A Fuzzy Based Decision Making Approach for Selecting and Evaluating Green Suppliers

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By

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Certificate of Approval

This is to certify that the thesis entitled **A Fuzzy Based Decision Making Approach for Selecting and Evaluating Green Suppliers** submitted by ***Sri DIPTATEJ MISHRA*** has been carried out under my supervision in partial fulfillment of the requirements for the Degree of ***Bachelor of Technology*** in ***Mechanical Engineering*** at **National Institute of Technology**, **NIT Rourkela**, and this work has not been submitted elsewhere before for any other academic degree/diploma.

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Abstract

In a competitive business environment, green supplier selection approach plays a pivotal role in supply chain management, because, due to growing global concern of environmental protection, green production has become an important factor for almost every manufacturer and will influence the sustainability of a manufacturer in the long run. A performance evaluation system for green suppliers is therefore required to determine the suitability of suppliers to cooperate with the industry. Supplier selection is basically depends on decision makers' (experts') assessments. This process inevitably involves various types of uncertainties such asdeception, fuzziness and incompleteness due to the shortcomings of the human being's subjective judgment and it's variance from one human being to another. However, the existing methods cannot properly integrate uncertainties into the determination of green suppliers and their selection. Nowadays, many companies have begun to implement green supply chain management and to consider environmental issues and the measurement of their suppliers' environmental performance. Here we have adopted, an effective method for selecting and evaluating green supplier selection; TOPSIS (*Technique for order preference by similarity to Ideal Solution*). In the process of supplier evaluation, data is mostly qualitative in nature. We know that the qualitative data are ambiguous and not distinct, so they have to be transformed into quantitative terms, this is accomplished by using fuzzy mathematics. We use here generalized trapezoidal fuzzy numbers to express linguistic values of Decision-Makers' (DMs') subjective preferences. According to the concept of the fuzzy-TOPSIS, a closeness coefficient is defined to determine

the ranking order of all suppliers(alternatives) by calculating the both fuzzy positive-ideal solution and fuzzy negative-ideal solution simultaneously. The proposed environmental friendly approach is demonstrated through a case study.

Keywords**:** Green Supplier Selection (GSS), Multi-Criteria Decision Making (MCDM), Technique for Order Preference by Similarity to Ideal Solution (TOPSIS), Fuzzy Logic, Green Supply Chain Management (GSCM).

1. Introduction

A supply chain can be defined as a network of autonomous or semi-autonomous business entities involved, through upstream and downstream links, in different processes and activities that yield physical goods or deliver services to the customer (Lee and Billington, 1993; Swaminathan et al. 1997). Supplier selection is increasingly recognized as a critical decision in supply chain management in manufacturing industries (Choi and Hartley, 1996; Dahel, 2003). So, supplier selection in procurement is one of the most researched problems in supply chain management. Many criteria have been identified for supplier evaluation and selection in a supply chain. In general, the supplier selection problem involves multiple criteria namely pollution production, resources consumption, eco design, green image, and environmental management system, use of environmentally friendly technology and use of environmentally friendly materials.

In the current situation, global business scenario is becoming increasingly volatile and the parameters that influence it are becoming more dynamic and less static with time ;the interest of members in business processes including governments, customers, vendors, distributors, suppliers, and competitors have been changing in response to competition, technological changes, and public concerns. There has been an increasing consideration for sustainable economic development all across the globe. Governments are trying to adjust legislations and pressure through individual activists, nongovernmental organizations, and international institutions is reaching alarming levels to exercise public mandate against the negative impacts of business activities on environment. Internally, the need to improve organizational efficiency, reduce waste, overcome supply chain risk, and achieve competitive position has made companies to start considering environmental issues from a competitive view point (Humphreys, 2003).

Supplier selection is usually referred to as one activity, yet comprises several tasks (Cousins et al., 2008; De Boer et al., 2001; Van Weele, 2010). GSS typically starts with the process of identifying needs. Then, purchasers agree on measurement criteria for potential suppliers, and a call for open tenders is communicated to potential suppliers. A selection is made after reviewing the information submitted by candidate suppliers. This usually takes several rounds, and the final choice is made from a number of qualified suppliers. In addition, it may also include a post-selection evaluation of the supplier's performance (Morton, 2002). The information obtained from a post-selection evaluation may be stored and made available for later use and improvement. The evaluation of supplier performance is sometimes also referred to as "monitoring suppliers" (Zhu and Geng, 2001) or "application feedback" (Wu and Barnes, 2011).

The report is organized as follows. Beginning with a literature research about Green Supply Chain Management (GSCM) and GSS followed by a review of methodologies used for the evaluation of the supplier's environmental performance and selection of green supplier to develop a structure for evaluating green supplier performance and selecting green suppliers. The next section illustrates the proposed green supplier evaluation and selection methodology through the instance of an automobile company in India. The report finishes with a precise, structured conclusion.

2. Literature Review

Environmental issues are no longer a concern solely for environmental experts; environmental awareness affects almost all parts of the society and it is a special concern for our industrial sectors (Sarkis, 1998; Hart and Dowell, 2011).

Green supply chain management is the integration of natural environmental concerns into supply chain management (Sarkis, 2006). The objective of green supply chain initiatives is to eliminate or minimize negative environmental impacts (air, water, and land pollution) and waste of resources (energy and materials) resulting from the phase of extraction of raw materials up to final use and disposal phase of products (Vachon and Klassen, 2008; Eltayeb et al., 2011). Organizations implementing successful GSCM initiatives stand to gain from both a reduction in the energy and logistics costs and by an enhanced competitive edge in the market. Many researchers have defined a green supply chain in various manners using different terms. (Srivastava (2007) describes GSCM as the combination of environmental consideration and supply chain management including the product design, material sourcing and selection, manufacturing processes, delivery of the final product to the consumer, and end-of-life management of the product. GSCM philosophy focuses on how industries utilize their suppliers' technologies, capabilities and processes to integrate environmental concerns and thereby enhance their competitive advantage (Vachon and Klassen, 2008).

Green purchasing has significant implications for the firms implementing it, especially when it comes to the criteria used in supplier selection. (Weber et al., 1991; Dowlatshahi, 2000) highlighted that until the early 1990s, purchasing policies, supplier selection and evaluation processes were dominated by criteria such as price, quality and delivery. Green purchasing, however, requires the inclusion of environmental criteria in the supplier selection process, which leads us to the concept of green supplier selection (GSS) (Lamming and Hampson, 1996; Noci, 1997).

Elkington (1998) proposed, by "green" we refer to the environmental aspects within the sustainability concept. Selecting a supplier can be regarded as a critical decision, not only for providing the purchasing organization with the right materials, products or solutions at competitive costs, but also in the sense of improving itsenvironmental performance, for example, through avoiding hazardous materials or considering alternative solutions that require less materials and/or energy. A firm's environmental endeavors will not produce any results without integrating the company's environmental goals with its purchasing activities (Walton et al., 1998). For GSS (Jabbour and Jabbour, 2009)there are multiple environmental criteria one could consider, and the operationalization of these criteria into distinct, practical, measurable and meaningfulparameters is often challenging, both for purchasers and suppliers.

Chiou et al. (2011) presented an empirical evidence to promote manufacturers to implement green supply chain and green innovation in order for improving environmental performance and increasing their competitive advantage in the market. Also found that GSCM practices in term of greening the suppliers have the positive influence on green product innovation, green process innovation, and green managerial innovation. They also suggested extending to other GSCM practices in examining more detail about the effect on green innovation.

(Kumar and Bali Subrahmanya (2010)said thatin today's global economy, the automobile industry transforms rapidly with the rapid expansion of leading automobile manufacturers (e.g.

Honda, Toyota, General Motor, Ford, Daimler Chrysler, Suzuki, Hyundai, and Fiat) into the Asian region. Greening the automobile industry has been disputed in international energy and environmental policy studies. Green supply chain in automobile industry has become the prime concern in many industrial fields. The evaluation and measurement of its performance is vital when environmental issues have been addressed all over the world (Olugu et al., 2010). However, there have been a few studies exploring the issue of GSS performance evaluation. Hence, applying green concepts into automobile manufacturing is necessary to reduce environmental effects, increase market competition, and guarantee regulation compliance (Gan, 2003). Zhu et al. (2008) claim that the automobile manufacturing industry in developing countries is a potential and promising industry because it creates a huge market, especially after entering WTO.

The technique for order preference by similarity to ideal solution (TOPSIS) initiated and developed by (Hwang and Yoon, 1981), is one of the famous methods for classical multi criteria decision making (Chen et al., 2006; Wang and Lee, 2007). This method is a widely accepted multi attribute decision making technique due to its sound logic, simultaneous consideration of the ideal solutions (Onut et al., 2009). According to the concept of the TOPSIS, a closeness coefficient is defined to determine the ranking of all suppliers by calculating the Euclidean distances to both the positive ideal solution (PIS) and negative ideal solution (NIS) simultaneously. It is based upon the concept that the chosen alternative should have the shortest distance from the PIS and the farthest from the NIS (Hwang and Yoon, 1981; Chen et al., 2006; Wang and Lee, 2007). Under many conditions, crisp data are insufficient to model real life situations because human judgments and preferences are often vague, subjective and relative to each other and cannot be estimated with an exact number. Fuzzy set theory proposed by Zadeh (1965), is helpful in dealing with the vagueness of human thought and expression in making such decisions. Characteristics such as fairness and satisfaction mention the applicability of fuzzy set theory in measuring the vagueness of concepts that appear in subjective human judgments. Thus fuzzy MCDM theory can strengthen the comprehensiveness and reasonableness of the decision making process (Chen, 2000; Chen et al., 2006; Wang et al., 2009). A review of articles based on the fuzzy logic concept for supplier selection problems is presented in (Yucel and Guneri, 2011). This paper focuses on a fuzzy TOPSIS approach to deal with supplier selection problems. The application of fuzzy TOPSIS for supplier selection has been investigated by researchers in recent years (Chen et al. 2006; Wang and Chang, 2007; Wang et al., 2009; Onut et al., 2009; Kannan et al., 2009; Awasthi et al., 2010; Zeydan et al., 2011; Dalalah et al., 2011; Buyukozkan and Cifci, 2012; Zouggari and Benyoucef, 2012). Chen et al. (2006) employed fuzzy TOPSIS that employs trapezoidal fuzzy numbers for supplier selection in a single sourcing problem. Wang and Chang (2007) generalized TOPSIS to fuzzy multiple-criteria group decision-making in their evaluation of initial training aircraft under a fuzzy environment. Wang et al. (2009) proposed a hierarchical TOPSIS that employs rules based on Euclidean distances for supplier selection.

In this proposed work for many criteria have been demarcated for supplier evaluation and selection, the selection of suppliers can be viewed as a multi-criteria decision making (MCDM) problem. There are many MCDM methods are used for selection and evaluating green supplier, out of them we focused on the most popular method, TOPSIS (Technique for order preference by similarity). Because environment management was not taken into consideration in the traditional supply chain management, the purpose of this work is to integrate this paradigm to the green supplier selection process by presenting a multi criteria decision making approach based on fuzzy TOPSIS for green supplier selection . Moreover, it allows the straight linguistic definition of weights and rating under each criterion, without of need of cumbersome pair wise comparisons and the risk of inconsistencies (Bottani and Rizzi, 2006). In this context, we analyzed the concept of TOPSIS to develop a methodology for solving supplier selection problems in fuzzy environment (Chen, 2000). Considering the fuzziness of the decision data and group decision-making process, linguistic variables are used to assess the weights of all criteria and the appropriateness ratings of each alternative with respect to each criterion. We can convert the decision matrix into a fuzzy decision matrix and construct a weighted-normalized fuzzy decision matrix once the decision-makers' fuzzy ratings have been collected. According to the concept of TOPSIS, we define the fuzzy positive ideal solution (FPIS) and the fuzzy negative ideal solution (FNIS). And, then, we can calculate the Euclidean distance of each alternative from FPIS and FNIS, respectively. Lastly, a closeness coefficient of each alternative is defined to determine the ranking order of all alternatives. The higher value of closeness coefficient indicates that an alternative is closer to FPIS and farther from FNIS simultaneously. The proposed green supplier evaluation and selection methodology analyzed through a case study of an automobile parts manufacturing company in the Indian industry.

3. General aspects about selecting green supplier

Below are a few strategies we may find useful in selecting a Green Suppliers. While this list is not all-inclusive, it includes strategies that other Corporate Champions have used successfully to engage suppliers. (Source: *www.greensuppliers.gov*)

• Forming a team

- Involving and including staff from purchasing and supply chain management departments in addition to environmental, health, and safety professionals when forming our internal Green Suppliers Network team. This approach allows for multiple perspectives on our selections and encourages internal dialogue about continuous improvement and overall efficiency as we select suppliers for review.

• Supplier selection

- Choosing suppliers with which we already enjoy a strong working relationship, and those who would be most open to the opportunity that a Green Suppliers Network review provides. These suppliers might already include an interest in sustainability as part of their own corporate goals.
- Select vital suppliers from which we purchase a significant amount of materials, or that already conduct a large amount of business with us. This might provide with significant leverage to encourage the supplier to engage in Green Suppliers Network reviews, as these companies have greater interests in our corporate initiatives.
- Consideringsuppliers that have the maximum impact of evolving manufacturing trends, such as energy efficiency or chemical management issues, to help focus supplier attention.
- Focus on suppliers from a particular industry with a high level of environmental impact. This is an opportunity to realize significant environmental gains and consequently, cost savings in supply chain.
- Choose suppliers that provide a particular product line within company. This approach might make it easier to identify and track cost savings in a single product. Additionally,

managers of these product lines can be included in the review process and become internal champions of the Green Suppliers Network within company.

- Nominate suppliers from a certain geographical area, such as those located closest to our corporate headquarters. After successful reviews, we might want to consider expansions to other states and regions of the country.
- Select suppliers that complement additional corporate goals. For example, choose among suppliers to achieve corporate goals related to diversity or social benefits.

Green Supplier Selection Criteria: taxonomy definitions

Performance indicator	Explanation
Pollution production	Presence of matter (gas, liquid, solid) or energy (heat, noise, radiation) whose nature, location, or quantity directly or indirectly modifies the characteristics or processes of any part of the environment, and causes (or has the potential to cause) damage to the condition, health, safety, or welfare of animals, humans, plants, or property per day during measurement period.www.businessdictionary.com
Resource consumption	Resource consumption is an umbrella term for the many different ways and rates that humans consume the products of the natural world. Some resources are finite, meaning that once they are used there are none left, such as fossil fuels and land. Other resources are renewable, such as wind and solar energy. Three most basic resources are land, labor, and capital; other resources include energy, entrepreneurship, information, expertise, management, and time.www.actpla.act.gov.au
Eco-design	Eco-design assumes that the effect a product has on the environment should be considered and reduced at all stages along the product life cycle. These stages include the extraction of the raw materials, the manufacturing of the product, its marketing and distribution, the use and finally, the disposal of a product. Eco-design products are "flexible, reliable, durable, adaptable, modular, dematerialized and reusable". Eco-design aims at advancing prosperity while reducing "environment spending". www.ecodesign.at
Green image	A business functioning in a capacity where no negative impact is made on the local or global environment, the community, or the economy. A

	green business will also engage in forward-thinking policies for environmental concerns and policies affecting human rights.www.businessdictionary.com
Environmental management system	An Environmental Management System (EMS) is a set of processes and practices that enable an organization to reduce its environmental impacts and increase its operating efficiency. An Environmental Management System (EMS) is a framework that helps a company achieves its environmental goals through consistent control of its operations. The assumption is that this increased control will improve the environmental performance of the company. The EMS itself does not dictate a level of environmental performance that must be achieved; each company's EMS is tailored to the company's business and goals. [Source: www.businessdictionary.com]
Commitment of GSCM from managers	The commitment and support of senior and mid level managers to improve green supply chain management practices and of environmental performance.
Use of environmentally friendly technology	The term "technology" refers to the application of knowledge for practical purposes. The field of “environmentally friendly technology " encompasses a continuously evolving group of methods and materials, from techniques for generating energy to non-toxic cleaning products. Environmentally friendly technology can help preserve the environment through energy efficiency and reduction of harmful waste. Green tech innovators use the latest environmental science and green chemistry to reduce the harmful impact of human activity on the earth. [Source: www.all-recycling-facts.com]
Use of environmentally friendly materials	Environmentally friendly materials are materials that do not harm the environment, whether in their production, use or disposal. Some of these going green products when in use, help conserve energy, minimize carbon footprint or the emission of green house gases, and does not lead to substantial toxicity or pollution to the environment. [Source: www.all-recycling-facts.com]
Staff environmental training	A successful environmental management system relies on the positive forces of responsibility and creativity of all employees. Alertness to important causes of inefficient use of inputs or emissions that may else go unnoticed. As inputs are also directly linked to costs and emissions signals a possible wasted input, sometimes even costly to handle, such alertness is of direct economic benefit, besides its merit for the environmental performance. [Source: www.lca-net.com]

4. Theory of Generalized Trapezoidal Fuzzy Numbers (GTFNs) Set

In the concept of fuzzy logic, fuzzy numbers are generally represented by the type of their membership function. Triangular, trapezoidal, *Gaussian* membership functions are some of the examples. By the definition given by (Chen, 1985), a generalized trapezoidal fuzzy number can be defined as a vector shown below (Fig. 1).

$\tilde{A} = (a_1, a_2, a_3, a_4; w_{\tilde{A}})$, and the membership function $a(x): R \to [0,1]$ is defined as follows:

$$a(x) = \begin{cases} \dfrac{x-a_1}{a_2-a_1} \times w_{\tilde{A}}, & x \in (a_1, a_2) \\ w_{\tilde{A}}, & x \in (a_2, a_3) \\ \dfrac{x-a_4}{a_3-a_4} \times w_{\tilde{A}}, & x \in (a_3, a_4) \\ 0, & x \in (-\infty, a_1) \cup (a_4, \infty) \end{cases}$$

Here, $a_1 \le a_2 \le a_3 \le a_4$ and $w_{\tilde{A}} \in [0,1]$

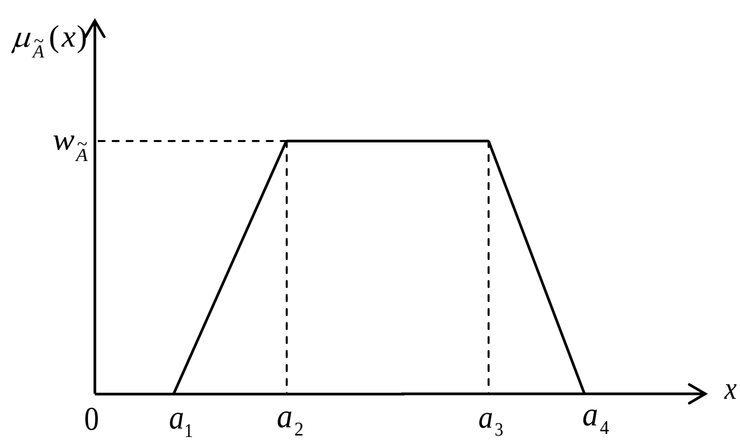

Fig. 1: Trapezoidal fuzzy number $\tilde{A}$

The elements of the generalized trapezoidal fuzzy numbers $x \in R$ are real numbers, and its membership function $a(x)$ is the regularly and continuous convex function, it shows that the membership degree to the fuzzy sets. If $-1 \le a_1 \le a_2 \le a_3 \le a_4 \le 1$, then $\tilde{A}$ is called the normalized trapezoidal fuzzy number. Especially, if $w_{\tilde{A}} = 1$, then $\tilde{A}$ is called trapezoidal fuzzy number (a_1, a_2, a_3, a_4); if $a_1 < a_2 = a_3 < a_4$, then $\tilde{A}$ is reduced to a triangular fuzzy number. If $a_1 = a_2 = a_3 = a_4$, then $\tilde{A}$ is reduced to a real number.

Suppose that $\tilde{a} = (a_1, a_2, a_3, a_4; w_{\tilde{a}})$ and $\tilde{b} = (b_1, b_2, b_3, b_4; w_{\tilde{b}})$ are two generalized trapezoidal fuzzy numbers, then the operational rules of the generalized trapezoidal fuzzy numbers $\tilde{a}$ and $\tilde{b}$ are shown as follows (Chen and Chen, 2009):

$$\tilde{a} \oplus \tilde{b} = (a_1, a_2, a_3, a_4; w_{\tilde{a}}) \oplus (b_1, b_2, b_3, b_4; w_{\tilde{b}}) = (a_1 + b_1, a_2 + b_2, a_3 + b_3, a_4 + b_4; \min(w_{\tilde{a}}, w_{\tilde{b}})) \tag{1}$$

$$\tilde{a} - \tilde{b} = (a_1, a_2, a_3, a_4; w_{\tilde{a}}) - (b_1, b_2, b_3, b_4; w_{\tilde{b}}) = (a_1 - b_4, a_2 - b_3, a_3 - b_2, a_4 - b_1; \min(w_{\tilde{a}}, w_{\tilde{b}})) \tag{2}$$

$$\tilde{a} \otimes \tilde{b} = (a_1, a_2, a_3, a_4; w_{\tilde{a}}) \otimes (b_1, b_2, b_3, b_4; w_{\tilde{b}}) = (a, b, c, d; \min(w_{\tilde{a}}, w_{\tilde{b}})) \tag{3}$$

Here,

$a = \min\left(a_1 \times b_1, a_1 \times b_4, a_4 \times b_1, a_4 \times b_4\right)$

$b = \min\left(a_2 \times b_2, a_2 \times b_3, a_3 \times b_2, a_3 \times b_3\right)$

$c = \max\left(a_2 \times b_2, a_2 \times b_3, a_3 \times b_2, a_3 \times b_3\right)$

$d = \max\left(a_1 \times b_1, a_1 \times b_4, a_4 \times b_1, a_4 \times b_4\right)$

If $a_1, a_2, a_3, a_4, b_1, b_2, b_3, b_4$ are real numbers, then

$\tilde{a} \otimes \tilde{b} = \left(a_1 \times b_1, a_2 \times b_2, a_3 \times b_3, a_4 \times b_4; \min\left(w_{\tilde{a}}, w_{\tilde{b}}\right)\right)$

$\tilde{a} / \tilde{b} = \left(a_1, a_2, a_3, a_4; w_{\tilde{a}}\right) \big/ \left(b_1, b_2, b_3, b_4; w_{\tilde{b}}\right)$

$= \left(a_1 / b_4, a_2 / b_3, a_3 / b_2, a_4 / b_1; \min\left(w_{\tilde{a}}, w_{\tilde{b}}\right)\right)$

(4)

5. Fuzzy-TOPSIS

Unlike AHP, fuzzy-TOPSIS is a group decision-making process, where a group of decision-makers are consulted for their assessment of a subject matter. Generally the MCDM problems may be divided into two types of problems. One is the classical MCDM problems, in which the ratings and the weights of criteria are measured in crisp numbers (Yoon and Hwang, 1985; Parkan and Wu, 1999; Chu, 2002). Under many conditions, crisp numbered data are inadequate to model real-life situations since human judgments including preferences are often vague, subjective and qualitative in nature and varying from person to person. Another is the fuzzy multi-criteria group decision-making (FMCGDM) problems, in which the ratings and the weights of criteria evaluated on imprecision, subjectivity and vagueness are usually expressed by linguistic terms and then converted into fuzzy numbers (Chen et al., 2006; Yang and Hung, 2007; Shih et al., 2007). The judgment values of linguistic data are quantified with generalized trapezoidal fuzzy numbers (GTFNs). The reason for using GTFNs to capture the vagueness of the linguistic assessments is that GTFNs is intuitive easy to use (Liang and Wang, 1994). The underlying logic of TOPSIS proposed by (Hwang and Yoon, 1981) is to define the ideal solution and negative ideal solution. The ideal solution is the solution that maximizes the benefit criteria and minimizes the cost criteria, whereas the negative ideal solution is the solution that maximizes the cost criteria and minimizes the benefit criteria. The best alternative is the one which has the shortest distance from the ideal solution and the farthest distance from the negative ideal solution. In this paper, we extend the concept of TOPSIS to develop a methodology for the selection of reverse logistics provider in fuzzy environment. Some basic definitions of fuzzy sets, fuzzy numbers and linguistic variables are reviewed from (Zimmermann, 1991; Chen, 1996; Kannan, 2008). A FMCGDM problem with '*m*' alternatives and '*n*' criteria can be expressed in matrix format as given below:

$$y = (f_{ij})_{m\times n} = \begin{matrix} \\ f_1 \\ f_2 \\ \vdots \\ f_m \end{matrix} \begin{pmatrix} x_1 & x_1 & .... & x_n \\ f_{11} & f_{12} & .... & f_{1n} \\ f_{21} & f_{22} & .... & f_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ f_{m1} & f_{m2} & .... & f_{mn} \end{pmatrix}$$

where, $f_1, f_2, \ldots, f_m$ are feasible alternatives, $x_1, x_2, \ldots, x_n$ are evaluation criteria, f_{ij} is the performance rating given by the decision-makers to alternative f_i against criterion X_j, and W_j is the weight of criterion X_j.

The Fuzzy TOPSIS based Ranking Procedure

TOPSIS (technique for order preference by similarity to ideal solution) method was firstly proposed by (Hwang and Yoon, 1981). The basic concept of this method is that the chosen alternative (appropriate alternative) should have the shortest distance from the positive ideal solution and the farthest distance from negative ideal solution. Positive ideal solution is a solution that maximizes the benefit criteria and minimizes adverse criteria, whereas the negative ideal solution minimizes the benefit criteria and maximizes the adverse criteria. The steps involved in TOPSIS method are as follows:

Step 1: A panel of five experts (decision-makers) was formed, and they identified the evaluation criteria.

Step 2: Every decision-maker states the importance level (weight) of each criterion using a linguistic variable.

Step 3: Evaluate the ratings of alternatives with respect to each criterion using linguistic rating variables.

Step 4**:** Construct a fuzzy multi-criteria group decision making (FMCGDM) matrix, which consist crisps values of criteria and alternatives. The crisps value C_V is calculated as,

$$C_v = \left(\frac{2a+7b+7c+2d}{18}\right)\left(\frac{7w}{18}\right) \qquad (5)$$

Here, a, b, c, d are the generalized trapezoidal fuzzy elements (Rao and Shankar, 2012).

Step 5: Construct the normalized decision matrix. The normalized value r_j is calculated as,

$$r_j = \frac{f_j}{\sqrt{\sum_{j=1}^{n} f_j^2}} \qquad (6)$$

Step 6: Construct weighted normalized decision matrix. The weighted normalized v_j is calculated as,

$$v_j = w \times r_j \tag{7}$$

Step 7: Determine positive ideal solution (maximum value on each criterion) and negative ideal solution (minimum value on each criterion) from the weighted normalized decision matrix. In the below equation F^1 is the set of benefit criteria and F^2 is the set of cost criteria.

$$V^{*+} = \left\langle \begin{array}{ll} \max\limits_{1 \le j \le n}(v_j) & (f_j \in F^1) \\ \min\limits_{1 \le j \le n}(v_j) & (f_j \in F^2) \end{array} \right. \tag{8}$$

$$V^{*-} = \left\langle \begin{array}{ll} \max\limits_{1 \le j \le n}(v_j) & (f_j \in F^1) \\ \min\limits_{1 \le j \le n}(v_j) & (f_j \in F^2) \end{array} \right. \tag{9}$$

Step 7: Calculate the Euclidean distance between positive ideal solution and negative ideal solution for each alternative.

$$D^{*+}(x_j) = \sqrt{\sum_{j=1}^{m}(v_j - V^{*+})^2} \tag{10}$$

$$D^{*-}(x_j) = \sqrt{\sum_{j=1}^{m}(v_j - V^{*-})^2} \tag{11}$$

Step 8: Calculate the closeness coefficient of each alternative.

$$C^*(x_j) = \frac{D^{*-}(x_j)}{D^{*+}(x_j) + D^{*-}(x_j)} \tag{12}$$

6. Empirical research

Supplier selection is an important part of the business as well as production strategy for industrial organizations. Selection of the best supplier enhances the quality and economic growth of enterprise but, still it is being a difficult task to select an appropriate supplier. Therefore, the proposed model has been used to evaluate and select the most suitable supplier of a automobile parts manufacturing industry in India. Fig. 2 shows represented a hierarchical structure of decision problem.

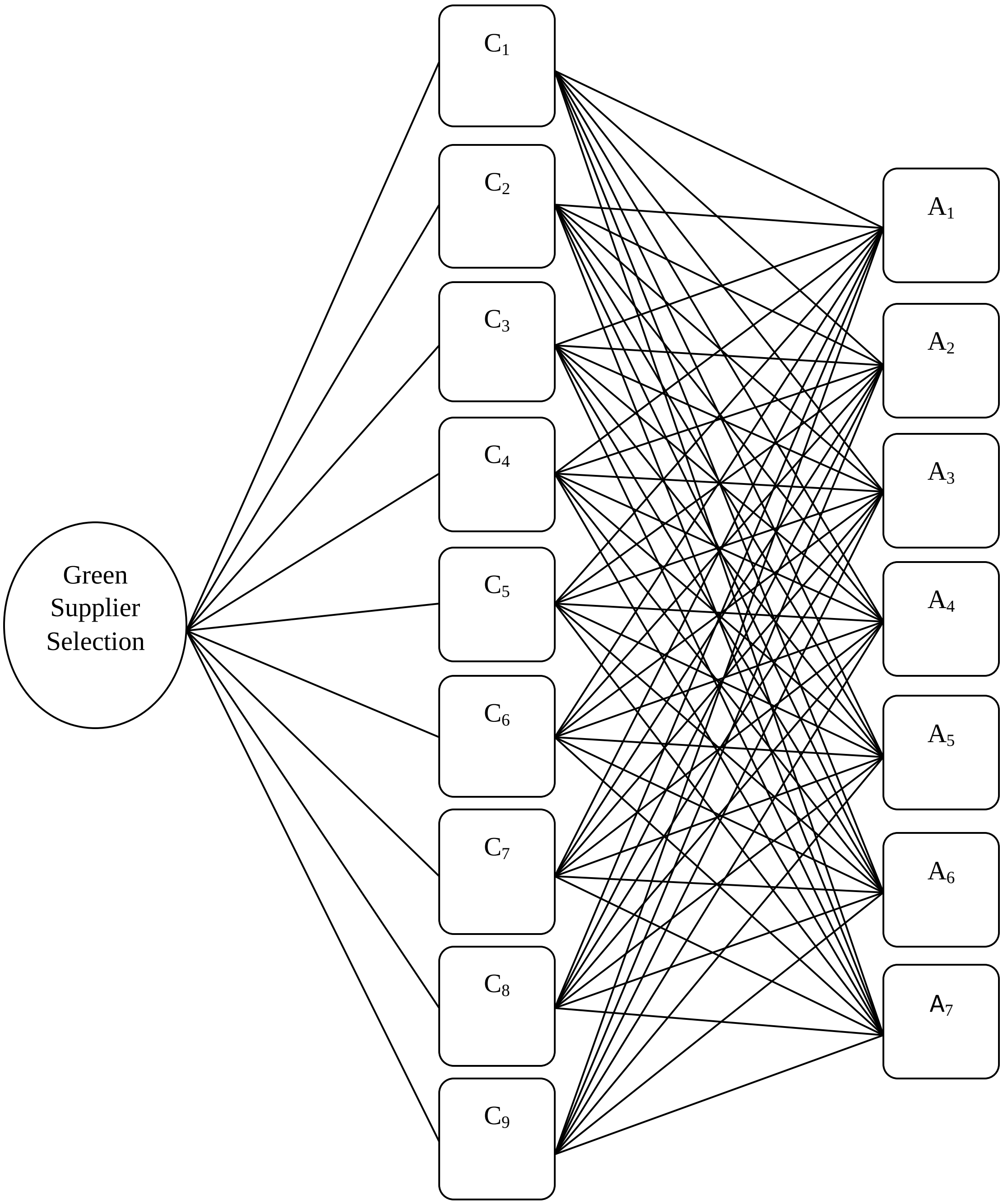

Fig. 2: Hierarchical structure of decision problem

Aforesaid appraisement module has been adopted as case application in an automobile parts manufacturing industry in India. A single-level performance appraisal hierarchy has been designed as shown in Table 1.

Table 1: Evaluation Index System of Green Supplier Selection

Evaluation Index of Green Supplier Selection, C	*Pollution production, (C_1)*
	Resource consumption, (C_2)
	Eco-design,(C_3)
	Green image,(C_4)
	Environmental management system,(C_5)
	Commitment of GSCM from managers,(C_6)
	Use of environmentally friendly technology,(C_7)
	Use of environmentally friendly materials,(C_8)
	Staff environmental training,(C_9)

For evaluating priority weight of evaluation indices, a committee of five decision-makers (DMs), has been formed to express their subjective preferences in linguistic terms. In order to provide priority weight against various criteria; the decision-making group has been instructed to use the following linguistic terms: Very Low (VL), Low (L), Medium (M), High (H), and Very High (VH). Similarly, the decision-making group has also been instructed to use the linguistic scale to express their subjective judgment against performance rating of each evaluation indices of alternatives. The following linguistic scale has been utilized to assign performance appropriateness rating against indices: Very Poor (VP), Poor (P), Medium, (M), Satisfactory (S) and Extremely Satisfactory (ES). The five-member linguistic terms and their corresponding fuzzy numbers are shown in Table 2.

Table 2: Five-member linguistic terms and their corresponding fuzzy numbers

Linguistic terms for weight assignment	Linguistic terms for ratings	Generalized trapezoidal fuzzy numbers
Very low, VL	Very poor, VP	(0, 0, 0.125, 0.25)
Low, L	Poor, P	(0.125, 0.25, 0.375, 0.5)
Medium, M	Medium, M	(0.375, 0.5, 0.5, 0.625)
High, H	Satisfactory, S	(0.5, 0.625, 0.75, 0.875)
Very High, VH	Extremely Satisfactory, ES	(0.75, 0.875, 1, 1)

After the linguistic variables for assessing the performance ratings and priority weight of different evaluation indices has been accepted by the decision-makers (DMs), the decision-makers have been asked to use aforesaid linguistic scales to assess performance rating against each of the alternatives criteria shown in Tables 4-10. Similarly, subjective priority weight evaluation index has been assessed by the DMs and that sown in Table 3.

Table 3: Fuzzy priority weight (in linguistic scale) of indices assigned by DMs

Performance metrics	Priority weights in linguistic term				
	DM1	DM2	DM3	DM4	DM5
C_1	VH	VH	H	H	H
C_2	H	H	H	H	VH
C_3	H	VH	H	VH	H
C_4	VH	VH	VH	VH	VH
C_5	H	M	H	H	H
C_6	H	H	VH	VH	H
C_7	VH	H	H	H	H
C_8	VH	H	VH	H	H
C_9	VH	VH	VH	VH	VH

Table 6: Appropriateness rating (in linguistic scale) of indices assigned by DMs **(Alternative 1)**

Performance metrics	Ratings in linguistic term (A_1)				
	DM1	DM2	DM3	DM4	DM5
C_1	S	S	M	M	M
C_2	M	M	M	M	P
C_3	M	M	P	P	P
C_4	P	P	P	VP	VP
C_5	M	P	M	P	P
C_6	M	M	M	S	S

C_7	P	M	M	M	M
C_8	P	P	P	M	M
C_9	VP	VP	P	P	P

Table 5: Appropriateness rating (in linguistic scale) of indices assigned by DMs **(Alternative 2)**

Performance metrics	Ratings in linguistic term (A_2)				
	DM1	DM2	DM3	DM4	DM5
C_1	M	M	S	M	M
C_2	M	M	S	S	S
C_3	S	P	P	P	S
C_4	S	M	M	M	S
C_5	S	P	S	P	P
C_6	S	M	M	M	M
C_7	S	S	S	M	M
C_8	P	P	S	S	P
C_9	S	S	M	M	M

Table 6: Appropriateness rating (in linguistic scale) of indices assigned by DMs **(Alternative 3)**

Performance metrics	Ratings in linguistic term (A_3)				
	DM1	DM2	DM3	DM4	DM5
C_1	M	M	M	M	P
C_2	P	P	M	P	P
C_3	M	P	M	P	P
C_4	M	M	M	M	M
C_5	S	S	M	S	S
C_6	P	M	M	M	M
C_7	M	P	P	P	P
C_8	M	M	P	P	P
C_9	M	M	M	M	M

Table 7: Appropriateness rating (in linguistic scale) of indices assigned by DMs **(Alternative 4)**

Performance metrics	Ratings in linguistic term (A_4)				
	DM1	DM2	DM3	DM4	DM5
C_1	S	S	M	M	S
C_2	S	S	P	P	P
C_3	M	M	M	P	P
C_4	S	M	M	M	S
C_5	S	S	S	P	P
C_6	M	M	S	S	S
C_7	P	P	P	S	S

C_8	P	P	M	M	M
C_9	S	S	M	M	M

Table 8: Appropriateness rating (in linguistic scale) of indices assigned by DMs **(Alternative 5)**

Performance metrics	Ratings in linguistic term (A_5)				
	DM1	DM2	DM3	DM4	DM5
C_1	S	M	M	M	M
C_2	M	M	P	P	P
C_3	S	P	P	S	P
C_4	P	P	P	VP	VP
C_5	P	P	S	S	P
C_6	M	M	M	M	S
C_7	P	P	P	M	M
C_8	S	P	P	P	S
C_9	VP	VP	P	P	P

Table 9: Appropriateness rating (in linguistic scale) of indices assigned by DMs **(Alternative 6)**

Performance metrics	Ratings in linguistic term(A_6)				
	DM1	DM2	DM3	DM4	DM5
C_1	M	S	S	S	S
C_2	M	M	M	ES	ES
C_3	S	S	S	ES	ES
C_4	S	ES	ES	ES	S
C_5	ES	ES	ES	ES	S
C_6	S	S	S	S	M
C_7	ES	ES	M	M	M
C_8	ES	ES	S	S	S
C_9	S	S	ES	ES	ES

Table 10: Appropriateness rating (in linguistic scale) of indices assigned by DMs **(Alternative 7)**

Performance metrics	Ratings in linguistic term (A_7)				
	DM1	DM2	DM3	DM4	DM5
C_1	M	S	S	M	M
C_2	ES	ES	M	M	ES
C_3	S	M	M	M	M
C_4	S	S	S	S	ES
C_5	S	S	S	ES	ES
C_6	S	S	M	M	M
C_7	M	M	ES	ES	ES
C_8	M	M	M	M	S
C_9	ES	S	S	S	S

Using the concept of Generalized Trapezoidal Fuzzy Numbers (GTFNs) in fuzzy set theory, the linguistic variables have been approximated by Trapezoidal Fuzzy Numbers. Next, the aggregated decision-making cum evaluation matrix has been constructed. The aggregated fuzzy appropriateness rating against an individual index with corresponding importance weight has been computed.

By using the fuzzy operational rules (Eq. 1-4), estimating the aggregated weight as well as aggregated rating (pulled opinion of the decision-makers) for each of the selection criterion and then convert linguistic term assigned (indices) by DMs to fuzzy number strictly follow the Five-member linguistic terms and their corresponding fuzzy numbers. So the aggregated fuzzy priority weight and aggregated fuzzy rating of indices calculated values are shown in Tables 11-13, respectively.

Table 11: Aggregated Priority weight (Level) and calculated crisps value

Level	Aggregated fuzzy weight, w_i	Crisps Value(C_V)
C_1	[0.600, 0.725, 0.850, 0.925]	0.304
C_2	[0.550, 0.675, 0.800, 0.900]	0.286
C_3	[0.600, 0.725, 0.850, 0.925]	0.304
C_4	[0.750, 0.875, 1.000, 1.000]	0.359
C_5	[0.475, 0.600, 0.700, 0.825]	0.253
C_6	[0.600, 0.725, 0.850, 0.925]	0.304
C_7	[0.550, 0.675, 0.800, 0.900]	0.286
C_8	[0.600, 0.725, 0.850, 0.925]	0.304
C_9	[0.750, 0.875, 1.000, 1.000]	0.359

Table 12: Aggregated Appropriateness rating (Level) (Alternative1-3)

Level	Alternative-1	Alternative-2	Alternative-3
C_1	[0.425, 0.55, 0.60, 0.725]	[0.40, 0.525, 0.55, 0.675]	[0.325, 0.45, 0.475, 0.60]
C_2	[0.325, 0.45, 0.475, 0.60]	[0.45, 0.575, 0.65, 0.775]	[0.175, 0.30, 0.40, 0.525]
C_3	[0.225, 0.35, 0.425, 0.55]	[0.60, 0.725, 0.85, 0.925]	[0.225, 0.35, 0.425, 0.55]
C_4	[0.075, 0.15, 0.275, 0.40]	[0.425, 0.55, 0.60, 0.725]	[0.375, 0.50, 0.50, 0.625]
C_5	[0.225, 0.35, 0.425, 0.55]	[0.65, 0.775, 0.900, 0.95]	[0.475, 0.60, 0.70, 0.825]
C_6	[0.425, 0.55, 0.60, 0.725]	[0.4, 0.525, 0.550, 0.675]	[0.325, 0.45, 0.475, 0.60]
C_7	[0.325, 0.45, 0.475, 0.60]	[0.45, 0.575, 0.65, 0.775]	[0.175, 0.30, 0.40, 0.525]

C_8	[0.225, 0.35, 0.425, 0.55]	[0.6, 0.725, 0.850, 0.925]	[0.225, 0.35, 0.425, 0.55]
C_9	[0.075, 0.15, 0.275, 0.40]	[0.425, 0.55, 0.60, 0.725]	[0.375, 0.50, 0.50, 0.625]

Table 13: Aggregated Appropriateness rating (Level) (Alternative 4-7)

Level	Alternative-4	Alternative-5	Alternative-6	Alternative-7
C_1	[0.45, 0.58, 0.65, 0.78]	[0.40, 0.53, 0.55, 0.68]	[0.48, 0.60, 0.70, 0.83]	[0.43, 0.55, 0.60, 0.73]
C_2	[0.28, 0.40, 0.53, 0.65]	[0.23, 0.35, 0.43, 0.55]	[0.53, 0.65, 0.70, 0.78]	[0.60, 0.73, 0.80, 0.85]
C_3	[0.28, 0.40, 0.45, 0.58]	[0.28, 0.40, 0.53, 0.65]	[0.60, 0.73, 0.85, 0.93]	[0.40, 0.53, 0.55, 0.68]
C_4	[0.43, 0.55, 0.60, 0.73]	[0.08, 0.15, 0.28, 0.40]	[0.58, 0.78, 0.60, 0.95]	[0.55, 0.68, 0.80, 0.90]
C_5	[0.35, 0.48, 0.60, 0.73]	[0.28, 0.40, 0.53, 0.65]	[0.70, 0.83, 0.95, 0.98]	[0.60, 0.73, 0.85, 0.93]
C_6	[0.45, 0.58, 0.65, 0.78]	[0.40, 0.53, 0.55, 0.68]	[0.48, 0.60, 0.70, 0.83]	[0.43, 0.55, 0.60, 0.73]
C_7	[0.28, 0.40, 0.53, 0.65]	[0.23, 0.35, 0.43, 0.55]	[0.53, 0.65, 0.70, 0.78]	[0.60, 0.73, 0.80, 0.85]
C_8	[0.28, 0.40, 0.45, 0.58]	[0.28, 0.40, 0.53, 0.65]	[0.60, 0.73, 0.85, 0.93]	[0.40, 0.53, 0.55, 0.68]
C_9	[0.43, 0.55, 0.60, 0.73]	[0.08, 0.15, 0.28, 0.40]	[0.58, 0.78, 0.60, 0.95]	[0.55, 0.68, 0.80, 0.90]

After estimated aggregated fuzzy priority weight and aggregated fuzzy rating of indices, then we proceed after converted the indices in to crisp value of estimated aggregated fuzzy priority weight and aggregated fuzzy rating by using Eq. (5) and the vales are shown in Table 11(crisps weight value) andTable 14 (crisps rating value). Then we constructed a fuzzy multi-criteria group decision making (FMCGDM) matrix (Table 14).

Table 14: A fuzzy multi-criteria group decision making (FMCGDM) matrix

Alternatives	Criteria								
	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9
A_1	0.224	0.180	0.151	0.085	0.151	0.224	0.18	0.151	0.085
A_2	0.209	0.238	0.304	0.224	0.322	0.209	0.238	0.304	0.224
A_3	0.180	0.136	0.151	0.194	0.253	0.180	0.136	0.151	0.194
A_4	0.238	0.180	0.165	0.224	0.209	0.238	0.180	0.165	0.224
A_5	0.209	0.151	0.180	0.085	0.180	0.209	0.151	0.180	0.085
A_6	0.253	0.260	0.304	0.274	0.341	0.253	0.260	0.304	0.274
A_7	0.224	0.293	0.209	0.286	0.304	0.224	0.293	0.209	0.286

Then we normalized the fuzzy multi-criteria group decision making (FMCGDM) matrix by help of Eq. (6) and the normalized decision matrix shown in Table 15.

Table 15: Normalized Decision Matrix

Alternatives	Criteria								
	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9
A_1	0.384	0.320	0.261	0.153	0.219	0.384	0.320	0.261	0.153
A_2	0.358	0.423	0.526	0.403	0.467	0.358	0.423	0.526	0.403
A_3	0.308	0.242	0.261	0.349	0.367	0.308	0.242	0.261	0.349
A_4	0.408	0.320	0.285	0.403	0.303	0.408	0.320	0.285	0.403
A_5	0.358	0.269	0.311	0.153	0.261	0.358	0.269	0.311	0.153
A_6	0.433	0.463	0.526	0.493	0.495	0.433	0.463	0.526	0.493
A_7	0.384	0.521	0.362	0.514	0.441	0.384	0.521	0.362	0.514

After constructed the normalization decision matrix, we proceed to calculate weighted normalized decision Matrix by using Eq. (7) and shown in Table 16.

Table 16: Weighted Normalized Decision Matrix

Alternatives	Criteria								
	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9
A_1	0.117	0.092	0.079	0.055	0.055	0.117	0.092	0.079	0.054
A_2	0.109	0.121	0.160	0.145	0.118	0.109	0.121	0.160	0.144
A_3	0.094	0.069	0.079	0.125	0.093	0.094	0.069	0.079	0.125
A_4	0.124	0.092	0.087	0.145	0.077	0.124	0.092	0.087	0.144
A_5	0.109	0.077	0.095	0.055	0.066	0.109	0.077	0.095	0.054
A_6	0.132	0.132	0.160	0.177	0.125	0.132	0.132	0.160	0.176
A_7	0.117	0.149	0.110	0.185	0.112	0.117	0.149	0.110	0.184

Then we calculated the fuzzy positive ideal solution (FPIS) and the fuzzy negative ideal solution (FNIS) by using (Eq. 8-9)and the values are shown in Table 17.

Table 17: Positive and Negative Ideal Solution

Ideal solution	Criteria								
	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9
V_1*^+	0.094	0.077	0.16	0.185	0.125	0.132	0.149	0.16	.184
V_2*^-	0.117	0.149	0.079	0.055	0.055	0.094	0.069	0.079	.054

According to the concept of TOPSIS, we calculated the fuzzy positive ideal solution (FPIS) and the fuzzy negative ideal solution (FNIS). And, then, we can calculate the Euclidean distance of each alternative from FPIS and FNIS, respectively. Finally, a closeness coefficient of each alternative is calculated by using the (Eq. 10-12) to determine the ranking order of all alternatives. The higher value of closeness coefficient (**0.060, 0.692, 0.533, 0.675,0.071, 0.913** and **0.906**) indicates that an alternative is closer to FPIS and farther from FNIS simultaneously. According to the closeness coefficient (C*), the ranking of each alternative are shown in Table 18.

Table 18: The Distance of alternative to positive/negative ideal solution, the related closeness coefficient and ranking

Serial number	Alternatives	Distance D^{*+}	Distance D^{*-}	Closeness coefficients(C*)	Ranking
i	A_1	0.2367	0.0656	0.217	6
ii	A_2	0.0819	0.8528	0.912	2
iii	A_3	0.5610	0.1350	0.194	7
iv	A_4	0.0206	0.1467	0.876	3
v	A_5	0.2273	0.0785	0.256	5
vi	$\mathbf{A_6}$	**0.0698**	**0.2317**	**0.968**	**1**
vii	A_7	0.1053	0.2412	0.670	4

According to theCloseness coefficients (C*), we clearly understood the assessment status of each alternative and also identified the ranking order (A_6> A_2> A_4> A_7> A_5>A_1> A_3) of all alternatives. So based on these ranking criteria a manager can easily choose the best green supplier among alternatives.

7. Conclusion

Green trends are the need of the hour to strike a balance in our ecological system. Thus the industries are emphasizes the importance of methodologies which allow the purchasing team to select only environmentally efficient suppliers. In order to develop their environmental performance, industry need to work together with the suppliers which have high environmental performance, and they have to work their suppliers cooperatively. This work presents a framework of environmental criteria that a company can consider during their supplier selection process. A fuzzy TOPSIS approach applied here to evaluate performance of green suppliers because there is an increasing need to develop appropriate green supplier selection.

The major contributions of this work have been summarized as follows:

- Development and implementation of an efficient decision-making tool to support green supplier evaluation.
- An overall green performance index evaluation platform has been introduced.
- Concept of fuzzy TOPSIS has been efficiently explored to facilitate this decision-making.
- The appraisement index system has been extended with the capability to search ill performing areas which require future progress.

This research suggests further studies in order to extend the scope of this study and this study can be extended toother industries. Evaluation criteria can be changed from one sector to another. Appropriate evaluation criteria of green performance should be selected according to the sector.Therefore, the green supply chain that is already a hot topic could become the new trend of the future.

List of Reference

Awasthi, A., Chauhan S.S, Goyal S.K, (2010), A fuzzy multi criteria approach for evaluating environmental performance of suppliers International Journal of Production Economics, 126 (2010), pp. 370–378.

Bottani, E., and Rizzi, A. (2006), A fuzzy TOPSIS methodology to support outsourcing of logistics services, Supply Chain Management: An International Journal, Vol.11, No.4, pp. 294-308.

Buyukozkan, G., Cifci G., (2012), A combined fuzzy AHP and fuzzy TOPSIS based strategic analysis of electronic service quality in healthcare industry.

Chen C.T, (2000), Extensions of the TOPSIS for group decision-making under fuzzy environment .Fuzzy Sets System, 114.pp. 1–9

Chen, C.T., Lin, C.T and Huang, S.F, (2006), A fuzzy approach for supplier evaluation and selection in supply chain management, International Journal of Production Economics, Vol. 102, pp. 289–301.

Chen, S.H. (1985) 'Ranking fuzzy numbers with maximizing set and minimizing set', *Fuzzy Sets and Systems*, Vol. 17, No. 2, pp. 113-129.

Chen, S.M. (1996), Evaluating weapon systems using fuzzy arithmetic operations, Fuzzy Sets and Systems, Vol. 77, pp. 265–76.

Chen, S.M. and Chen, J.H. (2009) 'Fuzzy risk analysis based on ranking generalized fuzzy numbers with different heights and different spreads', *Expert Systems with Applications*, Vol. 36, No. 3, pp. 6833-6842.

Cheng, C.H. and Lin, Y. (2002), Evaluating the best main battle tank using fuzzy decision theory with linguistic criteria evaluation, European Journal of Operational Research, Vol. 142, pp. 174–86.

Chiou, T.-Y., Chan, H. K., Lettice, F., and Chung, S. H. (2011), The influence of greening the suppliers and green innovation on environmental performance and competitive advantage in Taiwan, Transportation Research Part E, Vol. 47, pp. 822-836.

Choi, T.Y. and Hartley, J.L. (1996), An exploration of supplier selection practices across the supply chain, Journal of Operations Management, Vol. 14, pp. 333-43.

Chu, T.C. (2002), Facility location selection using fuzzy TOPSIS under group decision, International Journal of Uncertainty, Fuzziness and Knowledge-Based Systems, Vol. 10, No.6, pp. 687–701.

Cousins, P., Lamming, R., Lawson, B. and Squire, B. (2008), Strategic Supply Management: Principles, Theories and Practice. Financial Times/Prentice Hall, Harlow.

Dahel, N.E. (2003), Vendor selection and order quantity allocation in volume discount environments, Supply Chain Management: An International Journal, Vol. 8, No. 4, pp. 334-42.

Dalalah, D ,Hayajneh, M, Batieha F, (2011), A fuzzy multi-criteria decision making model for supplier selection .Expert Systems with Applications, 38 (2011), pp. 8384–8391

De Boer, L., Labro, E. and Morlacchi, P. (2001), A review of methods supporting supplier selection,European Journal of Purchasing & Supply Management, Vol. 7, pp. 75–89.

Dowlatshahi, S. (2000), Designer–buyer–supplier interface: theory versus practice, International Journal of Production Economics, Vol. 63, pp. 111–130.

Elkington, J. (1998), Cannibals with Forks: The Triple Bottom Line of 21st Century Business, New Society Publishers, Stoney Creek, CT.

Eltayeb, T.K., Zailani, S. and Ramayah, T. (2011), Green supply chain initiatives among certified companies in Malaysia and environmental sustainability: investigating the outcomes, Resources, Conservation and Recycling, Vol. 55, pp. 495-506.

Gan, L. (2003), Globalization of the automobile industry in China: dynamics and barriers in greening of the road transportation, Energy policy, Vol. 31, pp. 537- 551.

Hart, S. L., and Dowell, G. (2011), Invited editorial: A natural-resource-based view of the firm fifteen years after, Journal of Management, Vol.37, No.5, pp. 1464–1479.

Hwang C. L. and Yoon K. (1981), Multiple Attribute Decision Making Methods and Applications, A State-of-the-Art Survey, Springer Verlag, New York.

Jabbour, A.B.L.S. and Jabbour, C.J.C. (2009), Are supplier selection criteria going green? Case studies of companies in Brazil, Industrial Management & Data Systems Engineering, Vol.109, pp. 477–495.

Kannan, G. (2008) .Fuzzy logic and fuzzy decision making, 1st ed. New Delhi, India: Galgotia Publications Pvt. Ltd.

Kumar, R.S. and BalaSubrahmanya, M.H., (2010), Influence of subcontracting on innovation and economic performance of SMEs in Indianautomobile industry, Technovation, Vol. 30, pp. 558- 569.

Lamming, R. and Hampson, J. (1996), The environment as a supply chain management issue, British Journal of Management, Vol. 7, pp. 45–62.

Lee, H.L. and Billington, C. (1993), Material management in decentralized supply chains, Journal of the Operation Research, Vol. 41, No. 5, pp. 835-47.

Liang, G.S. and Wang, M.J. (1994), Personnel selection using fuzzy MCDM algorithm, European Journal of Operational Research, Vol. 78, pp. 22–33.

Lloyd, M. (1994), How green are my suppliers? Buying environmental risk, Purchasing & Supply Management Oct, pp. 36–39.

Morton, B. (2002), Purchasing and 'green' issues. In: Day, M. (Ed.), Gower Handbook of Purchasing Management, third ed. Gower Publishing Limited, Aldershot, pp. 207–222.

Noci, G. (1997), Designing green vendor rating systems for the assessment of a supplier’s environmental performance, European Journal of Purchasing and Supply Management, Vol. 3, pp. 103–114.

Olugu, E.U., Wong, K.Y. and Shaharoun, A.M., (2010), Development of key performance measures for the automobile green supply chain. Resources, Conservation and Recycling, Vol.55, No.6, pp. 567-579.

Onut S., Kara S.S, Isik E.,(2009) , Long term supplier selection using a combined fuzzy MCDM Approach: a case study for a telecommunication company. Expert Systems with Applications, 36 (2009), pp. 3887–3895.

P.K Humphreys, Y. W. (2003), Integrating environmental criteria into supplier selection process, Journal of Materials processing technology, Vol.138, pp. 349-356.

Parkan, C. and Wu, M.L. (1999), Decision-making and performance measurement models with applications to robot selection, Computers and Industrial Engineering, Vol. 36, pp. 503–23.

Rao, P.P.B. and Ravi Shankar, N. (2012), Ranking Generalized Fuzzy Numbers using Area, Mode, Spreads and Weights, International Journal of Applied Science and Engineering, Vol. 10, No.1, pp. 41-57.

Sarkis, J. (1998), Evaluating environmentally conscious business practices, European Journal of Operational Research, Vol. 107, pp. 159–174.

Sarkis, J. (Ed.), (2006), Greening the Supply Chain. Springer, Berlin

Shih, H.S., Shyur, H.J. and Lee, E.S. (2007), An extension of TOPSIS for group decision making, Mathematical and Computer Modelling, Vol. 45, pp. 801–13.

Srivastava, S.K. (2007), Green supply-chain management: a state-of-the-art literature review, International Journal of Management Reviews, Vol. 9, No. 1, pp. 53-80.

Swaminathan, J.M., Smith, S.F. and Sadeh, N.M. (1997), Modeling supply chain dynamics: a multi agent approach, Decision Sciences, Vol. 39, No. 3, pp. 607-32.

Vachon, S. and Klassen, R.D. (2008), Environmental management and manufacturing performance: the role of collaboration in the supply chain, International Journal of Production Economics, Vol.111, pp. 299-315.

Van Weele, A.J. (2010), Purchasing & Supply Chain Management: Analysis, Strategy, Planning and Practice. Cengage Learning, Andover

Walton, S.V., Handfield, R.B. and Melnyk, S.A. (1998), The green supply chain: integrating suppliers into environmental management processes, Journal of Supply Chain Management, Vol. 34, pp. 2–11.

Wang J.W, Cheng C, Cheng H.K, (2009) Fuzzy hierarchical TOPSIS for supplier selection Journal of Applied Soft Computing, pp. 377–386.

Wang, T.C, Chang T.H (2007), Application of TOPSIS in evaluating initial training aircraft under a fuzzy environment .Expert Systems with Applications, 33 (2007), pp. 870–880.

Wang, Y.J, Lee H.S, (2007), Generalizing TOPSIS for fuzzy multi criteria group decision Making, Journal of Computers and Mathematics with Applications, 53 (2007), pp.1762-1772

Weber, C.A., Current, J.R. and Benton, W.C. (1991), Vendor selection criteria and methods, European Journal of Operational Research, Vol. 50, pp. 2–18.

Wu, C. and Barnes, D. (2011), A literature review of decision-making models and approaches for partner selection in agile supply chains, Journal of Purchasing and Supply Management, Vol. 17, pp. 256–274.

Yang, T. and Hung, C.C. (2007), Multiple-attribute decision making methods for plant layout design problem, Robotics and Computer-Integrated Manufacturing, Vol. 23, pp. 126–37.

Yucel, A. and Guneri, A. F, (2011), A weighted additive fuzzy programming approach for multi-criteria supplier selection .Expert Systems with Applications, 38 (2011), pp. 6281–6286

Yoon, K. and Hwang, C.L. (1985), Manufacturing plant location analysis by multiple attribute decision making, Part I. Single-plant strategy, International Journal of Production Research, Vol. 23, pp. 345–59.

Zadeh, L.A (1965), Information and Control, 8 (1965), pp.338-353.

Zeydan, M., Colpan, C, Cobanoglu C., (2011) A combined methodology for supplier selection and performance evaluation. Expert Systems with Applications, 38 (2011), pp. 2741–2751

Zhu, Q., Geng, Y. (2001), Integrating environmental issues into supplier selection and management: a study of large and medium-sized state-owned enterprises in China, Greener Management International, Vol. 35, pp. 27–40.

Zimmermann, H.J. (1991), Fuzzy set theory and its applications. 2nd ed. Boston, Dordrecht, London: Kluwer Academic Publishers.

Zouggari A., Benyoucef L, Simulation based fuzzy TOPSIS approach for group multi-criteria supplier selection problem .Engineering Application of Artificial Intelligence, 25 (3) (2012), pp. 507–519