Selection of Green Supplier in Automotive Industry: An Expert Choice Methodology

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Abstract. Today, businesses need to develop their strategies in managing the green supply chain to honour green practices and developments to maximize sustainability. Many managers and owners of businesses depend on green suppliers to achieve competitive advantages worldwide, but the identification of the right green supplier is a challenge for them. This research aims to identify environmental selection criteria for suppliers and establish a structure that will allow decision-makers to evaluate and prioritize green suppliers. In this study, we have taken the data from different automobile companies to analyze the importance of environmentally friendly practices, operation life-cycle, and other factors in selecting suppliers. Based on different green practices, the best supplier selection has been done by using Expert Choice software. This research contributes primarily to establishing a framework which will enable managers to identify their green supplier.

Keywords. Green Supply Chain; Green Supplier Selection; Operational Life-Cycle, Environmentally-Friendly Practice.

Abbreviations. GSCM: Green Supply Chain Management, GSS: Green Supplier's Selection, MCDM: Multiple Criteria Decision Making, AHP: Analytic hierarchy process, TOPSIS: The Technique for Order of Preference by Similarity to Ideal Solution, BWM: Best-Worse Method, VIKOR: VlseKriterijumska Optimizacija Kompromisno Resenje, TODIM: TOmada de Decisão Interativa e Multicritério, DEA: Data envelopment analysis, ANP: Analytic network process, GRA: Grey Relational Analysis.

1. Introduction
In India and other developing countries, the exponential growth of the human population has been observed, putting pressure on the natural resources available in the future. Natural resource depletion has prompted policymakers and businesses to implement environmental conservation initiatives in industrial sectors [1]. Furthermore, rising demands and challenges to boost environmental and economic efficiency contributed to the consideration and application of green supply chain practices in many industrial sectors, especially automotive companies. Today many companies and organizations paying careful attention to green practices to achieve a comparative advantage in the world [2]. At every point of the commodity life cycle, from the extraction of materials to fabrication, consumption, reutilization, storage, and disposal, environmental influence (e.g. carbon emissions) is present [3]. Hervani et al. [4] suggested that sustainability thinking should be used in the supply chain management activities of GSCM, including Green sourcing, Green Manufacture, Inventory Management, Green Distribution/Marketing & Reverse Logistics, from the extraction of raw materials to product development, manufacture procedures, the supply of finished product to the customer and end of the operation. As a result, GSCM has proved to be an effective way to reduce
environmental risks and environmental burdens and increase benefit and competitive advantages for production and disposal in the supply chain [5]. On the other hand, in GSCM, suppliers' selection is generally the step where manufacturers decide which suppliers join the business and eventually specify how much risk the manufacturer could take. The study on GSS by researchers and professionals is rapidly attracted due to the growing concern of environmental conservation and its long-term implications in business. A company's strong environmental reputation can be compromised by its non-environmentally responsive suppliers. According to Wu et al. [6], the emphasis of green suppliers is on energy conservation, recycling, re-use, eco-packaging, and green construction for GSCM operations. However, it is more difficult to choose appropriate green suppliers than conventional suppliers [7], as the consistency and contradictory environmental standards need to be considered. This allows GSS to be considered as an MCDM problem because the evaluation of selected suppliers is based on many green standards. Green standards cover sustainability considerations such as pollution reduction level of pollutants, environmental protection qualification, hazardous materials storage levels, etc. [8]. GSS has gained substantial interest in academic and industry sectors by improving environmental consciousness. A variety of GSS approaches have been recently developed, including Kannan et al. [9] applied the fuzzy TOPSIS approach to administer the GSCM and to choose the best environmentally sustainable supplier in the electronics industry, based on a combination of green criteria for measuring the environmental governance and capability class and the sustainable production and product efficiency division. For the GSS evaluation, Wen and Chi [10] applied the DEA combined with the AHP. This integrated model resolved the constraint of a traditional approach used for the assessment of suppliers. Azimifard et al. [11] suggested AHP and TOPSIS approach for choosing sustainable suppliers for the Irish steel industry at a global arena between various countries. Hashemi et al. [12] used an adaptive GSS methodology by implementing the ANP to deal with interdependencies between the criteria and suggested a better grey contextual analysis to resolve ambiguity in the decisions of the GSS. Rostamzadeh et al. [13] employed a fuzzy VIKOR technique that focused on green multi-criteria, primarily part of the environmental governance group, to identify and assess the leading sustainable supplier for the considered manufacturing industry. To address the inherent problem of choosing the right sustainable supplier, Qin et al. [14] used TODIM with fuzzy parameters for the vehicles industry on the criteria of the sustainable governance and efficiency criterion. Awasthi et al. [16] adopted a strategy using Fuzzy AHP and VIKOR by taking into account green supplier risks to improve the environment and to operate on sustainability criteria, primarily from the list of inventions and ecological implications in the electronics company. Fallahpour et al. [17] applied fuzzy programming along with fuzzy TOPSIS methodologies, used for the identification of green criteria and sub-criteria relevant mostly to the sustainable regulation classification, and to recognize and assess the best green supplier for the considered industry. Mohammed et al. [18] adopted a combination of different approaches by using fuzzy AHP, TOPSIS and multi-objective optimization focused on the green criteria of the environmentally-friendly policy of the metal industry and to assess and select the optimum number of green suppliers. Liu et al. [19] introduced green management and capacity-related strategy, using the Alternative Queuing Method and BWM, to discuss the procurement and assessment of environmental supplies within the manufacturing sector. He and Zhang [20] used factor analysis with DEA and AHP to establish a zero-carbon supply chain.
in the metal industries. This approach allowed GSS and assessment in light of adequate green requirements mainly related to green management. In the current time, environmentally friendly supplies are big assets for an organization to produce green products. Therefore, this study will deal with the selection of a green supplier for the auto sector. The proposed supplier selection model is based on the AHP tool which solves by software "Expert Choice". A brief theoretical orientation of each issue is presented to show the work already done and to justify the selection of prioritizing model.

2. Research Methodology
This study helps suppliers to know about the different criteria on which basis they can be going to evaluate or they have been evaluated in the recent globalized world, wherein the selection process of supplier's environment-friendly strategy performs an important role. For our study, we have considered the Indian Automotive sector that has witnessed significant shifts or changes in product and process design in the two-decade. After the liberalization, many automotive companies have come to India to set up their manufacturing plant and markets. All this company needs suppliers for their raw material and local company components to reduce the product's lead time. Due to government pressure, they all are searching for a green supplier for the procurement of auto components. XYZ international company assembles a two-wheeler in Delhi and needs a green supplier to procure its Gearbox for the bike. Based on specific environmental and performance criteria, they select four suppliers for further analysis. The manager of the company is facing an issue to analyze their four suppliers for final analysis. The current study is a proposed green supplier selection model for the automotive industry. The application of the AHP model presented in this study is assessed for the case of an XYZ Automobile Company. A set of criteria covering a wide range of parameters is submitted in the form of a table and the opinion of the expert is taken to select pertinent criteria for supplier selection in the context of XYZ Automotive Company. The supplier selections are based on certain criteria and the score of criteria's, the study use scale 1-5.

2.1 Objective of the study
Based on the above discussion, the following goals have been established for the current study by examining the literature in-depth:

- Understanding and classification of GSS evaluation criteria in the GSCM context;
- Determine the prioritization of the GSS criteria;
- Select the best green supplier from a set of suppliers in the supply chain, and
- Propose the management consequences of the suggested work.

2.2 Statement of the study
Analyze different factors which play an important role in the selection of supplier in the automotive industry. Factors which we considered-

2.2.1. Operational life-cycle stages (OLC)
The physical capability of the supplier to meet the demand of the manufacturer is one of the key factors in their consideration. Obviously, because of capacity shortage or issues with scheduling, a manufacturer would not want to choose a supplier who would have trouble reaching the amount demanded at the right time. Numerous assessment criteria and selection frameworks were established in several previous studies
on supplier selection [3,9,21], which includes on-time delivery, performance history of supplier and warranties and claimed policies, and so on. Among the operational life-cycle stages used for the GSS, the following criteria have been considered for this study that includes, Product design, Procurement, Manufacture/Design, Distribution, Logistics, and Packing.

2.2.2. Effective environmentally-friendly practices (EFP)
There are growing numbers of individuals, entrepreneurs, and communities who want to do something to sustain and conserve our natural resources, but they don't know where to start to get sustainability. Being eco-friendly means making a sustainable production for the world. Firms require such checklists from their suppliers prohibiting the use of hazardous compounds. The decline in uses is on these manufacturers’ priority list. The large sections of contaminants are toxic products [6-9]. Among the effective environmentally-friendly practices used for the GSS, the following criteria have been considered for this study that includes, Waste Reduction, Recycle, Reproduce, Reuse, and Disposable.

2.2.3. Sustainable Overall Performance (SOP)
The environmental performance indicators have been now the most important to the procurement processes of the green supplier. The environmental performance of an organization is related not only to the internal actions of the company to protect the environment but also to the environment and reputation of manufacturers. The implementation of environmental performance mechanisms and the negative environmental effects of goods are sensitive to the climate and affect the final decisions made by the businesses [22-23]. Environment cost, quality, and flexibility can be counted as the most significant consideration while deciding about the supplier. Choosing the best suppliers cuts environmental costs and improve quality and flexibility, and allows more business expertise. Among the Environmental performance used for the GSS, the following criteria have been considered for this study that includes, Cost, Quality, and Flexibility.

Figure 1. Green Supplier Selection Model
Based on these different variables we compare all the four suppliers with the help of Expert Choice and get the best from all the points of view. The supplier selection model is shown in figure 1.

3. Analysis

The Analytic Hierarchy Process (AHP) is a powerful and flexible decision-making process to help people set priorities and make the best green supplier selection when both qualitative and quantitative aspects of a decision need to be considered. Saaty and Kears (24) have developed AHP and software expert choice to solve multi-criteria problems. The software uses a certain step to analyze the green supplier selection problem. The steps are as follow:

Step 1: Construct Hierarchy Structure: The problem must be structured into a hierarchy (see figure 1).
Step 2: Comparison of Criteria
Step 3: Comparison of Sub Criteria concerning Criteria
Step 4: Comparison of Strategies for Sub Criteria
Step 5: Obtaining the Overall Ranking:
Step 6: Sensitivity of Alternatives: It shows that which strategy alternate is best on different criteria. It is graphically represented in Figure 4.

3.1 Evaluating the alternative green suppliers: The pair-wise comparisons and weight determination are carried out as per the stepwise procedure of AHP. The hierarchy of the selected alternatives and criteria is given in Figure 1. The analysis is following base on various criteria.

3.1.1 Operational Life-Cycle Stages (OLC): The analysis shows max. weightage to product design (26%) and min. to lacking (8% in OLC criteria (Figure 2). Based on the analysis of OLC criteria, the study finds the following observations:

- Supplier one is best as compared to other suppliers based on all parameters of OLC criteria.
- Based on procurement and product design, supplier 2 is a better performer as compared to others
- Supplier 1 and 2 are best in the manufacturing facility

While if we view overall performance then supplier 1 is best, but supplier 2 is close to it.

3.1.2 Effective Environmentally-Friendly Practices (EFP): EFP criteria is very curial for green supplier selection because it covers all aspects of environmental sustainability (25, 26). The analysis suggests that supplier 2 is best as compared to others because supplier 2 have all types of waste minimization process in their organizations (figure 3). It also has a recycled, reuse process. Supplier 1 (37%) is close to supplier 2 with a 36% score. Based on these variables following observations are:

- In the case of waste reduction Supplier, 2 is best.
- If we consider Recycle Variable, then Supplier 3 is best.
- In the same way, if we consider reproducing variable then Supplier 2 is best
- In the case of Reuse and Disposal Supplier, 1 is best.
- While if we view overall performance then supplier 2 is best, but supplier 1 is close to it.
Figure 2. Overall performance of different suppliers on different variables of OLC

Figure 3. Overall performance of different suppliers based on different variables of EFP
3.1.3 Sustainable Overall Performance (SOP): Overall performance is very important for the selection of suppliers because it tells the operational performance of suppliers. Based on the SOP indicator and weightage given to variables (Figure 4), some find is following:

- In the case of cost, Supplier 3 is best.
- If we consider quality Variables, then Supplier 1 is best.
- In the same way, if we consider the flexibility variable then Supplier 2 is best.
- While if we view overall performance then supplier 1 is best.

Figure 4. Overall performance of different suppliers based on different variables of SOP

4. Finding
Supplier one scored highest as compared to other suppliers based on all indicators (Figure 5). According to the OLC factor supplier, 1 is best, EFP factor supplier 2 is best, and EP factor supplier 1 is best, but supplier 1 and supplier 2 have almost relative values of each factor. Based on the priorities obtained from expert choice, supplier 1 has the highest priority coefficient of 36% followed by supplier 2 and supplier 3 with 34% and 16%, and last placed is supplier 4 with the overall priority of 14%. Therefore, the company should select supplier one for its procurement of raw materials. That Means, AHP is evaluating the supplier problems with the help of expert choice software.
5. Conclusion
The conceptual green supplier selection framework has presented in the current study. The study suggested that effective environmentally-friendly practices indicators are most important for a green supplier selection model. An AHP methodology with software has been applied to an automobile company by identifying the related criteria of purchasing activities from the proposed framework. Suppose a company wants to incorporate environmental factors into supplier selection and evaluation in Green practice. In that case, the company can adopt the presented model, including all the criteria for understanding its suppliers' competence and prioritizing the suppliers.

References
[1] Zhu Q, Sarkis J, Geng Y 2005 Green supply chain management in China: pressures, practices, and performance International Journal of Operations & Production Management 25(5) 449-468.
[2] Zhu Q, Sarkis J 2007 The moderating effects of institutional pressures on emergent green supply chain practices and performance International journal of production research 45(18-19) 4333-4355.
[3] Zhu, Q., Joseph, S., Lai, K.H., 2007. Green supply chain management: pressures, practices, and performance within the Chinese automobile industry. Journal of Cleaner Production 15, 1041-1052.
[4] Hervani A A, Helms M M, Sarkis J 2005 Performance measurement for green supply chain management Benchmarking: An International Journal 12(4), 330-353.
[5] Chen W, Zou Y 2017 An integrated method for supplier selection from the perspective of risk aversion Applied Soft Computing 54 449-455.
[6] Wu Q, Zhou L, Chen Y, Chen H 2019 An integrated approach to green supplier selection based on the interval type-2 fuzzy best-worst and extended VIKOR methods Information Sciences 502 394–417.

[7] Yousefi S, Jahangoshai Rezaee M, Solimanpur M (2019) Supplier selection and order allocation using two-stage hybrid supply chain model and game-based order price Operational Research International Journal, https://doi.org/10.1007/s12351-019-00456-6

[8] Kumar D, Rahman Z, Chan F T 2017 A fuzzy AHP and fuzzy multi-objective linear programming model for order allocation in a sustainable supply chain: a case study International Journal of Computer Integrated Manufacturing 30(6) 535-551.

[9] Kannan D, de Sousa Jabbour A B L, Jabbour C J C 2014 Selecting green suppliers based on GSCM practices: Using fuzzy TOPSIS applied to a Brazilian electronics company European Journal of Operational Research 233(2) 432-447.

[10] Wen U P, Chi J M 2010 Developing green supplier selection procedure: a DEA approach. In 2010 IEEE 17th International Conference on Industrial Engineering and Engineering Management 70-74. IEEE.

[11] Azimifar A, Moosavirad S H, Ariafar S 2018 Selecting sustainable supplier countries for Iran's steel industry at three levels by using AHP and TOPSIS methods Resources Policy 57 30-44.

[12] Hashemi S H, Karimi A, Tavana M 2015 An integrated green supplier selection approach with analytic network process and improved Grey relational analysis International Journal of Production Economics 159, 178-191.

[13] Rostamzadeh R, Govindan K, Esmaeili A, Sabaghi M 2015 Application of fuzzy VIKOR for evaluation of green supply chain management practices Ecological Indicators 49, 188-203.

[14] Qin J, Liu X, Pedrycz W 2017 An extended TODIM multi-criteria group decision making method for green supplier selection in interval type-2 fuzzy environment European Journal of Operational Research 258(2) 626-638.

[15] Banacian N, Mobli H, Fahimnia B, Nielsen I E, Omid M 2018 Green supplier selection using fuzzy group decision making methods: A case study from the agri-food industry Computers & Operations Research 89 337-347.

[16] Awasthi A, Govindan K, Gold S 2018 Multi-tier sustainable global supplier selection using a fuzzy AHP-VIKOR based approach International Journal of Production Economics 195 106-117.

[17] Fallahpour A, Olugu E U, Musa S N, Wong K Y, Noori S 2017 A decision support model for sustainable supplier selection in sustainable supply chain management Computers & Industrial Engineering 105 391-410.

[18] Mohammed A, Harris I, Govindan K 2019 A hybrid MCDM-FMOO approach for sustainable supplier selection and order allocation International Journal of Production Economics 217 171-184.

[19] Liu H C, Quan M Y, Li Z, Wang Z L 2019 A new integrated MCDM model for sustainable supplier selection under interval-valued intuitionistic uncertain linguistic environment Information Sciences 486 254-270.
[20] He X, Zhang J 2018 Supplier selection study under the respective of low-carbon supply chain: A hybrid evaluation model based on FA-DEA-AHP Sustainability 10(2) 564.

[21] Weber C A, Current J R, Benton W C 1991 Vendor selection criteria and methods European journal of operational research 50(1) 2-18.

[22] Nielsen I E, Banaeian N, Golińska P, Mobli H, Omid M 2014 Green supplier selection criteria: from a literature review to a flexible framework for determination of suitable criteria In Logistics operations, supply chain management and sustainability, Springer, Cham 79-99.

[23] Konyš A 2019 Green supplier selection criteria: from a literature review to a comprehensive knowledge base Sustainability 11(15) 4208.

[24] Saaty T L, Kearns K P 1985 Analytical planning Pergamon press, Oxford.

[25] Vijayvargy L, Thakkar J, Agarwal G 2017 Green supply chain management practices and performance: The role of firm-size for emerging economies Journal of manufacturing technology management, 28(3), 299-323.

[26] Sahoo S, Vijayvargy L 2020 Green supply chain management practices and its impact on organizational performance: evidence from Indian manufacturers Journal of manufacturing technology management, https://doi.org/10.1108/JMTM-04-2020-0173