Supplier Selection using Fuzzy-AHP approach for Consumer Durables Start-ups

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ABSTRACT

Purpose - The purpose of this paper is to select the best possible supplier for start-up organizations operating in consumer durables sector

Design/Methodology/Approach - This research adopts a combination of Fuzzy and AHP model built in MS Excel considering the ease of use and unavailability of resources with start-ups. Model integrates qualitative as well as quantitative factors for evaluating the alternatives available. The factors considered are based on organization's discretion and can be changed as per the strategy of that particular firm.

Findings - Model adopted helps the firm to choose the best possible supplier based on holistic evaluation of all the factors considered. It also reduces the time to select the supplier and results in cost savings for the firm.

Research Implications/Limitations - This research helps the firms to focus more on using simple models for supplier selection in case of unavailability of ERP systems and considering their strategy as being cost effective in initial stages of their launch in the market.

Practical Implications - Research encourages firms to adopt simple models and focus on reducing cost through proper selection of their suppliers which can help them to reduce significant cost in upstream supply chain.

Originality Value - There are lot of existing studies based on Fuzzy AHP model. But this study solely focuses on consumer durables sector of India and targets small enterprises which lacks infrastructure and spend lot of time in supplier selection through extensive documentation comparison

Keywords

AHP (Analytical Hierarchy Process), FUZZY, Supply Chain, MSME, Consumer Durables, Strategic Sourcing, Procurement

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Introduction

There is continuous increase in customer demand in Consumer Durables Segment with strong penchant towards affordable items equipped with improved and latest technologies. Considering the global competition with governments across the world easing regulations with respect to import and export and growing environmental consciousness, companies have started focusing more on their supply chains. Supply Chain Management is a methodology of improving the business processes, making them more resilient, more agile and as a result, more competitive(Parkhi, 2015). Supply chain involves procuring the material in right quantities at right time with right quality. The goal of the supply chain would thus involve improving the performance on both supplier side as well as buyer side. This would help to establish confidence and long-term relationships between them. Supplier Selection thus play a key role in organization's effectiveness and efficiency since it directly responsible for cost reduction, profitability and flexibility of a company resulting in reduction in indirect purchasing costs and increasing competitiveness. Consumer durables is a highly volatile industry considering technological changes on fortnight basis which leads to low product life cycle of most of the products. Also, there are continuous changes in consumer preferences, increasing product portfolio leading to lot of SKU's and fluctuation in capacity requirement leads to issues like improper demand visibility, inventory pile-up. In such cases, selecting a complete supplier who can supply upgraded raw materials is very important. Also, if a firm has to go for alternate suppliers, standard procedures can help them choose suppliers wisely with holistic evaluation of all the parameters.

Supplier Selection is multi-criteria problem which includes qualitative as well as quantitative factors(C. Cristea, 2017)**.**Main objective of supplier selection is to select best possible supplier who can meet all the expected requirements of the firm at affordable cost. Criteria used for selecting the supplier for a particular firm depends on the particular needs which are required.

A lot of Multiple Criteria Decision-Making methods are used for solving the complex decision-making problem. Analytical Hierarchy Process (AHP) is widely refereed for solving MCDM (Multiple Criteria Decision Making) problems, but it is still insufficient to explain undetermined conditions when we have to carry out pair-wise comparison stage. For problems expressed quantitatively, it is easy to rate them as per their performance but in cases which involves qualitative data it becomes very difficult to rate them and compare them pair-wise. Hence, fuzzy is used along with AHP (Analytical Hierarchy process) to review the criteria comprehensively.

To select the best possible supplier for a consumer durable company, this paper proposes a FUZZY-AHP (Analytical Hierarchy process) approach which uses triangular fuzzy numbers helping the decision maker to draw comparison and analysing the final priority of decision criteria. The applied Fuzzy-AHP (Analytical Hierarchy process) process makes use of linguistic variables which are rated with the

help of triangular fuzzy numbers as pair-wise comparison scale to derive the priorities of different selection criterion and alternatives. After pair-wise comparisons in between the criteria, each criterion is compared with the alternatives which are various suppliers to derive at performance of alternative with respect to that criteria. Finally, criteria weights and alternative weights with criteria are compared against each other and supplier with highest priority weight is selected as best possible supplier. MS Excel is used to make calculate weights of criteria and criteria evaluation with alternatives in which ratings are given as per the quotations and feedback received from the suppliers which are compared against each other and rated as per Fuzzy Satty Scale. This method will help the companies to select the best possible supplier which can handle any uncertainty and bias involved in human decisions and also provides pliability for the decision maker to arrive at the right choice. This paper starts by giving an outline about existing literature present on the methodology used for arriving at the best possible supplier. The concept behind using the Fuzzy-AHP approach is defined in the research methodology part and criteria used for evaluation of supplier are stated. Calculations made in MS – Excel are presented giving the idea about criteria evaluation and results are presented.

The main objectives are

1. To select the best possible supplier for the start-up consumer durables firm specialized in LED (Light Emitting Diode) TV
2. To develop a model which can reduce the time and complexity of the supplier selection process
3. Developing a holistic model which can be implemented across various department of the firm

Literature Review

Supplier selection is one of the crucial decision-making problems in supply chain management domain. According to (Thiruchelvam, July 2011), crucial element of supply chain management is supplier selection. It consists of Multiple Criteria Decision-making (MCDM) problems which considers and evaluates both qualitative as well as quantitative criteria (Cengiz, 2017).

There are lot of MCDM methods available which play a great role in helping individuals, companies across the industry to arrive at decision based on various factors. Initial citations of Fuzzy AHP(Analytical Hierarchy process) were in Laarhoven and Pedrycz (1983), who made the comparison of Fuzzy ratios which were defined by triangular membership functions (Kahraman C. &., 2004). In (1985) Buckley proposed a comparison between fuzzy priorities for which membership functions were trapezoidal. After Buckley, Stam et. al. in (1996) identified that how can newly developed AI (Artificial Intelligence) techniques are used to determine or calculate the ratings using AHP. (Kahraman C. &., 2004). They concluded that feed-forward neural network formulation is a powerful tool when analysing multiple criteria problems which have improper or fuzzy-ratio preferred judgements (Kahraman C. &., 2004). Chang (1996) introduced new approach for dealing with Fuzzy AHP problems, using triangular fuzzy numbers for a pairwise comparison evaluating criteria and also introduced extent analysis methodology for synthetic extent values for the same approach.(Kahraman C. &., 2004).

Analytical Hierarchy Process (AHP) is mostly used for categorical methods considering it is most widely used MCDM (Multiple Criteria Decision Making) methods. It constructively considers both quantitative and qualitative data in decision making which makes it easier to understand. Hence, it is extensively used for supplier selection across organizations.(Muralidharan, 2006) proposed a method which estimated rating by grouping on an individual level based on principal of anonymity. (Handfield, 2002) used AHP (Analytical Hierarchy process) in a decision support model helping managers understand the trade-off between various environmental dimensions. (Pi, 2006) also proposed a supplier selection and evaluation through Taguchi loss function and AHP (Analytical Hierarchy process). (Şevkli, 2007) makes use of data envelopment AHP (Analytical Hierarchy Process) to select the best supplier for a TV company. (Ounnar, 2007) did not use supplier selection approach in their research, rather best relationship between customer and supplier was determined using all the criteria used for supplier selection in the literature.

To deal with the uncertainties and vagueness of the decision-making problems and eliminate the disadvantages of AHP, Fuzzy along with AHP (Analytical Hierarchy Process) is most preferred method for supplier selection studies. (Altinoz, 2001) studied the supplier selection using the methodology for the textile sector. (Feng, 2005) developed a comprehensive method which is based on Fuzzy decision theory and characteristics of SCM (Supply Chain Management) for optimal combination and selection among candidate supplier and outsourced parts. (Haq, 2006) demonstrated how Fuzzy AHP (Analytical Hierarchy Process) model can help solve supplier selection problem through a practical approach.(Lu, 2007) makes use of environmental principles in supplier selection process by using Fuzzy AHP (Analytical Hierarchy Process). (Chan F. &., 2008) proposed Fuzzy AHP for Global Supplier Selection problem making use of criteria involved in international logistics. (Chamodrakas, 2010) proposed method for supplier selection in Electronics sector. The common approach used across all Fuzzy AHP (Analytical Hierarchy Process) models is extent analysis which was proposed (Chang, 1992). (Kahraman C. C., 2003) integrated Fuzzy AHP (Analytical Hierarchy Process) approach to select the best suited supplier satisfying the most criteria involved in white goods sector.

Fuzzy AHP (Analytical Hierarchy Process) method as also used for selecting the best catering firm which satisfied the customer to maximum extent (Kahraman C. &., 2004). (Chan F. T., 2007) discussed a Fuzzy AHP extended approach using triangular fuzzy numbers to represent and rate the decision makers judgements and synthetic fuzzy extent analysis method used to decide the final priority of different decision criteria. There are lot of start-up's across India from various industries which are formed every day. During their nascent stages, there is a lot of cash crunch and un-availability of technologies like ERP. They heavily rely in Excel as their toll for carrying out daily activities. Also, considering the overall parameters involved in the supplier selection process, it is cumbersome to evaluate each and every factor individually and select a supplier based on

holistic review in absence of any model. This study helps them to understand what criteria to be considered initially for selection best supplier as well as provide them with Excel Model which will help them save time and money.

Research Methodology

Concept of fuzzy sets was first introduced by Zadeh in 1965 which helped the draw conclusions from information of ambiguous form or is uncertain. Fuzzy sets refer to class of objects with continuum of membership grade. If a set is identified as fuzzy set, a tilde "~" symbol will be placed above the set. A triangular fuzzy number (TFN) is shown in Fig. 1. TFN is normally denoted by (l,m,u) where l is smallest possible value, m is most promising value and u is largest possible value (Kahraman C. &., 2004). When l=m=u, it is a non-fuzzy number. Every Triangular Fuzzy Number (TFN) have linear representation on either side viz. left and right so that membership can be defined as(Kahraman C. &., 2004)

$$u_{\tilde{m}} = \begin{cases} 0, x < l, \\ (x-l)/(m-l), l \le x \le m \\ (u-x)/(u-m), m \le x \le u \\ 0, x > u \end{cases}$$

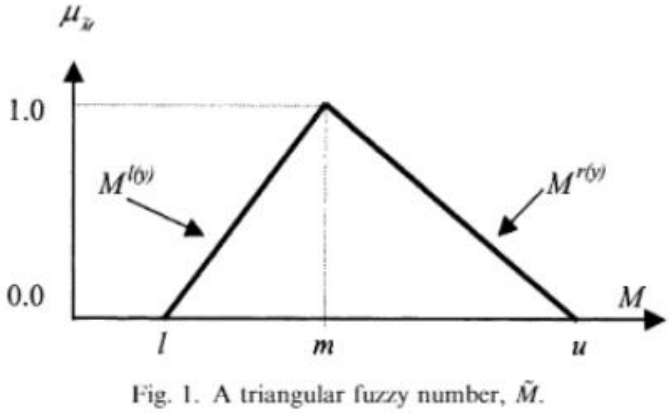

Fig. 1. A triangular fuzzy number, $\tilde{M}$.

Fig 1. Visual Representation of Triangular Fuzzy Number

Fuzzy method along with AHP is used when problem have qualitative parameters. Fuzzy numbers are always represented as right and left for each degree of membership (Kahraman C. &., 2004).

$$\tilde{M} = (Ml(y), Mr(y)) = (l + (m-l)y, u + (m-u)y), y \in [0,1]$$

In the above equation, r(y) and l(y) represent right and left side of the fuzzy number. Fuzzy numbers with algebraic operations can be found in (Kilincci, 2011)

Whenever AHP is used in the process, discrete scale is used for deciding the priority weights of variables quantitate in nature or which are scales accordingly, whereas for Fuzzy-AHP, linguistic variables or fuzzy numbers are used. In practical application, decision makers prefer to use triangular or trapezoidal numbers since they help remove the judgement vagueness of the decision maker. Commonly, method proposed by (Chang, 1992) as extent analysis is mostly used for Fuzzy AHP problems.

The extent analysis method which proposed by (Chang, 1992) considers the extent of an object for which goal needs to be satisfied. Extent means the fuzzy number that is used to determine priority weights and based on that fuzzy synthetic degree is derived which is defined below.

As per (Chang, 1992) method extent analysis method, every object is selected and extent analysis on each goal, g_i is calculated. So, m values can be obtained from extent analysis with the following signs.

$$M_{gi}^{1}, M_{gi}^{2}, \ldots, M_{gi}^{m}, \quad i = 1, 2, \ldots, n$$

"Where all the M_{gi}^{j} (j = 2, . . ., m) are TFN's

Steps followed used in Chang's Extent Analysis are given as following (Kahraman C. &., 2004)

(1) The value of fuzzy synthetic extent with respect to i^{th} object is defined as

$$\sum_{j=1}^{m} M_{gi}^{j} * \left[\sum_{i=1}^{n}\sum_{j=1}^{m} M_{gi}^{j}\right] - 1$$

(2) To obtain $\sum_{j=1}^{m} M_{gi}^{j}$, perform the fuzzy addition operation of m extent analysis values for a particular matrix such that

$$\sum_{j=1}^{m} M_{gi}^{j} = \left(\sum_{j=1}^{m} lj, \sum_{j=1}^{m} mj, \sum_{j=1}^{m} uj\right)$$

and to obtain $[\sum_{i=1}^{n}\sum_{j=1}^{m} M_{gi}^{j}]^{-1}$, perform the fuzzy addition operation of M_{gi}^{j} (j = 1, 2, . . . ,m) values such that

$$\sum_{i=1}^{n}\sum_{j=1}^{m} M_{gi}^{j} = \left(\sum_{j=1}^{m} lj, \sum_{j=1}^{m} mj, \sum_{j=1}^{m} uj\right)$$

and then compute the inverse of the vector in such that

$$\left[\sum_{j=1}^{m} M_{gi}^{j}\right]^{-1} = \left(\frac{1}{\sum_{j=1}^{m} uj}, \frac{1}{\sum_{j=1}^{m} mj}, \frac{1}{\sum_{j=1}^{m} lj}\right)$$

(3) The degree of possibility of $M_2 = (l_2, m_2, u_2) \ge$ is defined as $M_1 = (l_1, m_1, u_1)$ is defined as

$$V(M2 \ge M1) = \sup_{y \ge x}[\min(\mu M1(x), \mu M2(y))]$$

And can be expressed as follows:

$$V(M_2 \ge M_1) = hgt(M_1 \cap M_2) = \mu_{M2}(d)$$

$$\begin{cases} 1 & \text{if } m2 \ge m1, \\ 0 & \text{if } l1 \ge u2, \\ \dfrac{l1 - u2}{(m2 - u2) - (m1 - l1)} & \text{Otherwise} \end{cases}$$

where d is the ordinate of the highest intersection point D between lM1 and lM2. In Fig. 2, the intersection between

M1 and M2 can be seen. To compare M1 and M2, we need both the values of V (M1 ≥ M2) and V (M2 ≥ M1). The degree of possibility for a convex fuzzy number to be greater than k convex fuzzy numbers Mi (i = 1, 2, ..., k) can be defined by

V (M ≥ M1, M2, . . ., M_k) = V [(M ≥ M1) and (M ≥ M2) and (M ≥ M_k) = min V (M ≥ M_i)

i = 1, 2, 3, . . ., k

Assume that

D' (A_i) = minV (S_i ≥ S_k) For K = 1,2, . . .n; k ≠ i The vector weight is given by

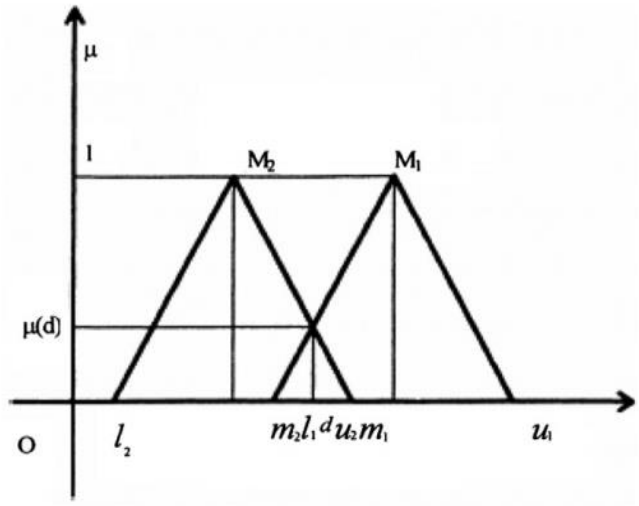

Fig 2. Intersection Between M1 and M2 (Zhu, Jing, & Chang, 1999)

W' = (d' (A_1),d' (A_2), . . ., d'(A_n))^T

Where A_i (i = 1, 2,. . ,n) are n elements.

Normalization and Normalized weight vectors are

W = (d(A_1), d(A_2), . . ., d (A_n)) T,

Where W is a non-fuzzy number. This gives the priority weights of alternative over another."

Application of Supplier Selection in Brown Goods Sector

A start-up based out of India is venturing in Indian Electronics market and currently source its materials from South-east Asia. Company wants to select supplier for one of the critical parts used in assembly of LED TV. Start-up is currently in production of Washing Machine and LED Tv's with current customer base as India itself. Considering the competition from other established brand, they are planning to provide their products to customer at low price with high end technology. Start-up wants to expand its customer base into other countries from Asia Pacific since electronic goods are available in cheaper rate than other markets across India. This would help them to procure the material at lower rates reducing the landed cost for the components and in turn for the final product. With number of suppliers available in various countries across South-East Asia, a well-defined model would help the start-up to select the best possible supplier based on comparison in between various factors.

Data Analysis and Interpretation using Fuzzy-AHP

In case of Supplier selection, ratings or importance given to different judgement criteria is highly based on individual preference which comes from company policy. For some parameters which are qualitative or linguistic, judgement made by humans cannot be precisely defined in exact numbers. It is preferable to give interval judgements. Triangular fuzzy numbers are used for the problem to rate one decision variable over other. The triangular fuzzy numbers were determined from reviewing literature (Kahraman C. C., 2003). As per Chang's extent method, synthetic analysis method is used to decide the final priority weights which are rated as per triangular fuzzy numbers.

Step 1: Defining the Criteria for Supplier Selection

Supplier Selection ultimate objective is to select the best possible supplier for the firm. Consider consumer durables as an industry and especially with brown goods, lot of criteria have to be considered before selecting the final supplier. Criteria selected for the problem at stake have been discussed with the procurement planner of the company. All the other literature was reviewed with the expert and what criteria needs to be included in the study were determined. Criteria selected for the selecting the supplier were Quality, Delivery, Quoted Price, Production Capacity and Financial Position.

Price: It indicates the listed price of the product. Buyer always wants to purchase the product at the lowest price to decrease the total cost.

Quality: Quality of the raw material is key indicator of quality of final product. Quality rate can be measured using the parts rejected from the supplier against part received.

Delivery: It indicates number of days from point supplier receives the order to the moment he ships it. Supplier actually required this number of days to manufacture the raw material without any availability of prior inventory.

Production Capacity: Suppliers production capacity indicates whether the firm can meet the consumer demand throughout the year or not. Supplier should be flexible enough to accommodate any changes made in the product structure by the customer. Also, if there are continuous orders from the customer, supplier should increase the capacity.

Financial Position: Relationship between supplier and the buyer is necessary for the long- term commitment. Financial status would help to assess whether supplier can be a potential business partner for the organization or not.

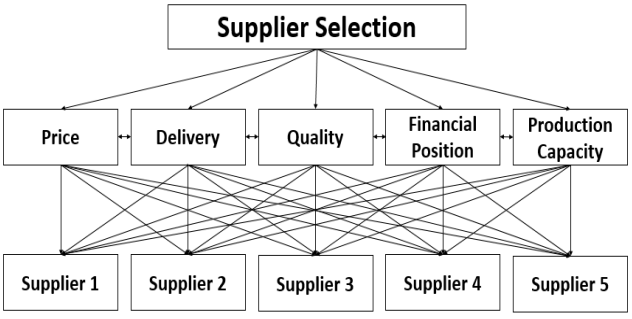

Fig 3. Hierarchy of Supplier Selection (Source-Author creation)

In reference to fig.3, top level of the hierarchy represents the problem statement which needs to be addressed and is the ultimate goal. Second level indicates what are the criteria on which supplier will be evaluated on as per company requirements to select the best possible supplier for the firm. Third hierarchy consist of alternatives which are basically the suppliers who have submitted their quotations for the requirement from Astorianz.

Step 2: Calculating the weights for Criteria

Once the hierarchy in designed, criteria weights need to be calculated to determine which criteria has relatively more importance over other. Each criteria importance was decided after thorough discussion with procurement team of the company and ratings as per fuzzy scale were calculated through formation of pairwise matrix. Geometric mean of all the criteria were calculated. After calculating the total value of the geometric weights, fuzzified weights are calculated by taking the average which are then normalized in case summation of value is more than 1.

Step 3: Calculate Priority Weights for Each Criteria with Alternatives

Criteria Comparision

	Price			Delivery			Production Capacity			Quality			Financial Position			Normalized Weights
Price	1	1	1	6	7	8	4	5	6	1	1	1	2	3	4	0.421
Delivery	1/6	1/7	1/8	1	1	1	6	7	8	2	3	4	2	3	4	0.256
Production Capacity	1/4	1/5	1/6	1/6	1/7	1/8	1	1	1	2	3	4	1	1	1	0.101
Quality	1	1	1	1/2	1/3	1/4	1/2	1/3	1/4	1	1	1	1/2	1/3	1/4	0.088
Financial Position	1/2	1/3	1/4	1/2	1/3	1/4	1	1	1	2	3	4	1	1	1	0.134

Fig 4. Criteria Comparison Weight Calculation (Authors Compilation)

Once we have calculated the normalized weights for the criteria, we evaluate our alternatives against each individual criterion to calculate the normalized weights of each criterion as shown in fig 4. This step is done to done to analyse where each supplier stands on the basis of each criteria and how much is the individual rating with respect to the same. Comparison of each criteria with selected alternatives are shown in Figure 5 (Price)., Figure 6. (Delivery), Figure 7. (Production Capacity), Figure 8. (Quality), Figure 9. (Financial Position).

Price

	Supplier 1			Supplier 2			Supplier 3			Supplier 4			Supplier 5			Normalized Weights
Supplier 1	1	1	1	9	9	9	4	5	6	6	7	8	2	3	4	0.530
Supplier 2	1/9	1/9	1/9	1	1	1	1/6	1/7	1/8	4	5	6	2	3	4	0.101
Supplier 3	1/4	1/5	1/6	6	7	8	1	1	1	2	3	4	4	5	6	0.247
Supplier 4	1/6	1/7	1/8	1/4	1/5	1/6	1/2	1/3	1/4	1	1	1	6	7	8	0.079
Supplier 5	1/2	1/3	1/4	1/2	1/3	1/4	1/4	1/5	1/6	1/6	1/7	1/8	1	1	1	0.043

Fig 5. Price Criteria Weight Calculation with Alternatives (Authors Compilation)

Delivery

	Supplier 1			Supplier 2			Supplier 3			Supplier 4			Supplier 5			Normalized Weights
Supplier 1	1	1	1	9	9	9	2	3	4	4	5	6	6	7	8	0.520
Supplier 2	1/9	1/9	1/9	1	1	1	1/6	1/7	1/8	1/4	1/5	1/6	2	3	4	0.052
Supplier 3	1/2	1/3	1/4	6	7	8	1	1	1	2	3	4	4	5	6	0.269
Supplier 4	1/4	1/5	1/6	4	5	6	1/2	1/3	1/4	1	1	1	1	1	1	0.107
Supplier 5	1/6	1/7	1/8	1/2	1/3	1/4	1/4	1/5	1/6	1	1	1	1	1	1	0.053

Fig 6. Delivery Criteria Weight Calculation with Alternatives (Authors Compilation)

Production Capacity

	Supplier 1			Supplier 2			Supplier 3			Supplier 4			Supplier 5			Normalized Weights
Supplier 1	1	1	1	9	9	9	4	5	6	6	7	8	2	3	4	0.484
Supplier 2	1/9	1/9	1/9	1	1	1	2	3	4	4	5	6	6	7	8	0.201
Supplier 3	1/4	1/5	1/6	2	3	4	1	1	1	6	7	8	4	5	6	0.225
Supplier 4	1/6	1/7	1/8	1/4	1/5	1/6	1/6	1/7	1/8	1	1	1	1	1	1	0.041
Supplier 5	1/2	1/3	1/4	1/6	1/7	1/8	1/4	1/5	1/6	1	1	1	1	1	1	0.049

Fig 7. Production Capacity Criteria Weight Calculation with Alternatives (Authors Compilation)

Quality

	Supplier 1			Supplier 2			Supplier 3			Supplier 4			Supplier 5			Normalized Weights
Supplier 1	1	1	1	9	9	9	6	7	8	2	3	4	4	5	6	0.536
Supplier 2	1/9	1/9	1/9	1	1	1	2	3	4	4	5	6	2	3	4	0.188
Supplier 3	1/6	1/7	1/8	1/2	1/3	1/4	1	1	1	1/6	1/7	1/8	6	7	8	0.074
Supplier 4	1/2	1/3	1/4	1/4	1/5	1/6	6	7	8	1	1	1	4	5	6	0.162
Supplier 5	1/4	1/5	1/6	1/2	1/3	1/4	1/6	1/7	1/8	1/4	1/5	1/6	1	1	1	0.039

Fig 8. Quality Criteria Weight Calculation with Alternatives (Authors Compilation)

Financial Position

	Supplier 1			Supplier 2			Supplier 3			Supplier 4			Supplier 5			Normalized Weights
Supplier 1	1	1	1	9	9	9	2	3	4	4	5	6	6	7	8	0.529
Supplier 2	1/9	1/9	1/9	1	1	1	2	3	4	2	3	4	4	5	6	0.186
Supplier 3	1/2	1/3	1/4	1/2	1/3	1/4	1	1	1	4	5	6	6	7	8	0.178
Supplier 4	1/4	1/5	1/6	1/2	1/3	1/4	1/4	1/5	1/6	1	1	1	2	3	4	0.071
Supplier 5	1/6	1/7	1/8	1/4	1/5	1/6	1/6	1/7	1/8	1/2	1/3	1/4	1	1	1	0.036

Fig 9. Financial Position Criteria Weight Calculation with Alternatives (Authors Compilation)

Step 4: Calculate the overall score of each supplier to select best supplier

Comparing the normalized weights of criteria as well as the alternatives with respect to each criterion are compared against each other and then sum product of the same is taken to calculate the final score which gives us the best possible supplier for the firm in the figure 10.

RESULTS

	Price	Delivery	Production Capacity	Quality	Financial Position
Supplier 1	0.530161866	0.520065196	0.484086983	0.53630718	0.5294602
Supplier 2	0.100605116	0.051824699	0.201014044	0.18798421	0.185561991
Supplier 3	0.246924701	0.268929894	0.225355673	0.074455943	0.177853177
Supplier 4	0.078824569	0.106559885	0.040834325	0.161811383	0.070761398
Supplier 5	0.043483747	0.052620326	0.048708975	0.039441284	0.036363235

	Criteria	Supplier 1	Supplier 2	Supplier 3	Supplier 4	Supplier 5
Price	0.420512625	0.530161866	0.100605116	0.246924701	0.078824569	0.043483747
Delivery	0.256304956	0.520065196	0.051824699	0.268929894	0.106559885	0.052620326
Production Capacity	0.10101118	0.484086983	0.201014044	0.225355673	0.040834325	0.048708975
Quality	0.088270293	0.53630718	0.18798421	0.074455943	0.161811383	0.039441284
Financial Position	0.133900947	0.5294602	0.185561991	0.177853177	0.070761398	0.036363235
		0.523368456	**0.117333662**	**0.225913418**	**0.088341433**	**0.045043031**

Fig 10. Result Calculation with Normalized Weights (Authors Compilation)

Results

As per the final score, we can select the best possible supplier for the firm according to their final ranking. Normalized score calculated for criteria as well as each criterion with alternatives are evaluated and sum product of the same is taken to calculate the final score for the suppliers. Once the weights are calculated, supplier are ranked according to their final scores. The model prepared will help the start-up to select the best possible supplier for LED TV parts. This can also be implemented horizontally across the organization for other departments such as Human Resources and Logistics. This model can be integrated in ERP systems across an organization. It helps to save the time spent in supplier selection process and making cost benefit analysis. Also, it is easy to operate the model since as per the convenience of user, only the criteria and ranking changes needs to be made. All the calculations are automatically made in the model without any interruptions shown in figure 11.

SUPPLIER RANKING	
RANK	SUPPLIER
1	Supplier 1
2	Supplier 3
3	Supplier2
4	Supplier 4
5	Supplier 5

Fig 11. Result Table

Conclusion

Supplier Selection I one of the important and strategic business activities for an organization. It is comparison between suppliers based on common criteria and measures to select supplier having the highest potential amongst all the alterative suppliers who ca constantly meets the firm need's at lower costs. Selecting the correct supplier would help any organization reduce purchasing costs which helps it provide service at costs lower than its competitors in the market.

In this study, Fuzzy-AHP MCDM methodology is used to select the best possible for the start-up which would help it to be cost competitive in the market dominated by multinationals and increase customer satisfaction. In total of 5 attributes were selected out of which four were quantitative whereas 1 was qualitative. Calculations were made in MS-Excel considering the ease of solving the decision-making problem. In case of any changes in the parameters as per organization's policy, it can be easily integrated in the model and no calculation are required to be done from scratch. The model can also be integrated in to ERP systems in case it is used in multinationals which would reduce time drastically in supplier selection process. For the problem, only single part is selected for LED TV but the model can also be used for other procured parts as well as Washing Machine parts.

This can further be extended to other vertical of the organizations like Human Resources for selecting the best candidate, Logistics for selecting the 3PL vendors. Thus, an integrated model of Fuzzy analogy along with AHP can be used to select the best possible suppliers.

References

[1] Altinoz, C. (2003). Supplier selection in textiles: A fuzzy approach.

[2] Çebi, F., & Bayraktar, D. (2003). An integrated approach for supplier selection. Logistics information management.

[3] Cengiz, A. E., Aytekin, O., Ozdemir, I., Kusan, H., &Cabuk, A. (2017). A multi-criteria decision model for construction material supplier selection. Procedia Engineering, 196, 294-301.

[4] Chamodrakas, I., Batis, D., &Martakos, D. (2010). Supplier selection in electronic marketplaces using satisficing and fuzzy AHP. Expert Systems with Applications, 37(1), 490-498.

[5] Chan, F. T., & Kumar, N. (2007). Global supplier development considering risk factors using fuzzy extended AHP-based approach. Omega, 35(4), 417-431.

[6] Chan, F. T., Kumar, N., Tiwari, M. K., Lau, H. C., & Choy, K. (2008). Global supplier selection: a fuzzy-AHP approach. International Journal of production research, 46(14), 3825-3857.

[7] Chang, D. Y. (1992). Extent analysis and synthetic decision, optimization techniques and applications (Vol. 1, p. 352).

[8] Cristea, C., & Cristea, M. (2017). A multi-criteria decision-making approach for supplier selection in the flexible packaging industry. In MATEC Web of Conferences (Vol. 94, p. 06002). EDP Sciences.

[9] Feng, D. Z., Chen, L. L., & Jiang, M. X. (2005, June). Vendor selection in supply chain system: An approach using fuzzy decision and AHP. In Proceedings of ICSSSM'05. 2005 International Conference on Services Systems and Services Management, 2005. (Vol. 1, pp. 721-725). IEEE.

[10] Handfield, R., Walton, S. V., Sroufe, R., & Melnyk, S. A. (2002). Applying

environmental criteria to supplier assessment: A study in the application of the Analytical Hierarchy Process. European journal of operational research, 141(1), 70-87.

[11] 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.

[12] Kahraman, C., Cebeci, U., &Ruan, D. (2004). Multi-attribute comparison of catering service companies using fuzzy AHP: The case of Turkey. International journal of production economics, 87(2), 171-184.

[13] Kahraman, C., Cebeci, U., &Ulukan, Z. (2003). Multi-criteria supplier selection using fuzzy AHP. Logistics information management.

[14] Lu, L. Y., Wu, C. H., &Kuo, T. C. (2007). Environmental principles applicable to green supplier evaluation by using multi-objective decision analysis. International journal of production research, 45(18-19), 4317-4331.

[15] Muralidharan, C., Anantharaman, N., & Deshmukh, S. G. (2002). A multi-criteria group decision-making model for supplier rating. Journal of supply chain management, 38(3), 22-33.

[16] Ounnar, F., Pujo, P., Mekaouche, L., &Giambiasi, N. (2007). Customer–supplier relationship management in an intelligent supply chain network. Production Planning & Control, 18(5), 377-387.

[17] Parkhi, S., Joshi, S., Gupta, S., & Sharma, M. (2015). A study of evolution and future of supply chain management. Supply Chain Management, 9(2), 95-106.

[18] Pi, W. N., & Low, C. (2006). Supplier evaluation and selection via Taguchi loss functions and an AHP. The International Journal of Advanced Manufacturing Technology, 27(5-6), 625-630.

[19] Sevkli, M., Lenny Koh, S. C., Zaim, S., Demirbag, M., &Tatoglu, E. (2007). An application of data envelopment analytic hierarchy process for supplier selection: a case study of BEKO in Turkey. International Journal of Production Research, 45(9), 1973-2003.

[20] Thiruchelvam, S., &Tookey, J. E. (2011). Evolving trends of supplier selection criteria and methods. International Journal of Automotive and Mechanical Engineering, 4(1), 437-454.