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A fuzzy NSGA-II for supplier selection and multi-product allocation order

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A B S T R A C T

In supply chain management, supplier performance is evaluated based on several criteria. In this paper, a fuzzy multi-objective mathematical programming model is presented to consider different qualitative and quantitative factors to choose appropriate suppliers and the optimal order quantity allocated to them. The proposed study uses analytical hierarchy process to rank different suppliers and a fuzzy multi-objective mathematical programming is presented to choose the best suppliers. The study uses NSGAII to solve the resulted problem and the model is analysed using some sample results under various circumstances. The study considers different Pareto solution set obtained by TOPSIS ranking algorithm, and eventually determines the best possible solutions.

1. Introduction

During the past three decades, there have been tremendous efforts on proposing good models for supplier selection (Ghodsypour & O'Brien, 1998; De Boer et al., 2001; Feng et al., 2011). Many supplied selection problems involve different criteria such as cost, quality, on time delivery, etc. (Ghodsypour & O'brien, 2001; Erol et al., 2011). Supplier selection models have been successfully implemented in various industries such as electronic industry (Gencer & Gürpinar, 2007), battery company (Alyanak & Armaneri, 2009), etc. Many supply chain problems are influenced by uncertainty and there have been many methods for handling uncertainty such as fuzzy programming (Amid et al., 2006; Awasthi et al., 2010), Analytical hierarchy process (Hsu & Hu, 2009); gray relational method (Bai & Sarkis, 2010), goal programming (Demirtas & Üstün, 2009; Chang, 2011), Neural network (Choy et al., 2003a,b,c), The Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) (Kannan et al., 2009), fuzzy TOPSIS (Jolai et al., 2011), fuzzy DEMATEL (Chang et al., 2011), decision support systems (Yigin et al., 2007), multi-objective (Demirtas & Üstün, 2008) and simulation technique. There are literally several factors influencing on choosing a good supplier such as price, quality, on time delivery, reliability, etc.

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2. The proposed study

In supply chain management, supplier performance is evaluated based on several criteria to reach sustainable development (Seuring & Müller, 2008). In this paper, a fuzzy multi-objective mathematical programming model (Zadeh, 1965, 1976) is presented to consider different qualitative and quantitative factors to choose appropriate suppliers and the optimal order quantity allocated to them is determined. The proposed study uses analytical hierarchy process (Saaty, 1980) to rank different suppliers and a fuzzy multi-objective mathematical programming (Weber & Current, 1993) is presented to choose the best suppliers. The following assumption holds for the proposed study of this paper.

1. It is possible to purchase multi products from each supplier (Rezaei & Davoodi, 2011; Ng, 2008).
2. Shortage is not allowed.
3. Demand is deterministic.
4. Defect items, delayed time and operating risks are considered in the form fuzzy form.

Symbols

m: Number of suppliers
n: Number of commodities
D_j *: Demand*
X_{ij}*: The amount of product j assigned to supplier i*
C_{ij}*: The capacity of product j assigned to supplier i*
W_i*: Weight of importance given to supplier i*
P_{ij}*: The price of product j purchased from supplier i*
Q_j *: The highest rate of acceptable defect for product j*
q_{ij}*: The average defect of product j purchased from supplier i*
t_{ij}*: The average delay of delivery of product j purchased from supplier i*
C_i *: The cost of risking each supplier*
CR: The maximum cost of risk
B: The maximum budget for purchase
M: A big number

Objective functions

Assigning the maximum amount of order to appropriate supplier (Talluri et al., 2008; Aissaoui et al., 2007),

$$\max Z_1 = \sum_{i=1}^{m}\sum_{j=1}^{n} w_{ij}x_{ij} \tag{1}$$

Minimization the amount of defects (Schott, 1995; Wang & Yang, 2009)

$$\min Z_2 = \sum_{i=1}^{m}\sum_{j=1}^{n} q_{ij}x_{ij} \tag{2}$$

Minimization the amount of delays (Wu & Barnes, 2011)

$$\min Z_3 = \sum_{i=1}^{m}\sum_{j=1}^{n} t_{ij}x_{ij} \tag{3}$$

Minimization the cost of purchases (Wadhwa & Ravindran, 2007)

$$\min Z_4 = \sum_{i=1}^{m}\sum_{j=1}^{n} p_{ij}x_{ij} \tag{4}$$

Minimization the amount of risks (Weber et al., 1991; Wu & Olson, 2008)

$$\min Z_5 = \sum_{i=1}^{m}\sum_{j=1}^{n} r_{ij}x_{ij} \tag{5}$$

Constraints

$$\sum_{j=1}^{n} x_{ij} \le My_i \quad \forall i \tag{6}$$

$$\sum_{i=1}^{m} c_i y_i \le CR \tag{7}$$

$$\sum_{i=1}^{m}\sum_{j=1}^{n} p_i x_{ij} \le B \tag{8}$$

$$\sum_{i=1}^{m} x_{ij} \le D_j \quad \forall j \tag{9}$$

$$\sum_{i=1}^{m} q_{ij}x_{ij} \le Q_j D_j \quad \forall j \tag{10}$$

$$x_{ij} \le c_{ij} \quad \forall i, j \tag{11}$$

Fuzzy objective functions

$$\min z_{31} = z_3^m = \sum_{i=1}^{m}\sum_{j=1}^{n} \boldsymbol{q^m}_{ij}\boldsymbol{x_{ij}} \tag{12}$$

$$\max z_{32} = (z_3^m - z_3^p) = \sum_{i=1}^{m}\sum_{j=1}^{n} (\boldsymbol{q^m}_{ij} - \boldsymbol{q_{ij}}^{\boldsymbol{p}})\boldsymbol{x_{ij}} \tag{13}$$

$$\min z_{43} = (z_4^o - z_4^m) = \sum_{i=1}^{m}\sum_{j=1}^{n} (\boldsymbol{q^o}_{ij} - \boldsymbol{q_{ij}}^{\boldsymbol{m}})\boldsymbol{x_{ij}} \tag{14}$$

$$\min z_{41} = z_4^m = \sum_{i=1}^{m}\sum_{j=1}^{n} \boldsymbol{t^m}_{ij}\boldsymbol{x_{ij}} \tag{15}$$

$$\max z_{42} = (z_4^m - z_4^p) = \sum_{i=1}^{m}\sum_{j=1}^{n} (\boldsymbol{t^m}_{ij} - \boldsymbol{t_{ij}}^{\boldsymbol{p}})\boldsymbol{x_{ij}} \tag{16}$$

$$\min z_{43} = (z_4^o - z_4^m) = \sum_{i=1}^{m}\sum_{j=1}^{n} (\boldsymbol{t^o}_{ij} - \boldsymbol{t_{ij}}^{\boldsymbol{m}})\boldsymbol{x_{ij}} \tag{17}$$

$$\min z_{61} = z_6^m = \sum_{i=1}^{m}\sum_{j=1}^{n} \boldsymbol{r^m}_{ij}\boldsymbol{x_{ij}} \tag{18}$$

$$\max z_{62} = (z_6^m - z_6^p) = \sum_{i=1}^{m}\sum_{j=1}^{n} (\boldsymbol{r^m}_{ij} - \boldsymbol{r_{ij}}^{\boldsymbol{p}})\boldsymbol{x_{ij}} \tag{19}$$

$$\min z_{63} = (z_6^o - z_6^m) = \sum_{i=1}^{m}\sum_{j=1}^{n} (\boldsymbol{r^o}_{ij} - \boldsymbol{r_{ij}}^{\boldsymbol{m}})\boldsymbol{x_{ij}} \tag{20}$$

Therefore we have,

$$Z_{31}^{PIS} = \min Z_3^m, \quad Z_{31}^{NIS} = \text{maz}\, Z_3^m\,, Z_{32}^{PIS} = \max(Z_3^m - Z_3^p\;)$$

$Z_{32}^{NIS} = \min(Z_3^m - Z_3^p), Z_{33}^{PIS} = \min(Z_3^o - Z_3^m), Z_{33}^{NIS} = \max(Z_3^o - Z_3^m)$
$Z_{41}^{PIS} = \min Z_4^m, Z_{41}^{NIS} = \text{maz}\, Z_4^m, Z_{42}^{PIS} = \max(Z_2^m - Z_2^p)$

$Z_{42}^{NIS} = \min(Z_4^m - Z_4^p), Z_{43}^{PIS} = \min(Z_4^o - Z_4^m), Z_{43}^{NIS} = \max(Z_4^o - Z_4^m),$
$Z_{61}^{PIS} = \min Z_6^m, \quad Z_{61}^{NIS} = \text{maz}\, Z_6^m, Z_{62}^{PIS} = \max(Z_2^m - Z_2^p)$

$Z_{62}^{NIS} = \min(Z_6^m - Z_6^p), Z_{63}^{PIS} = \min(Z_4^o - Z_4^m) \quad , \quad Z_{63}^{NIS} = \max(Z_4^o - Z_4^m).$

Now the fuzzy model becomes as follows,

$$\max Z_1 = \sum_{i=1}^{m}\sum_{j=1}^{n} w_{ij} x_{ij} \tag{21}$$

$$\max Z_2 = \lambda_2 \tag{22}$$

$$\max Z_3 = \lambda_3 \tag{23}$$

$$\min Z_4 = \sum_{i=1}^{m}\sum_{j=1}^{n} p_{ij} x_{ij} \tag{24}$$

$$\max Z_5 = \lambda_5 \tag{25}$$

$$\lambda_2(Z_{21}^{NIS} - Z_{21}^{PIS}) \leq Z_{21}^{NIS} - Z_2^m \tag{26}$$

$$\lambda_2(Z_{22}^{PIS} - Z_{22}^{NIS}) \leq \left(z_2^m - z_2^p\right) - Z_{22}^{NIS} \tag{27}$$

$$\lambda_2(Z_{33}^{NIS} - Z_{33}^{PIS}) \leq Z_{33}^{NIS} - (z_3^o - z_3^m) \tag{28}$$

$$\lambda_4(Z_{41}^{NIS} - Z_{41}^{PIS}) \leq Z_{41}^{NIS} - Z_4^m \tag{29}$$

$$\lambda_4(Z_{42}^{PIS} - Z_{42}^{NIS}) \leq \left(z_4^m - z_4^p\right) - Z_{42}^{NIS} \tag{30}$$

$$\lambda_4(Z_{43}^{NIS} - Z_{43}^{PIS}) \leq Z_{43}^{NIS} - (z_4^o - z_4^m) \tag{31}$$

$$\lambda_6(Z_{61}^{NIS} - Z_{61}^{PIS}) \leq Z_{61}^{NIS} - Z_6^m \tag{32}$$

$$\lambda_6(Z_{62}^{PIS} - Z_{62}^{NIS}) \leq \left(z_6^m - z_6^p\right) - Z_{62}^{NIS} \tag{33}$$

$$\lambda_6(Z_{63}^{NIS} - Z_{63}^{PIS}) \leq Z_{63}^{NIS} - (z_6^o - z_6^m) \tag{34}$$

$$z_{31} = z_3^m = \sum_{i=1}^{m}\sum_{j=1}^{n} \boldsymbol{q^m}_{\boldsymbol{ij}}\boldsymbol{x_{ij}} \tag{35}$$

$$z_{32} = (z_3^m - z_3^p) = \sum_{i=1}^{m}\sum_{j=1}^{n} (\boldsymbol{q^m}_{\boldsymbol{ij}} - \boldsymbol{q_{ij}}^{\boldsymbol{p}})\boldsymbol{x_{ij}} \tag{36}$$

$$z_{43} = (z_4^o - z_4^m) = \sum_{i=1}^{m}\sum_{j=1}^{n} (\boldsymbol{q^o}_{\boldsymbol{ij}} - \boldsymbol{q_{ij}}^{\boldsymbol{m}})\boldsymbol{x_{ij}} \tag{37}$$

$$z_{41} = z_4^m = \sum_{i=1}^{m}\sum_{j=1}^{n} \boldsymbol{t^m}_{\boldsymbol{ij}}\boldsymbol{x_{ij}} \tag{38}$$

$$z_{42} = (z_4^m - z_4^p) = \sum_{i=1}^{m}\sum_{j=1}^{n} (\boldsymbol{t^m}_{\boldsymbol{ij}} - \boldsymbol{t_{ij}}^{\boldsymbol{p}})\boldsymbol{x_{ij}} \tag{39}$$

$$z_{43} = (z_4^o - z_4^m) = \sum_{i=1}^{m}\sum_{j=1}^{n} (\boldsymbol{t^o}_{\boldsymbol{ij}} - \boldsymbol{t_{ij}}^{\boldsymbol{m}})\boldsymbol{x_{ij}} \tag{40}$$

$$z_{61} = z_6^m = \sum_{i=1}^{m}\sum_{j=1}^{n} \boldsymbol{r^m}_{\boldsymbol{ij}}\boldsymbol{x_{ij}} \tag{41}$$

$$z_{62} = (z_6^m - z_6^p) = \sum_{i=1}^{m}\sum_{j=1}^{n} (\boldsymbol{r^m}_{\boldsymbol{ij}} - \boldsymbol{r_{ij}}^{\boldsymbol{p}})\boldsymbol{x_{ij}} \tag{42}$$

$$z_{63} = (z_6^o - z_6^m) = \sum_{i=1}^{m}\sum_{j=1}^{n} (\boldsymbol{r^o}_{\boldsymbol{ij}} - \boldsymbol{r_{ij}}^{\boldsymbol{m}})\boldsymbol{x_{ij}} \tag{43}$$

Eqs.(6-1)

2.1 Solution strategy

In this section, we present the implementation of NSGAII as a solution strategy to solve the resulted model. Fig. 1 demonstrates the organization of a chromosome used in our survey.

j ↓, i →

120	140	145
300	0	165
250	260	177
0	145	0
0	500	0

Fig. 1. The structure of the proposed study

According to Fig. 1, the rows represent the suppliers and columns represent products. When cell (i, j) is greater than zero, it means supplier i provides product j and the amount of cell determines the number of product supplied from supplier i for product j. For instance, in Fig. 1, 250 units of products of type 1 are supplied by supplier 3. The crossover operator in this survey is executed as follows,

$$ch_1 = round(Paret_1 \times Alpha + Paret_2 \times (1 - Alpha)),$$
$$ch_2 = round(Paret_2 \times Alpha + Paret_1 \times (1 - Alpha)),$$

where child one (ch_1) and child two (ch_2) are arranged parent 1 ($Paret_1$) and parent 2 ($Paret_2$) using an arbitrary number *Alpha* and Fig. 2 demonstrates the sample.

$Paret_1 \times Alpha$

20	**0**	**30**
50	**30**	**0**
0	**0**	**40**

×

$Paret_2 \times (1 - Alpha)$

0	**50**	**60**
30	**40**	**20**
40	**30**	**0**

→ Child one

8	**30**	**48**
38	**36**	**12**
24	**18**	**16**

$Paret_1 \times (1 - Alpha)$

20	**0**	**30**
50	**30**	**0**
0	**0**	**40**

×

$Paret_2 \times Alpha$

0	**50**	**60**
30	**40**	**20**
40	**30**	**0**

→ Child two

12	**20**	**42**
42	**34**	**8**
16	**12**	**24**

Fig. 2. The structure of crossover

In addition, the mutation operator is accomplished by randomly exchanging the locations of two cells. Fig. 3 demonstrates the structure of the proposed study,

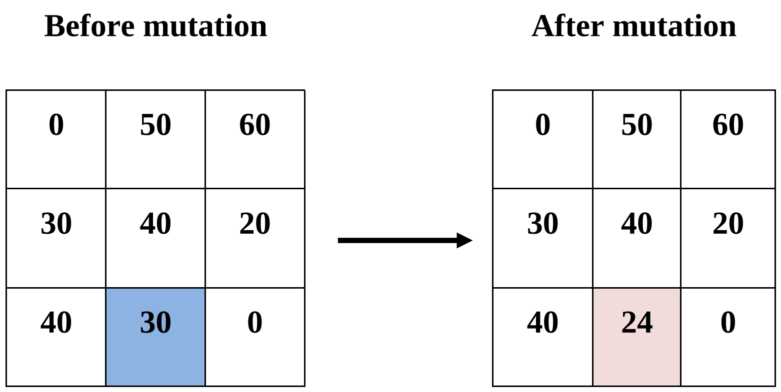

Fig. 3. The structure of mutation

2.2. Parameter tuning

In this survey, for tuning parameters used in our survey the implementation of the proposed study uses different numbers for small, medium and large-scale problems. Table 1 demonstrates the summary of the parameters.

Table 1
The summary of the parameters used for the implementation of NSGAII

Problem size	Number of repeats	Initial population	Cross over rate	Mutation rate
Small	500	30	0.6	0.4
Medium	750	40	0.7	0.3
Large	750	40	0.6	0.4

In our survey, we have generated 9 different sample problems in three different sizes of small, medium and large-scale. The number of products is varied from 3 to 8 and the number of products is changed from 5 to 50. Since there is more than one objective function, different criteria of non-dominated solutions (NOS), diversity, Mean ideal distance (MID), Coverage criteria set (NH) and spread are used to compare the final solutions. Table 2 shows details of the parameters used for sample size.

Table 2
The summary of sample size parameters

Variable	$U(a, b)$
w_{ij}	*U(3,10)*
q_{ij}	*U(0.02,.07)*
p_{ij}	*U(150,350)*
t_{ij}	*U(.1,.15)*
r_{ij}	*U(.1,.6)*
D_j	*U(50000,70000)*
c_i	*U(1500,3500)*
Q_j	*U(.07,.09)*
C_{ij}	*U(40000,50000)*
T_j	*U(.13,.17)*

Table 3 demonstrates the results of the implementation of the proposed method of some sample data.

Table 3

The summary of the results of the implementation of the proposed method

Test Problem Number	NSGA II SPREAD	SPACING	Diversity	MID	NOP	NH	Time
1	491620	190360	3450.3	45196000	182	0.0385	4.3666
2	434840	108340	3654.6	48686000	150	0.3933	5.2221
3	637190	314250	4112.7	51646000	124	0.3145	3.2001
4	1116200	169310	3336	87064000	111	0.0991	2.8160
5	1136700	135190	4125.4	86990000	150	0.6000	4.5723
6	866720	344690	2094.2	103050000	116	0.1897	2.8396
7	889600	155030	4188.3	101230000	139	0.6187	3.8840
8	1530700	228070	2175.1	118860000	156	0.1154	11.2943
9	1346100	655990	1117.6	137290000	190	0.0789	13.9236

The proposed method of this paper has implemented analytical hierarchy process (AHP) (Saaty, 1980) to assign weight to five objective functions given in Eq. (1) to Eq. (5) and the weights for these five objective functions are 0.25, 0.15, 0.25, 0.15 and 0.20, respectively. Now, we rank the set of Pareto solution using TOPSIS method (Hwang & Yoon, 1981; Shih et al., 2007). The implementation of TOPSIS uses five objective functions as criteria and suppliers as alternatives. The implementation is accomplished under two different circumstances. When all objective functions are given equal weights, Pareto solution number 18 is selected as the best alternative solution and Table 4 demonstrates the results of our survey. In addition, the objective functions for Eq. (1) to Eq. (5) are 1568147, 0.71, 0.53, 43096673 and 0.32, respectively.

Table 4

The summary of Pareto solution when all objective functions are assigned equal weights

Supplier	First product	Second product	Third product
Supplier 1	0	0	0
Supplier 2	0	0	0
Supplier 3	0	0	0
Supplier 4	26238	0	0
Supplier 5	0	41362	0
Supplier 6	0	0	25915
Supplier 7	40762	0	19615
Supplier 8	0	0	0
Supplier 9	0	28638	25470
Supplier 10	0	0	0

We have also used the weights obtained by AHP method and Table 5 demonstrates the results of our survey.

Table 5

The summary of Pareto solution when all objective functions are assigned weights obtained by AHP

Supplier	First product	Second product	Third product
Supplier 1	0	0	43437
Supplier 2	47356	0	0
Supplier 3	0	0	0
Supplier 4	0	0	0
Supplier 5	19644	17718	0
Supplier 6	0	18773	0
Supplier 7	0	0	0
Supplier 8	0	0	0
Supplier 9	0	33509	27563
Supplier 10	0	0	0

2.3. Sensitivity analysis

The sensitivity analysis has been accomplished under six different circumstances shown in Table 6.

Table 6
Different scenarios

Scenario	Criteria 1	2	3	4	5
1	0.6	0.1	0.1	0.1	0.1
2	0.1	0.6	0.1	0.1	0.1
3	0.1	0.1	0.6	0.1	0.1
4	0.1	0.1	0.1	0.6	0.1
5	0.1	0.1	0.1	0.1	0.6
6	0.2	0.2	0.2	0.2	0.2

The implementation of the TOPSIS method has resulted different production plan for three products and Fig. 4 demonstrates the results.

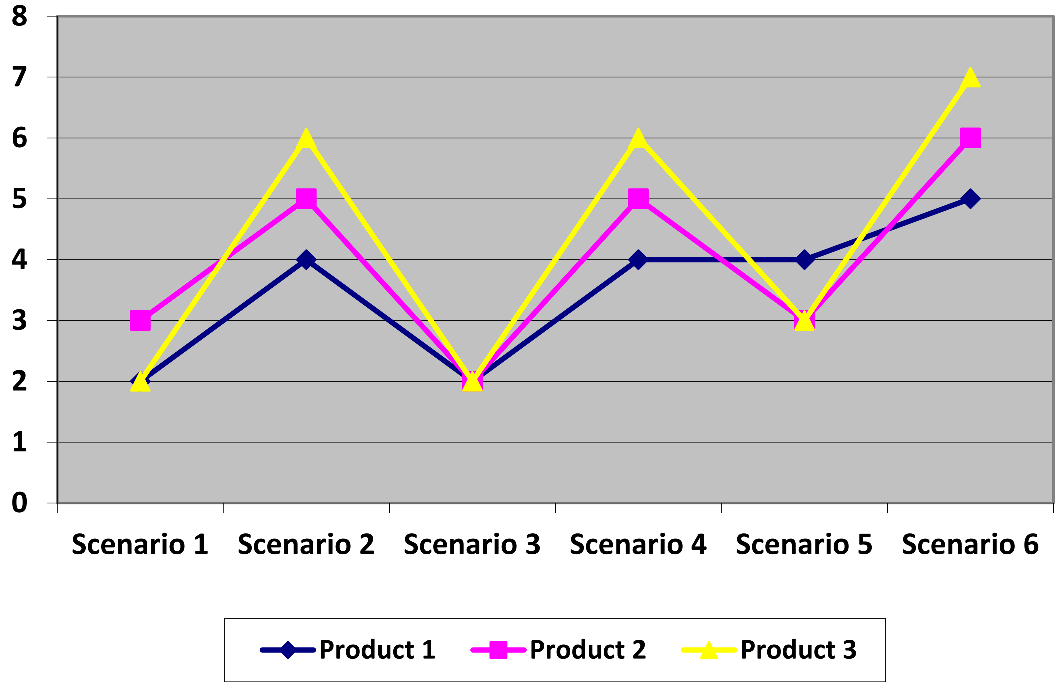

Fig. 4. Production plan under different scenarios

As we can see there is not much change on the pattern of production order in six different scenarios.

3. Conclusion

In this paper, we have developed a multi-objective decision making problem by considering various criteria such as assigning the maximum amount of order to appropriate supplier, minimization the amount of defects, delays, cost and risks. The resulted mathematical problem has been formulated as mixed integer programming and it was solved using NSGAII for some small, medium and large-scale problems. The implementation of the proposed method has been investigated under different scenarios by generating various data. The implementation of the proposed method for some real-world case studies may influence profitability of the production system and we leave it for interested researchers as future studies. Another opportunity is to consider life cycle as part of mathematical model using the idea of Narasimhan et al. (2006). In addition, the proposed study of this paper has used TOPSIS method for ranking purpose but we may use grey relational analysis for ranking used by Noorul Haq and Kannan (2006). Another breakthrough for development of this paper is to consider competition among existing suppliers and we may develop the model using the idea of Ha and Krishnan (2008). Reverse logistic and environment taking issues are another possible contributions, which could be considered for the proposed model of this paper (Kannan et al., 2012; Amin & Zhang, 2012; Govindan et al., 2012).

References

Aissaoui, N., Haouari, M., & Hassini, E. (2007). Supplier selection and order lot sizing modeling: A review. *Computers & operations research*, *34*(12), 3516-3540.

Alyanak, G., & Armaneri, O. (2009). An integrated supplier selection and order allocation approach in a battery company. *Makine Mühendisleri Odasi*, 19 (4), 2-19.

Amid, A., Ghodsypour, S. H., & O'Brien, C. (2006). Fuzzy multiobjective linear model for supplier selection in a supply chain. *International Journal of Production Economics*, *104*(2), 394-407.

Amin, S. H., Razmi, J., & Zhang, G. (2011). Supplier selection and order allocation based on fuzzy SWOT analysis and fuzzy linear programming. *Expert Systems with Applications*, *38*(1), 334-342.

Amin, S. H., & Zhang, G. (2012). An integrated model for closed-loop supply chain configuration and supplier selection: Multi-objective approach. *Expert Systems with Applications*, *39*(8), 6782-6791.

Awasthi, A., Chauhan, S. S., & Goyal, S. K. (2010). A fuzzy multicriteria approach for evaluating environmental performance of suppliers. *International Journal of Production Economics*, *126*(2), 370-378.

Bai, C., & Sarkis, J. (2010). Integrating sustainability into supplier selection with grey system and rough set methodologies. *International Journal of Production Economics*, *124*(1), 252-264.

Borade, A. B., Kannan, G., & Bansod, S. V. (2013). Analytical hierarchy process-based framework for VMI adoption. *International Journal of Production Research*, *51*(4), 963-978.

Büyüközkan, G., & Çifçi, G. (2011). A novel fuzzy multi-criteria decision framework for sustainable supplier selection with incomplete information. *Computers in Industry*, *62*(2), 164-174.

Chai, J., Liu, J. N., & Ngai, E. W. (2013). Application of decision-making techniques in supplier selection: A systematic review of literature. *Expert Systems with Applications*, *40*(10), 3872-3885.

Coello, C. C., Lamont, G. B., & Van Veldhuizen, D. A. (2007). *Evolutionary algorithms for solving multi-objective problems*. Springer Science & Business Media.

Chang, B., Chang, C. W., & Wu, C. H. (2011). Fuzzy DEMATEL method for developing supplier selection criteria. *Expert Systems with Applications*, *38*(3), 1850-1858.

Chang, C. T. (2011). Multi-choice goal programming with utility functions. *European Journal of Operational Research*, *215*(2), 439-445.

Chang, D. Y. (1996). Applications of the extent analysis method on fuzzy AHP. *European Journal of Operational Research*, *95*(3), 649-655.

Chen, C. T., Lin, C. T., & Huang, S. F. (2006). A fuzzy approach for supplier evaluation and selection in supply chain management. *International Journal of Production Economics*, *102*(2), 289-301.

Chen, Y. J. (2011). Structured methodology for supplier selection and evaluation in a supply chain. *Information Sciences*, *181*(9), 1651-1670.

Choy, K. L., Lee, W. B., & Lo, V. (2003a). Design of an intelligent supplier relationship management system: a hybrid case based neural network approach. *Expert Systems with Applications*, *24*(2), 225-237.

Choy, K. L., Fan, K. K., & Lo, V. (2003b). Development of an intelligent customer-supplier relationship management system: the application of case-based reasoning. *Industrial Management & Data Systems*, *103*(4), 263-274.

Choy, K. L., Lee, W., & Lo, V. (2003c). Design of a case based intelligent supplier relationship management system—the integration of supplier rating system and product coding system. *Expert Systems with Applications*, *25*(1), 87-100.

De Boer, L., Labro, E., & Morlacchi, P. (2001). A review of methods supporting supplier selection. *European Journal of Purchasing & Supply Management*,*7*(2), 75-89.

Demirtas, E. A., & Ustun, O. (2009). Analytic network process and multi-period goal programming integration in purchasing decisions. *Computers & Industrial Engineering*, *56*(2), 677-690.

Demirtas, E. A., & Üstün, Ö. (2008). An integrated multiobjective decision making process for supplier selection and order allocation. *Omega*, *36*(1), 76-90.

Dickson, G.W. (1966). An analysis of vendor selection system and decisions. *Journal of Purchasing*, 2(1), 5-17.

Ding, H., Benyoucef, L., & Xie, X. (2005). A simulation optimization methodology for supplier selection problem. *International Journal of Computer Integrated Manufacturing*, *18*(2-3), 210-224.

Erol, I., Sencer, S., & Sari, R. (2011). A new fuzzy multi-criteria framework for measuring sustainability performance of a supply chain. *Ecological Economics*,*70*(6), 1088-1100.

Feng, B., Fan, Z. P., & Li, Y. (2011). A decision method for supplier selection in multi-service outsourcing. *International Journal of Production Economics*,*132*(2), 240-250.

Gencer, C., & Gürpinar, D. (2007). Analytic network process in supplier selection: A case study in an electronic firm. *Applied Mathematical Modelling*,*31*(11), 2475-2486.

Ghodsypour, S. H., & O'Brien, C. (1998). A decision support system for supplier selection using an integrated analytic hierarchy process and linear programming. *International Journal of Production Economics*, *56*, 199-212.

Ghodsypour, S. H., & O'brien, C. (2001). The total cost of logistics in supplier selection, under conditions of multiple sourcing, multiple criteria and capacity constraint. *International Journal of Production Economics*, *73*(1), 15-27.

Govindan, K., Palaniappan, M., Zhu, Q., & Kannan, D. (2012). Analysis of third party reverse logistics provider using interpretive structural modeling. *International Journal of Production Economics*, *140*(1), 204-211.

Govindan, K., Khodaverdi, R., & Jafarian, A. (2013). A fuzzy multi criteria approach for measuring sustainability performance of a supplier based on triple bottom line approach. *Journal of Cleaner Production*, *47,* 345-354.

Ha, S. H., & Krishnan, R. (2008). A hybrid approach to supplier selection for the maintenance of a competitive supply chain. *Expert Systems with Applications*,*34*(2), 1303-1311.

Noorul Haq, A., & Kannan, G. (2006). An integrated approach for selecting a vendor using grey relational analysis. *International Journal of Information Technology & Decision Making*, *5*(02), 277-295.

Haq, A. N., & Kannan, G. (2006). Fuzzy analytical hierarchy process for evaluating and selecting a vendor in a supply chain model. *The International Journal of Advanced Manufacturing Technology*, *29*(7-8), 826-835.

Ho, W., Xu, X., & Dey, P. K. (2010). Multi-criteria decision making approaches for supplier evaluation and selection: A literature review. *European Journal of Operational Research*, *202*(1), 16-24.

Hong, G. H., Park, S. C., Jang, D. S., & Rho, H. M. (2005). An effective supplier selection method for constructing a competitive supply-relationship. *Expert Systems with Applications*, *28*(4), 629-639.

Hsu, C. W., & Hu, A. H. (2009). Applying hazardous substance management to supplier selection using analytic network process. *Journal of Cleaner Production*, *17*(2), 255-264.

Huang, S. H., & Keskar, H. (2007). Comprehensive and configurable metrics for supplier selection. *International journal of production economics*, *105*(2), 510-523.

Hwang, C.L., & Yoon, K. (1981). *Multiple Attribute Decision Making*. Springer-Verlag, Berlin.

Jolai, F., Yazdian, S. A., Shahanaghi, K., & Khojasteh, M. A. (2011). Integrating fuzzy TOPSIS and multi-period goal programming for purchasing multiple products from multiple suppliers. *Journal of Purchasing and Supply Management*, *17*(1), 42-53.

Kannan, D., Diabat, A., Alrefaei, M., Govindan, K., & Yong, G. (2012). A carbon footprint based reverse logistics network design model. *Resources, Conservation and Recycling*, *67*, 75-79.

Kannan, G., Murugesan, P., Senthil, P., & Noorul Haq, A. (2009). Multicriteria group decision making for the third party reverse logistics service provider in the supply chain model using fuzzy TOPSIS for transportation services .*International Journal of Services Technology and Management*, *11*(2), 162-181.

Kannan, G., Pokharel, S., & Kumar, P. S. (2009). A hybrid approach using ISM and fuzzy TOPSIS for the selection of reverse logistics provider. *Resources, conservation and recycling*, *54*(1), 28-36.

Govindan, K., & Murugesan, P. (2011). Selection of third-party reverse logistics provider using fuzzy extent analysis. *Benchmarking: An International Journal*,*18*(1), 149-167.

Kokangul, A., & Susuz, Z. (2009). Integrated analytical hierarch process and mathematical programming to supplier selection problem with quantity discount.*Applied mathematical modelling*, *33*(3), 1417-1429.

Ku, C. Y., Chang, C. T., & Ho, H. P. (2010). Global supplier selection using fuzzy analytic hierarchy process and fuzzy goal programming. *Quality & Quantity*, *44*(4), 623-640.

Kull, T. J., & Talluri, S. (2008). A supply risk reduction model using integrated multicriteria decision making. *Engineering Management, IEEE Transactions on*,*55*(3), 409-419.

Kumar, M., Vrat, P., & Shankar, R. (2004). A fuzzy goal programming approach for vendor selection problem in a supply chain. *Computers & Industrial Engineering*, *46*(1), 69-85.

Lee, A. H., Kang, H. Y., & Chang, C. T. (2009). Fuzzy multiple goal programming applied to TFT-LCD supplier selection by downstream manufacturers. *Expert Systems with Applications*, *36*(3), 6318-6325.

Lee, A. H. (2009). A fuzzy supplier selection model with the consideration of benefits, opportunities, costs and risks. *Expert systems with applications*,*36*(2), 2879-2893.

Liao, C. N., & Kao, H. P. (2011). An integrated fuzzy TOPSIS and MCGP approach to supplier selection in supply chain management. *Expert Systems with Applications*, *38*(9), 10803-10811.

Lin, C.C. (2004). A weighted maxmin model for fuzzy goal programming. *Fuzzy Sets and Systems*, 142 (3), 407-420.

Mafakheri, F., Breton, M., & Ghoniem, A. (2011). Supplier selection-order allocation: a two-stage multiple criteria dynamic programming approach. *International Journal of Production Economics*, *132*(1), 52-57.

Marufuzzaman, M., Ahsan, K. B., & Xing, K. (2009). Supplier selection and evaluation method using Analytical Hierarchy Process (AHP): a case study on an apparel manufacturing organisation. *International Journal of Value Chain Management*, *3*(2), 224-240.

Mehrjerdi, Y. Z. (2012). Developing fuzzy TOPSIS method based on interval valued fuzzy sets. *International Journal of Computer Applications*, *42*(14), 7-18.

Narasimhan, R., Talluri, S., & Mahapatra, S. K. (2006). Multiproduct, multicriteria model for supplier selection with product life-cycle considerations. *Decision Sciences*, *37*(4), 577-603.

Ng, W. L. (2008). An efficient and simple model for multiple criteria supplier selection problem. *European Journal of Operational Research*, *186*(3), 1059-1067.

Rezaei, J., & Davoodi, M. (2011). Multi-objective models for lot-sizing with supplier selection. *International Journal of Production Economics*, *130*(1), 77-86.

Saaty, T. L. (1980). The analytic hierarchy process: planning, priority setting, resources allocation. *New York: McGraw*.

Sarkis, J. (1998). Evaluating environmentally conscious business practices. *European Journal of Operational Research*, *107*(1), 159-174.

Schott, J. R. (1995). *Fault Tolerant Design Using Single and Multicriteria Genetic Algorithm Optimization* (No. AFIT/CI/CIA-95-039). Air Force Inst. of Tech. WRIGHT-PATTERSON AFB OH.

Seuring, S., & Müller, M. (2008). From a literature review to a conceptual framework for sustainable supply chain management. *Journal of cleaner production*, *16*(15), 1699-1710.

Shih, H. S., Shyur, H. J., & Lee, E. S. (2007). An extension of TOPSIS for group decision making. *Mathematical and Computer Modelling*, *45*(7), 801-813.

Talluri, S., Vickery, S. K., & Narayanan, S. (2008). Optimization models for buyer-supplier negotiations. *International Journal of Physical Distribution & Logistics Management*, *38*(7), 551-561.

Wadhwa, V., & Ravindran, A. R. (2007). Vendor selection in outsourcing. *Computers & operations research*, *34*(12), 3725-3737.

Wang, T. C., & Chang, T. H. (2007). Application of TOPSIS in evaluating initial training aircraft under a fuzzy environment. *Expert Systems with Applications*,*33*(4), 870-880.

Wang, T. Y., & Yang, Y. H. (2009). A fuzzy model for supplier selection in quantity discount environments. *Expert Systems with Applications*, *36*(10), 12179-12187.

Weber, C. A., & Current, J. R. (1993). A multiobjective approach to vendor selection. *European Journal of Operational Research*, *68*(2), 173-184.

Weber, C. A., Current, J. R., & Benton, W. C. (1991). Vendor selection criteria and methods. *European journal of operational research*, *50*(1), 2-18.

Wu, C., & Barnes, D. (2011). A literature review of decision-making models and approaches for partner selection in agile supply chains. *Journal of Purchasing and Supply Management*, *17*(4), 256-274.

Wu, D., & Olson, D. L. (2008). Supply chain risk, simulation, and vendor selection. *International journal of production economics*, *114*(2), 646-655.

Wu, D. D., Zhang, Y., Wu, D., & Olson, D. L. (2010). Fuzzy multi-objective programming for supplier selection and risk modeling: A possibility approach. *European Journal of Operational Research*, *200*(3), 774-787.

Yigin, I. H., Taşkin, H., Cedimoglu, I. H., & Topal, B. (2007). Supplier selection: an expert system approach. *Production Planning and Control*, *18*(1), 16-24.

Zadeh, L.A. (1965). Fuzzy sets. *Journal of Information and Control*, 8, 338-353.

Zadeh, L.A. (1976). A fuzzy algorithmic approach to the definition of complex or imprecise concepts. *International Journal of Man-Machine Studies*, 8, 249-291.