Optimization
Iranian Journal of Optimization
Volume 10, Issue 1, 2018, 41-49
Research Paper
Online version is available on: www.ijo.iaurasht.ac.ir

Islamic Azad University
Rasht Branch
E-ISSN:2008-5427

A Model for Allocating Orders to Suppliers in Case of Quantity Discounts

Amir Amini[1*], Alireza Alinezhad[2] and Behzad Nourizad Heydarlou[3]

[1] M.Sc. Student of Industrial Engineering, Department of Industrial Engineering, Urmia University of Technology, Urmia, Iran
[2] Associate professor, Faculty of Industrial and Mechanical Engineering, Qazvin Branch, Islamic Azad University, Qazvin, Iran
[3] PhD Student of Industrial Engineering, Science and Research Branch, Islamic Azad University, Tehran, Iran

Received: 21 August 2017
Accepted: 19 September 2017

Abstract

One of the most important activities in the management of input items of a company is focusing on the process of purchasing, supplier selection and allocating order to suppliers. Decisions about supplier selection due to simultaneously taking inconsistent and diverse issues into account in a wide range of strategic to operational factors, and from quantitative to qualitative criteria will be complex by nature. In order to select the best suppliers it is necessary to make a trade-off between these tangible and intangible factors some of which may conflict. When business volume discounts exist, this problem becomes more complicated. In this paper a multi-objective model for order allocation under volume discount conditions is presented. In this context, suppliers offer price discounts on total business volume. A solution methodology is presented to solve the multi-objective model, and the model is illustrated using a numerical example. Studying various combinations of constraints such as capacity, timely delivery, disadvantages and cost, taking into account quantity discounts, considering the weight of the suppliers in order allocation and integration of these cases with each other, have made the current research quite unique.

Keywords:
Order allocation
supplier selection
Volume discount
Multi-criteria and Multi-Objective decision making

***Correspondence E_mail**: a.amini@ine.uut.ac.ir

INTRODUCTION

Supplier selection is an important decision in supply chain management and the right choice in this matter will strengthen the competitiveness of the supply chain. Supplier evaluation and selection Decisions are important part of supply chain management. This issue is true for both manufacturing and services companies and for the acquisition of goods and services including material and equipment. In the current intense competition, low cost production and high quality products is not possible without satisfying suppliers (Christopher, 1998).

The selection of suppliers is inherently a multi-purpose decision that looks for minimizing the cost of procurement and at the same time maximizing the quality and performance of services. The issue of selecting suppliers with the fact that a variety of factors must be considered in the decision-making process becomes more complex. In addition, the problem become more complex with the fact that supplier may have different performance characteristics for various criteria. For example, a supplier that could offer a product with a minimum unit price may not provide the best quality or performance of services in competition between suppliers.

Price discounts offered by supplier are the most difficult aspect for buyer. In the multi-objective programming model, some limitations such as supplier's capacity, quality, and timely submission of goods are considered. In other words, none of the suppliers may be able to meet the requirements of the buyer alone. And the buyer may purchase a part of his demand from a supplier and another part from the other supplier to compensate lack of capacity or low quality of suppliers (Levi & Kaminsky, 2004).

The multi-objective model for allocating orders to suppliers presented in this study, has Taken into account quantity discounts. Studying various combinations of constraints such as capacity, timely delivery, disadvantages and cost, taking into account quantity discounts, considering the weight of the suppliers in order allocation and integration of these cases with each other, have made the current research quite unique.

This study adopts a multi-objective model approach first to identify top suppliers by considering the effects of interdependence among selection criteria and to handle inconsistent and uncertain judgments. Then it is integrated with multi- objective linear programming (MOLP) in selecting the best suppliers for achieving optimal order allocation under problem conditions.

LITERATURE REVIEW

When an organization is dealing with selecting the best supplier to deliver a good or service, the decision can often be very complex. Supplier selection problems are multi-criteria problems which have many qualitative and quantitative concerns.

Supplier selection is considered as one of the most crucial and decisive competitive factors (Çebi & Otay, 2016). Decisions about supplier selection due to simultaneously taking inconsistent and diverse issues into account in a wide range of strategic to operational factors, and from quantitative to qualitative criteria will be complex by nature (Yu et al., 2013). Considering various criteria and when each of the suppliers cannot meet all of them alone its complexity will be increased (Ayhan & Kilic, 2015). In 1966 for the first time Dixon identified and analyzed the significance of the 23 criteria for supplier selection and took advantage of a survey method of managers for this purpose. He concluded that "quality" is the most important criterion and “timely delivery" and "performance history" place behind it (Dickson, 1966).

In addition, in a recent review by Weber et al. (1991) on supplier selection criteria and methods, they found that from 76 reviewed studies 47 articles considered more than one criterion. They finally determined the three criteria for supplier selection that were more popular compared to others as: net price, delivery and quality. Therefore, supplier selection is a multi- criteria decision making problem and to select the best suppliers it is necessary to establish a balance between inconsistent tangible and intangible factors (Xia & Wu, 2007).

In 1988 Spekman emphasized on establishing long term relationships between buyer and supplier to achieve strong competitive position. Also on creation of cooperation and improvement relationships with lean and unique suppliers rather than short-term relationships with them has been emphasized (Wang, 2001).

Thompson (1990 & 1991) and Thompson et al. (1998) developed the Analysis of suppliers' records and history in order to rank them in an unstable environment based on a number of criteria given weight through a simulation technique, after that Li et al. 2004 introduced a new measure for supplier performance evaluation Then, Wang and Yang, 2009 used 12 performance indicators to assess supplier performance.

MODELS AND METHODS FOR SUPPLIER EVALUATION AND SELECTION

There are four major decisions that are related to the supplier selection problem: what product or services to order, from which suppliers, in what quantities, and in which time periods? In an attempt to provide reasonable answers to the second and third questions, many models have been developed for supplier selection. The most basic models were classification models that presented by Timmerman (1986). These models are based on past history and experiences of suppliers in connection with a series of established criteria. If the supplier meets the criterion, he receives a positive score; otherwise a negative score is allocated to him which subsequently algebraic summation of scores shows the final ranking of supplier (Croom et al., 2000).

Ghodsypour and O'Brien, (1998) proposed a model for evaluation of supplier selection in the presence of multi-source, multi- criteria and price discount. They have considered impacts of budgetary, and suppliers' quality and capacity constraints and developed an integrated Analytic Hierarchy Process (AHP) and linear programming model to help managers which considers both quantitative and qualitative factors in a systematic policy. Moreover, they have also suggested an algorithm to analyze the sensitivity in order to take into account different procedures of the decision making process.

In many of these models, the net price is given as logistic cost, while storage, transport and ordering are also important in the decision-making. Only in models such as Benton and Krajewski (1990), Weber et al. (1991), Hong and Hayya (1992), Ghodsypour and O'Brien (1998), Aguezzoul and Ladet (2004), Mendoza (2007) and Jafari Songhori et al. (2010)'s, ordering and storage costs are considered. But in the meantime Benton and Krajewski (1990) have not considered supplier's capacity and quality constraints.

Amid et al. (2006) solved a supplier selection problem in a supply chain by providing a Fuzzy multi- objective linear model and using fuzzy hierarchical decision making technique. Mohammad Ebrahim et al. (2009) presented a scatter search algorithm for supplier selection and order lot sizing under multiple price discount environment.

Some researchers such as Nydick and Hill (1992) used the analytic hierarchy process to structure the supplier selection procedure. Chen et al. (2006) presented a fuzzy decision making approach to deal with the supplier selection problem in supply chain system. They used linguistic values to assess the ratings and weights for the criteria. These linguistic ratings can be expressed in trapezoidal or triangular fuzzy numbers. Then, a hierarchy multiple criteria decision making (MCDM) model based on fuzzy sets theory is proposed to deal with the supplier selection problems in the supply chain system. According to the concept of the technique for order preference by similarity to ideal solution (TOPSIS), a closeness coefficient is defined to determine the ranking order of all suppliers by calculating the distances to the both fuzzy positive ideal solution (FPIS) and fuzzy negative ideal solution (FNIS) simultaneously.

Demirtas Ustun (2008 & 2009) used an integrated multi-objective decision making process for supplier selection and order allocation and an analytic network process and multi-period goal programming integration in purchasing decisions. Lin (2009a & 2009b), Lin et al. (2009) and Lin (2012) used fuzzy analytic network process (FANP) approach first to identify top suppliers by considering the effects of interdependence among selection criteria and to handle inconsistent and uncertain judgments. FANP is then integrated with fuzzy multi- objective linear programming (FMOLP) in selecting the best suppliers for achieving optimal order allocation under fuzzy conditions. However, their model has not considered general discount conditions of suppliers.

Dağdeviren and Yüksel (2010) applied fuzzy ANP method to measure the competitive level organizations considering Porter's 5 competitive forces. They have studied fuzzy judgment of decision makers using the developed fuzzy extension of the ANP by Mikhailov and Singh (2003).

In a study in volume discount Ayhan and Kilic (2015) considered 4 criteria including; price, quality, delivery time and after sales performance for the selection of preferred suppliers. Çebi and Otay (2016) developed a two-phased fuzzy approach for supplier selection and order allocation. . In the first stage fuzzy Multi-Objective Optimization by Ratio Analysis (MULTI MOORA) was used for assessing and selecting suppliers taking into account subjective criteria. In the second stage, fuzzy goal programming was used to determine the order quantity allocated to the selected supplier. By integrating multi-criteria decision analysis and linear programming, Sodenkamp et al. (2016) proposed a superior innovative approach in order to support collaborative multi-objective supplier selection and order allocation decisions.

MODEL DEVELOPMENT

Model assumptions

Before deciding about the selection of suppliers the buyer must determine purchase criteria and evaluate supplier performance. In this study, price, flaws and timely delivery criteria have been used as purchase criteria in the model. Since these criteria are three of the top factors that influence supplier selection.

Assume that i= 1, 2, 3… I products are purchased from j= 1, 2, 3… J suppliers that each of which offer different levels of price, quality, timely delivery performance and supply capacity for each product they sell.

Based on the total value of buyer's purchase, the supplier j suggests relative discount price that has r = 1, 2 , …m_j discount intervals on the basis of deal size.

Defining Symbols

A list of symbols used to formulate the problem is listed as follows:

i: Goods or products

j: supplier

S_j: Suppliers that offer product i

K_j : a set products that are provided by the supplier j

W_j : The final weight of supplier j

R_j : A set of intervals of supplier j discounts

m_j :the amount of Discount of supplier j

r: discount distance- The number of discount intervals in table: $1 \le r \le m_j$

b_{jr}: $0= b_{j0} < b_{j1} <\ldots <b_j, m_j$: The upper limit from discount distance in discount table

d_{jr}: Discount coefficient related to the level of Discount of Discount table of supplier j

P_{ij}: Unit price of product i provided by of supplier j

q_{ij}: The rate or amount of defective products which are provided by supplier j

Q_i: The maximum rate of defective products that is acceptable to buyer

t_{ij}: The on time delivery rate of product i suggested by supplier j

T_i: The minimum rate of on-time delivery of product i which is acceptable to buyer

C_{ij}: The maximum supply capacity of product i that provided by supplier j

D_i: The total demand of product i

X_{ij}: The amount of product i which is purchased from supplier j

V_{jr}: The deal volume purchased from supplier j at r Discount level

Y_{jr}: A variable which is equal to 0 or 1

If deal volume purchased from supplier j is placed in r level of discount table, then we have: $Y_{jr}= 1$

MODELING THE PROBLEM

Objective functions

In the model presented in this study three criteria including price, defective rate and delivery (shipping) are used for supplier selection. Multi-objective programming model has been developed to help the decision maker to select the best supplier.

The first objective function:

$$\sum_{i\epsilon K_j} \sum_{j\epsilon S_i} (1 - t_{ij}) X_{ij} \le (1 - T_i) D_i \qquad (1)$$

Since W_j is the final weight of supplier j and is the number of purchased units of product i from supplier j Therefore, more products are bought from the supplier which has more weight. So the value of W_j X_{ij} should be maximized. This objective function is described as above.

The second objective function:

$$Min\ Z_2 = \sum_{j\epsilon S_i} \sum_{r\epsilon R_j} (1 - d_{jr}) V_{jr} \quad (2)$$

Where:

$$\sum_{r\epsilon R_j} V_{jr} = \sum_{i\epsilon K_j} P_{ij} X_{ij} \quad j\epsilon S_i$$

Consider the cumulative decline in supplier's prices; the buyer makes purchase decisions in the direction of minimizing the total cost of the purchase. This objective function is stated as above.

The third objective function:

$$Min\ Z_3 = \sum_{i\in K_j} \sum_{j\in S_i} q_{ij} X_{ij} \quad (3)$$

The buyer expects the minimum possible number of defective i goods received from suppliers j. This objective function can be indicated as above.

The fourth objective function:

$$Max\ Z_4 = \sum_{i\in K_j} \sum_{j\in S_i} t_{ij} X_{ij} \quad (4)$$

The buyer expects the maximum number of i goods be submitted timely by the supplier j, to its reach. The intended objective function is declared as above.

Limitations

The important limitations of the problem expressed in this research include the capacity of the supplier and of price discounts of supplier. Also, buyer's demand requires desired quality and timely delivery which can be formulated as follows:

The first limitation: Capacity constraint

$$\sum_{i\in K_j} X_{ij} \leq C_{ij} \quad j \in S_i \quad (5)$$

The total number of i goods that is purchased from a specified supplier cannot exceed from supply capacity of that supplier. This limitation can be expressed in the above form.

The second limitation: discount constraint

$$b_{j,r-1} Y_{jr} \leq V_{jr} < b_{jr} Y_{jr} \quad j \in S_i$$
$$\sum_{r\in R_j} Y_{jr} \leq 1 \quad j \in R_j \quad (6)$$

V_{jr} Trading volume from supplier j should be occurred at reasonable discount distance of the price discount table and emerge at only one distance. Eq. 6 represents this limitation

The third limitation: demand constraint

$$\sum_{j\in S_i} X_{ij} = D_i \quad i \in K_j \quad (7)$$

All suppliers that provide product i must meet the demands of the buyer for product i. This limitation can be stated as Eq. 7.

The fourth limitation: quality constraint

$$\sum_{i\in K_j} \sum_{j\in S_i} q_{ij} X_{ij} \leq Q_i D_i \quad (8)$$

The total number of defective i products that is received by buyer from different suppliers must be smaller than the maximum acceptable defective i products. This limitation is reflected in Eq. 8.

The fifth limitation: delivery or shipping constraint

$$\sum_{i\in K_j} \sum_{j\in S_i} (1 - t_{ij}) X_{ij} \leq (1 - T_i) D_i \quad (9)$$

Since T_i is the minimum acceptable rate of on-time delivery of i goods to the buyer and t_{ij} is the rate of on-time delivery of goods by supplier j, so the whole i goods from different suppliers that are not delivered to the buyer on time should be smaller than the maximum rate of delivery of i goods which is acceptable for the buyer. This limitation has been shown above.

NUMERICAL EXAMPLE

In order to validate the model a numerical example is designed and implemented by the actual data. Let us assume that there are 4 suppliers in the evaluation process. Quantitative data about all criteria and sub criteria for different suppliers is shown in Table 1.

Table 1: The final weight Suppliers

supplier	Price	Technical level	Flaws	Reliability	Timely delivery	Supply Capacity	Time of Turn-around Repair	Warranty period	Weight of Suppliers
1	55	2	0.04	80	0.85	400	2	4	0.2016
2	40	1	0.01	95	0.95	700	1	3	0.3222
3	45	1	0.02	90	0.98	600	1	3	0.2734
4	50	3	0.06	70	0. 90	500	3	4	0.2028

Now assume that the buyer wants to purchase a product from the best suppliers and allocate them the optimum order quantity. If the total product demand is 1,200 units and the maximum rate of acceptable defective units is 0.02 and minimum rate of acceptable on-time delivery is 0.92. Also the 4 suppliers apply a similar volume discount plan with 3 are discount distance, as shown in Table 2.

Table 2: Volume discount plans of 4 suppliers

R	deal volume ($ 1,000)	discount percent
1	0 to below 10	0
2	10 to below 20	5
3	20 and above	10

SOLVING METHOD

The following multifunction programming model must be solved to find the optimal order quantities allocated to suppliers.

$$Max\ Z = [Z_1,\ -Z_2,\ -Z_3, Z_4]$$

$$Z_2 = \sum_{j=1}^{4} \sum_{r \in R_i} (1 - d_{jr}) V_{jr}$$

$$Z_1 = 0.2016X_1 + 0.3222X_2 + 0.2734X_3 + 0.2028X_4$$
$$z_3 = 0.04X_1 + 0.01X_2 + 0.02X_3 + 0.06X_4$$
$$Z_4 = 0.85X_1 + 0.95X_2 + 0.98X_3 + 0.90X_4$$
$$\text{S.t}$$
$$V_{jr} = P_j X_j \qquad j = 1, 2, 3, 4 \qquad r \in R_j$$
$$X_1 + X_2 + X_3 + X_4 = 1200$$
$$0.04X_1 + 0.01X_2 + 0.02X_3 + 0.06X_4 \leq 1200 * 0.02$$
$$0.015X_1 + 0.05X_2 + 0.02X_3 + 0.10X_4 \leq 1200 * (1 - 0.92)$$
$$X_1 \leq 400 \qquad X_2 \leq 700 \qquad X_3 \leq 600 \qquad X_4 \leq 500$$
$$b_{j,r-1}\ \ Y_{jr} \leq V_{jr} < b_{jr} Y_{jr} \quad j = 1, 2, 3, 4 \qquad r \in R_j$$
$$\textstyle\sum_{r \in R_i} Y_{jr} \leq 1 \qquad j \in S_i \qquad j = 1,2,3,4$$
$$X_j \geq 0 \quad j = 1, 2, 3, 4$$
$$R_j = \{1, 2, 3\}$$

In this study to solve the multi-objective model, first using comprehensive criterion method (p = 1) the multi-objective model is turned into a single objective problem. For this purpose, we use the following formula:

$$Min\ \ \frac{f_4^* - f_4}{|f_4|} + \ ...+ \frac{f_1^* - f_1}{|f_1|} \tag{10}$$

Then using Lingo software we solve the model.

RESULTS

Supplier selection as an essential component of supply chain management is usually a multi-criteria decision problem which, in actual business contexts, may have to be solved in the absence of precise information. To tackle with the multiple criteria and the inherent uncertainty in supplier selection, this study proposes a multi-objective model for order allocation under volume discount conditions. In this context, suppliers offer price discounts on total business volume. A solution methodology is presented to solve the multi-objective model, and the model is illustrated using a numerical example. Studying various combinations of constraints such as capacity, timely delivery, disadvantages and cost, taking into account quantity discounts, considering the weight of the suppliers in order allocation and integration of these cases with each other, have made the current research quite unique.

All calculations to optimize individual

functions as well as general optimization (the objective function obtained by L-P-metric method) are done using Lingo software. After running the problem in Lingo software, the results can be seen as follows:

```
Global optimal solution found at iteration:          5
Objective value:                                0.2590674E-02

                Variable           Value        Reduced Cost
                      X1        0.000000            0.000000
                      X2        700.0000            0.000000
                      X3        500.0000            0.000000
                      X4        0.000000            0.000000
                      D1       0.1000000            0.000000
                      V1        0.000000        0.2343499E-04
                      D2       0.1000000            0.000000
                      V2        28000.00            0.000000
                      D3       0.1000000            0.000000
                      V3        22500.00            0.000000
                      D4       0.1000000            0.000000
                      V4        0.000000        0.5035829E-04
               PRICE( 1)        55.00000            0.000000
               PRICE( 2)        40.00000            0.000000
               PRICE( 3)        45.00000            0.000000
               PRICE( 4)        50.00000            0.000000

                     Row    Slack or Surplus      Dual Price
                       1       0.2590674E-02       -1.000000
                       2        7.000000            0.000000
                       3        1044.600            0.000000
                       4        0.000000        0.1315653E-02
                       5        400.0000            0.000000
                       6        0.000000        0.5980360E-03
                       7        100.0000            0.000000
                       8        500.0000            0.000000
                       9        0.000000        0.4323697E-04
                      10        0.000000            0.000000
                      11        0.000000        0.1980198E-04
                      12        0.000000          -0.6160616
                      13        0.000000        0.1980198E-04
                      14        0.000000          -0.4950495
                      15        0.000000        0.7016027E-04
                      16        0.000000            0.000000
```

Fig. 1. Lingo software output

The results obtained from the case shows that the new presented model can make the supplier selection process more accurate and so it introduces a new point of view which has been misled up to now.

REFERENCES

Aguezzoul, A., & Ladet, P. (2004, April). A nonlinear multi-objective approach for the supplier selection taking into account transportation. In *International conference on Multi Objective Programming and Goal Programming "New Trends and Applications* (pp. 14-16).

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.

Ayhan, M. B., & Kilic, H. S. (2015). A two stage approach for supplier selection problem in multi-item/multi-supplier environment with quantity discounts. *Computers & Industrial Engineering, 85*, 1-12.

Benton, W. C., & Krajewski, L. (1990). Vendor performance and alternative manufacturing environments. *Decision Sciences, 21*(2), 403-415.

Çebi, F., & Otay, İ. (2016). A two-stage fuzzy approach for supplier evaluation and order allocation problem with quantity discounts and lead time. *Information Sciences, 339*, 143-157.

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.

Christopher, M. (1998). Logistics and Supply

Chain Management: Strategies for Reducing Cost and Improving Service Financial Times: Pitman Publishing. London, 1998 ISBN 0 273 63049 0 (hardback) 294+ 1× pp.
Croom, S., Romano, P., & Giannakis, M. (2000). Supply chain management: an analytical framework for critical literature review. *European journal of purchasing & supply management, 6*(1), 67-83.
Dağdeviren, M., & Yüksel, İ. (2010). A fuzzy analytic network process (ANP) model for measurement of the sectoral competititon level (SCL). *Expert systems with applications, 37*(2), 1005-1014.
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.
Dickson, G. W. (1966). An analysis of vendor selection and the buying process. *journal of Purchasing, 2*(1), 5-17.
Ebrahim, R. M., Razmi, J., & Haleh, H. (2009). Scatter search algorithm for supplier selection and order lot sizing under multiple price discount environment. *Advances in Engineering Software, 40*(9), 766-776.
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.
Hong, J. D., & Hayya, J. C. (1992). Just-in-time purchasing: single or multiple sourcing?. *International Journal of Production Economics, 27*(2), 175-181.
Li, C. C., Fun, Y. P., & Hung, J. S. (2004). A new measure for supplier performance evaluation. *IIE transactions, 29*(9), 753-758.
Lin, R. H. (2009a). An integrated FANP–MOLP for supplier evaluation and order allocation. *Applied Mathematical Modelling, 33*(6), 2730-2736.
Lin, R. H. (2009b). Potential use of FP-growth algorithm for identifying competitive suppliers in SCM. *Journal of the Operational Research Society, 60*(8), 1135-1141.
Lin, R. H., Chuang, C. L., Liou, J. J., & Wu, G. D. (2009). An integrated method for finding key suppliers in SCM. *Expert Systems with Applications, 36*(3), 6461-6465.
Mendoza, A. (2007). *Effective methodologies for supplier selection and order quantity allocation*. The Pennsylvania State University.
Mikhailov, L., & Singh, M. G. (2003). Fuzzy analytic network process and its application to the development of decision support systems. *IEEE Transactions on Systems, Man, and Cybernetics, Part C (Applications and Reviews), 33*(1), 33-41.
Nydick, R. L., & Hill, R. P. (1992). Using the analytic hierarchy process to structure the supplier selection procedure. *Journal of supply chain management, 28*(2), 31-36.
Simchi-Levi, D., Kaminsky, P., & Simchi-Levi, E. (2004). *Managing The Supply Chain: Definitive Guide*. Tata McGraw-Hill Education.
Sodenkamp, M. A., Tavana, M., & Di Caprio, D. (2016). Modeling synergies in multi-criteria supplier selection and order allocation: An application to commodity trading. *European Journal of Operational Research, 254*(3), 859-874.
Songhori, M. J., Tavana, M., Azadeh, A., & Khakbaz, M. H. (2010). A supplier selection and order allocation model with multiple transportation alternatives. *The International Journal of Advanced Manufacturing Technology, 52*(1-4), 365-376.
Spekman, R. E. (1988). Perceptions of strategic vulnerability among industrial buyers and its effect on information search and supplier evaluation. *Journal of Business Research, 17*(4), 313-326.
Thompson, K. N. (1990). Vendor profile analysis. *Journal of Supply Chain Management, 26*(1), 11-18.
Thompson, K. N. (1991). Scaling evaluative criteria and supplier performance estimates in weighted point prepurchase decision models. *Journal of Supply Chain Management, 27*(1), 27-36.
Thompson, K., Mitchell, H., & Knox, S. (1998). Organisational buying behaviour in changing times. *European Management Journal, 16*(6), 698-705.
Timmerman, E. (1986). An approach to vendor performance evaluation. *Journal of Supply Chain Management, 22*(4), 2-8.
Ustun, O., & Demı, E. A. (2008). An integrated

multi-objective decision-making process for multi-period lot-sizing with supplier selection. *Omega, 36*(4), 509-521.

Wang, G. (2001). Theory and knowledge acquisition of rough sets. *Xi'an Jiao tong University Publication*.

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

Xia, W., & Wu, Z. (2007). Supplier selection with multiple criteria in volume discount environments. *Omega, 35*(5), 494-504.

Yu, X., Xu, Z., & Liu, S. (2013). Prioritized multi-criteria decision making based on preference relations. *Computers & Industrial Engineering, 66*(1), 104-115.