A Combined approach for supplier selection using AHP and Fuzzy AHP in Indian Gear Manufacturing MSMEs

Dr. Ashish J. Deshmukh¹; Dr. Hari Vasudevan²
¹Associate Professor, SVKMs NMIMS MPSTME, Vile Parle (W), Mumbai, India.
²Principal, D. J. Sanghvi College of Engineering, Vile Parle (W), Mumbai, India.

¹ashish.deshmukh@nmims.edu; ²principaldjs@gmail.com

Abstract: Industries these days across the world are required to be a part of single economy and work-culture. As a result, manufacturing industries are moving towards adding higher value activities and therefore even the requirements for suppliers in many cases undergo significant changes. By ensuring the best supplier, industries save material costs and increase their competitive advantage. Gear manufacturing companies are main suppliers for India’s leading manufacturing firms, as they outsource manufacturing of gears to Micro, Small and Medium Enterprises (MSMEs). Extant literature indicate that the Gear manufacturing companies follow traditional supply chain process and partially follows green supply chain as well as sustainability aspects. It is therefore important to understand the role, Gear manufacturing industries play in their supplier selection process. This study has explored the traditional and green manufacturing factors considered during the supplier selection in the Indian MSME Gear manufacturing sector, using tools such as AHP and FAHP. AHP is one of the best tools for deciding among the complex criteria structure at different levels. FAHP, being synthetic extension of classical AHP, considers the fuzziness of the decision makers. Results of this study indicate that, from amongst all 8 main traditional and green supply chain performance measures, cost is found to be the most important criteria for supplier selection even today in Indian industries. But, looking at the sub-factors, it is clear that the industries not only focus on purchase cost, but they also think of the disposal cost of the component, meaning they consider few aspects of green criteria as well in their decisions.

1. Introduction
In a competitive business environment, the selection of suppliers represents one of the most crucial issues faced by manufacturing firms. The cost of raw materials comprises of a major portion of the product’s final cost and the selection of appropriate suppliers significantly reduces the purchasing costs in industries. Two types of supplier selection approaches are prominent in practice today. In the first type (single sourcing), only one supplier can satisfy the buyer’s entire requirements. In the second and more common type (multiple sourcing), more than one supplier must be selected, because no single supplier can satisfy all of buyer’s requirements. Hence, for effective supply chain management, companies need to select both the best set of suppliers and also find as to how much quantity should be allocated among them for creating a constant environment of competitiveness [5]. Moreover, with the changing environmental requirements affecting the manufacturing business, attention is also to develop effective environmental management strategies for supply chain. As the world economy and businesses move on, there are always new demands to be met with. For example, people now prefer cars with light weight and low engine sound. This opens up demand for suitable power transmission. Light weight gears with high reliability are necessary to make light-weight
automobiles. The success in engine noise reduction and high reliability are necessary to make lightweight automobiles and it promotes the production of quieter gears. Reduction in noise, while transferring power is important in today’s rapidly growing field of automobile industry. Gear manufacturing companies are the main suppliers for India’s leading manufacturing firms, mostly because, most of the companies outsource the gear from Micro, Small and Medium Enterprises (MSMEs). There are many companies in India, which manufacture different variety of Gears for a wide range of application.

This study is an attempt to compare traditional supply chain and green supply chain and to explore the importance of green supply chain management in the current context in Indian gear manufacturing MSMEs. It also lists out various criteria in supplier selection and is structured in the following manner. In section 2, an elaborate literature survey is presented that explores the literature pertaining to traditional and green supply chain management. In section 3, a brief section on micro small and medium enterprises is covered. Section 4 gives the research methodology and section 5 highlights the comparative results between AHP and FAHP, including various criteria for supplier selection in the traditional and green supply chain and Section 6 ends with the conclusion.

2. Literature Review

Analytic Hierarchy Process (AHP) is a multiple criteria decision-making tool. This involves an Eigen value approach, which is used to compare the alternatives with respect to various criteria and to estimate criteria weights. AHP was quite common in the literature reviewed during this study and was developed by Thomas L. Saaty in 1980 [15]. However, since AHP has been applied in a huge variety of application fields, some recent reviews have focused on the application of AHP in specific fields: marketing [14], energy [6], medical and health care decision making allocation [6]. Adoptive AHP is used for customized marketing decisions and problems [10]. Application of AHP was reviewed in R&D project selection and resource allocation [17]. Dickson and Weber et.al supplier selection criteria was reviewed, ranked and compared by Ashish J. Deshmukh and Archana A. Chaudhari [3] from 1992-2007. The authors collected 49 articles on traditional supplier selection criteria and observed that if organizations have to maintain their sustainability and competitiveness in the market, A. Deshmukh and H. Vasudevan [1] considered a systematic and integrated approach for supplier selection and suggested that more concern is required towards environmental protection. A. Deshmukh and H. Vasudevan [2] examined the practices and issues related to the implementation of traditional and green supplier selection criteria among various MSMEs based in India. The proposed approach consisted of 12 criteria.

Zadeh [18] proposed a fuzzy set theory in 1965 to tackle the vagueness in information and fuzziness in human judgment. Fuzzy logic itself has proven to be an effective Multi Criteria Decision Making (MCDM) method. Since then, many more research studies have used fuzzy set theory to deal with uncertainty in supplier selection and other problems. Many a times, decision makers (DMs) give us uncertain answers than that of precise value and in such situations, it is very difficult to quantify this into a qualitative value. AHP method is used to capture the decision maker’s preferences for pair-wise comparison, but AHP method cannot refract the human thinking style. This is because fuzziness is present in a real life decision making and problems involved in the use of AHP is restricted scale, group decision making and relativity of decision attributes. Therefore, FAHP, which is nothing but an extension of AHP, has been developed to solve the hierarchical problem. Lee A. H. I. et al. [12] incorporated FAHP to solve a green supplier selection problem. In this, integrated fuzzy theory and extent analysis method was used into the AHP approach. FAHP model also used for the selection of global suppliers in a Pharmaceutical company of Turkey. Extended FAHP method used to calculate risk factors in supplier selection with different decision criteria like cost, quality, service performance, delivery, geographical location and suppliers profile [4,8,9,11,16].

3. Micro, Small and Medium Enterprises in India

The role of the large scale manufacturing buyers becomes more crucial in building relationship with their suppliers; where the suppliers belong to MSMEs. Most of the large scale manufacturing industries
are dependent on micro-small and medium manufacturing units. The term MSME covers a wide range of definitions and measures, varying from county to country and varying between the sources referred in literature. In India enterprises are classified on the basis of two categories, namely enterprise that engages in the production/manufacturing of goods and enterprises that engage in providing /rendering services. According to the Micro, Small and Medium Enterprise Development (MSMED) Act, 2006 of government of India; MSMEs in India is defined, based on the plant and machinery investment made (Excluding land and buildings) as explained in table 1 below.

**Table 1. Details of Fabricated Composite**

|                         | Manufacturing Enterprises | Service Enterprises |
|-------------------------|---------------------------|---------------------|
| Micro                   | Up to Rs. 2.5 millions/25 Lacks | Rs. 1 millions/10 Lacks |
| Small                   | More than Rs. 2.5 millions/25 Lacks and up to Rs. 50 millions/5 Crore | More than Rs. 1 millions/10 Lacks and up to Rs. 20 millions/2 Crore |
| Medium                  | More than Rs. 50 millions/5 Crore and up to Rs. 100 millions/10 Crore | More than Rs. 20 millions/2 Crore and up to Rs. 50 millions/5 Crore |

Total number of MSMEs operating in India increased from 361 lacks in 2006-07 to 510 lacks in 2014-15 and the employment generation has grown by annual compound rate of 11.74% [13]. Research has suggested that MSMEs are major job providers and contributes positively to India’s economy and growth. MSME sector contributes not only to increase economic growth, but also builds an inclusive and sustainable society. In today’s age, sustainable development is of highest priority, because of continuous pressure from government and customers. It can be observed that by and large, MSMEs in India meet the expectations of the Government. Figure 1 below shows the distribution (sector wise) of the MSMEs in India. It is being observed that in the whole sector, manufacturing companies have a space of around 67%, followed by service and repair & maintenance at 16.77% and 16.13% respectively.

![Growth Rate](image_url)

**Figure 1. Growth rate of MSMEs in India (MSME report 2015-16)**

4. **Research Methodology**

In this section of the paper, both tools such as AHP and FAHP as applied in the gear manufacturing sector are discussed as in the illustration of the applicability of both methods as well as the data
collection. It should be noted that data obtained for both of the AHP and FAHP for gear manufacturing sector have been derived from the judgments of the experts and decision-makers by using questionnaires and direct interviews. Data obtained from the decision-makers and the experts were represented in quantitative and qualitative forms. Hierarchy for main criteria, sub-criteria and alternatives with goal at the top i.e. selection of the best supplier. The main criteria include cost, quality, service performance, environmental manufacturing system, delivery, environmental performance assessment, risk and innovation & learning. Sub-criteria contributing to the decision are represented at the intermediate levels, cost includes (purchase cost, fright cost, discount for early payment, tax &custom duties, recycling cost, cost of component disposal), quality includes (quality performance ISO 9000 or 14000, provide sample before ordering, durability of the component, less rejection/rate of return, quality management in organization, reliability of the component), service performance includes (supply capacity, buffer stock, sales competency, reaction to demand, production facility and capacity, supply variety), environmental manufacturing management includes (technology and R&D management, green design, green procurement, green manufacturing, green distribution, environmental planning), delivery includes (on time delivery, production volume changes, short delivery lead time, consistency in delivery, reliable delivery methods, adoption of reusable packaging material), environmental performance assessment includes (air emission and water waste management, hazardous waste management, toxic waste and pollution management, public disclosure of environmental records, achievement of cleaner production), risk includes (production risk, green risk), innovation & learning includes (Flexible work force, Product innovation, Process innovation).

Respondents were asked to set the preference concerning for each hierarchical level, including main criterion, sub-criterion and suppliers. Table 2 shows the pair-wise comparison matrix for eight selected main criteria according to the rank given by the respondents using Satty’s scale. After obtaining the pair-wise comparison, the next step was the computation of Eigen vector or vector priorities or local weights of each element in the matrix. In terms of matrix, algebra, this consists of calculating the Eigen vector or vector priorities or local weights of the matrix by adding the member of each column to find the total. In the next step, in order to normalize each column to the sum to 1, element of the column values was divided by the total of the column and then summed up. Finally, the element in each resulting row were added and this sum was divided by the number of element in the row to get the average shown in the last column of table 2.

| Goal | Cost | Quality | SP | EMM | Risk | Delivery | EPA | I&L | Local Weights |
|------|------|---------|----|-----|------|----------|-----|-----|--------------|
| Cost | 1    | 3.0000  | 5.0000 | 4.0000 | 6.0000 | 3.0000 | 6.0000 | 5.0000 | 0.4660 |
| Quality | 0.3333 | 1 | 2.0000 | 1.0000 | 3.0000 | 1.0000 | 3.0000 | 2.0000 | 0.1120 |
| SP | 0.2000 | 0.5000 | 1 | 0.5000 | 1.0000 | 0.5000 | 1.0000 | 1.0000 | 0.0790 |
| EMM | 0.2500 | 1.0000 | 2.0000 | 1 | 2.0000 | 0.5000 | 0.5000 | 1.0000 | 0.0660 |
| Risk | 0.1667 | 0.3333 | 1.0000 | 0.5000 | 1 | 0.3333 | 1.0000 | 0.5000 | 0.0660 |
| Delivery | 0.3333 | 1.0000 | 2.0000 | 2.0000 | 3.0000 | 1 | 3.0000 | 2.0000 | 0.0910 |
| EPA | 0.1667 | 0.3333 | 1.0000 | 2.0000 | 1.0000 | 0.3333 | 1 | 0.5000 | 0.0770 |
| I&L | 0.2000 | 0.5000 | 1.0000 | 1.0000 | 2.0000 | 0.5000 | 2.0000 | 1 | 0.0440 |

5. Results of AHP and Fuzzy AHP
First time, when both the methods (AHP &FAHP) are combined (as shown in table 3 and figure 2), it is observed that in Indian gear manufacturing MSME sector, cost has the highest priority with normalized weight 0.3120 and 0.2968 (when combined result is calculated for 50 companies in this sector). It reflects cost is even today the highest priority for supplier selection in gear manufacturing companies followed by quality. Along with cost, environmental criterion are also showing its
importance in supplier selection and it proves that supplier selection with only traditional or green criteria will not give full justice to the supplier selection process. In many of the research, when AHP is applied to the given case of selection, the criteria and sub-criteria, whose weights are found be higher are used for FAHP calculations and remaining criteria and sub-criteria are neglected, but in some literature it is mentioned that it will not give full justice to FAHP calculations. Hence, in this study, all the criteria and sub-criteria are used for FAHP calculation. Results found in this study using AHP and FAHP are almost same it proves that there is no inconsistency in human judgments.

Table 3. Comparison of gear manufacturing MSMEs for Main Criteria using AHP & FAHP

| Goal   | Gear Mfg. Co.(AHP) | Gear Mfg. Co.(FAHP) |
|--------|--------------------|---------------------|
| Cost   | 0.312              | 0.2968              |
| Quality| 0.1493             | 0.1455              |
| SP     | 0.0905             | 0.0517              |
| EMM    | 0.0835             | 0.0776              |
| Risk   | 0.0712             | 0.0831              |
| Delivery| 0.1191            | 0.1096              |
| EPA    | 0.0855             | 0.1559              |
| I&L    | 0.0888             | 0.0796              |

Based on its level of consideration and significance, traditional and green costs are the major measure for efficient supplier selection and evaluation in supply chain management for MSMEs. Results under the metrics of purchase cost (PC), fright cost (FC), discount for earlier payment (DFEP), tax and custom duties (T&CD), recycling cost (RC) and cost of component disposal (COCD) are shown in figure 3. The observation is that, PC is highly important in gear manufacturing companies (when combined result is calculated for 50 companies in this sector) compared with both AHP and FAHP methods, and at the
same time, RC and COCD are having higher weights in these companies it means these companies are very careful while selecting suppliers because along with PC, for them RC and COCD, which is purely green criteria are also very important. Results of this study also show that the factors such as FC, DFEP and T&CD are less important for supplier selection in gear manufacturing sectors as their weights are very low, when it is compared with both AHP and FAHP. Similarly weights for all sub-criteria were calculated and compared. Finally, it was observed that the same results were found by using AHP and FAHP for all the 50 gear manufacturing MSMEs. Now it proves that after applying AHP and FAHP, results are consistent and the trends are same. It proves the statement of Askin OZDAGOGLU and Guzin OZDAGOGLU [7] that if the information/evaluation is certain, classical AHP is preferred and if the information/evaluation is not certain, fuzzy method should be preferred. This result also proves that in supplier selection process, traditional criteria shows their relevance and pertinence in Indian manufacturing industries even today. But trends also show that companies are slowly thinking for adoption of green supplier selection criterion in supply chain process. It proves that thinking of only traditional or green criteria are not enough for supplier selection in the Indian manufacturing context, particularly in case of MSMEs.

Supplier’s pair-wise comparison matrix was also formed for all main and sub-criteria. Supplier 1 has highest ranking with weight 0.5973 using AHP and 0.5611 using FAHP, hence supplier 1 is the best supplier among the three followed by supplier 2 and supplier 3 with weights 0.3033, 0.1883 using AHP and 0.2508, 0.1881 using FAHP, ranking of the suppliers are shown in figure 4.

![Figure 4. Overall Ranking of the Supplier using AHP and FAHP](image)

6. Conclusion

- In this study, the combination of traditional and green supplier selection criteria using analytic hierarchy process (AHP) and fuzzy analytic hierarchy process (FAHP) was employed with respect to developing a mixed methodology for evaluating the criteria selection adopted for their relative comparison and assessment in gear manufacturing MSME sectors. The insights from the cases have helped to identify and compare the important of performance evaluation factors in the Indian gear manufacturing MSMEs.

The findings involved the analysis of supplier selection and performance evaluation in gear manufacturing MSMEs. According to the extant literature, traditional supply chain focuses only on using internal resources of supply chain adequately and does not concede the impact on environment & people, use of natural resources, energy conservation, recycling and waste disposal. In recent times, many researchers have given considerable stress and importance on quality, cost, delivery, reliability, quality, trust, financial position, supplier profile and risk. In this study also, by using AHP and FAHP on the same measures, it was found that the cost is the first and most important criteria, followed by quality and delivery used for supplier selection and performance evaluation. But at the same time, trends also show that the gear manufacturing MSME companies in India are slowly adopting green supplier selection criteria in supply chain management to promote compatibility of enterprise and natural environment, and also maintain sustainable development. Finally suppliers’ ranking using AHP and
FAHP remains the same and the best supplier for every organization is identified in the MSME gear manufacturing sector.

References

[1] A. Deshmukh and H. Vasudevan, (2016), “Emerging supplier selection criterion in the context of traditional and green supply chain management”, International Journal of Managing Value and Supply Chain (IJMVSC), Vol. 5, No.1, pp.19-33.

[2] A. Deshmukh and H. Vasudevan, (2016) “Analysis of Supplier Selection Criteria in Traditional as well as Green Supply Chain Management in Indian MSMEs, International journal of Business Quantitative Economics and Applied Management Research, Vol. 3, No. 3, pp. 73-85.

[3] A. Deshmukh and A. Chaudhari, (2011), “A Review for Supplier Selection Criteria and Methods” Technology System and Management, Springer, 145, pp283-291.

[4] A. R. Singh, P.K. Mishra and Rajeev Jain (2013), “Prioritization of Supplier Selection Criteria: A Fuzzy-AHP Approach”, MIT International Journal of Mechanical Engineering, Vol. 3, No. 1, pp. 34–42.

[5] Alyank G., Armaneri O., (2009), “An Integrated Supplier Selection and Order Allocation Approach in battery company”, Makine MühendisleriOdasi Vol. 19 No. 4, pp.2-19.

[6] Alessio Ishizaka, Ashraf Labib, (2011), “Review of the main development in Analytic Hierarchy Process”, Expert System with Applications, Vol. 30, No. 11, pp. 14336-14345.

[7] Askin Ozdagoglu, Guzin Ozdagoglu, (2007), “Comparison of AHP and Fuzzy AHP for the Multi-criteria Decision Making Processes with Linguistic Evaluations”, Istanbul Ticaret University Journal of Institute of Science, Vol. 11, pp. 65-85.

[8] Chamodrakas I., Batis D., Martakos D., (2010), “Supplier selection in electronic marketplaces using saisficing and fuzzy AHP”, Expert System with Applications, Vol. 37, pp. 490–498

[9] Chan F.T.S., Kumar N., (2007), “A green supplier selection model for high-tech industry”, Expert Systems with Applications, Vol. 35, No. 4, pp. 417-431.

[10] Hui-Feng Chiu, Tzong-Ru Lee, Ching-Kuei Kao, (2015), “The key factors for selecting electronics manufacturing service suppliers-An example of company in Taiwan”, Management and Production Engineering Review, Vol. 6, No. 4, pp. 4-14.

[11] Jafar Rezaei, Roland Ortt, (2013), “Multi-criteria supplier segmentation using a fuzzy preference relations based AHP”, European Journal of Operational Research, Vol. 225, pp. 75–84

[12] Lee A.H.I., Kang H.Y., Hsu C.F., Hung H.C., (2009), “A green supplier selection model for high-tech industry”, Expert Systems with Applications, Vol. 36, No. 4, pp. 791-798.

[13] Ministry of Micro, Small and Medium Enterprises Annual report 2015-16.

[14] Muralidharan C., Anantharaman N., Deshmukh S.G., (2002), “A multi-criteria group decision-making model for supplier rating”, Journal of Supply Chain Management, Vol. 38, No. 4, pp. 22-33.

[15] Saaty T.L., (1980), “The Analytic Hierarchy Process: planning, priority setting, resource allocation”, McGraw Hill, New York.

[16] Tas A., (2012), “A fuzzy AHP approach for selecting a global supplier in pharmaceutical industry”, African Journal of Business Management, Vol. 6, No. 14, pp. 5073-5084.

[17] Y. L. Hsu, C.H. Lee, V.B. Kreng, (2010), “The application of Fuzzy Delphi Method and Fuzzy AHP in lubricant regenerative selection”, Expert System with Applications, Vol. 37, No. 1, pp. 419-425.

[18] Zadeh L., (1965), “Fuzzy sets”, Information and control, Vol. 8, No. 3, pp. 338-353.