Available online www.ejaet.com

European Journal of Advances in Engineering and Technology, 2016, 3(9):55-61

Research Article **ISSN: 2394 - 658X**

Optimal Procurement Strategy for Uncertain Demand Situation and Imperfect Quality by Genetic Algorithm

Md. Sanowar Hossain, Nur-E-Zannat, Umme Aftahaune Mohana and Md. Mosharraf Hossain

Department of Industrial and Production Engineering,
Rajshahi University of Engineering and Technology, Bangladesh
sanowar@ruet.ac.bd

ABSTRACT

This paper determines a procurement strategy where demand over a finite planning horizon is uncertain. Demand variations make forecasting and inventory management more difficult and tend to increase inventory levels which emphasis on proper procurement strategy. Here procurement strategy is developed by considering limited approved suppliers and multiple products. It is assumed that the suppliers are approved for the case with limited capacity but not free from imperfect quality. Defective items from supplier are sold at a discounted lower price. Some critical parameters for determining optimal procurement strategies like maximum storage space for the buyer, standard deviation of lead time demand and the corresponding product dependent compensation cost for imperfect quality are also considered here where an order is placed on a supplier depend on transaction cost for each period. Here shortage or backordering is not allowed. To make such problems realistic, the triangular possibility distribution of fuzzy numbers and the concept of minimum accepted level method are employed to formulate the problem. The whole mathematical model is structured and represented as linear programming model and was solved by an efficient meta-heuristic algorithm (Genetic Algorithm). Some computational studies were also carried on to prove its acceptance in the real world.

Key words: Procurement strategy, Inventory control, Genetic Algorithm, integer linear programming and Supplier Selection

INTRODUCTION

Under the age of globalization and competitive business environment organizations are focused on outsourcing strategies to implement procurement and vendor operating policies with the production capacity that not only smooth out material and/or service flows but also reduce manufacturing costs and improve quality and customer service performances. Again create long-term buyer/seller partnerships, Grossman *et al* [1] and Chen *et al* [2].

Today, procurement plays far more strategic and important role as it used to a few decades ago because of diverse factors. Procurement strategy, supplier selection and inventory control largely depends on each other to optimize related system. Among others, supplier selection under procurement strategy combined with inventory management is a central problem of any organization with a remarkable amount of relative work in literature. Supplier's performance has a key role on cost, quality, delivery and service in achieving the objectives of a supply chain.

Anupindi and Akella [3] were the first to analyse a multi-period procurement problem with two suppliers, however, assuming that any order is either delivered completely without any yield loss, or not at all. After that many researches paper have been focused on procurement strategy. The normal procurement strategy mainly focused on the lowest unit prices for obtaining the products. As a result, it trade-offs of poor quality, ignore delivery performance, and the other problems have been buffered by inventory stock, quality control personnel. Again multiple vendors are considered with short-term interests without approval by company policy [4]. In that regards many researchers showed that now a day's firms have been attempting to achieve greater collaborative advantages with their supply chain partners in the past few decades, and that supply chain collaborative advantages have a bottom-line influence on firm performance [5]. Much researcher emphasis on the importance of procurement cost. Gencer and Gurpinar [6] pointed out that the cost of purchased goods and services accounts for more than 60% of the cost of goods sold, and over 50% of all quality defects can be traced back to purchase material. Weber and Current [7] stated that in high-technology industries, material purchased externally can represent up to 80% of total product cost. As a result, it is vital to reduce such purchasing costs to a minimum.

The supplier selection is often done by multi-criteria decision- making (MCDM) and QFD process where decision maker influences the conflicting criteria (Aissaoui *et al*., [8], Talluri *et al*. [9] and Bevilacqua *et al*. [10]). But sometimes this type of evaluation could not found optimal result. Systems with an arbitrary set of suppliers have been analyzed only by Agrawal and Nahmias [11] Dada *et al*. [12] and Federgruen *et al*., [13] and only in a single-period setting. Federgruen *et al*. [13] derive an efficient algorithm to determine the optimal set of suppliers and order quantities in a single-period setting. Nagali *et al*. [14] published a paper on Procurement Risk Measurement framework that "enables the simultaneous measurement and management of multi-period and correlated demand, cost, and availability uncertainties. Again ecological, social and economic sustainability of business for many organizations is of important issue now a day. Therefore, sustainability oriented procurement is recognized as an important contributor for alignment of internal and external factors and the enabler of sustainable development of business (Walker and Jones [15]. At the same time Ronchi *et al* [16] emphasis on IT based e-procurement system. Extensions on lot–sizing with supplier selection for multi–period and multi–product cases have been studied, along with cases with limited capacities on suppliers (Basnet *et al*. [17] and Hassini [18]. In procurement system checking of defective item and maintaining another inventory policy is required. The defective items were sold at a discounted price after screening. This paper has been extended a number of times recently, for example by Wee *et al*. [19], Maddah *and* Jaber [20] and Khan *et al*. [21]. Benson [22] presented a paper on this issue by introducing capacities for the suppliers, considered a supply chain with multiple suppliers. Many paper presented on this regard that incorporates defective items from the vendor for a vendor-retailer supply chain [23]. Rezaei *et al*, [24] were proposed a model refers to the problem of lot sizing with supplier selection, considering crucial concepts such as imperfect items and limited storage capacity but did not consider uncertainty. At the same time, they consider 100% inspection of lot.

On this regard, researchers have used various technique and algorithm to solve the procurement problem. Genetic algorithm (GA), replicates the mechanism of biological evolution and natural selection process is a popular global search meta-heuristic algorithm for solving complex optimization problem invented by Holland [25]. The fittest individuals have the highest chance of survival is the base of the GA.

The problem that was formulated by Rezaei *et al*., [24] was highly constrained mixed–integer optimization it was solved by deterministic and a stochastic approach. Multi-period models also offer the opportunity to change suppliers for a product from one period to the next. Several researchers also use GA and other heuristic algorithm for inventory decision. Again fuzzy programming and goal programming also have been used on this regard Jadidi *et al*. [26]. Wang & Yang [27] propose a fuzzy model for supplier selection in quantity discount environments. Jolai *et al* [28] presented a paper on integrating fuzzy TOPSIS and multi-period goal programming for purchasing multiple products from multiple suppliers.

In this paper, a multi-item inventory model is discussed having demand uncertainty/lumpiness as well as imperfect quality items. The demand uncertainty is expressed in terms of the demand variation in the lead time which eventually causes the cost of compensation for the organization concerned. Later, a way for determining optimal procuring quantities from supplier along with the selection of suppliers in a particular period is formulated as an integer programming model. Then the model is solved with Genetic Algorithm.

PROBLEM FORMULATION

Following the aforementioned assumptions, Rezaei *et al*., [24] developed a mathematical model that refers to the scenario of supply chain with multiple products and multiple suppliers, all of which have limited capacity that shown in (*Fig.* 1). The demand over a finite planning horizon is also known and an optimal procurement strategy for this multi–period horizon is to be determined without considering compensation cost for non-conformance of lead time demands. But here demand over a finite planning horizon is considered uncertain and triangular fuzzy numbers and the concept of minimum accepted level method are employed to incorporate these uncertainties with respect to the satisfaction level of decision maker. The minimum accepted level of decision maker is normally considered to 0.5 but in real world case it would be above or below the limit.

ASSUMPTIONS & NOTATIONS

Some assumptions & notations are adopted to develop the model-

T_j Transaction cost for supplier j does not depend on the variety and quantity of products involved

H_i	Holding cost of product i per period is product-dependent
D_{it}	Demand of product i in period t is known over a planning horizon
β_{ij}	Each lot of product i received from supplier j contains an average percentage of defective items
p_{ij}	Purchasing price of product i from supplier j
γ_{gi}	Good-quality items i have a selling price per unit
γ_{di}	Discounted price of defective items i are sold as a single batch
v_i	screening cost of product i,
W	Available total storage space
w_i	Product i needs a storage space
σ_L	Standard deviation of demand during lead time
C_i	Corresponding compensation cost for this variation is considered to be of product i

The assumptions are

- 100% screening process of the lot is conducted.
- The received items are not free from imperfect quality and these imperfect quality items kept in stock and sold before to the next at lower discounted price.
- Each of the suppliers approved by the organization has a limited capacity.
- Shortage or backordering is not allowed.
- Also $\gamma_{gi}>\gamma_{di}$

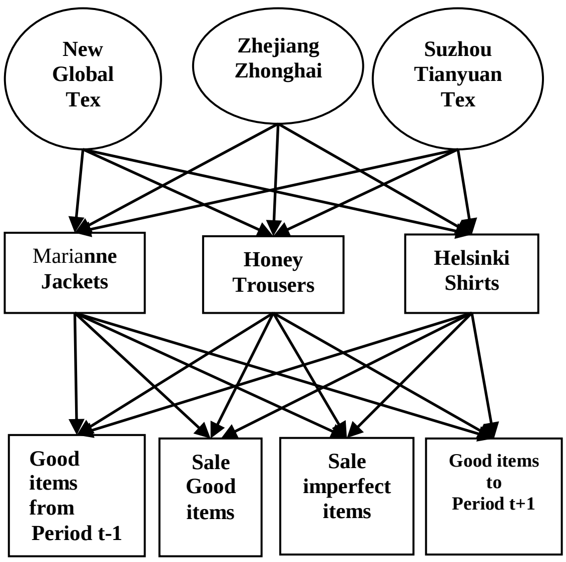

Fig. 1Behavior of the model in period t

MODEL DESCRIPTION: MIXED INTEGER LINEAR PROGRAMMING MODEL

Here a single objective mixed integer programming model is formulated to represent multi-product, multi-supplier procurement strategy and multi-time period with compensation. A product-dependent compensation cost is incorporated for each type of product due to the variation of demand during lead time. It is assumed that the products or materials that would be purchased from the supplier are all not free from imperfect quality. That means some of them may be of imperfect quality that would require another inventory situation to manage. These nonconforming items will be sold at a lower discounted rate. In *Fig.*1, it is shown that each of the suppliers is providing each of the products. That is each of the products can be sourced from a number of approved suppliers. After receiving the products, screening takes place to sort out the imperfect quality items. Then production is carried out and demand is fulfilled with the inventories of currently produced ones along with the inventories from the previous period. Eventually, the unsold items remain in the inventory for use in next period. However, when an order is placed, a supplier– dependent transaction cost is considered as the main criteria to select that supplier along with the lead time variation. The lead time variation is considered to incorporate a product–dependent holding cost per period for each product in the inventory for the planning horizon.

Objective Function

It consists of the sum of the revenues of selling good quality & imperfect products and compensation cost received from the supplier, subtracting the purchase cost of the products, the transaction cost for the suppliers, the screening cost of the products and the holding cost for the remaining inventory at each time period. From the objective function it seen that the first three term consist total revenue. The next part consists total cost of the problem. Here

'~' represent the fuzziness of the corresponding number and this fuzziness is tackled by fuzzy ranking method proposed by Liau and Wang 1992. Obviously, since the problem is defined as maximization, the negative of the objective function defines the corresponding minimization task. The parameters y_{jt} are binary and they are defined as $y_{jt} = 1$ if an order is placed to supplier j at time period t, while $y_{jt} = 0$ otherwise. At the same time compensation cost regarding to the deviation of lead time. Assuming that i denote the product, j denotes the supplier and t denotes the time period, the required quantity is denoted as λ_{ijt}. Also a maximum available storage capacity at each period is considered. In order to maximize the total profit, the decision maker needs to decide about the type and number products to order along with the suppliers to be selected to the corresponding time periods. The problem is to find the number of product i ordered from supplier j in period t so as to maximize the total profit function subject to restrictions and boundary conditions.

$$Maxprofit = \Big[\sum_i\sum_j\sum_t \lambda_{ijt}(1-\beta_{ij})\gamma_{gi} + \sum_i\sum_j\sum_t \lambda_{ijt}\beta_{ij}\gamma_{di} + \sum_i\sum_j\sum_t \lambda_{ijt}\sigma_L C_i - \Big\{\sum_i\sum_j\sum_t \lambda_{ijt}p_{ij} + \sum_i\sum_j\sum_t T_j Y_{ij} + \sum_i\sum_j\sum_t \lambda_{ijt}V_i + \sum_i\sum_t H_i\Big(\sum_{t=1}^{k}\sum_j \lambda_{ijt}(1-\beta_{ij}) - \sum_{t=1}^{k}\frac{1}{2}\big[\alpha D_{it}^{o} + D_{it}^{m} + (1-\alpha)D_{it}^{p}\big]\Big)\Big\}\Big] \quad (1)$$

Constraints

- **Constraints on demand**

$$\sum_{t=1}^{k}\sum_j \lambda_{ijt}(1-\beta_{ij}) - \sum_{t=1}^{k}\frac{1}{2}\big[\alpha D_{it}^{o} + D_{it}^{m} + (1-\alpha)D_{it}^{p}\big] \geq 0, \quad for\ all\ i,t \quad (2)$$

- **Constraints on supplier capacity**

$$\Big(\sum_{t=1}^{k}\frac{1}{2}\big[\alpha D_{it}^{o} + D_{it}^{m} + (1-\alpha)D_{it}^{p}\big]\Big)Y_{jt} - \lambda_{ijt}(1-\beta_{ij}) \geq 0, \quad \text{for all i, j, t} \quad (3)$$

- **Warehouse space constraints**

$$\sum_i W_i\,\Big[\sum_{t=1}^{k}\sum_j \lambda_{ijt}(1-\beta_{ij}) - \sum_{t=1}^{k}\frac{1}{2}\big(\alpha D_{it}^{o} + D_{it}^{m} + (1-\alpha)D_{it}^{p}\big)\Big] \leq W, \quad \text{for all t} \quad (4)$$

- **Non negativity constraints on decision variables**

$$\lambda_{ijt} \geq 0\ for\ all\ i,j,t \quad and \quad Y_{ij} = 0\ or\ 1 \quad (5)$$

The constraints (2) indicate that the demand for each time period can never be determined precisely because of the dynamic nature of market demand and supply. Here the symbol "~" is used to show fuzziness especially for fuzzy numbers. Using equation (6) this imprecise number is converted into crisp value. The required quantity of perfect quality item i, from the supplier j and the time period t is less than or equal to the demand of product i in period t is known over a planning horizon. The constraints (3) represents that each Suppliers have limited capacities and it is considered for uncertain demand. The constraint (4) represents that the available total storage space capacity is limited.

Treatment of the Fuzzy Number

In this work decision maker adopt the pattern of triangular possibility distribution to represent the fuzzy variables. The primary advantages of the triangular fuzzy number are the simplicity and flexibility of the fuzzy arithmetic operations (Liou *et al*., [29] and Rommelfanger [30]). In a real-life situation on can often estimate the maximum and minimum values, and the most likely outcome, even if he does not know the mean and standard deviation. The triangular distribution has a definite upper and lower limit, so one can avoid unwanted extreme values.

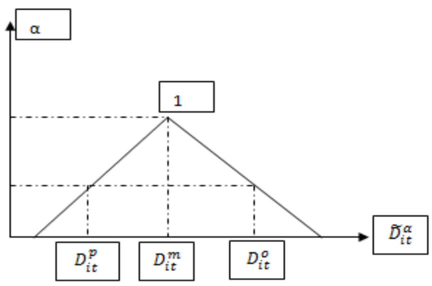

Fig. 2 Triangular Membership function of $\widetilde{D}_{it}^{\alpha}$

The fuzzy demand is $\widetilde{D}_{it} = D_{it}^{p}, D_{it}^{m}, D_{it}^{o}$

$$\widetilde{D}_{it}^{\alpha} = \frac{1}{2}\big[\alpha D_{it}^{o} + D_{it}^{m} + (1-\alpha)D_{it}^{p}\big] \quad (6)$$

In the process of defuzzification, this work applies Liou *et al*., [29] approach for ranking fuzzy method to convert fuzzy number into a crisp number. If the minimum acceptable membership level α, corresponding auxiliary crisp of triangular fuzzy number of fuzzy demand given in equation (6)

In practical situations, the triangular distribution of D_{it} may: (1) the most pessimistic value (D_{it}^{p}) that has a very low likelihood; (2) the most likely value (D_{it}^{m}) that definitely belongs to the set of available values; and (3) the most optimistic value (D_{it}^{o}) that has a very low likelihood of belonging to the set of available values

MODEL IMPLEMENTATION

Case Description

To solve the model and to observe how profit is maximized, data are collected from one of the reputed garment industries in Bangladesh namely Talisman Ltd. which is a sub-company of FCI group and it's a UK-based company. Garments of different styles are usually produced by Talisman Ltd. each year. But considering all the styles will make the maximization problem more cumbersome and also the collection of such a huge data is quite arduous. Thus three particular styles namely Marianne jackets, Honey trousers and Helsinki shirts are taken into consideration. These products are supplied from each of the three suppliers i.e. New Global Tex, Zhejiang Zhonghai Printing & Dyeing Co. Ltd. and Suzhou Tianyuan.

In this paper, result is actually representing the type and quantity of products to order, with which suppliers and in which periods. That means the result is associated with the variables λ_{ijt} and Y_{jt}. Thus for the two variables a nearly optimal outcome is reached such that it maximizes the profit. The MATLAB R2012a is used with genetic algorithm being the solver to solve the maximization problem.

For that, the required data include demand, purchase price, transaction cost, average percentage of defective items, selling price of both the good & defective items, holding cost, screening cost, compensation cost for a variation in demand during lead time and warehouse space. Data of three products i.e. jackets, trousers, shirts are collected over a planning horizon of four periods. In this paper, data for only fabrics are considered since it incurs 95 % of the total cost. Demand in pieces of three products over four periods (Table 1).

There are three suppliers and their prices and transaction cost are shown in tables 2 and average percentage of the defective items shown in table 3. In Table 4, selling price of good product i (γ_{gi}), selling price of defective product i (γ_{di}), storage space of product i (W_i), holding cost of product i per period (H_i) and screening cost of product i(v_i) are shown.

Table -1 Demand in Pieces of Three Products Over Four Periods

Products	Planning horizon (periods in four quarters of a year)			
	1st	2nd	3rd	4th
Marianne jackets	320,330,340	1575,1594,1620	325,357,375	1440,1461,1480
Honey trousers	315,320,335	1965,1977,1900	1860,1886,1895	415,426,430
Helsinki shirts	390,405,420	1900,1925,1950	2690, 2712,2725	642,653,670

Table -2 γ_{gi}, γ_{di}, C_i, H_i, V_i, σ_L, W_i for Three Products

Parameter	Products		
	1	2	3
S_{gi}	\$ 16.15	\$ 12.5	\$ 10
S_{di}	\$ 9.5	\$ 6.8	\$ 5.75
C_i	\$ 0.80	\$ 0.30	\$ 0.10
H_i	\$ 2.75	\$ 2	\$ 2.5
V_i	\$ 0.20	\$ .15	\$ .18
σ_l	5 pcs	5 pcs	5 pcs
W_i	28.14 m^2	16 m^2	20.6 m^2

Table -3 Average Percentage of Defective Items for Three Suppliers

Products	Average percentage of defective items		
	1	2	3
Marianne jackets	13	15	16
Honey trousers	12	11	14
Helsinki shirts	14	13	10

Total storage space, W = 3521.03 m^2

Table -4 Ordering Quantities for Marianne Jackets

Jackets (i=1)		Periods (t)			
		1	2	3	4
Suppliers (j)	1	9688	55	9	55
	2	13	151	29	20
	3	9935	181	8	23

Table -5 Ordering Quantities for Honey Trousers

Trousers (i=2)		Periods (t)			
		1	2	3	4
Supplier j	1	27	108	100	70
	2	323	1576	25	9597
	3	21	6498	337	9930

Table -6 Ordering Quantities for Helsinki Shirts

Shirts (i=3)		Periods (t)			
		1	2	3	4
Suppliers (j)	1	93	10001	139	9516
	2	122	9848	50	8169
	3	145	171	9963	24

Table -7 Decision for the Selection of Suppliers

Supplier	Periods			
	1	2	3	4
1	0	1	0	1
2	1	0	1	0
3	1	1	0	0

RESULTS AND DISCUSSIONS

In this section the numerical example of the above model is solved by using a Real Parameter Genetic Algorithm. At first fuzzy ranking method of defuzzification is used to convert fuzzy number into a crisp number. If the minimum acceptable membership level $\alpha = 0.5$, then corresponding auxiliary crisp of triangular fuzzy number using equation (9) is used as crisp demand. So, after running the problem in MATLAB software, the magnitudes of the variables λ_{ijt} & Y_{jt} are obtained. The nearly optimal values of ordering frequency (λ_{ijt}) of the three products i.e. jackets (Table 4), trousers (Table 5) and shirts (Table 6) from each of the three suppliers at each quarter of a year is summarized. As the model has been formulated with vague parameters, the decision maker may choose that solution which suits him best with respect to resources. At the same time the standard deviation of lead time demand and the percentage of defective item supplied by supplier are considered.

Here uncertainty is incorporate to the analysis by the standard deviation of demand during lead time i.e. σ_L. For 5% standard deviation of demand during lead time i.e. σ_L the corresponding result is obtained the genetic algorithm. Since the suppliers have limited capacities, thus the quantities that the supplier can provide are also restrained. Depending on that restriction, the decision of which supplier is selected (Y_{jt}) in which quarter of a year that summarized in (Table 7). Also imperfect quality and compensation cost incorporated to the model to find the actual scenario of inventory control system.

In the table, the binary values represent yes/no decisions. 1 for yes and 0 for no i.e. 1 means to select the supplier where 0 indicates those suppliers that should not be selected for particular period of a year. Thus order should be received from supplier 1 in periods 2 and 4, from supplier 2 in periods 1 and 3, from supplier 3 in periods 1 and 2. The objective function value for the concerned problem is 282518.85, which actually indicates the magnitude of annual profit of the concerned company. Thus the profit is determined to be $ 282518.85.

For sensitivity analysis, the main parameter to be considered in this paper is the standard deviation of demand during lead time i.e. σ_L which is the indicator of uncertain demand. So, by both increasing and decreasing the values of σ_L will show how it has affected the result. For increased value of σ_L (σ_L=10 pcs) it is seen that the ordering quantities of each product has changed a lot. Not only that but also the supplier selection situation has also changed. The profit has decreased tremendously. For decreased value of σ_L (σ_L=1 pcs) it is seen that the ordering quantities of each product remain the same so do the supplier selection situation. The profit here has increased approximately by 42%. So, comparing the profit indicates that a little larger value of σ_L can cause a great loss to the concerned organization while keeping it as lower as possible can enlarge the profit. Again if the minimum acceptable level is increased from 0.5 to higher value that is if the decision maker wants to take risk on the basis of market demand then the result will have changed.

CONCLUSIONS

This paper gives emphasis on procurement strategy with multiple suppliers and multiple products under uncertain environment. Here multi-item vendor-buyer inventory control policy for items with imperfect quality and as a result of corresponding compensation cost is also considered here. The major aim is to provide a realistic platform for planning and controlling the inventory in supply chain and the selection of supplier for multi-products and multi periods. Then the above formulated mixed integer programming problem combined supplier selection with traditional inventory lot sizing, imperfect items and compensation cost for non-conformance. From this it is possible for the decision maker (DM) to decide appropriate suppliers from multiple approved suppliers and type and quantities products to order to the corresponding periods that matches with the real world condition. Fuzzy based Genetic approach is used to solve the problem.

At the same time Genetic Algorithm is used to solve the problem but Fuzzy Logic solver or other heuristic approaches can also be used to solve the problem. Then a comparison can be made among the techniques. This study considers fabric cost of three products. So in future one may also consider accessories cost for as high number of products as possible. The 5 percent accessories cost can be considered. Then the result will be more optimal. This study considers fabric cost of three products. So in future one may also consider accessories cost for as high number of products as possible.

REFERENCES

[1] M Gene Grossman and Elhanan Helpman, Outsourcing in a Global Economy, *The Review of Economic Studies*, **2005**, 72 (1),135-159.

[2] Chen, Chen-Tung, Ching-Torng Lin, and Sue-Fn Huang, A Fuzzy Approach for Supplier Evaluation and Selection in Supply Chain Management, *International Journal of Production Economics,* **2006**, 102 (2), 289-301.

[3] Ravi Anupindi and Ram Akella, Diversification Under Supply Uncertainty, *Management Science*, **1993**, 39 (8), 944-963.
[4] Richard H Evans, Product Involvement and Industrial Buying, *Journal of Purchasing and Materials Management*, **1981**, 17 (2), 23-28,
[5] Maurizio Bevilacqua and Alberto Petroni, From Traditional Purchasing to Supplier Management: A Fuzzy Logic-based Approach to Supplier Selection, *International Journal of Logistics*, **2002**, 5(3), 235-255.
[6] Cevriye Gencer and Didem Gürpinar, Analytic Network Process in Supplier Selection: A Case Study in an Electronic Firm, *Applied Mathematical Modelling*, **2007**, 31(11), 2475-2486.
[7] Charles A Weber and R John, A Multiobjective Approach to Vendor Selection, *European Journal of Operational Research*, **1993**, 68 (2), 173-184.
[8] Aissaoui, Najla, Mohamed Haouari and Elkafi Hassini, Supplier Selection and Order Lot Sizing Modeling: A Review, *Computers & Operations Research*, **2007**, 34 (12), 3516-3540.
[9] Srinivas Talluri and Joseph Sarkis, A Model for Performance Monitoring of Suppliers, *International Journal of Production Research*, 2002, 40 (16), 4257-4269.
[10] Maurizio Bevilacqua, FE Ciarapica and G Giacchetta, A Fuzzy-QFD Approach to Supplier Selection, *Journal of Purchasing and Supply Management*, **2006**, 12 (1), 14-27.
[11] Narendra Agrawal and Steven Nahmias, Rationalization of the Supplier Base in the Presence of Yield Uncertainty, *Production and Operations Management*, **1997**, 6 (3), 291-308.
[12] Maqbool Dada, C Nicholas Petruzzi, and B Schwarz Leroy, A Newsvendor's Procurement Problem When Suppliers Are Unreliable, *Manufacturing & Service Operations Management*, **2007**, 9 (1), 9-32.
[13] Awi Federgruen and Nan Yang, Optimal Supply Diversification under General Supply Risks, *Operations Research*, **2009**, 57 (6),1451-1468.
[14] V Nagali, J Hwang, D Sanghera, M Gaskins, M Pridgen, T Thurston, P Mackenroth, D Branvold, P Scholler and G Shoemaker, Procurement Risk Management (PRM) at Hewlett-Packard Company, *Interfaces*, **2008**, 38 (1), 51-60.
[15] Helen Walker and Neil Jones, Sustainable Supply Chain Management Across the UK Private Sector, *Supply Chain Management: An International Journal*, **2012**, 17 (1), 15-28.
[16] Stefano Ronchi, A Brun, R Golini and X Fan, What is the Value of an IT e-Procurement System? *Journal of Purchasing and Supply Management*, **2010**, 16 (2), 131-140.
[17] Chuda Basnet and Janny MY Leung, Inventory Lot-Sizing with Supplier Selection, *Computers & Operations Research*, **2005**, 32 (1), 1-14.
[18] E Hassini, Order Lot Sizing with Multiple Capacitated Suppliers Offering Lead Time-Dependent Capacity Reservation and Unit Price Discounts, *Production Planning & Control*, **2008**, 19 (2), 142-149.
[19] Hui M Wee, Yu Jonas and Mei C Chen, Optimal Inventory Model for Items with Imperfect Quality and Shortage Backordering, *Omega*, **2007**, 351 (1), 7-11.
[20] Maddah Bacel and Mohamad Y Jaber, Economic Order Quantity for Items with Imperfect Quality: Revisited, *International Journal of Production Economics*, **2008**, 112 (2), 808-815.
[21] M Khan, MY Jaber and MIM Wahab, Economic Order Quantity Model for Items with Imperfect Quality with Learning in Inspection, *International Journal of Production Economics*, **2010**, 124 (1), 87-96.
[22] HY Benson, Optimal Pricing and Procurement Strategies in a Supply Chain with Multiple Capacitated Suppliers, *Computers & Operations Research*, **2005**, 32 (1), 1-14.
[23] Mehmood Khan, Jaber Y Mohamad and Bonney Maurice, An Economic Order Quantity (EOQ) for Items with Imperfect Quality and Inspection Errors, *International Journal of Production Economics*, **2011**, 133 (1), 113-118.
[24] Jafar Rezaei and Davoodi Mansoor, A Deterministic, Multi-Item Inventory Model with Supplier Selection and Imperfect Quality, *Applied Mathematical Modelling*, **2008**, 32, (10), 2106-2116.
[25] JH Holland, *Adaptation in Natural and Artificial Systems: An Introductory Analysis with Applications to Biology, Control and Artificial Intelligence*, University of Michigan Press, **1975**.
[26] OMID Jadidi, S Zolfaghari and Sergio Cavalieri, A New Normalized Goal Programming Model for Multi-Objective Problems: A Case of Supplier Selection and Order Allocation, *International Journal of Production Economics*, **2014**, 148, 158-165.
[27] Tai-Yue Wang and Yang Yih-Hwang, A Fuzzy Model for Supplier Selection in Quantity Discount Environments, *Expert Systems with Applications*, **2009**, 36 (10), 12179-12187.
[28] Fariborz Jolai, SA Yazdian, K Shahanaghi and MA Khojasteh, Integrating Fuzzy TOPSIS and Multi-Period Goal Programming for Purchasing Multiple Products from Multiple Suppliers, *Journal of Purchasing and Supply Management*, **2011**, 17 (1), 42-53.
[29] Tian-Shy Liou and Mao-Jiun J Wang, Ranking Fuzzy Numbers with Integral Value, *Fuzzy Sets and Systems*, **1992**, 50(3), 247-255,
[30] H Rommelfanger, Fuzzy Linear Programming and Applications, *European Journal Operations Research*, **1996**, 92, 512–527.