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A New Method for Solving Bi-Objective Transportation Problems

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Abstract: A new method namely, dripping method is proposed for finding a set of efficient solutions to a bi-objective transportation problem which differs from all existing methods. The percentage level of satisfaction of a solution for a transportation problem is introduced. An illustrative example is presented to clarify the idea of the proposed approach. The dripping method can be served as an important tool for the decision makers to obtain efficient solutions, according to their level of satisfaction on the objective functions when they are handling various types of logistic problems involving two objectives.

Key words: Bi-objective transportation problem, level of satisfaction, dripping method, efficient solution.

INTRODUCTION

Transportation problem (TP) nourishes economic and social activity and is cardinal to operations research and management science. In the classical TP of linear programming, the traditional objective is one of minimizing the total cost. In general, the real life problems are modeled with multi-objectives which are measured in different scales and at the same time in conflict. In actual TP's, the multi-objective functions are generally considered, which includes average delivery time of the commodities, reliability of transportation, product deterioration and so on. The bi-criteria TP is the basis in processing multi-objective TP, which had been proposed by Aneja and Nair, (1979). Isermann, (1979) introduced an algorithm for solving linear multiple-objective TP, which provides effective solutions. Ringuest and Rinks, (1987) have made a mention of the existing solution procedures for the multiobjective TP. Bit *et al*., (1992) have shown the application of fuzzy programming to multicriteria decision making classical TP. Yang and Gen, (1994) have proposed an approach called evolution program for bi-criteria TP. Gen *et al*., (1998) introduced a hybrid genetic algorithm for solving bi-criteria TP. Waiel F. Abd El-Wahed, (2001) developed a fuzzy programming approach to determine the optimal compromise solution of a multi-objective TP. Bodkhe *et al*., (2010) used the fuzzy programming technique with hyperbolic membership function to solve a bi-objective TP as vector minimum problem. Pandian and Natarajan, (2010) have introduced the zero point method for finding an optimal solution to a classical TP without using any optimality checking methods.

In this paper, we propose a new method namely, dripping method for finding the set of efficient solutions to bi-objective transportation problem. In the proposed method, we can identify next solution to the problem from the current solution which differs from utility function method, goal programming approach, fuzzy programming technique, genetic approach and evolutionary approach. The percentage level of satisfaction of a solution of the bi-objective problem is introduced. The dripping method is illustrated with help of a numerical example. This new approach enables the decision makers to evaluate the economical activities and make self satisfied managerial decisions when they are handling a variety of logistic problems involving two objectives.

2 Bi-objective Transportation Problem:

Consider the following bi-objective transportation problem (BTP):

(P) Minimize $Z_1 = \sum_{i=1}^{m}\sum_{j=1}^{n} c_{ij}x_{ij}$

Minimize $Z_2 = \sum_{i=1}^{m}\sum_{j=1}^{n} d_{ij}x_{ij}$

subject to

$$\sum_{j=1}^{n} x_{ij} = a_i\ , \quad for \quad i = 1,2,...,m \tag{2.1}$$

$$\sum_{i=1}^{m} x_{ij} = b_j\ , \quad for \quad j = 1,2,...,n \tag{2.2}$$

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$x_{ij} \geq 0$, for all i and j and are integers (2.3)

where a_i is the amount of the material available at ith source; b_j is the amount of the material required at jth destination; c_{ij} is the cost of transporting a unit from ith source to jth destination; d_{ij} is the deterioration of a unit while transporting from ith source to jth destination; x_{ij} is the amount transported from ith source to jth destination.

Definition 2.1:

A set $X^{\circ} = \{x_{ij}^{\circ}, i = 1,2,...,m;\ j = 1,2,...n\}$ is said to be feasible to the problem (P) if X° satisfies the conditions (2.1) to (2.3).

Definition 2.2:

A feasible solution X° is said to be an efficient solution to the problem (P) if there exists no other feasible X of BTP such that $Z_1(X) \leq Z_1(X^{\circ})$ and $Z_2(X) < Z_2(X^{\circ})$ or $Z_2(X) \leq Z_2(X^{\circ})$ and $Z_1(X) < Z_1(X^{\circ})$. Otherwise, it is called non-efficient solution to the problem (P).

For simplicity, a pair $(Z_1(X^{\circ}), Z_2(X^{\circ}))$ is called an efficient / a non-efficient solution to the problem (P) if X° is efficient / non-efficient solution to the problem (P).

We introduce the following new concept namely, percentage satisfaction level of the objective at a solution to a transportation problem for identifying the level of a solution from its optimal solution.

Definition 2.3:

The percentage satisfaction level of the objective at a solution, U to a transportation problem is defined as follows.

Percentage Satisfaction Level of the objective at $U = \left(1 - \frac{(O(U) - O_o)}{O_o}\right) \times 100$

$$= \left(\frac{(2O_o - O(U))}{O_o}\right) \times 100$$

where $O(U)$ is the objective value at the solution U and O_0 is the optimal objective value of the transportation problem.

Now, we need the following theorem which is used in the proposed method .

Theorem 2.1:

Let $X^{\circ} = \{x_{ij}^{\circ}, i = 1,2,...,m;\ j = 1,2,...,n\}$ be an optimal solution to (P_1) where

(P_1) Minimize $Z_1 = \sum_{i=1}^{m} \sum_{j=1}^{n} c_{ij} x_{ij}$

subject to (2.1), (2.2) and (2.3) .

and $Y^{\circ} = \{y_{ij}^{\circ}, i = 1,2,...,m;\ j = 1,2,...n\}$ be an optimal solution to (P_2) where

(P_2) Minimize $Z_2 = \sum_{i=1}^{m} \sum_{j=1}^{n} d_{ij} x_{ij}$

subject to (2.1), (2.2) and (2.3) .

Then, $U^{\circ} = \{u_{ij}^{\circ}, i = 1,2,...,m;\ j = 1,2,...n\}$ which is obtained from $X^{\circ} = \{x_{ij}^{\circ}, i = 1,2,...,m;\ j = 1,2,...,n\}$ or $Y^{\circ} = \{y_{ij}^{\circ}, i = 1,2,...,m;\ j = 1,2,...n\}$, is an efficient / non efficient solution to the problem (P).

Proof:

Now, since $X^{\circ} = \{x_{ij}^{\circ}, i = 1,2,...,m;\ j = 1,2,...n\}$ is an optimal solution of (P_1), $X^{\circ} = \{x_{ij}^{\circ}, i = 1,2,...,m;\ j = 1,2,...n\}$ is a feasible solution of (P_2).

Clearly, $X^{\circ} = \{x_{ij}^{\circ}, i = 1,2,..., m; j = 1,2,...n\}$ is an efficient solution to the problem (P) which is trivial. Let us choose the allocated cell (t, r) with maximum d_{ij} in (P_2).

Now, we float a quantity from the allocated cell (t, r) cell to the lowest cost cell through a closed loop so that total deterioration cost is minimum.

Construct a rectangular loop ABCDA where AC are in the rth column and BD are in the sth column such that A is the (t, r) allocated cell, D is the (p, s) allocated cell, C is the (p, r) cell, and B is the (t, s) unallocated cell with minimum deterioration cost.

Let θ = Min{ $x_{tr}^{\circ}, x_{ps}^{\circ}$ }.

We flow the quantity λ where $1 \le \lambda \le \theta$ through the closed loop ABCDA. First, allocate λ unit to the unallocated cell (t, s) and subtract λ unit to the allocated cells (t, r) and (p, s) and also add λ unit to the cell (p, r). Then, we obtain a new allotment for A, B, C and D are v_{tr}°, v_{ts}°, v_{pr}° and v_{ps}°. Thus, we have the following feasible solution $U^{\circ} = \{u_{ij}^{\circ}, i = 1,2,..., m; j = 1,2,...n\}$ to (P_1) and (P_2) where

$$u_{ij}^{\circ} = \begin{cases} x_{ij}^{\circ} & if\ i \ne t, p\ and\ j \ne r, s \\ v_{ij}^{\circ} & if\ i = t, p\ and\ j = r, s \end{cases}$$

which is better than $X^{\circ} = \{x_{ij}^{\circ}, i = 1,2,..., m; j = 1,2,...n\}$ for the problem (P_2). Thus $U^{\circ} = \{u_{ij}^{\circ}, i = 1,2,..., m; j = 1,2,...n\}$ is an efficient / a non-efficient solution to the problem (P).

Similarly, we can also obtain an efficient solution to the problem (P) from the optimal solution $Y^{\circ} = \{y_{ij}^{\circ}, i = 1,2,..., n; j = 1,2,..., m\}$ of (P_2) by repeating the same procedure.

Hence the theorem.

Remark 2.1:

For each λ, $1 \le \lambda \le \theta$, we obtain a solution to the problem (P) which is an efficient / a non-efficient solution to the problem (P). Thus, we can obtain atmost θ different solutions to the problem (P) using the above procedure.

Remark 2.2:

The above solution procedure will terminate if the improved solution of (P_1) obtained from an optimal solution of (P_2) is an optimal one or the improved solution of (P_2) obtained from an optimal solution of (P_1) is an optimal one.

Remark 2.3:

If the loop cannot be formed for the highest cost, then we move to the next highest cost so as to construct a loop. If such a loop is not possible, the procedure can not be applied to the problem. This indicates that the current solution is an optimal solution to the problem.

3 Dripping Method:

We now propose a new method namely, dripping method for finding all the solutions to the bi-objective transportation problem (P).

The dripping method proceeds as follows:

Step 1:

Construct two individual problems of the given BTP namely, first objective transportation problem (FOTP) and second objective transportation problem (SOTP).

Step 2:

Obtain an optimal solutions to the problems FOTP and SOTP by the zero point method.

Step 3:

Start with an optimal solution of FOTP in the SOTP as a feasible solution which is an efficient solution to BTP.

Step 4:

Select the allocated cell (t,r) with the maximum penalty in the SOTP. Then, construct a rectangular loop that starts and ends at the allocated cell (t,r) and connect some of the unallocated and allocated cells.

Step 5:

Add and subtract λ to and from the transition cells of the loop in such a way that the rim requirements remain satisfied and assign a sequence of values to λ one by one in such a way that the allocated cell remains non-negative. Then, obtain a feasible solution to SOTP for each value of λ which is also an efficient / a non-efficient solution to BTP by the Theorem 2.1 .

Step 6:

Check whether the feasible solution to SOTP obtained from the step 5. is the optimum solution. If not, repeat the Steps 4 and 5 until an optimum solution to SOTP is found. If so, the process can be stopped and movement to the next step can be made.

Step 7:

Start with an optimal solution of the SOTP in the FOTP as a feasible solution which is an efficient/ non-efficient solution to BTP.

Step 8:

Repeat the steps 4, 5 and 6 for the FOTP.

Step 9:

Combine all solutions (efficient / non efficient) of BTP obtained using the optimal solutions of FOTP and SOTP. From this, a set of efficient solutions and a set of non-efficient solutions to the BTP can be obtained.

4 Numerical Example:

The proposed method namely, dripping method for solving a BTP is illustrated by the following example.

Example:

Consider a transportation model of a company involving three factories, denoted by F_1, F_2 and F_3, and four warehouses, denoted by W_1, W_2, W_3 and W_4. A particular product is transported from the ith factory to the jth warehouse. Assume there are two objectives under consideration: (i) the minimization of total transportation cost consumed in transportation, and (ii) the minimization of total product deterioration during transportation. The cost of the transportation of a product and the deterioration cost of a product during transportation are given in the following table.

	Warehouses *j*				Supply
	W_1	W_2	W_3	W_4	
F_1	(1,4)	(2,4)	(7,3)	(7,4)	8
Factory *i*, F_2	(1,5)	(9,8)	(3,9)	(4,10)	19
F_3	(8,6)	(9,2)	(4,5)	(6,1)	17
Demand	11	3	14	16	

The goal is to locate the set of all solutions for the bi-objective transportation problem.

Now, the FOTP of BTP is given below:

	Warehouses *j*				Supply
	W_1	W_2	W_3	W_4	
F_1	1	2	7	7	8
Factory *i*, F_2	1	9	3	4	19
F_3	8	9	4	6	17
Demand	11	3	14	16	

Now, using the zero point method, the optimal solution to the FOTP is $x_{11} = 5$, $x_{12} = 3$, $x_{21} = 6$, $x_{24} = 13$, $x_{33} = 14$, $x_{34} = 3$ and also, the minimum transportation cost is 143.

Now, the SOTP of BTP is given below:

	Warehouses *j* W$_1$	W$_2$	W$_3$	W$_4$	Supply
F$_1$	4	4	3	4	8
Factory *i*, F$_2$	5	8	9	10	19
F$_3$	6	2	5	1	17
Demand	11	3	14	16	

Now, using the zero point method, the optimal solution to the SOTP is $x_{13} = 8$, $x_{21} = 11$, $x_{22} = 2$, $x_{23} = 6$, $x_{32} = 1$, $x_{34} = 16$ and also, the minimum deterioration cost is 167.

Now, as in Step 3, we consider the optimal solution of the FOTP in the SOTP as a feasible solution in the following table.

	Warehouses *j* W$_1$	W$_2$	W$_3$	W$_4$	Supply
F$_1$	4 (5)	4 (3)	3	4	8
Factory *i*, F$_2$	5 (6)	8	9	10 (13)	19
F$_3$	6	2	5 (14)	1 (3)	17
Demand	11	3	14	16	

Thus, (143,265) is the bi-objective value of BTP for the feasible solution $x_{11} = 5$, $x_{12} = 3$, $x_{21} = 6$, $x_{24} = 13$, $x_{33} = 14$ and $x_{34} = 3$.

According to Step 4, we construct a rectangular loop $(2,4)-(2,3)-(3,3)-(3,4)-(2,4)$. By using the Step 5, we have the following reduced table.

	Warehouses *j* W$_1$	W$_2$	W$_3$	W$_4$	Supply
F$_1$	4 (5)	4 (3)	3	4	8
Factory *i*, F$_2$	5 (6)	8	9 (λ)	10 (13- λ)	19
F$_3$	6	2	5 (14- λ)	1 (3+ λ)	17
Demand	11	3	14	16	

Now, for any value $\lambda \in \{1,2,....,13\}$, the deterioration cost of SOTP is $265-5\lambda$ and the transportation cost of FOTP is $143+\lambda$. Thus, $(143+\lambda, 265-5\lambda)$ is the bi-objective value of BTP for the feasible solution $x_{11} = 5$, $x_{12} = 3$, $x_{21} = 6$, $x_{23} = \lambda$, $x_{24} = 13-\lambda$, $x_{33} = 14-\lambda$ and $x_{34} = 3+\lambda$. For the maximum value of λ, that is λ =13, the deterioration cost of SOTP is 200 and FOTP is 156. Thus, (156, 200) is the bi-objective value of BTP for the feasible solution $x_{11} = 5$, $x_{12} = 3$, $x_{21} = 6$, $x_{23} = 13$, $x_{33} = 1$ and $x_{34} = 16$.

Now, the current solution to SOTP is not an optimum solution. While repeating Step 4 and Step 5, we have the following feasible solution which is better than the prior feasible solution of SOTP.

	Warehouses *j* W$_1$	W$_2$	W$_3$	W$_4$	Supply
F$_1$	4 (5- λ)	4 (3)	3 (λ)	4	8
Factory *i*, F$_2$	5 (6+ λ)	8	9 (13 - λ)	10	19
F$_3$	6	2	5 (1)	1 (16)	17
Demand	11	3	14	16	

Now, for any value $\lambda \in \{1,...,5\}$, the deterioration cost of SOTP is $200-5\lambda$ and FOTP is $156+4\lambda$. Thus, $(156+4\lambda, 200-5\lambda)$ is the bi-objective value of BTP for the feasible solution $x_{11} = 5-\lambda$, $x_{12} = 3$, $x_{13} = \lambda$, $x_{21} = 6+\lambda$, $x_{23} = 13-\lambda$, $x_{33} = 1$ and $x_{34} = 16$. For the maximum value of λ, that is λ =5, the deterioration cost of SOTP is 175 and FOTP is 176. Thus, (176, 175) is the bi-objective value of BTP for the feasible solution $x_{12} = 3$, $x_{13} = 5$, $x_{21} = 11$, $x_{23} = 8$, $x_{33} = 1$ and $x_{34} = 16$.

Now, the current solution to SOTP is not the optimum solution. Repetition of Step 4 and 5 results in the following feasible solution which is better than the prior feasible solution of SOTP.

	Warehouses *j*				Supply
	W_1	W_2	W_3	W_4	
F_1	4	4 (3- λ)	3 (5+ λ)	4	8
Factory *i*, F_2	5 (11)	8 (λ)	9 (8 - λ)	10	19
F_3	6	2	5 (1)	1 (16)	17
Demand	11	3	14	16	

Now, for any value $\lambda \in \{1,2,3\}$, the deterioration cost of SOTP is $175-2\lambda$ and FOTP is $175+11\lambda$. Thus, $(176+11\lambda, 175-2\lambda)$ is the bi-objective value of BTP for the feasible solution $x_{12}=3-\lambda$, $x_{13}=5+\lambda$, $x_{21}=11$, $x_{22}=\lambda$, $x_{23}=8-\lambda$, $x_{33}=1$ and $x_{34}=16$. For the maximum value of λ, that is λ =3, the deterioration cost of SOTP is 169 and FOTP is 209. Thus, (209, 169) is the bi-objective value of BTP for the feasible solution $x_{13}=8$, $x_{21}=11$, $x_{22}=3$, $x_{23}=5$, $x_{33}=1$ and $x_{34}=16$.

Now, the current solution to SOTP is not the optimum solution of SOTP. Repeating Step 4 and Step 5, we have the following feasible solution which is better than the current feasible solution of SOTP.

	Warehouses *j*				Supply
	W_1	W_2	W_3	W_4	
F_1	4	4	3 (8)	4	8
Factory *i*, F_2	5 (11)	8 (3- λ)	9 (5+ λ)	10	19
F_3	6	2 (λ)	5 (1- λ)	1 (16)	17
Demand	11	3	14	16	

Now, since the maximum value of λ =1, the deterioration cost of SOTP is 167 and FOTP is 208. Thus, (208, 167) is the bi-objective value of BTP for the feasible solution $x_{13}=8$, $x_{21}=11$, $x_{22}=2$, $x_{23}=6$, $x_{33}=1$ and $x_{34}=16$.

Now, since 167 is the optimal value for the SOTP, we stop the computations.

Therefore, the set of all solutions S_1 of the BTP obtained from FOTP to SOTP is
{(143,265), (144,260), (145,255), (146,250), (147,245), (148,240), (149,235), (150,230), (151,225), (152,220), (153,215), (154,210), (155,205), (156,200), (160,195), (164,190), (168,185), (172,180), (176,175), (187,173), (198,171), (209,169) and (167,208) }.

Similarly, by using Steps 7 and 8, we obtain the set of all solutions S_2 from SOTP to FOTP is given below:

Iteration	λ	Solution of BTP	Bi-objective value
1	{1,2}	$x_{12}=\lambda$, $x_{13}=8-\lambda$, $x_{21}=11$, $x_{22}=2-\lambda$, $x_{23}=6+\lambda$, $x_{32}=1$, $x_{34}=16$.	$(208-11\lambda, 167+2\lambda)$
2	{1}	$x_{12}=2+\lambda$, $x_{13}=6-\lambda$, $x_{21}=11$, $x_{23}=8$, $x_{32}=1-\lambda$, $x_{33}=\lambda$, $x_{34}=16$.	(176, 175)
3	{1,...,5}	$x_{11}=\lambda$, $x_{12}=3$, $x_{13}=5-\lambda$, $x_{21}=11-\lambda$, $x_{23}=8+\lambda$, $x_{33}=1$, $x_{34}=16$.	$(176-4\lambda, 175+5\lambda)$
4	{1,...,13}	$x_{11}=5$, $x_{12}=3$, $x_{21}=6$, $x_{23}=13-\lambda$, $x_{24}=\lambda$, $x_{33}=1+\lambda$, $x_{34}=16-\lambda$	$(156-\lambda, 200+5\lambda)$

Therefore, the set of all solutions S_2 of the BTP obtained from SOTP to FOTP is
{(208,167), (197,169), (186,171), (176,175), (172,180), (168,185), (164,190), (160,195), (156,200), (155,205), (154,210), (153,215), (152,220), (151,225), (150,230), (149,235), (148,240), (147,245), (146,250), (145,255), (144,260), (143,265)}.

Now the set of all solutions S of the BTP obtained from FOTP to SOTP and from SOTP to FOTP is given below:

$S = S_1 \bigcup S_2$
$= \{(143,265), (144,260), (145,255), (146,250), (147,245), (148,240), (149,235), (150,230), (151,225), (152,220), (153,215), (154,210), (155,205), (156,200), (160,195), (164,190), (168,185), (172,180), (176,175), (186,171), (187,173), (197,169), (198,171), (209,169), (208,167) \}.$

Graphical Representation Of Bi-Objective Values Of BTP

From the Figure 1, we see that the proposed approach can find the set of efficient solutions not only those produced by Aneja, Bit *et al*. , Cohen *et al*. , Yang, but also new efficient / non efficient solutions. In Bit *et al*. (1992), it is claimed that the point (160,195) is nearer to the ideal solution point (143,167) than the point (156,200) obtained by Aneja's algorithm. In Yang (1994) applying the evoloution program to this example, the solution which is nearer to the ideal solution is the point (168,185). It is much closer than the point (160,195). Hence, (168,185) is the optimal compromise solution. Using the above proposed method, we also obtain the best optimal compromise solution to this example as (168,185) which is as same as in Yang.

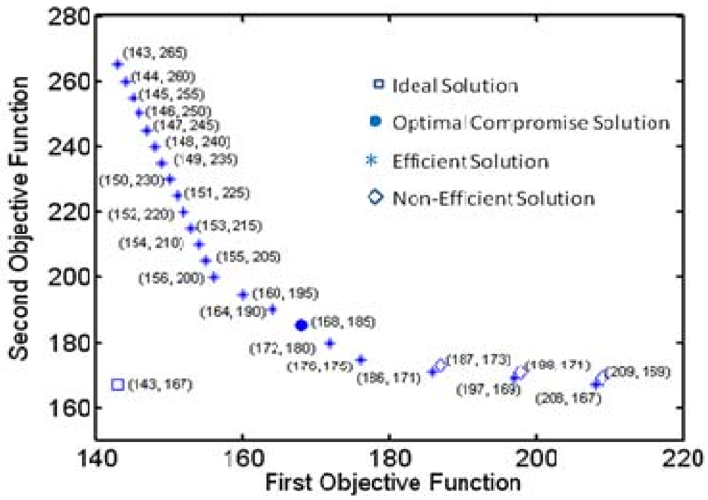

Fig. 1: The solutions obtained by the dripping method.

The following table shows the satisfaction level of objectives of the problem at each efficient solution.

Sl. No.	Bi-objective value of BTP	Satisfaction level	
		Objective of FOTP	Objective of SOTP
1	(143,265)	100	41.3
2	(144,260)	99.30	44.31
3	(145,255)	98.60	47.31
4	(146,250)	97.90	50.30
5	(147,245)	97.20	53.29
6	(148,240)	96.50	56.29
7	(149,235)	95.80	59.28
8	(150,230)	95.10	62.28
9	(151,225)	94.41	65.27
10	(152,220)	93.71	68.26
11	(153,215)	93.01	71.26
12	(154,210)	92.31	74.25
13	(155,205)	91.61	77.25
14	(156,200)	90.91	80.24
15	(160,195)	88.11	83.23
16	(164,190)	85.31	86.23
17	(168,185)	82.52	89.22
18	(172,180)	79.72	92.22
19	(176,175)	76.92	95.21
20	(186,171)	69.93	97.60
21	(197,169)	62.24	98.80
22	(208,167)	54.55	100

The above satisfaction level table is very much useful for the decision makers to select the appropriate efficient solutions to bi-objective transportation problems according to their level of satisfaction of objectives.

Conclusion:

In this paper, the proposed method provides the set of efficient solutions for bi-objective transportation problems. Here the two objectives are inherently taken care of at each iteration and the pairs recorded at any step identify the next efficient pair, thus providing a direction of movement without making use of any utility function, goal programming approach and any fuzzy programming technique. This method enables the decision makers to select an appropriate solution, depending on their financial position and also, their level of satisfaction of objectives.

REFERENCES

Aneja, Y.P., K.P.K. Nair, 1979. Bi-criteria transportation problem, Management Science, 21: 73-78.

Bit, A.K., M.P. Biswal, S.S. Alam, 1992. Fuzzy programming approach to multicriteria decision making transportation problem, Fuzzy Sets and Systems, 50: 135-141.

Bodkhe, S.G., V.H. Bajaj, R.M. Dhaigude, 2010. Fuzzy programming technique to solve bi-objective transportation problem, International Journal of Machine Intelligence, 2: 46-52.

Cohen, R., L. Church, D.P. Sheer, 1979. Generating multiobjective Trade offs: An algorithm for bicriteria problems, Wat. Resour. Res., 15: 1001-1010.

Gen, M., K. Ida, Y.Z. Li, 1998. Bicriteria transportation problem by hybrid genetic algorithm, Computers and Industrial Engineering, 35 : 363-366.

Isermann, H., 1979. The enumeration of all efficient solution for a linear multiple-objective transportation problem, Naval Research Logistics Quarterly, 26 : 123-139.

Kasana, H.S., K.D. Kumar, 2005. Introductory Operations Research Theory and Applications, Springer International Edition, New Delhi.

Pandian, P., G. Natarajan, 2010. A new method for finding an optimal solution for transportation problems, International J. of Math. Sci. and Engg. Appls., 4 : 59-65

Ringuest, J.L., D.B. Rinks, 1987. Interactive solutions for the Linear multiobjective transportation problem, Eur. J. Oper. Res., 32 : 96-106.

Waiel Abd El- Wahed, F., 2001. A multi objective transportation problem under fuzziness, Fuzzy Sets and Systems, 117: 27-33.

Yang, X.F., M. Gen, 1994. Evolution program for bicriteria transportation problem, Computers and Industrial Engineering, 27: 481-484.