U.P.B. Sci. Bull., Series A, Vol. 76, Iss. 3, 2014 ISSN 1223-7027

A NEW FUZZY APPROACH TO SOLVE A NOVEL MODEL OF OPEN SHOP SCHEDULING PROBLEM

F. KHALILI GOODARZI[1], N. A. TAGHINEZHAD[2], S. H. NASSERI[3,]

In this study, we present a new mixed integer linear programming model for an open shop scheduling problem, considering setup times, processing times, sequence dependent removal times and inaccessibility time for machines. Objective in this problem is minimizing maximum completion times (makespan). Due to uncertainty of the data, in continuation, we present a new method to solve single objective fully fuzzy mixed integer linear programming and implement the method to open shop scheduling problem. Computational results present the application of the model and the proposal solving method.

Keywords: Scheduling, Open shop, fully fuzzy mixed integer linear programming problem, Sequence dependent removal times, Inaccessibility time for machines.

1. Introduction

Scheduling consists of assignment resources in order to perform a set of tasks in a given time horizon that optimizes the usage of available resources .The pure sequencing problem is a specialized scheduling problem in which an ordering of the jobs completely determines a schedule. Whereas the scheduling is one of the important and complex issues in engineering fields, considering different criteria has been lionize by many researches.

Nowadays, in many manufacturing factories and service systems providing timely information and services to customers is crucial. The tardiness and earliness costs in these issues, not only makes the customers affected but also reduces the credit of the company or manufacturing plant.

In an open shop scheduling problem, no restrictions are placed on the processing order for any job. An open shop scheduling problem may be encountered in testing facilities where units go through a series of diagnostic tests that do not have to be performed in any specified order. Since different testing equipment is usually required for each test, it is not possible to conduct any two

[1] M. S. Student, Department of Mathematics, University of Mazandaran, Babolsar, Iran, e-mail: : farzaneh.goodarzii@gmail.com
[2] PhD Student, Department of Mathematics, University of Mazandaran, Babolsar, Iran, e-mail: n.taghinezhad@gmail.com
[3] Assistant professor, Department of Mathematics, University of Mazandaran, Babolsar, Iran, e-mail: nasseri@umz.ac.ir

tests concurrently. The above situation is frequently encountered in testing the components of an electronic system and in general repair facilities when repairs can be performed in an arbitrary order [13].

Besides precisely characterizing a scheduling problem, recently, application of mathematical models to optimally solve scheduling problems is gaining more attention due to the progress obtained in computer capacities and advent of specific software. However, many studies have been conducted to model the flow shops and job shops [16,17]. The formulation of the open shops has been given far less attention. In the literature, Liaw [10] propose a linear programming model to formulate the two-machine preemptive open shop problems. Since he considers a special preemptive case, his model is not adaptable to classical OSS. Lin et al. [11] formulate another variant of OSS where jobs are no-wait and there are movable dedicated machines. Unfortunately, this model is non-linear and consequently ineffective. Another attempt to model OSS is conducted by Low and Yeh [12]. They propose a mixed integer linear programming model for a specific problem of OSS with setup and removal times.

Although the open shop scheduling problem has a considerably larger solution space than the job shop or flow shop scheduling problems, and it seems to receive less attention from researchers and practitioners, thus remaining an important and universal problem. In this paper, the discussion is focused on the problem of scheduling open shops. In addition, to better representing the real nature of scheduling environments, certain processing restrictions such as independent setup, dependent removal times and machine availability are also introduced. With regard to uncertainty in data of this problem, we consider a fully fuzzy view of this problem. Objective in this problem is minimizing maximum completion times.

2. Problem formulation

Like all scheduling problem, an open shop scheduling problem contains n jobs and m machines. Each job contains at most m operations. There is no predetermined processing route for the jobs, meaning that jobs could visit machines by any order. In this section, we present a new MILP model for an open shop scheduling problem.

2.1. Problem assumption

The problem assumptions are as follow:

At any time, each job can be processed on at most one machine and each machine can process at most one job.

All parameters, coefficients, and variables are triangle fuzzy number.

All m machines and all n jobs are available at start point.

- The machine breakdown is not permitted.
- Setup times are dependent to machine and job and are sequence independent.
- Removal times are dependent of sequencing.
- Machines inaccessibility on some predetermined time intervals are associated.
- There is only one machine of each type in the shop.

The setup task can be started in advance when the certain machine is free.

2.2. Notation

Before presenting the model, it is necessary to introduce the notations including parameters, indices, and variables used in our model. The parameters and indices are defined in Table 1.

Table 1.

Parameters and indices of the proposed model

NOTATION	DESCRIPTION
$i, l \in \{0,1,\dots,n\}$	JOB INDICES
$k \in \{1,\dots,n\}$	JOB INDICES
$h, j \in \{1,\dots,m\}$	MACHINE INDICES
$t \in \{1,\dots,T\}$	MACHINES INACCESSIBILITY TIME INTERVALS
O_{ij}	OPERATION OF PROCESSING JOB i ON MACHINE j
$\tilde{p}_{ij}$	PROCESSING TIME OF JOB i ON MACHINE j
s_{ij}	SETUP TIME OF JOB i ON MACHINE j
R_{ikj}	REMOVAL TIME OF JOB i ON MACHINE k IF k BE THE NEXT MACHINE THAT PROCESS i
$Start_{t,j}$	STARTING TIME OF t-TH INACCESSIBILITY INTERVAL FOR MACHINE j
$End_{t,j}$	END TIME OF t-TH INACCESSIBILITY INTERVAL FOR MACHINE j

The proposed model contains the following variables:

Table 2.

Variables of the proposed model

NOTATION	DESCRIPTION
St_{ij}	STARTING TIME OF A SETUP TASK FOR OPERATION O_{ij}
C_{ij}	COMPLETION TIME OF OPERATION O_{ij}
X_{ikj}	BINARY VARIABLE; IF O_{ij} PROCESSES BEFORE O_{kj} ON MACHINE j
Y_{ijh}	BINARY VARIABLE; IF O_{ij} PROCESSES BEFORE O_{ih}
Z_{ikj}	BINARY VARIABLE; IF O_{kj} IMMEDIATELY PROCESSES AFTER O_{ij} ON MACHINE j
A_{ijt}	BINARY VARIABLE; IF O_{ij} PROCESSES AFTER t-TH INACCESSIBILITY INTERVAL FOR MACHINE j
C_{max}	MAXIMUM COMPLETION TIME (MAKESPAN)

2.3. Arithmetic on fuzzy numbers

As mentioned in the problem assumptions subsection, all parameters and variables (except binary variables) are fuzzy numbers with the triangular possibility distribution as follows:

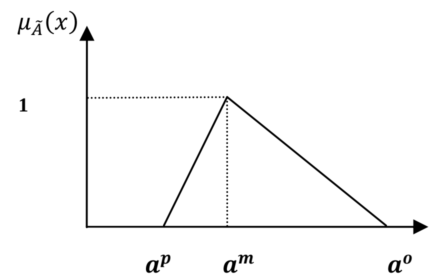

Fig. 1. Triangular possibility distribution of fuzzy number $\tilde{A} = (a^p, a^m, a^o)$

Definition 1: Let $\tilde{A} = (a, b, c)$ and $\tilde{B} = (d, e, f)$ be two triangular fuzzy numbers. Then, arithmetic operation on these fuzzy numbers can be defined as follows:

1) Addition: $\tilde{A} \oplus \tilde{B} = (a + d, b + e, c + f)$.
2) Symmetry: $-\tilde{A} = (-c, -b, -a)$.
3) Subtraction: $\tilde{A} \ominus \tilde{B} = (a - f, b - e, c - d)$.
4) Equality: $\tilde{A} = \tilde{B}$ iff $a = d, b = e, c = f$.
5) Multiplication: Suppose $\tilde{A}$ be any triangular fuzzy number and $\tilde{B}$ be non-negative triangular fuzzy number, then we define:

$$\tilde{A} \otimes \tilde{B} \simeq \begin{cases} (ad, be, cf), a \geq 0 \\ (af, be, cf), a < 0, c \geq 0 \\ (af, be, cd), c < 0 \end{cases}$$

2.4. Mathematical model

Our model could be formulated as follows:

$$\min Z = \tilde{C}_{max}$$

$$\tilde{C}_i - \tilde{S}t_{ij} - \sum_{\substack{k=1\\k\neq i}}^{n} \tilde{R}_{ikj} \times Z_{ikj} \geqslant +\tilde{s}_{ij} + \tilde{p}_{ij} \qquad \forall i,j$$

$$St_{ij} + s_{ij} + \tilde{p}_{ij} + \sum_{\substack{k=1\\k\neq i}}^{n} R_{ikj} \times Z_{ikj} - M\left(1 - X_{ilj}\right) \leqslant St_{lj} \qquad \forall i,j,l; i \neq l$$

$$St_{lj} + s_{lj} + \tilde{p}_{lj} + \sum_{\substack{k=1\\k\neq l}}^{n} R_{lkj} \times Z_{lkj} - MX_{ilj} \leqslant St_{ij} \qquad \forall i,j,l; i \neq l$$

$$St_{ij} + s_{ij} + \tilde{p}_{ij} - M(1 - Y_{ijh}) \leqslant St_{ih} + s_{ih} \qquad \forall i,j,h;\ j \neq h$$

$$St_{ih} + s_{ih} + \tilde{p}_{ih} - MY_{ijh} \leqslant St_{ij} + s_{ij} \qquad \forall i,j,h;\ j \neq h$$

$$X_{ilj} + X_{lij} = 1 \qquad \forall i,l; i \neq l;\ i > l$$

$$Y_{ijh} + Y_{ihj} = 1 \qquad \forall i,j,h; h > j$$

$$\sum_{i=0}^{n} Z_{ikj} = 1 \qquad \forall k,j$$

$$\sum_{k=1}^{n} Z_{ikj} \leq 1 \qquad \forall i,j$$

$$X_{ilj} - Z_{ilj} \geq 0 \qquad \forall i,j,l;\ i \neq l$$

$$X_{ilj} - Z_{lij} \leq 1 \qquad \forall i,j,l;\ i \neq l$$

$$St_{ij} + s_{ij} + \tilde{p}_{ij} + \sum_{\substack{k=1\\k\neq i}}^{n} R_{ikj} \times Z_{ikj} \leqslant Start_{t,j} + (M - Start_{t,j}) \times A_{ijt} \qquad \forall i,j,t$$

$$St_{ij} \geq A_{ijt} \times End_{t,j} \qquad \forall i,j,t$$

$$A_{ijt}, Z_{ilj}, X_{ilj}, Y_{ijh} \in \{0,1\}, St_{ij} \geq 0 \qquad \forall i,l,j,h,t;\ i \neq l, j \neq h$$

3. A new solution method for solving the problem

A FFMILP problem with m fuzzy constraints and n variables may be formulated as follows:

$$maximize\ (\ minimize)\ \sum_{j=1}^{n} \tilde{c}_j \otimes \tilde{x}_j$$

$$s.t. \begin{cases} \sum_{j=1}^{n} \tilde{a}_{ij} \otimes \tilde{x}_j \preccurlyeq, =, \succcurlyeq \tilde{b}_i, \forall i = 1, \dots, m \\ \ \tilde{x}_j \succcurlyeq 0\ ;\ j = 1, \dots, p \\ \tilde{x}_j \succcurlyeq 0, \tilde{x}_j \in \mathbb{Z}\ ; j = p+1, \dots, n \end{cases} \tag{3.1}$$

where $\tilde{C}^T = [\tilde{c}_j]_{1\times n}, \tilde{X} = [\tilde{x}_j]_{n\times 1}, \tilde{A} = [\tilde{a}_{ij}]_{m\times n}, \tilde{b} = [\tilde{b}_i]_{m\times 1} \&\ \tilde{a}_{ij}, \tilde{c}_j, \tilde{x}_j, \tilde{b}_i \in \boldsymbol{F}(\mathbb{R})$. According to this definition, the steps of our proposed solution algorithm are as follows:

Initialization Step: If all $\tilde{c}_j$, $\tilde{x}_j$, $\tilde{a}_{ij}$ and $\tilde{b}_i$ are represented by triangular fuzzy numbers (p_j, q_j, r_j), (a_{ij}, b_{ij}, c_{ij}), (b_i, g_i, h_i) and (x_j, y_j, z_j) respectively then by substituting these values, the FFMILP problem, obtained in (3.1), may be written as follows:

$$max\ (\ min)\ \sum_{j=1}^{n} (p_j, q_j, r_j), \otimes (x_j, y_j, z_j)$$

$$s.t. \begin{cases} \sum_{j=1}^{n} (a_{ij}, b_{ij}, c_{ij}) \otimes (x_j, y_j, z_j)\ \preccurlyeq, =, \succcurlyeq (b_i, g_i, h_i), \forall i = 1, \dots, m \\ \quad (x_j, y_j, z_j) \geq 0; \qquad\qquad j = 1, \dots, p \\ (x_j, x_j, x_j) \geq 0\ , x_j \in \mathbb{Z}; \qquad j = p+1, \dots, n \end{cases}$$

Step 2: By arithmetic operations defined in subsection 2.2, the fuzzy linear programming problem of Step 1, converted into the following equivalent problem:

$$max(min)\ \sum_{j=1}^{n} (p_j, q_j, r_j) \otimes (x_j, y_j, z_j) = \sum_{j=1}^{n} (\alpha_j, \beta_j, \gamma_j)$$

$$
s.t.\begin{cases}
\sum_{j=1}^{n} m_{ij} \leq = \geq b_i, & \forall i = 1, \dots, m \\
\sum_{j=1}^{n} n_{ij} \leq = \geq g_i, & \forall i = 1, \dots, m \\
\sum_{j=1}^{n} o_{ij} \leq = \geq h_i, & \forall i = 1, \dots, m \\
(x_j, y_j, z_j) \geq 0; & j = 1, \dots, p \\
x_j \geq 0 \,, x_j \in \mathbb{Z}; & j = p+1, \dots, n
\end{cases}
$$

where
$(a_{ij}, b_{ij}, c_{ij}) \otimes (x_j, y_j, z_j) = (m_{ij}, n_{ij}, o_{ij}) \& \, (p_j, q_j, r_j) \otimes (x_j, y_j, z_j) = (\alpha_j, \beta_j, \gamma_j)$.

Step 3: Suppose the problem is in minimizing form, (we can easily expand the problem to the minimizing form), then we convert the objective function into three objectives as follows:

$$Z_1 = Max \sum_{j=1}^{n} \beta_j - \alpha_j$$

$$Z_2 = Min \sum_{j=1}^{n} \beta_j$$

$$Z_3 = Min \sum_{j=1}^{n} \gamma_j - \beta_j$$

$$
s.t.\begin{cases}
\sum_{j=1}^{n} m_{ij} \leq = \geq b_i, & \forall i = 1, \dots, m \\
\sum_{j=1}^{n} n_{ij} \leq = \geq g_i, & \forall i = 1, \dots, m \\
\sum_{j=1}^{n} o_{ij} \leq = \geq h_i, & \forall i = 1, \dots, m \\
(x_j, y_j, z_j) \geq 0; & j = 1, \dots, p \\
x_j \geq 0 \,, x_j \in \mathbb{Z}; & j = p+1, \dots, n
\end{cases}
$$

Step 4: Determine the Positive Ideal Solution (PIS) and Negative Ideal Solution (NIS) for each objective function by solving the corresponding model as follows:

$$Z_1{}^{PIS} = Max \sum_{j=1}^{n} \beta_j - \alpha_j \qquad Z_2{}^{PIS} = Min \sum_{j=1}^{n} \beta_j \qquad Z_3{}^{PIS} = Min \sum_{j=1}^{n} \gamma_j - \beta_j$$

$$X \in \boldsymbol{F} \qquad X \in F \qquad X \in F$$

$$Z_1{}^{NIS} = Min \sum_{j=1}^{n} \beta_j - \alpha_j \qquad Z_2{}^{NIS} = Max \sum_{j=1}^{n} \beta_j \qquad Z_3{}^{NIS} = Max \sum_{j=1}^{n} \gamma_j - \beta_j$$

$$X \in F \qquad X \in F \qquad X \in F$$

Assume that, $\boldsymbol{F}$ is the set of all constraints. To reduce the computational time, the negative ideal solutions can be estimate as follows. Let v_h^* and $Z_h(v_h^*)$ denote the decision vector associated with the PIS of *h*th objective function and the corresponding value of *h*-th objective function, respectively. So, we can estimate the related NIS as follows:

$$Z_1^{NIS} = min_{\,k=1,2,3}\{Z_1(v_k^*)\} \qquad Z_h^{NIS} = max_{k=1,2,3}\{Z_h(v_k^*)\}\,; h = 2, 3$$

Step 5: Determine a linear membership function for each objective function according to positive and negative ideal points. In practice, $\mu_i(v); i = 1, 2, 3$ presents the satisfaction level of *i*th objective function for the given solution vector *v*. The graphs of these membership functions were represented in Figures 2 and 3 see also in [19].

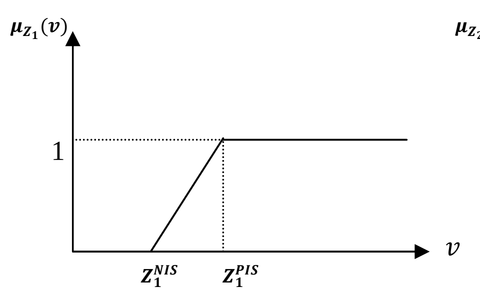

Fig.2. Linear membership function for $\boldsymbol{Z_1}$

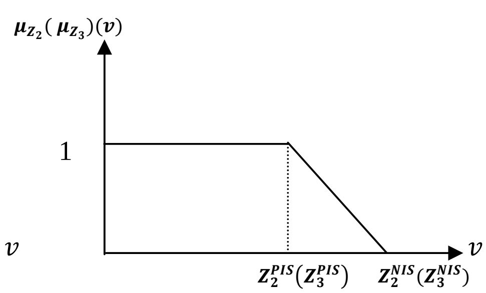

Fig.3. Linear membership function for $\boldsymbol{Z_2}(\boldsymbol{Z_3})$

Step 6: Convert the auxiliary MILP model into an equivalent single-objective MILP by using the following auxiliary crisp formulation:

(3.2)

Where presents the satisfaction level of *i*-th objective function for the given solution vector and denote the minimum satisfaction degree of all objectives. This formulation has a new achievement function defined as a convex combination of the lower bound for satisfaction degree of objectives ( ), and the weighted sum of satisfaction degree of objectives to ensure yielding an adjustably balanced compromise solution. Moreover, and indicate the relative importance of the -th objective function and the coefficient of compensation, respectively. The selection of depends to the aims and opinion of decision maker. The main aim in this problem is to find the maximum of minimum satisfaction degree of all objectives in order to find a better solution for the primal FFLP problem.

Step 7: After solving (3.2), the solutions must be put into the objective function of primal FFLP problem in order to find the fuzzy objective value of problem.

4. Numerical examples

We consider an example to illustrate the performance of our model. For this reason, first we consider the certain form of our model. To illustrate the performance of our approach, we solve an example. By solving this problem, results are expressed as follows:

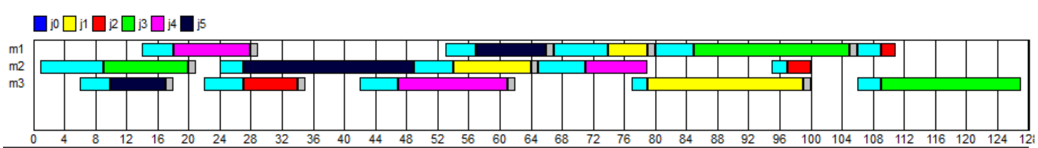

Fig.3. Gantt chart of the proposed model (3 machines, 5 jobs)

Table 3.

Results of 6 × 2 problem ($\theta_1 = \theta_3 = \theta_2 = \frac{1}{3}$)

γ	Z_1	Z_2	Z_3	μ_1	μ_2	μ_3	Z
0	0	127	3	1	0	1	0.667
0.1	0	127	3	1	0	1	0.6
0.2	0	127	3	1	0	1	0.553
0.3	1.5	126	1.5	0.5	0.5	0.5	0.5
0.4	1.5	126	1.5	0.5	0.5	0.5	0.5
0.5	1.5	126	1.5	0.5	0.5	0.5	0.5
0.6	1.5	126	1.5	0.5	0.5	0.5	0.5
0.7	1.5	126	1.5	0.5	0.5	0.5	0.5
0.8	1.5	126	1.5	0.5	0.5	0.5	0.5
0.9	1.5	126	1.5	0.5	0.5	0.5	0.5
1	1.5	126	1.5	0.5	0.5	0.5	0.5

Table 4.

Results of 6 × 2 problem ($\theta_1 = \theta_3 = \frac{1}{4}, \theta_2 = \frac{2}{4}$)

γ	Z_1	Z_2	Z_3	μ_1	μ_2	μ_3	Z
0	0	127	3	1	0	1	0.5
0.1	1.5	126	1.5	0.5	0.5	0.5	0.5
0.2	1.5	126	1.5	0.5	0.5	0.5	0.5
0.3	1.5	126	1.5	0.5	0.5	0.5	0.5
0.4	1.5	126	1.5	0.5	0.5	0.5	0.5
0.5	1.5	126	1.5	0.5	0.5	0.5	0.5
0.6	1.5	126	1.5	0.5	0.5	0.5	0.5
0.7	1.5	126	1.5	0.5	0.5	0.5	0.5
0.8	1.5	126	1.5	0.5	0.5	0.5	0.5
0.9	1.5	126	1.5	0.5	0.5	0.5	0.5
1	1.5	126	1.5	0.5	0.5	0.5	0.5

Table 5.

Results of 6 × 2 problem ($\theta_1 = \theta_3 = \frac{1}{6}, \theta_2 = \frac{4}{6}$)

γ	Z_1	Z_2	Z_3	μ_1	μ_2	μ_3	Z
0	3	124	0	0	1	0	0.667
0.1	3	124	0	0	1	0	0.6
0.2	3	124	0	0	1	0	0.528
0.3	1.5	126	1.5	0.5	0.5	0.5	0.5
0.4	1.5	126	1.5	0.5	0.5	0.5	0.5
0.5	1.5	126	1.5	0.5	0.5	0.5	0.5
0.6	1.5	126	1.5	0.5	0.5	0.5	0.5
0.7	1.5	126	1.5	0.5	0.5	0.5	0.5
0.8	1.5	126	1.5	0.5	0.5	0.5	0.5
0.9	1.5	126	1.5	0.5	0.5	0.5	0.5
1	1.5	126	1.5	0.5	0.5	0.5	0.5

Acknowledgments

This research is supported by University of Mazandaran and the Research Center of Algebraic Hyper Structures and Fuzzy Mathematics, Babolsar, Iran.

R E F E R E N C E S

[1] *Allahviranloo, T., Shamsolkotabi, KH., Kiani, N. A. and Alizadeh, L.*, "Fuzzy integer linear programming problems", *Int. J. Contemp. Math. Sciences*", Vol. 2, No. 4, 167-181, 2007.

[2] *Allahviranloo, T., Lotfi, F. H., Kiasary, M. K., Kiani, N.A., Alizadeh, L.*, "Solving full fuzzy linear programming problem by the ranking function", *Appl. Math. Sci.* Vol. 2, pp. 19-32, 2008.

[3] *Bellman, R. E., and Zadeh, L.A.*, "Decision making in a fuzzy environment", Management Science, Vol. 17, pp. 141-164, 1970.

[4] *Cao, B. Y.*, "Optimal Models and Methods with Fuzzy Quantities", Springer, Studies in Fuzziness and Soft Computing, Vol. 248, 2010.

[5] *Dehghan, M. Hashemi B. and Ghatee, M.*, "Computational methods for solving fully fuzzy linear systems", Appl. Math. Comput. Vol. 179, pp. 328–343, 2006.

[6] *Hosseinzadeh Lotfi, F., Allahviranloo, T., Alimardani Jondabeh M., and Alizadeh, L.*, "Solving a full fuzzy linear programming using lexicography method and fuzzy approximate solution", Applied Mathematical Modeling, Vol. 33, pp. 3151–3156, 2009.

[7] *Jime´nez, M., Arenas, M., Bilbao, A., Victoria Rodrı´guez, M.,* "Linear programming with fuzzy parameters: An interactive method resolution", European Journal of Operational Research, Vol. 177, pp. 1599-1609, 2007.

[8] *Kumar, A., Kaur, J. and Singh, P.,* "A new method for solving fully fuzzy linear programming problems", Applied Mathematical Modelling, Vol. 35, pp. 817–823, 2011.

[9] *Kumar, A., Kaur, J., and Singh, P.,* "Fuzzy Optimal Solution of Fully Fuzzy Linear Programming Problems with Inequality Constraints", International Journal of Mathematical and Computer Sciences, Vol. 6, No. 1, pp. 37-41, 2010.

[10] *Liaw, C. F.,* "An efficient tabu search approach for the two machine preemptive open shop scheduling problem", Comput. Oper. Res., Vol. 30, pp. 2081–2095, 2003.

[11] *Lin, H. T., Lee H. T. and Pan, W. J.*, "Heuristics for scheduling in a no-wait open shop with movable dedicated machines", Int. J. Prod. Econ.,Vol. 111, pp. 368-377, 2008.

[12] *Low, C. and Yeh, Y.,* "Genetic algorithm-based heuristics for an open shop scheduling problem with setup, processing, and removal times separated", Rob. Comput. Integr. Manuf., Vol. 23, No. 2, pp. 314-322, 2009.

[13] *Matta, M. E., "* A genetic algorithm for the proportionate multiprocessor open shop", Comput. Oper. Res,. Vol. 36, pp. 2601-2618, 2009.

[14] *Naderi, B., Fatemi Ghomi, S. M. T., Aminnayeri, M. and Zandieh M.,* "Modeling and scheduling open shops with sequence-dependent setup times to minimize total completion time", Int. J. Adv. Manuf. Technol., Vol. 53, pp. 751–760, 2011.

[15] *Nasseri, S. H. and Ebrahimnejad, A.,* "A fuzzy primal simplex algorithm and its application for solving flexible linear programming problems", Eur. J. Ind. Eng. Vol. 4, No. 3, 372–389, 2010.

[16] *Pan, C. H.,* "A study of integer programming formulations for scheduling problems", Int. J. Syst. Sci., Vol. 28, No. 1, pp. 33-41, 1997.

[17] *Stafford, E. F. Jr, Tseng, F. T. and Gupta, J. N. D.,* "Comparative evaluation of MILP flow shop models", J. Oper. Res. Soc. Vol. 56, pp. 88-101, 2005.

[18] *Tanaka, H. Okuda, T. and Asai, K., "*On fuzzy mathematical programming", J. Cybernet., Vol. 3, pp. 37–46, 1974.

[19] *Torabi, S. T., Hassini, E.,* "An interactive possibilistic programming approach for multiple objective supply chain master planning", Fuzzy Sets and Systems, Vol. 159, pp. 193-214, 2008.

[20] *Zimmermann, H. J.,* "Fuzzy programming and linear programming with several objective functions", Fuzzy Sets and Systems, Vol. 1, pp. 45–55, 1978.