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Recruitment Model in Manpower Planning Under Fuzzy Environment

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Authors' contributions

This work was carried out in collaboration between bothl authors. Author MJ formulated the basic Linear programming model to be applied on Recruitment of manpower along with the application of Cluster Analysis Technique. Author NG applied fuzzy technique into this model, validated with a hypothetical example and wrote the first draft of the manuscript. Both the authors read and approved the final manuscript.

Research Article

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ABSTRACT

In this competitive world, administrative and production oriented organizations require people with specialized skills in various fields. In this context it is important to develop recruitment models which help organization to determine the optimum time/cost for recruitment in manpower planning. Generally problems related to recruitment are solved by applying stochastic and optimization techniques. In this paper, we consider recruitment under fuzzy environment and solution is obtained using cluster analysis and fuzzy techniques.

Keywords: Fuzzy number; cluster analysis; ranking function.

1. INTRODUCTION

Manpower planning plays an important role in the arena of industrialization. In this modern world, it is well known that manpower is inevitable, inspite of the existence of advanced techniques. It is a device with which an attempt is made to match the supply of people with the demand in the form of jobs available in any organization so that the cost incurred is

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optimum. Thus through manpower planning, the management of any organization can choose the optimum number and the right kind of persons at the right place at the right time. The basic works of modern manpower planning are found in the works of Seal (1945) and Vajda [1] during the Second World War and major growth was in the period 1965 to 1975. The statistical approach to manpower planning has mainly been contributed by Bartholomew [2]. Manpower models together with stochastic process and operation techniques help an organization to achieve their goals. A number of manpower models exist in the literature. It is being reckoned as an effective scientific tool to solve several managerial decision making problems. Increase in cost related to various activities(like recruitment, training and so on) force the organization for a proper planning of manpower, so that the cost incurred due to the above mentioned factors is minimum.

Various stochastic models on manpower planning have been developed and studied in the past by many well known researchers like Bartholomew [2], Smith [3], Forbes [4] and Vajda [5], Grinold and Marshall [6]. As manpower planning mainly depends on the highly unpredictable human behavior, stochastic and fuzzy concepts have been introduced and upgraded the manpower systems with various models in various fields.

Recruitment is a main activity for every organization, whenever they expand or wants to increase its efficiency or wants to fill up the vacancies that arise in a large amount. Researchers like Davies [7,8], A.C.Georgiou and Grinold [9] had dealt with recruitment models in manpower systems under certain and uncertain conditions. Sathiyamoorthy and Elangovan [10,11,12], studied an optimal recruitment policy for training, prior to placement. They also determined the expected time for recruitment through the shock model approach & discussed the optimum time interval between recruitment programmes. The behavior of manpower system and the distribution of the vacancy level are studied by Yadavalli and Natarajan [13]. Nirmala and Jeeva [14] used optimization approach and developed a mathematical model which minimizes the manpower system cost during the recruitment and promotion period which are determined by the changes that take place in the system. Designing of Fuzzy Mathematical Model for Manpower Planning (Case: Twenty Millions Army) was done by Azar and Najafi [15]. Fuzzy input and output data were applied for manpower forecasting by Hong Tau Lee [16]. T De Feyter [17] and other co-authors evaluated Recruitment Strategies using Fuzzy Set Theory in Stochastic Manpower Planning.

Recruitment in fuzzy environment arises due to the uncertainty in human behavior. The recruitment problem can be modeled based on the principles of fuzzy set theory. The main contribution by Zadeh & Bellman [18] to fuzzy and decision theory have led to many fuzzy models in various fields and particularly in manpower systems. To mention a few, Guerry [19] used fuzzy sets in manpower planning and Mutingi M. [20] has applied fuzzy dynamics to manpower systems. In this paper, we have extended the recruitment model, solved using stochastic process by Jeeva [21], to a fuzzy model and solved it using a fuzzy technique. The paper is as follows: In section 2, cluster analysis technique is explained. In section 3, the problem is framed into a fuzzy linear programming model. In section 4, the methodology to the problem is explained. In section 5, the methodology is illustrated with a numerical example. Finally section 6 is a conclusion.

2. APPLICATION OF CLUSTER ANALYSIS TECHNIQUE

Consider a new organization with n jobs that needs employee who are talented in areas that are related to their jobs. By cluster analysis technique the job seekers are grouped (or clustered) based on their knowledge required for the company. The problem is to find the optimal number of persons from each cluster to various sections of a job, so as to minimize the time required to complete the job. Assume that there are n jobs available in the organization for which new recruitment is made. Here we apply a well known cluster analysis technique, namely the k – means method to divide the given n jobs seekers into K (=n) homogeneous clusters, (say) G_1, G_2, …, G_n. Each cluster is formed based on their specialization in each job as stated by them in their applications required for the organization. Based on various criteria of the organization (each organization has their own criteria), the applicants in each cluster are examined and are selected (Fig 2.1). The selected clusters be denoted as C1,C2,. . . , Cn where $Ci \subset Gi$, i = 1,2, ... , n. Within the selected clusters candidates are ranked based on their performance skills. As this denotes a fuzzy quantity we need to rank them using a fuzzy technique. So Yager's [22] ranking is applied to rank them. Once they are selected, the time taken to complete a job by each candidate is considered. The time taken by a candidate, the available time for a given job and the availability of persons from each cluster are all considered to a fuzzy quantity.

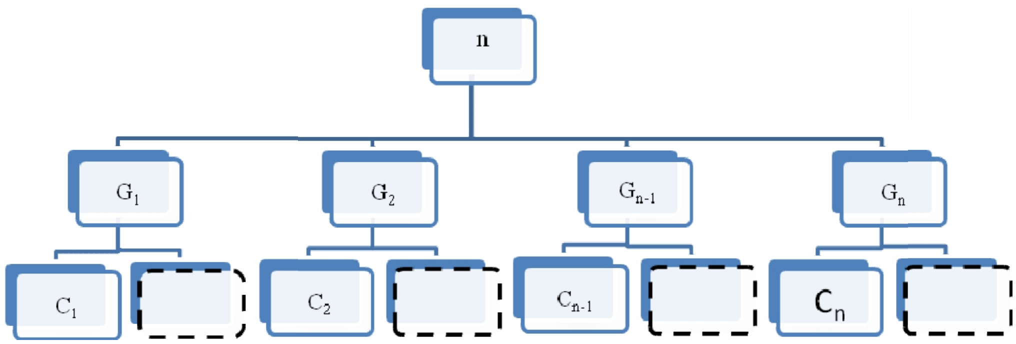

Fig. 2.1 Cluster analysis technique-k (=n) means method
n- No. of Candidates, G_i – Homogeneous clusters, C_i – selected clusters
– Non-selected clusters

3. FUZZY LINEAR PROGRAMMING MODEL

The problem discussed above is been modeled into a fuzzy linear programming model. In this model our goal is to determine the optimal number of persons selected from various clusters to perform various jobs with the objective of minimizing the total time taken to complete all the jobs. Here in order to avoid infeasible solution we assume that the number of persons required for the jobs from the j^{th} cluster should not exceed the number of persons available in the j^{th} cluster. Also the number of persons required to complete all the jobs should not exceed the number of persons available from all the clusters. Let $\tilde{x}_i$ denote the number of persons selected for the i^{th} job from j^{th} cluster and $\tilde{t_{ij}}$ be the mean time taken to complete a unit production of a product from the i^{th} job by a person from the j^{th} cluster. Here in this paper we have made some assumptions which are listed below.

3.1 Assumptions

1. The time $\tilde{t_{ij}}$ is considered to be a fuzzy number, as it need not be deterministic always.
2. The expected man hours from each cluster are fixed as a fuzzy number.

3. The available machine hours for each Job are fixed as a fuzzy number.
4. The organization fixes a range for target on the number of employees for each job
5. The number of persons in the clusters must be same as the number of persons required to complete all the jobs, so as to employ all the persons selected.
6. The organization also wants every employee to be capable of handling any kind of job given by them, even though they are specialized in particular area.

The details of the problem are mentioned in the table below:

Table 1. Cluster Analysis Technique – k-means Method

Clusters / Jobs	C_1	C_2	. . .	C_j	. . .	C_n	Available machine time	Required no. of persons
Job 1	$\widetilde{t_{11}}$	$\widetilde{t_{12}}$	…	$\widetilde{t_{1j}}$	. . .	$\widetilde{t_{1n}}$	$\widetilde{a_1}$	$\widetilde{x_1}$
Job 2	$\widetilde{t_{21}}$	$\widetilde{t_{22}}$	…	$\widetilde{t_{2j}}$	. . .	$\widetilde{t_{2n}}$	$\widetilde{a_2}$	$\widetilde{x_2}$
. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
Job i	$\widetilde{t_{i1}}$	$\widetilde{t_{i2}}$	…	$\widetilde{t_{ij}}$		$\widetilde{t_{in}}$	$\widetilde{a_i}$	$\widetilde{x_i}$
. . .	. . .	. . .	. . .		. . .	. . .	. . .	. . .
Job n	$\widetilde{t_{n1}}$	$\widetilde{t_{n2}}$	…	$\widetilde{t_{nj}}$	. . .	$\widetilde{t_{nn}}$	$\widetilde{a_n}$	$\widetilde{x_n}$
Expected man hours	$\widetilde{b_1}$	$\widetilde{b_2}$	…	$\widetilde{b_j}$	…	$\widetilde{b_n}$		
Expected persons	$\widetilde{y_1}$	$\widetilde{y_2}$	…	$\widetilde{y_j}$	…	$\widetilde{y_n}$		

$\widetilde{t_{ij}}$- *The time taken by a candidate from the given cluster j^{th} to complete the i^{th} job.*
$\widetilde{a_i}$- *Available machine time for i^{th} job,* $\widetilde{b_j}$- *Expected man hours of j^{th} cluster,* $\widetilde{x_i}$- *Number of persons required for i^{th} job and* $\widetilde{y_j}$ *– Expected number of person from j^{th} cluster.*

3.2 Mathematical Formulation of FLPP Model

To determine x_{ij}, for which $\sum_{i=1}^{n}\sum_{j=1}^{n}\widetilde{t_{ij}}\ \widetilde{x_{ij}}$ is minimum, (3.2.1)

subject to $\sum_{i=1}^{n}\widetilde{x_{ij}} = \widetilde{y_j}$, for all j = 1,2, … , n (3.2.2)

$\sum_{j=1}^{n}\widetilde{x_{ij}} = \widetilde{x_i}$, for all i = 1,2, … , n (3.2.3)

$\sum_{i=1}^{n}\widetilde{x_i} = \sum_{j=1}^{n}\widetilde{y_j}$ (3.2.4)

$\sum_{j=1}^{n}\widetilde{t_{ij}}\ \widetilde{x_{ij}} \le \widetilde{a_i}$ for i = 1,2, … , n (3.2.5)

$\sum_{j=1}^{n}\widetilde{t_{ij}}\ \widetilde{x_{ij}} \le \widetilde{b_j}$ for j = 1,2, … , n (3.2.6)

$\widetilde{x_{ij}} \ge 0$ for all i, j = 1, 2,…, n (3.2.7)

The above model can be treated as a fuzzy transportation problem with additional constraints and can be solved to obtain an optimal solution to the problem. This FLPP is solved by considering two cases. The first case shows how the model is solved under the assumption that the inequalities (3.2.5) and (3.2.6) are not involved, where as the next case shows how the model is solved using fuzzy techniques after the inclusion of the inequality constraints.

4. METHODOLOGY

The methodology is discussed for two different cases.

Case 4.1 Fuzzy Transportation Problem without Additional Constraints

This is the case where the inequality is not taken into consideration. Here the problem is again solved in two ways. One is solving the problem by defuzzifying the fuzzy numbers and the other is solving in a fuzzy way. The next subdivision explains the procedure for solving the problem.

4.1.1 Defuzzification process - application of Yager's ranking procedure

In this section the fuzzy numbers are defuzzified using Yager's ranking function [22]. The Yager's ranking function R: F(X) → (-∞, ∞), is defined as

$$R(A) = \frac{1}{2}\int_0^1 [c_L + c_R]\,d\alpha,$$

where A є F(X), the set of all fuzzy sets defined on an universal set X and c_L , the lower bound and c_R, the upper bound of the α-cut of A. After defuzzification, the problem reduces to ordinary transportation problem. The problem is then solved by the methods available in crisp case. The algorithm to this process is as follows.

Algorithm to 4.1.1

Step 1: Consider table 1 by deletion of the constraint 3.2.5 and 3.2.6.
Step 2: Check the problem to be a balanced one. If not so, make it a balanced one by adding a dummy row/column, whichever is required.
Step 3: Defuzzify the fuzzy numbers using Yager 's ranking function.
Step 4: Solve the problem using any of the method available in the crisp case. Here in this paper Vogel's Approximation Method (VAM) is adopted.
Step 5: Obtain the optimal solution and the optimal value.

4.1.2 Application of fuzzy technique

This is the sub-case discussed in case 4.1. The problem is solved by applying fully a fuzzy technique. The algorithm to this case is as follows.

Algorithm to 4.1.2

Step 1: Consider table1 by the deletion of the constraint 3.2.5 and 3.2.6.
Step 2: Check whether the problem is balanced. If not so, make it a balanced one by adding a dummy row/column whichever is required.

Step 3: Using Fuzzy Vogel's Approximation Method (FVAM) [23], obtain the solution to the problem in table 1 by considering $\widetilde{x_i}$'s and $\widetilde{y_j}$'s as the supply and demand respectively.

Case 4.2 Fuzzy Transportation Problems with Additional Constraints

Suppose the inequalities (3.2.5) & (3.2.6) are not eliminated, then the problem becomes a fuzzy transportation problem with additional constraints and is solved by split and bound method introduced by Pandian and Anuradha [24]. The method applied here is particularly used to solve the transportation problem with additional constraints.

Procedure to Split and Bound Method:

1. Find α – cuts to each fuzzy numbers.
2. Using the upper bound of α – cuts, solve the problem and obtain the solution using VAM method.
3. Similarly obtain the solution with the lower bound of α – cuts.
4. Combine the solutions that are obtained in step 2 & 4, so that the solution obtained in step 2 forms the upper- bound and the solution from step 3 forms the lower bound.
5. Similarly combine the optimal values obtained in step 2 and 3.
6. From this solution the required fuzzy solution is obtained.

5. NUMERICAL ILLUSTRATIONS

Consider a new organization with three different types of jobs, which wants to employ people for the posts with the condition that every employee must be capable of handling all the three jobs. First the applicants are grouped into three clusters G_1, G_2, G_3 using k (k=n=3) means method by applying some similar conditions on the efficiency in each job required by the organization. Then the persons from each cluster are examined by means of interview by the organization based on its designed norms on efficiency in each job and each cluster is divided into binary clusters of selected and non-selected ones. The persons from the selected clusters are ranked based on their efficiency. Let the three final selected clusters for the jobs J_1, J_2, J_3 be C_1, C_2, C_3 respectively. The matrix related to the time is given below:

Table 2. Fuzzy time matrix

clusters / Jobs	C_1	C_2	C_3	Available time	Required no. of persons
Job 1	[3, 5,11]	[4,6,16]	[3, 8, 9]	[40, 180, 400]	[16,20,24]
Job 2	[4, 6,16]	[3, 4, 9]	[3,5,11]	[60, 180,480]	[20,25,30]
Job 3	[4, 9,18]	[6,8,14]	[2, 4, 6]	[50,270,630]	[26,30,34]
Exp man hrs	[70,270,630]	[60,200,480]	[30,150,410]		
Expected persons	[26,30,34]	[20,25,30]	[16,20,24]		

The solution to this problem is obtained for different cases 4.1.1 and 4.1.2.

5.1 Application of Yager's Ranking Method

Step1: Eliminating the inequality constraints the problem reduces to a balanced fuzzy transportation problem.

Table 3. Fuzzy time matrix without additional constraints

Clusters / Jobs	C_1	C_2	C_3	Required no. of persons
Job 1	[3, 5,11]	[4,6,16]	[3, 8, 9]	[16,20,24]
Job 2	[4, 6,16]	[3, 4, 9]	[3,5,11]	[20,25,30]
Job 3	[4, 9,18]	[6,8,14]	[2, 4, 6]	[26,30,34]
Expected persons	[26,30,34]	[20,25,30]	[16,20,24]	

Step 2: On applying Yager's ranking function, the above table reduces to the following table:

Table 4. Crisp time matrix for table 3

Clusters / Jobs	C_1	C_2	C_3	Required no. of persons
Job 1	6	8	7	20
Job 2	8	5	6	25
Job 3	10	9	4	30
Expected persons	30	25	20	75

Step 3: the solution to the above problem is as follows:

The optimal solution is $X_{11} = 20$, $X_{22} = 25$, $X_{31} = 10$, $X_{33} = 20$
and the optimal value is 425hrs.

5.2 Application of FVAM

By algorithm 4.1.2 the given problem is solved and the solution is obtained as
$X_{11}= (16,20,24)$ $X_{22}= (20,25,30)$ $X_{31}= (10,10,10)$ $X_{33} = (16,20,24)$
Optimal value: (180, 370, 858).

The corresponding crisp solution:
$X_{11}= 20$, $X_{22}= 25$, $X_{31}= 10$, $X_{33} = 20$ and the optimal value: 444.5 hours.

5.3 Application of Split and Bound Method

The above problem mentioned problem is solved using split and bound method. In this method, we calculate the α – cut for each fuzzy number and then solve the problem.

Step 1: α – cut for each fuzzy number in Table 2 is obtained.

Table 5. α-cuts to fuzzy numbers in table 2

Job/Clusters	C_1	C_2	C_3	Job completion time	Reqd. no. of persons
J_1	[3+2α,11-6α]	[4+2α, 16-10α]	[3+5α, 9-α]	[40+140α, 400-220α]	[16+4α, 24-4α]
J_2	[4+2α,16-10α]	[3+α, 9-5α]	[3+2α, 11-6α]	[60+120α, 480-300α]]	[20+5α, 30-5α
J_3	[4+5α,18-9α]	[6+2α, 14-6α]	[2+2α, 6-2α]	[50+220α, 630-360α]	[26+4α, 34-4α]
Expected man hours	[70+200α, 630-360α]	[60+140α, 480-280α]	[30+120α, 410-260α]		
Expected no of persons	[26+4α,34-4α]	[20+5α, 30-5α	[16+4α, 24-4α]		

Step 2: Fuzzy transportation problem with upper bound of α-cuts.

Table 6. The upper bound of the α-cuts

JOB/Clusters	C_1	C_2	C_3	Job completion time	Reqd. no of persons
J_1	11 - 6α	16-10α	9- α	400-220α	24-4α
J_2	16-10α	9-5α	11 - 6α	480-300α	30-5α
J_3	18-9α	14-6α	6-2α	630-360α	34-4α
Expected man hrs	630-360α	480-280α	410-260α		
Expected no of persons	34-4α	30-5α	24-4α		

The solution to the problem is obtained as:
X_{11}= 24-4α, X_{22}= 30-5α, X_{31}= 10, X_{33} = 24-4α and the optimal value : 858-488α.

Step 3: Fuzzy transportation problem with lower bound of α-cuts.

Table 7. The lower bound of the α-cuts

Job/Clusters	C_1	C_2	C_3	Job completion time	Reqd. no. of persons
J_1	3+2α	4+2α	3+5α	40+140α	16+4α
J_2	4+2α	3+α	3+2α	60+120α	20+5α
J_3	4+5α	6+2α	2+2α	50+220α	26+4α
Expected. Man hours	70+200α	60+140α	30+120α		
Expected no of persons	26+4α	20+5α	16+4α		

The solution to this problem:

X_{11}= 16+4α, X_{22}= 20+5α, X_{31}= 10, X_{33} = 16+4α

Optimal value: 180+190α

Step 4: Combining the results from step 2 & step 3, the solution to table 5 is:
X_{11}= [16+4α, 24-4α], X_{22}= [20+5α, 30-5α], X_{31}= [10, 10], X_{33} = [16+4α, 24-4α]

Step 5: Optimal value: [180+190α, 858-488α].

The solution to table 5 is discussed for different values of α as follows

A	X_{11}	X_{22}	X_{31}	X_{33}	Optimal value
0	[16, 24]	[20, 30]	[10,10]	[16, 24]	[180, 858]
½	[18, 22]	[17.5, 27.5]	[10,10]	[18, 22]	[275, 614]
1	[20, 20]	[25, 25]	[10,10]	[20, 20]	[370, 370]

The corresponding fuzzy solution and the fuzzy optimal value for the problem given by Table 2 is given by X_{11}= (16,20,24) X_{22}= (20,25,30) X_{31}= (10,10,10) X_{33} = (16,20,24)
Optimal value: (180, 370, 858).

The corresponding crisp solution to Table 2 is:
X_{11}= 20, X_{22}= 25, X_{31}= 10, X_{33} = 20
Optimal value: 444.5hours.

6. CONCLUSION

The main challenges that Industries face ever in Manpower planning are recruitment of personnel at various levels. This can be overcome by having an empowered, enlightened Manpower Planning Cell and adopting the right selection policy for recruitment and updating technical and field knowledge after careful assessment, since in the present business environment, to retain an efficient hand is equally important and cost effective as to recruit a suitable talented person. This paper explains how an optimal recruitment is done using cluster analysis technique in a fuzzy environment when an average time for completing a job is given as a fuzzy number. The recruitment model discussed here has been studied under crisp case using stochastic linear programming technique. But in this paper the situation is modeled into a fuzzy linear programming model and is solved both in crisp conversion form as well as in fuzzy form. This paper paves a way for further development of the fuzzy recruitment theory in different directions. This paper will be of more use to the firm who look forward recruiting their employees where their job completion timings are not certain.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Vajda S. The stratified semi-stationary population. Biometrika. 1947;34:243-254.
2. Bartholomew DJ. The statistical approach to manpower planning. Statistician. 1971;20:3-26.

3. Smith AR, (Ed). Some statistical techniques of manpower planning, CAS occasional paper, No. 15, HMSO, London; 1970.
4. Forbes AF. Markov chain models for manpower systems, manpower and management science, Eds. 93-113,English University Press, London; 1971.
5. Vajda S. Mathematical aspects of manpower planning, Operat. Res. Quart. 1975;26, 527-542.
6. Grinold RC, Marshall KL. Manpower planning models, North Holands, New York; 1977.
7. Davies GS. Maintainability of grade structure in Markov models under recruitment control, J. Appl. Prob. 1975;12:376-382.
8. Davies GS. Maintainable region in a Markov manpower model, J. Appl. Prob., 1981;18:738-742.
9. Georgiou AC, Grinold RC. Manpower planning with uncertain recruitment, Oper. Res. 1976;24(3):387-399.
10. Sathiyamoorthy R, Elangovan R. Optimal recruitment policy for training prior to placement, J. of Deci. and Mathematika Sciences. 1997;2(1-3): 87-93.
11. Sathiyamoorthy R, Elangovan R. Shock Model Approach to determine the expected time for recruitment, J.of Deci. and Mathematika Sciences, 1998;3(1-3):67-78.
12. Sathiyamoorthy R, Elangovan R. Optimal time interval between recruitment programmes, International Journal of Management and Systems, 1999;15(2):117-128.
13. Yadavalli VSS, Natarajan R. A semi-Markov model of a manpower system. Stochastic Analysis and Applications. 2001;19(6):1077-1086.
14. S. Nirmala and M. Jeeva. A dynamic programming approach to optimal manpower recruitment and promotion policies for the two grade system. African Journal of Mathematics and Computer Science Research. 2010;3(12):297–301.
15. Azar A, Najafi E. Designing of fuzzy mathematical model for manpower planning (Case: Twenty Millions Army), Modarres Human Sciences; Spring. 2002;6(1(Tome 24));135-156.
16. Hong Tau Lee, Sheu Hua Chen, Fuzzy regression model with fuzzy input and output data for manpower forecasting. Fuzzy Sets and Systems. 01/2001;119:205-213.
17. De Feyter, Tim, Guerry, Marie - Anne. Evaluating recruitment strategies using fuzzy set theory in stochastic manpower planning. Stochastic Analysis and Applications. Taylor and Francis Ltd. 2009;27(6):1148-1162(15).
18. Bellman RE, Zadeh LA. Decision making in a fuzzy environment. Management Science. 1970;17:141-164.
19. Guerry MA. Using fuzzy sets in manpower planning. Journal of Applied Probability. 1999;36:155-162.
20. Mutingi M, Mbohwa C. Fuzzy system dynamics and optimization with application to manpower systems. International Journal of Industrial Engineering Computations. 2012;3(5):873-886.
21. Rajalakshmi Rajagopal, Jeeva M. Stochastic programming in manpower planning – cluster based optimum allocation of recruitment. Notable Publications Inc., New Jersy, USA; 2002.

22. Yager RR. A procedure for ordering fuzzy subsets of the unit interval. Information Sciences. 1981;24:143-161.
23. Kadhirvel K, Balamurugan K. Method for solving the transportation problems using trapezoidal fuzzy numbers. International Journal of Engineering Research and Applications, ISSN: 2248-9622. 2012;2(5):2154-2158.
24. Pandian P, Anuradha D. Solving interval transportation problems with additional impurity constraints. Journal of Physical Sciences. 2011;15:103-112.

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