-efficient solutions thus obtained.

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