ANALYZING THE SUPPLIER SELECTION PROCESS OF A LEAN MANUFACTURING FIRM: A CASE STUDY

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ABSTRACT
Suppliers play an important role in a supply chain and therefore decision of supplier selection is also important. Supplier selection is a widely studied subject in the literature. This study addressed the supplier selection issue of a lean manufacturing firm with the aim of finding the relative importance of the supplier selection criteria. To this end, a furniture manufacturing firm which applies lean production was chosen and its supplier selection process was analyzed. The fuzzy AHP method was used to determine the ranking of the supplier selection criteria. It was found that delivery performance was ranked as the first criterion among the seven criteria and it was followed by quality, cost / price, reliability, flexibility, geographical location and technological capability. Finally, limitations of the study and areas of future research were discussed.

KEYWORDS: *Fuzzy AHP, Lean Production, Supplier Selection, Supply Chain Management.*

JEL CLASSIFICATION: *C6, L6, M1.*

1. INTRODUCTION

According to Hillier and Lieberman (2001) a supply chain is a network of facilities that procure raw materials, transform them into intermediate goods and then final products, and finally deliver the products to customers through a distribution system. A typical supply chain involves some stages such as suppliers, manufacturers, distributors, retailers, and customers (Chopra and Meindl, 2007) and the supply chain management is a total systems approach to delivering manufactured products to the end customer (Fitzsimmons and Fitzsimmons, 2008). Suppliers play vital role in a supply chain and therefore supplier selection process is very important in supply chain management.
The origin of the lean production is the Toyota Production System and its popularization is mostly based upon the book of "The Machine that Changed the World" of Womack, Jones, and Roos (1990). According to Shah and Ward (2007), lean production is an integrated socio-technical system whose main objective is to eliminate waste by concurrently reducing or minimizing supplier, customer, and internal variability. Furthermore, according to Doğan and Unutulmaz (2014), the most efficient way of doing business is researched, found, and monitored in a lean production system and the philosophy of trying to do things right the first time, with no mistakes, comprises the core of it.
The aim of this study is to find the relative importance of the supplier selection criteria of a lean manufacturing firm. Fuzzy AHP is used to determine the ranking of the supplier selection criteria for this firm. To our knowledge, a study focusing on the supplier selection of a lean firm has not been conducted. Thus, this study aims to fulfill this gap in the literature.
The rest of the paper is organized as follows. Section 2 reviews the literature. Section 3 explains the methodology. Section 4 presents the data, findings, and results. Finally, Section 5 concludes.

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2. LITERATURE

Supplier selection is one of the most important decision making problems and a widely studied subject in the literature. It can be stated that studies on supplier selection starts with the early work of Dickson (1966). Some other studies conducted on this subject are mentioned in this section.
Bevilacqua and Petroni (2002) developed a system for supplier selection using fuzzy logic and they applied this methodology effectively in the supplier selection process of a bottling machinery manufacturer firm. Yigin et al. (2007) designed an expert system for supplier selection in the automotive sector. They concluded that an expert system is a suitable tool for selecting suppliers.
Araz and Ozkarahan (2007) focused on supplier evaluation and management for strategic sourcing and used a new multi criteria sorting method based on the PROMETHEE methodology. They applied their methodology to a hypothetic problem and showed the flexibility and responsiveness of the proposed method. Chan et al. (2008) used fuzzy AHP for global supplier selection and demonstrated the effectiveness of the proposed method with an application of a manufacturing firm.
Kokangul and Susuz (2009) used integrated analytical hierarch process and mathematical programming to select the best supplier and to place the optimal order quantities. Guneri and Kuzu (2009) used the fuzzy logic method for supplier selection and tested their method with a case study focusing on a plaster and cement-based productions manufacturer company. As a result the best supplier among the alternative suppliers was found for the case study company.
Aydin and Kahraman (2010) used the modified fuzzy AHP for multicriteria supplier selection process in an air conditioner seller firm and came to a conclusion that the modified fuzzy AHP was appropriate for group decision making in supplier selection problems. Sevkli (2010) used fuzzy ELECTRE method for supplier selection and applied the proposed method to a manufacturing company in Turkey.
Aksoy and Öztürk (2011) analyzed the supplier selection processes of just-in-time manufacturers. They used neural network based supplier selection and supplier performance evaluation systems and tested these systems effectively with the data taken from an automotive factory. Chang et al. (2011) used fuzzy DEMATEL method for developing supplier selection criteria and they conclude that stable deliver of goods was the most important criterion.
Hadi-Vencheh (2011) proposed a new weighted nonlinear model to solve the multiple criteria supplier selection problem and presented an illustrative example to test the efficiency of the proposed model. Kuo and Lin (2012) proposed an integrated analytic network process and data envelopment analysis method for supplier selection. They proved the effectiveness of their method with an application in the high-tech industry.
Kim and Wagner (2012) investigated the supplier selection problem from the perspective of product configuration and presented a smartphone configuration example. They explained the distinguishing features of supplier configuration from the classical multi criteria decision making based models. Partovi (2013) developed a quantitative methodology based on data envelopment analysis for supplier selection and also considered suppliers' self-efficiency as a new criterion.
Jassbi et al. (2014) used dynamic multi-criteria decision making model for supplier selection and successfully implemented it in a real case study in the automotive industry. Chang (2015) proposed a novel OWA-based ranking technique to deal with the supplier selection problem and illustrated the use of the proposed approach with a numerical supplier selection example. Banaeian et al. (2015) focused on green supplier selection problem and presented a case study in the food industry. They took two kinds of qualitative and quantitative data into consideration in supplier selection process.
When the above mentioned literature is investigated, it can be seen that supplier selection has become a widely studied subject and its applications are spread over many areas. The difference of this study from the previous studies is that this study focused on the ranking of supplier selection criteria of a lean manufacturing firm.

3. METHODOLOGY

The Analytic Hierarchy Process (AHP) is a multi-criteria decision making method developed by Thomas L. Saaty in 1980. It is a very popular method and it is being widely used all over the world. Over time, some extensions of this method are developed and used for overcoming some shortages of AHP. The fuzzy AHP is one of the such methods and it can tackle with the uncertainty and vagueness.

Various fuzzy AHP methods exist in the literature. Chang's extent analysis, which is one of the such methods, is used in this study. The steps of the Chang's extent analysis method are described as follows (Chang, 1996):

1. Let $M_{g_i}^1, M_{g_i}^2, ..., M_{g_i}^m$ be values of extent analysis of i-th object for m goals. Then the value of fuzzy synthetic extent with respect to the i-th object is defined as

$$S_i = \sum_{j=1}^{m} M_{g_i}^j \otimes [\sum_{i=1}^{n} \sum_{j=1}^{m} M_{g_i}^j]^{-1} \quad (1)$$

2. The degree of possibility of $M_1 \geq M_2$ is defined as

$$V(M_1 \geq M_2) = \sup_{x \geq y} [\min(\mu_{M_1}(x),\ \mu_{M_2}(y))]. \quad (2)$$

When a pair of $(x,\ y)$ exists such that $x \geq y$ and $\mu_{M_1}(x) = \mu_{M_2}(y) = 1$, then we have $V(M_1 \geq M_2) = 1$. Since M_1 and M_2 are convex fuzzy numbers we have that

$$\begin{aligned} &V(M_1 \geq M_2) = 1 \Leftrightarrow m_1 \geq m_2, \\ &V(M_2 \geq M_1) = hgt(M_1 \cap M_2) = \mu_{M_1}(d), \end{aligned} \quad (3)$$

where d is the ordinate of the highest intersection point D between μ_{M_1} and μ_{M_2} (Figure 1).

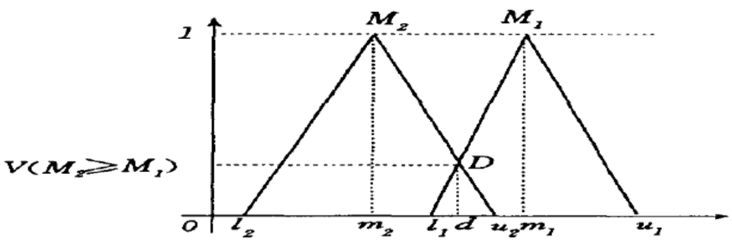

Figure 1. Intersection of M_1 and M_2

When $M_1 = (l_1,\ m_1,\ u_1)$ and $M_2 = (l_2,\ m_2,\ u_2)$, the ordinate of D is given by

$$V(M_2 \geq M_1) = hgt(M_1 \cap M_2) = \frac{l_1 - u_2}{(m_2 - u_2) - (m_1 - l_1)}. \quad (4)$$

To compare M_1 and M_2, we need both the values of $V(M_1 \geq M_2)$ and $V(M_2 \geq M_1)$.

3. The degree of possibility for a convex fuzzy number to be greater than k convex fuzzy numbers M_i $(i = 1, 2, ..., k)$ can be defined by

$$\begin{aligned} &V(M \geq M_1,\ M_2,\ ...,\ M_k) \\ &= V[(M \geq M_1)\ and\ (M \geq M_2)\ and...and\ (M \geq M_k)] \\ &= \min V(M \geq M_i),\ i = 1,\ 2,\ ...,\ k. \end{aligned} \quad (5)$$

Assume that

$$d'(A_i) = \min\ V(S_i \geq S_k), \quad (6)$$

for $k = 1, 2, \ldots, n$ and $k \neq i$. Then the weight vector is given by

$$W' = (d'(A_1),\ d'(A_2), \ldots,\ d'(A_n))^T,$$

where A_i ($i = 1, 2, \ldots, n$) are n elements.

4. Via normalization, the normalized weight vectors are found as

$$W = (d(A_1),\ d(A_2), \ldots,\ d(A_n))^T,$$ where *W*, is a nonfuzzy number.

4. RESULTS

This study is conducted in a furniture manufacturing firm which adopts lean production in its production processes. It is a big firm located in the middle Anatolia region of Turkey and it has approximately 300 employees. The manufacturing firm has started to apply lean production philosophy since 2010. The lean journey of the firm has begun with 5S efforts and continues with Kaizen applications. Sofa, seating group, bed, box spring, home textile and modular furniture are among the main product types of this firm. This firm is one of the biggest firms in the Turkish furniture industry and it exports its products to more than twenty countries.

There are mainly two types of production; the soft and the panel production. In general, the soft production starts with preparation and continues with cutting, sewing, furnishing and packaging operations. On the other side the panel production includes the panel cutting, calibre, lamination, side band, perforation, CNC, assembly, drawer and packaging operations.

Purchasing department is directly responsible for the supply process of the firm. In the supply process, the overall aim of the firm is to supply quality products to its customers with minimum costs. The purchasing process is composed of following eight sequential steps: Market research, supplier research, negotiations with potential suppliers, taking price offers, supplier selection, agreement, order placement and delivery to warehouse. The purchasing department of the firm uses five different procurement methods. These are related procurement, order based procurement, immediate demand satisfaction, importation and commercial product procurement.

There is not a strict rule in the categorization of the suppliers. Briefly stated, the firm prefers its long-term suppliers when order based procurement is made. If immediate demand occurs the purchasing department seeks for the optimum supplier in the sector. Finally, when it comes to buy the critical parts like the basic raw materials another category of supplier is preferred. The basic raw materials used in the production are chipboard, fabric, sponge, foil, spring wire and profile. The firm sometimes works with a single strategic supplier and sometimes with multiple strategic suppliers especially in the supply process of basic raw materials.

In this study, the supplier selection process of the firm is analyzed and the priority weights of this process are determined. To this end, seven leading supplier selection criteria are determined (Dickson, 1966; Weber et al., 1991; Choi and Hartley, 1996; Stevenson, 2009; Ho et al., 2010; Sevkli, 2010; Mohanty and Gahan, 2013; Dargi et al., 2014; Gharakhani et al., 2014; Abdollahi et al., 2015; Azadi et al., 2015; Nair et al., 2015) and used in this study: Cost/price (C), quality (Q), delivery performance (DP), reliability (R), flexibility (F), technological capability (TC) and geographical location (GL).

The production manager of the firm was determined as the decision maker and he is asked to make evaluations concerning the supplier selection criteria. The evaluations are made as pairwise comparisons of these seven criteria. The triangular fuzzy conversion scale was used while evaluating these criteria. Table 1 shows the triangular fuzzy conversion scale.

Table 1. Triangular fuzzy conversion scale

Linguistic scale	Triangular fuzzy scale	Triangular fuzzy reciprocal scale
Equally important	(1/2, 1, 3/2)	(2/3, 1, 2)
Weakly more important	(1, 3/2, 2)	(1/2, 2/3, 1)
Strongly more important	(3/2, 2, 5/2)	(2/5, 1/2, 2/3)
Very strongly more important	(2, 5/2, 3)	(1/3, 2/5, 1/2)
Absolutely more important	(5/2, 3, 7/2)	(2/7, 1/3, 2/5)

Source: adapted from Büyüközkan et al. (2008), p. 154.

The evaluation of the decision maker is based on the scale given in Table 1 and it is composed of fuzzy values. Table 2 shows the fuzzy evaluation matrix of the decision maker regarding the supplier selection criteria.

Table 2. Supplier selection criteria

	C	**Q**	**DP**	**R**	**F**	**TC**	**GL**
C	(1, 1, 1)	(1/2, 2/3, 1)	(2/5, 1/2, 2/3)	(1, 3/2, 2)	(3/2, 2, 5/2)	(2, 5/2, 3)	(2, 5/2, 3)
Q	(1, 3/2, 2)	(1, 1, 1)	(2/5, 1/2, 2/3)	(3/2, 2, 5/2)	(2, 5/2, 3)	(5/2, 3, 7/2)	(5/2, 3, 7/2)
DP	(3/2, 2, 5/2)	(3/2, 2, 5/2)	(1, 1, 1)	(2, 5/2, 3)	(5/2, 3, 7/2)	(5/2, 3, 7/2)	(5/2, 3, 7/2)
R	(1/2, 2/3, 1)	(2/5, 1/2, 2/3)	(1/3, 2/5, 1/2)	(1, 1, 1)	(1, 3/2, 2)	(3/2, 2, 5/2)	(3/2, 2, 5/2)
F	(2/5, 1/2, 2/3)	(1/3, 2/5, 1/2)	(2/7, 1/3, 2/5)	(1/2, 2/3, 1)	(1, 1, 1)	(1, 3/2, 2)	(1, 3/2, 2)
TC	(1/3, 2/5, 1/2)	(2/7, 1/3, 2/5)	(2/7, 1/3, 2/5)	(2/5, 1/2, 2/3)	(1/2, 2/3, 1)	(1, 1, 1)	(1/2, 2/3, 1)
GL	(1/3, 2/5, 1/2)	(2/7, 1/3, 2/5)	(2/7, 1/3, 2/5)	(2/5, 1/2, 2/3)	(1/2, 2/3, 1)	(1, 3/2, 2)	(1, 1, 1)

Chang's extent analysis method is applied on the fuzzy values of Table 2 as follows:
By applying formula (1);

$$S_C = (8.4,\ 10.67,\ 13.17) \otimes (\frac{1}{77.19},\ \frac{1}{63.27},\ \frac{1}{50.67}) \Rightarrow S_C = (0.11,\ 0.17,\ 0.26)$$

$$S_Q = (10.9,\ 13.5,\ 16.17) \otimes (\frac{1}{77.19},\ \frac{1}{63.27},\ \frac{1}{50.67}) \Rightarrow S_Q = (0.14,\ 0.21,\ 0.32)$$

$$S_{DP} = (13.5,\ 16.5,\ 19.5) \otimes (\frac{1}{77.19},\ \frac{1}{63.27},\ \frac{1}{50.67}) \Rightarrow S_{DP} = (0.17,\ 0.26,\ 0.38)$$

$$S_R = (6.23,\ 8.07,\ 9.84) \otimes (\frac{1}{77.19},\ \frac{1}{63.27},\ \frac{1}{50.67}) \Rightarrow S_R = (0.08,\ 0.13,\ 0.19)$$

$$S_F = (4.52,\ 5.9,\ 7.57) \otimes (\frac{1}{77.19},\ \frac{1}{63.27},\ \frac{1}{50.67}) \Rightarrow S_F = (0.06,\ 0.09,\ 0.15)$$

$$S_{TC} = (3.31,\ 3.9,\ 4.97) \otimes (\frac{1}{77.19},\ \frac{1}{63.27},\ \frac{1}{50.67}) \Rightarrow S_{TC} = (0.04,\ 0.06,\ 0.10)$$

$$S_{GL} = (3.81,\ 4.73,\ 5.97) \otimes (\frac{1}{77.19},\ \frac{1}{63.27},\ \frac{1}{50.67}) \Rightarrow S_{GL} = (0.05,\ 0.07,\ 0.12)$$

The comparison of the fuzzy values of each criterion is made using formulas (3) and (4). Then these values which are obtained from formulas (3) and (4) are used in formula (6);

$$d'(C) = V(S_C \geq S_Q,\ S_{DP},\ S_R,\ S_F,\ S_{TC},\ S_{GL}) = \min(0.75,\ 0.50,\ 1,\ 1,\ 1,\ 1) = 0.50\ ,$$

$$d'(Q) = V(S_Q \geq S_C,\ S_{DP},\ S_R,\ S_F,\ S_{TC},\ S_{GL}) = \min(1,\ 0.75,\ 1,\ 1,\ 1,\ 1) = 0.75\ ,$$

$$d'(DP) = V(S_{DP} \geq S_C,\ S_Q,\ S_R,\ S_F,\ S_{TC},\ S_{GL}) = \min(1,\ 1,\ 1,\ 1,\ 1,\ 1) = 1,$$

$d'(R) = V(S_R \geq S_C,\ S_Q,\ S_{DP},\ S_F,\ S_{TC},\ S_{GL}) = \min(0.67,\ 0.38,\ 0.13,\ 1,\ 1,\ 1) = 0.13$,

$d'(F) = V(S_F \geq S_C,\ S_Q,\ S_{DP},\ S_R,\ S_{TC},\ S_{GL}) = \min(0.33,\ 0.08,\ -0.13,\ 0.64,\ 1,\ 1) = -0.13$,

$d'(TC) = V(S_{TC} \geq S_C,\ S_Q,\ S_{DP},\ S_R,\ S_F,\ S_{GL}) = \min(-0.1, -0.36, -0.54,\ 0.22,\ 0.57,\ 0.83) = -0.54$,

$d'(GL) = V(S_{GL} \geq S_C,\ S_Q,\ S_{DP},\ S_R,\ S_F,\ S_{TC}) = \min(0.09, -0.17, -0.36,\ 0.4,\ 0.75,\ 1) = -0.36$.

From here; $W' = (0.50,\ 0.75,\ 1,\ 0.13,\ -0.13,\ -0.54,\ -0.36)^T$ and via normalization the weights of the supplier selection criteria is obtained as $W = (0.20,\ 0.25,\ 0.30,\ 0.13,\ 0.08,\ 0,\ 0.04)^T$.

It can be interpreted from these weights that the most important supplier selection criterion is “delivery performance”; followed by “quality” ,“cost / price”, “reliability”, “flexibility”, “geographical location” and “technological capability”.

5. DISCUSSION AND CONCLUSIONS

Suppliers play important roles in the integration of a supply chain and this makes the supplier selection decision important. Supplier selection problem is analyzed in various sectors focusing on various firms. In this study the supplier selection problem of a lean manufacturing firm is addressed with the aim of finding the relative importance of the supplier selection criteria in this firm.

This study is conducted in a lean furniture manufacturing firm operating in Turkey and the supplier selection process of the firm was dealt with. In accordance with this purpose seven leading supplier selection criteria were determined and the importance of these criteria was specified from the point of view of this lean manufacturing firm. The fuzzy AHP method was used to rank these seven criteria and “delivery performance” was found to be the most important criterion. The rest of the criteria were ranked in decreasing order of importance as follows: Quality, cost/price, reliability, flexibility, geographical location and technological capability.

These results are consistent with the results of some previous studies. For example; Dickson (1966) and Weber et al. (1991) concluded that cost, quality, and delivery performance were the most important criteria in supplier selection. Ho et al. (2010) also found supporting results from their comprehensive research and showed that these criteria were ranked in top three. However, care must be taken in generalizing the results of this study because it is a case study of a single firm. This is one of the limitations of this study. Another limitation is that this is a country specific study.

In future research, more comprehensive studies can be conducted by dealing with multiple lean firms. This makes it possible to compare various lean firms in terms of their supplier selection criteria. Focusing on different sets of supplier selection criteria or utilizing from other methods can also thought to be included in future studies.

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