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Evaluation and selection of an effective green supply chain management strategy: A case study

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Abstract

This study describes the application of Fuzzy-AHP for evaluating and selecting an effective green supply chain management strategy in a cement manufacturing industry. As a multi-criteria decision analysis, five decision criteria were considered in the order of their priority to the cement manufacturing industry to evaluate four green supply chain management strategies. This method is used in such a way that the top management of the industry and other experts considered carefully which type of green management perceptive they had, and assessed the importance of each activity objectively to develop the pairwise comparisons, and the result was used in the hierarchy prioritization of criteria and later expressed in fuzzy number with triangular membership function. This method is applied at two levels: the first is finding the fuzzy weights for the decision criteria, while the second is finding the fuzzy weights for the strategies under each of the decision criteria. Fuzzy scores for the strategies were obtained.

Keywords: Fuzzy-AHP; green, supply chain; priority; strategies; multi-criteria decision analysis; triangular membership

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1. Introduction

Based on the continuous deterioration of the environment and the ecosystem due to human activities, there is no doubt that people need to opt for a sustainable and green alternatives. Supply chain involves activities that could affect the natural environment and also generate environmental performance change. This is why the strategies in carrying out supply chain operations must be properly evaluated. The strategies of green supply chain management according to Simpson and Samson (2008) are; Risk-based, Efficiency-Based, Innovation Based and Close-loop strategies. These strategies work optimally based on the operations of the industry in consideration. Evaluating and selecting the best GSCM strategies is very crucial, in order to reduce the negative impact of the supply chain on the environment. The aim of this study is to provide a guideline for industries on how to select an appropriate GSCM strategy, which incorporates environmental perception with corporate functional strategies in order to achieve an effective green management. According to William Thomson *"Until you can measure something and express it in numbers, you cannot manage it* (Odeyale, Alamu, & Odeyale, 2013a). Hence the objective of this paper is to:

- To perform a quantitative evaluation of GSCM strategies.
- To analysis various strategies and select the best strategy for a cement manufacturing company.

1.1 Case Study

KLM cement manufacturing industry is one of the largest cement manufacturing companies in Nigeria. Cement manufacturing consumes large quantities of non-renewable raw materials (mineral and fossil fuel) which is an important source of carbon dioxide. The supply chain activities of a KLM industry gives priority to green manufacturing, green procurement , environmental management, green design and green marketing, in the said order, this is because firstly, the manufacturing section of the cement factory has a highest threat to the ecosystem followed by raw material procurement activities. Secondly, the cement factory like any other cement factories carry out manufacturing and procurement operations most frequently than design, marketing operations. This is the reason why higher emphases were given to these sections in order to make it green and sustainable. It may be different for other industries. Thus decision makers should confirm the green management perspective in their own organization first, and then use it has a guideline to determine the pairwise comparison. For the case of KLM cement industry, the top management and other experts considered carefully which type of green management perceptive they had, and assessed the importance of each activity objectively to develop the pairwise comparisons.

2. Literature Review

The classic green supply chain management strategies are listed below (Simpson & Samson, 2008).

(1) Risk-based strategy (RBS): This strategy involves the addition of fundamental clauses in procurement contracts for suppliers to meet all relevant environmental regulatory requirements such as ISO, industries that wish to select this kind of GSCM strategy mostly invest minimal resources of organization for green management, and also asked their suppliers to adhere to the environmental requirements to minimize risks. Although some international environmental rules are difficult to refer to, RBS is the simplest GSCM strategy compared to other types (Chiau-Ching et al, 2011). However, judging from competitive advantage, the benefits are limited because of the ease of implementation, lack of uniqueness, and also a growing use by other supply

chains. Thus, industries choosing this kind of GSCM could not create unique competitive advantage, and then do not obtain many economic benefits from this strategy. Furthermore, these industries did not naturally introduce environmental programs; it is not possible to expect any innovation to happen. The ultimate aim of this type of GSCM is risk minimization with accomplishing environmental programs passively.

(2) Efficiency-based strategy (EBS): This type of strategy is more complex owing to efficiency improving through specific approaches; it involves meeting operation based efficiency targets like quality standard which has been the ‘eco-efficiency’ or ‘lean-and-green’ approach to the green supply chain management. This kind of strategy enables facilitated industries to allow increase economic benefit and also win the environmental benefits resulted from waste reduction and efficient utilization of resources. Despite all these advantages, this strategy still aimed more on increasing productivity, thus it is impossible to completely avoid any toxic or harmful substances during production processes. Efficiency based strategy can provide a cost-reduction advantage to the supply chain and easily goes in line with existing organizational goals of optimization. However, it does not allow for more knowledge-intensive environmental management activities such as product design, material substitution, or innovation (Simpson & Samson, 2008).Thus, the efficiency-based strategy is considered technically weak but more socially complex than the risk-based strategy.

(3) Innovation-based strategy (IBS): This type of strategy involves guarantying more comprehensive product life-cycle management consideration for consumers of their own products during the design stages. Innovation-based strategy guides industries to develop their products from product life-cycle perspective, and give stricter environmental requirements to their suppliers, and even train them to adjust operational processes and just follow the newest environmental regulations. Industries selecting this kind of strategy should possess professional environmental expertise, and integrate specific relevant green activities, such as green design, sustainable procurement to improve current processes, product developments. In essence, this strategy force industries to invest more resources and cultivate innovative capabilities to green managements

(4) Closed-loop strategy (CLS): It is the most complex and collaborative type of GSCM strategy. It links the environmental performance to the entire supply chain activities. It involves product take-back and reverse logistics implemented in supply chain for waste reduction, it involves taking back materials produced from any production processes and end-of-life products, and disposed them in various methods. This kind of strategy represents an approach that perfectly integrates matters of economic, operational, and environmental performance. Industries that select this kind of strategy require high levels of control over the capture and return of used materials. However, it is difficult to track all of the products distributed from factories due to too many channels. Also, the amount of return goods also accumulated enough to create economic scale. Based on these reasons, industries implementing this type of strategy successfully could incorporate efficiently economic, operational and environmental performance as well.

The decision criteria used for the evaluation for green supply chain management based on different sections of industrial operation are listed below and briefly explained

Green Design (GD): This is also known as sustainable design or environmental design. It involves the designing physical objects, services, and the built environment to conform to the principles of social, economic and ecological sustainability. It aims at eliminating negative environmental impact completely, through green skillful and sensitive design. Green design requires no non-renewable resources, impacts the environment minimally, and connect consumers with the natural environment. The concept of green design involves; abstaining from the use of toxic substance, energy savings, complying with design for disassembly, reuse and recycling (DfDRR) and increasing innovation capabilities.

Green Procurement (GP): Green procurement or sustainable procurement involves considering environmental aspects, potential impacts and costs, associated with the life-cycle assessment of goods and services being purchased. It involves the practice of procuring products and services that are less harmful to the environment. Products acquired should be those that are made with less harmful materials or which when produced or used or consumed would have minimal impacts on the environment. This concept involves green logistics, green competencies, green image and green management abilities.

Green Manufacturing (GM): Green manufacturing involves the creation of manufactured products that use processes that are non-polluting, conserves energy and natural resources and are economically sound and safe for the environment and consumers. The concept of green manufacturing involves re-manufacturing, use of environmental friendly materials, recycling, pollution reduction capabilities and many others.

Environmental Management (EM): This involves the management of all components of the bio-physical environment, both living (biotic) and non-living (abiotic). The main role of environmental management is to manage the productive use of natural resources without reducing their efficiency and quality. Environmental management is a practice by which environmental resources and its impact are regulated. Environmental management involves use of natural raw materials, emission control, and resource recovery, recycle of waste

Green Marketing (GMt): This is the marketing of products that are presumed to be environmentally safe. It involves incorporating a broad range of activities which includes product modification, amendments to the production process, packaging changes, as well as modifying advertising. The concept of green marketing includes making good use of ICT tools, disclosure of environmental information of products and services, green market share, stakeholders' relationship, green packaging, green advertisement etc.

2.1 The proposal method of GSCM selection: Fuzzy-AHP

Multi criteria decision making (MCDM) is an important branch of decision making that deals with the decision problems under the presence of a number of decision criteria. It involves multi objective decision making (MODM) and multi attribute decision making (MADM) (Climao, 1997). In the MODM approach, there are no predetermined alternatives and criteria to be ranked; the MODM tries to optimize more than one objective function subject to a set of constraints. On the other hand, MADM includes sets of alternative solutions to be evaluated against a set of attribute or criteria which are difficult to quantify (Pohekar & Ramachandran, 2004). Analytical hierarchy process (AHP) is one of the most frequently applied MADM methods for various decision making problems.

AHP is a multi-criteria decision-making method developed by Saaty (Saaty & Vargas, 1982). It aims at quantifying relative weights for a given set of criteria on a ratio scale. AHP has two features that differentiate it from other decision-making approaches. The first is; it provides a comprehensive structure to combine the intuitive rational and irrational values during the decision making process while the other is its ability to judge the consistency in the decision-making process using the consistency index. Despite the various benefits and usefulness of AHP, several limitations have been reported in the literature and some modifications are suggested to deal with these limitations. The said method tries to capture the decision maker's knowledge but, it lacks the ability of fully reflecting the human thinking style. In other words, the AHP method is not capable of handling the inherent subjectivity and ambiguity associated with the mapping of one's perception to an exact number (Pan, 2008). Linguistic and vague descriptions could not be solved easily by the AHP unless by the development of fuzzy decision-making.

Based on this problem, Buckley (1985) developed a fuzzy-AHP model and after this study various developments of fuzzy-AHP methods and applications have been carried out (Wang & Yang, 2007). Yager (1978) presented some ideas on the application of fuzzy sets to multi-objective decision making and emphasis on a means of including diverging degrees of importance to different objectives. Van Laarhoven and Pedrcyz (1983) presented a fuzzy method for choosing among a number of alternatives under conflicting criteria. All these were fuzzy version of Saaty's pair wise comparison method. The opinions of these decision-makers i.e. ratios are expressed in the form of fuzzy numbers with triangular fuzzy sets/ functions. First fuzzy weights for the decision criteria are computed followed by the fuzzy weights of alternatives under each of the decision criteria. Finally, using suitable combination of these results, fuzzy scores of the alternatives are obtained based on which optimal choice is made. Zimmerman also established this fuzzy set based approach that can be found in his book (Zimmermann, 1987).

Some recently published studies on fuzzy-AHP are given as follows; Huang, Chu, and Chiang (2008) used fuzzy-AHP for selection of government sponsored research and development project in Taiwan. Wang and Chin (2008) proposed a method for fuzzy-AHP which utilizes a linear goal programming model to derive normalized fuzzy weights for fuzzy pairwise comparison matrices. Tuzkaya (2009) used fuzzy-AHP in evaluating the environmental effect of transportation mode. However the application of fuzzy-AHP methodology for the evaluation and selection of green supply chain management strategy in a cement manufacturing industry from the perceptive of green design, green procurement, green manufacturing environmental management and green marketing has not been seen in literature.

2.2 Reliability of study.

In AHP the pairwise comparisons in a judgment matrix are considered to be adequately consistent if the corresponding consistency ratio (CR) is less than 0.10 (Saaty & Vargas, 1982). If the CR value is greater than 0.10, then it is a good idea to study the problem further and re-evaluate the pairwise comparisons (this was calculated for each decision matrix before converting it to TFN). AHP is normally used to capture experts' knowledge. Regular AHP cannot reflect experts' thinking. In decision-making environment of AHP, the input and the relation between criteria and alternatives are uncertain and inaccurate. To overcome this disadvantage of AHP, Fuzzy logic is used, which has the ability to deal with inaccurate, uncertain and subjective problems in pair-wise comparison. Therefore, fuzzy AHP is proposed to solve the hierarchical and the multi criteria decision making (MCDM) problems in this paper.

Combining expert judgment

The expert team asked several questions from the management and the supply chain department (*sample of questions shown below*). After getting the answers from experts in linguistic terms, they were transformed into triangular fuzzy sets as defined in the latter section. In this paper, opinions of four knowledge experts from the field of green energy and supply chain management were involved.

Some of the questions asked under criterion Green manufacturing are presented below;

- What is the degree of green energy utilization?
- What is the reuse time of hazardous waste?
- Is there a provision for re-manufacturing process?
- What quantities of environmental friendly material / resources are used during manufacturing?
- Are there provisions for recycling operations?
- Does the management embark on pollution reduction capabilities?
- What is the total amount of energy or / and resource utilization?
- How can you quantify the amount of hazardous waste during and after manufacturing process?

3. The Concept of Fuzzy-AHP

Special class of fuzzy numbers suitable for this application is used in this paper. Triangular fuzzy numbers and some operations performed on them, such as addition, multiplication and inversion are defined in this section. Some of the definitions, being special cases of definitions of fuzzy numbers by (Dubois & Prade, 1980) are given as follow;

3.1 Triangular Fuzzy Numbers

A fuzzy number, which indicates a fuzzy set, addresses the definition of fuzzy set theory (Kahraman, 2003). A triangular fuzzy number shown in Figure 1 must have the following properties:

$\mu_M(x) = 0$, *for all* $x \in (-\infty, L)$

$\mu_M(x)$ *is increasing on* $[L, M]$

$\mu_M(x) = 1$ *for* $x = M$

$\mu_M(x)$ *is strictly decreasing on* $[M, U]$

$\mu_M(x) = 0$, *for all* $x \in (U, \infty)$

A fuzzy number M on $\check{R}$ (= $(-\infty, +\infty)$) is said to be a triangular fuzzy number if its membership function (Odeyale, Alamu & Odeyale, 2013b) $\mu M: R \rightarrow [0, 1]$ is equal to:

$$\mu_M(X) = \begin{cases} \frac{l}{m-l}x - \frac{l}{m-l}, & x \in [l, m] \\ \frac{l}{m-u}x \ \frac{u}{m-u}, & x \in [m, u] \\ 0, & otherwise \end{cases} \qquad (1)$$

with $l \leq m \leq u$, l and u stand for the lower and the upper limit of the support M, respectively, and m for the modal value. The triangular fuzzy number, as given by equation, will be denoted by (l, m, u), as shown in Figure. 1. The support of M is the set of elements $\{x \in \check{R} / 1 < x < u\}$.

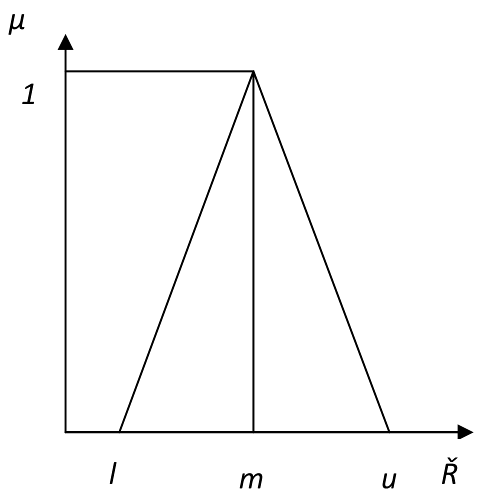

Figure 1. Membership function of a triangular fuzzy Number

3.2 Arithmetic Operations on Triangular Fuzzy Numbers

Some important fuzzy arithmetic operations (Van Larhoven & Pedrcyz, 1983) used in this paper are given in this section.

a) Addition: Consider two TFNs $M_1 = (l_1, m_1, u_1)$ and $M_2 = (l_2, m_2, u_2)$. Then,

$$M_1 \oplus M_2 = (l_1 + l_2 , m_1 + m_2 , u_1 + u_2) \quad (2)$$

b) Multiplication:

$$M_1 \otimes M_2 \approx (l_1 l_2 , m_1 m_2 , u_1 u_2) \quad (3)$$

c) Inverse:

$$(l, m, u)^{-1} \approx \left(\frac{1}{u}, \frac{1}{m}, \frac{1}{l}\right) \quad (4)$$

d) Defuzzication (Centroid method)

$$x_{crisp} = (l + m + u)/3 \quad (5)$$

3.3 Saaty's priority theory

The Analytic Hierarchy Process (AHP) is a powerful and flexible decision making process to help people set priorities and make the best decision when both qualitative and quantitative aspects of a decision need to be considered. By reducing complex decisions to a series of one-on-one comparisons, then synthesizing the results, AHP not only helps decision makers arrive at the best decision, but also provides a clear rationale that it is the best. Designed to reflect the way people actually think, Dr. Thomas Saaty developed AHP in the 1970's. The AHP engage decision makers in structuring a decision into smaller parts, proceeding from the goal to objectives to sub-objectives down to the alternative courses of action (Odeyale, Alamu & Odeyale, 2013a). Decision makers then make simple pair wise comparison judgments throughout the hierarchy to arrive at overall priorities for the alternatives. The analytic hierarchy process allows users to assess the relative weight of multiple criteria (or multiple alternatives against a given criterion) in an intuitive manner (Odeyale, Alamu & Odeyale, 2013a). Its major innovation was the introduction of pair wise comparisons. Pair wise comparisons is a method that is informed by research showing that when quantitative ratings are unavailable and also, humans are good at recognizing whether one criteria is more important than another. Dr. Thomas Saaty, the inventor of the AHP methodology, established a consistent way of converting such pair wise comparisons (X is more important than Y) into a set of numbers (Yager 1978; Verma 2006) representing the relative priority of each of the criteria. For this, we devise a new fuzzy (in the form of TFN's) intensity scale of importance as given in Table 1.

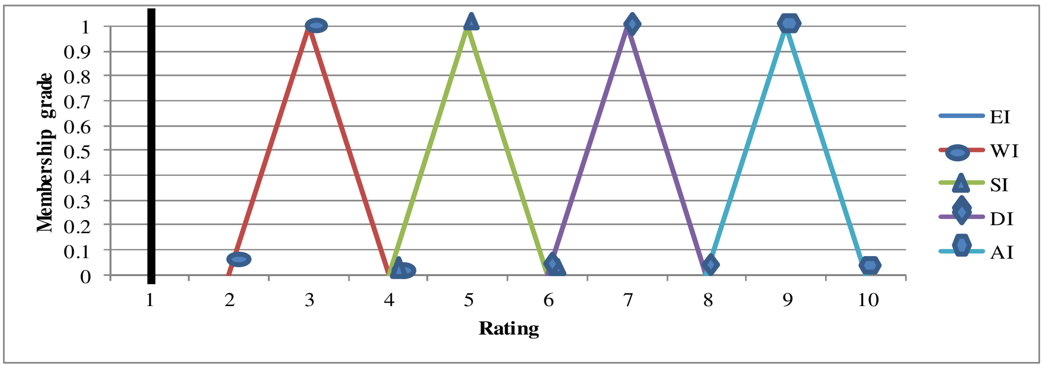

Figure 2. Graphical representation of Fuzzy set scale

Table 1

Intensity of Importance on Fuzzy Set Scale

Intensity of importance as T.F.N's	Definition	Explanation
[1,1,1]	Equal importance (EI)	Two activities contribute equally to the objective
[2,3,4]	Weak importance of one over another (WI)	Experience and judgment slightly favour one activity over another
[4,5,6]	Essential or strong importance (SI)	Experience and judgment strongly favour one activity over another
[6,7,8]	Demonstrated importance (DI)	An activity is strongly favoured and its dominance demonstrated in practice
[8,9,10]	Absolute importance (AI)	The evidence favouring one activity over another is of the highest possible order of affirmation
Reciprocals of above nonzero	If activity i has one of the above nonzero numbers assigned to it when compared with activity j, then j has the reciprocal value when compared with i.	

3.4 The procedure of Fuzzy-AHP

The basic aim is to choose between set of strategies, given some decision criteria. Let $A = \{ a_i \}; i = 1,2,.....n$ be the set of decision alternatives and $C = \{ c_j \}; j = 1,2,.....m$ be the set of criteria according to which the desirability of an alternative is to be judged. The aim here is to obtain the optimal alternative with highest degree of desirability with respect to all relevant criteria. This problem is multi-criteria decision making problem that is tackled by many researchers working in the area of decision-making in a non-fuzzy as well as fuzzy environment (Zimmermann 1987)

Four green supply chain management strategies were considered: Risk-Based(A_1), Efficiency-Based (A_2), Innovation-Based (A_3) , and Close-Loop (A_4). The decision criteria are: green design (C_1), green procurement (C_2), green manufacturing (C_3), environmental management (C_4), and green marketing (C_5) by which to evaluate the four alternatives.

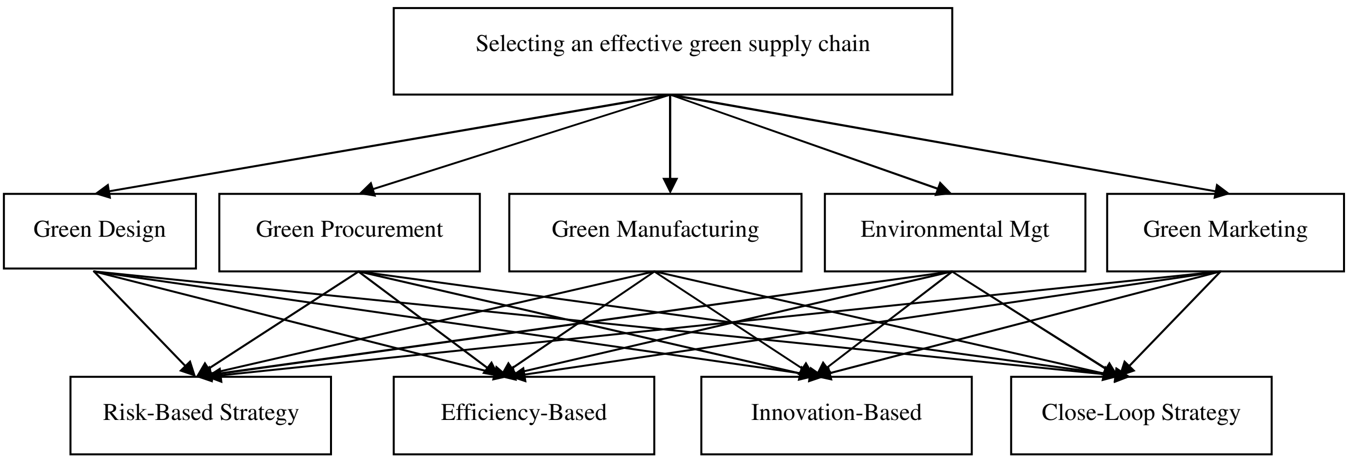

Figure. 3 Hierarchical structure of the criteria and alternatives

3.5 Using fuzzy sets in multi-criterion decision making

Let r_{ij} denote the numerical value assigned to the relative significance/ importance (i.e. ratios) of criteria C_i and C_j according to the "intensity of importance" fuzzy scale given in Table 1. If C_i and C_j are equally important, then r_{ij} =1; if C_i is more important than C_j, then $r_{ij} > 1$; and if C_i is less important than C_j, then $r_{ij} < 1$; Table 2-8 has positive entries everywhere and it satisfies the reciprocal property i.e. $r_{ji} = 1/r_{ij}$. Here r_{ij} are in the form of TFNs and therefore, inverse operation on TFNs is used to get their reciprocals. Normalized average weights (priorities) are computed from the matrix, as shown in Table 3. Lootsama showed that normalized column and row weights are as good enough as normalized Eigen vectors (Lootsama, 1980). In this, the average of the two (row and column) normalized weights is used as the final weight. Alternative strategies were also compared in pair-wise manner under each criterion.

Table 2– 9 was computer by using equation 2-5. The row sum (RS) and column sum (CS) were computed using equation 2 while the inverse normalization (IN) was computed by using equation 4. Priority of criteria and priority of strategies are then multiplied together using equation 3 (fuzzy multiplication) as shown in Table 9 and added for each of the strategies to obtain the final scores. The defuzzication is done using Centroid method given by equation 5 (Opricovic & Tzeng, 2003), to get the crisp score of the strategies and it is shown on Table 10.

Table 2

Matrix of Relative Significance of Decision Criteria

	GD	GP	GM	EM	GMt	**RS**
GD	[1,1,1]	[0.25,0.33,0.5]	[0.17,0.2,0.25]	[0.25,0.33,0.5]	[2,3,4]	**[3.67,4.86,6.25]**
GP	[2,3,4]	[1,1,1]	[0.25,0.33,0.5]	[2,3,4]	[4,5,6]	**[9.25,12.33,15.5]**
GM	[4,5,6]	[2,3,4]	[1,1,1]	[2,3,4]	[4,5,6]	**[13,17,21]**
EM	[2,3,4]	[0.25,0.33,0.5]	[0.25,0.33,0.5]	[1,1,1]	[2,3,4]	**[5.5,7.66,10]**
GMt	[0.25,0.33,0.5]	[0.17,0.2,0.25]	[0.17,0.2,0.25]	[0.25,0.33,0.5]	[1,1,1]	**[1.84,2.06,2.5]**
CS	**[9.25,12.3,15.5]**	**[3.67,4.86,6.25]**	**[1.84,2.06,2.5]**	**[5.5,7.66,10]**	**[13,17,21]**	**[33.26,43.91,55.25]**

Note. *RS = Row Sum CS = Column Sum

Table 3

Average Priority T.F.N.'s of Criteria

	GD	GP	GM	EM	GMt
RS	[3.67,4.86,6.25]	[9.25,12.33,15.5]	[13,17,21]	[5.5,7.66,10]	[1.84,2.06,2.5]
CS	[9.25,12.3,15.5]	[3.67,4.86,6.25]	[1.84,2.06,2.5]	[5.5,7.66,10]	[13,17,21]
N	[0.07,0.11,0.19]	[0.17,0.28,0.47]	[0.24,0.39,0.63]	[0.10,0.17,0.30]	[0.03,0.05,0.08]
IN	[0.06,0.08,0.11]	[0.16,0.21,0.27]	[0.40,0.49,0.54]	[0.10,0.13,0.18]	[0.05,0.06,0.08]
Average priority of criteria	[0.07,0.10,0.15]	[0.17,0.25,0.37]	[0.32,0.44,0.59]	[0.10,0.15,0.24]	[0.04,0.06,0.08]

Note. * N = Normalization, IN = Inverse Normalization

Table 4

Matrix of Relative Significance of Strategies with Respect to Green Design (C1)

Criteria	RB	EB	IB	CL
RB	[1,1,1]	[2,3,4]	[0.13,0.14,0.17]	[0.17,0.2,0.25]
EB	[0.25,0.33,0.5]	[1,1,1]	[0.17,0.2,0.25]	[0.25,0.33,0.5]
IB	[6,7,8]	[4,5,6]	[1,1,1]	[2,3,4]
CL	[4,5,6]	[2,3,4]	[0.25,0.33,0.5]	[1,1,1]
CS	**[11.3,13.3,15.5]**	**[9,12,15]**	**[1.55,1.67,1.92]**	**[3.42,4.53,5.75]**
IN	[0.06,0.08,0.09]	[0.07,0.08,0.11]	[0.52,0.60,0.65]	[0.17,0.22,0.29]

Criteria	**RS**	N	Avg Priority
RB	**[3.3,4.34,5.42]**	[0.09,0.14,0.21]	[0.08,0.11,0.15]
EB	**[1.67,1.86,2.25]**	[0.04,0.06,0.09]	[0.06,0.07,0.10]
IB	**[13,16,19]**	[0.34,0.51,0.74]	[0.43,0.56,0.70]
CL	**[7.25,9.33,11.5]**	[0.19,0.30,0.46]	[0.19,0.26,0.38]
CS	**[25.22,31.53,38.17]**		

Table 5

Matrix of Relative Significance of Strategies with Respect to Green Procurement (C2)

Criteria	RB	EB	IB	CL
RB	[1,1,1]	[1,1,1]	[0.25,0.33,0.5]	[0.17,0.2,0.25]
EB	[1,1,1]	[1,1,1]	[0.25,0.33,0.5]	[0.25,0.33,0.5]
IB	[2,3,4]	[2,3,4]	[1,1,1]	[1,1,1]
CL	[4,5,6]	[2,3,4]	[1,1,1]	[1,1,1]
CS	**[8,10,12]**	**[6,8,10]**	**[2.5,2.66,3]**	**[2.42,2.53,2.75]**
IN	[0.08,0.10,0.13]	[0.10,0.13,0.17]	[0.33,0.38,0.40]	[0.36,0.40,0.41]

Criteria	**RS**	N	Avg Priority
RB	**[2.42,2.53,2.75]**	[0.09,0.11,0.15]	[0.09,0.11,0.14]
EB	**[2.5,2.66,3]**	[0.09,0.11,0.16]	[0.10,0.12,0.17]
IB	**[6,8,10]**	[0.22,0.34,0.53]	[0.28,0.36,0.47]
CL	**[8,10,12]**	[0.29,0.43,0.63]	[0.33,0.42,0.52]
CS	**[18.92,23.19,27.75]**		

Table 6

Matrix of Relative Significance of Strategies with Respect to Green Manufacturing (C3)

Criteria	RB	EB	IB	CL
RB	[1,1,1]	[0.25,0.33,0.5]	[0.25,0.33,0.5]	[0.17,0.2,0.25]
EB	[2,3,4]	[1,1,1]	[0.25,0.33,0.5]	[0.25,0.33,0.5]
IB	[2,3,4]	[2,3,4]	[1,1,1]	[0.25,0.33,0.5]
CL	[4,5,6]	[2,3,4]	[2,3,4]	[1,1,1]
CS	**[9,12,15]**	**[5.25,7.33,9.5]**	**[3.5,4.66,6]**	**[1.67,1.86,2.25]**
IN	[0.07,0.08,0.11]	[0.11,0.14,0.19]	[0.17,0.21,0.29]	[0.44,0.54,0.60]

Criteria	**RS**	N	Avg Priority
RB	**[1.67,1.86,2.25]**	[0.05,0.07,0.12]	[0.06,0.08,0.12]
EB	**[3.5,4.66,6]**	[0.11,0.18,0.31]	[0.11,0.16,0.25]
IB	**[5.25,7.33,9.5]**	[0.16,0.28,0.49]	[0.17,0.25,0.39]
CL	**[9,12,15]**	[0.27,0.46,0.77]	[0.36,0.50,0.69]
CS	**[19.42,25.85,32.75]**		

Table 7

Matrix of Relative Significance of Strategies with Respect to Environmental Management (C4)

Criteria	RB	EB	IB	CL
RB	[1,1,1]	[0.25,0.33,0.5]	[0.17,0.2,0.25]	[0.17,0.2,0.25]
EB	[2,3,4]	[1,1,1]	[0.25,0.33,0.5]	[0.25,0.33,0.5]
IB	[4,5,6]	[2,3,4]	[1,1,1]	[1,1,1]
CL	[4,5,6]	[2,3,4]	[1,1,1]	[1,1,1]
CS	**[11,14,17]**	**[5.25,7.33,9.5]**	**[2.42,2.53,2.75]**	**[2.42,2.53,2.75]**
IN	[0.06,0.07,0.09]	[0.11,0.14,0.19]	[0.36,0.40,0.41]	[0.36,0.40,0.41]

Criteria	**RS**	N	Avg Priority
RB	**[1.59,1.73,2]**	[0.05,0.07,0.09]	[0.06,0.07,0.10]
EB	**[3.5,4.66,6]**	[0.11,0.18,0.28]	[0.11,0.16,0.25]
IB	**[8,10,12]**	[0.25,0.38,0.57]	[0.31,0.39,0.49]
CL	**[8,10,12]**	[0.25,0.38,0.57]	[0.31,0.39,0.49]
CS	**[21.09,26.39,32]**		

Table 8

Matrix of Relative Significance of Strategies with Respect to Green Marketing (C5)

Criteria	RB	EB	IB	CL
RB	[1,1,1]	[2,3,4]	[2,3,4]	[1,1,1]
EB	[0.25,0.33,0.5]	[1,1,1]	[0.25,0.33,0.5]	[0.17,0.2,0.25]
IB	[0.25,0.33,0.5]	[2,3,4]	[1,1,1]	[0.25,0.33,0.5]
CL	[1,1,1]	[4,5,6]	[2,3,4]	[1,1,1]
CS	**[2.5,2.66,3]**	**[9,12,15]**	**[5.25,7.339.55]**	**[2.42,2.53,2.75]**
IN	[0.33,0.38,0.40]	[0.07,0.08,0.11]	[0.11,0.14,0.19]	[0.36,0.40,0.41]

Criteria	**RS**	N	Avg Priority
RB	**[6,8,10]**	[0.20,0.33,0.52]	[0.27,0.36,0.47]
EB	**[1.67,1.86,2.25]**	[0.06,0.08,0.12]	[0.07,0.08,0.12]
IB	**[3.5,4.66,6]**	[0.12,0.29,0.21]	[0.12,0.17,0.26]
CL	**[8,10,12]**	[0.26,0.41,0.63]	[0.32,0.41,0.52]
CS	**[19.17,24.52,30.25]**		

Table 9

Computation of Final Scores of Strategies

	GD	GP	GM	EM	GMt
APC	**[0.07,0.10,0.15]**	**[0.17,0.25,0.37]**	**[0.32,0.44,0.59]**	**[0.10,0.15,0.24]**	**[0.04,0.06,0.08]**
RB	[0.08,0.11,0.15]	[0.09,0.11,0.14]	[0.06,0.08,0.12]	[0.06,0.07,0.10]	[0.27,0.36,0.47]
EB	[0.06,0.07,0.10]	[0.10,0.12,0.17]	[0.11,0.16,0.25]	[0.11,0.16,0.25]	[0.07,0.08,0.12]
IB	[0.43,0.56,0.70]	[0.28,0.36,0.47]	[0.17,0.25,0.39]	[0.31,0.39,0.49]	[0.12,0.17,0.26]
CL	[0.19,0.26,0.38]	[0.33,0.42,0.52]	[0.36,0.50,0.69]	[0.31,0.39,0.49]	[0.32,0.41,0.52]
	0.0056,0.011,0.0225	0.0153,0.0275,0.0518	0.0192,0.0352,0.066	0.006,0.0105,0.024	0.0108,0.0216,0.0376
APS	0.0042,0.007,0.015	0.017,0.03,0.0629	0.0352,0.0704,0.1375	0.011,0.024,0.06	0.0028,0.0048,0.0096
	0.0301,0.056,0.105	0.0476,0.09,0.1739	0.0544,0.11,0.2145	0.031,0.0585,0.1176	0.0048,0.0102,0.0208
	0.0133,0.026,0.057	0.0561,0.105,0.1924	0.1152,0.22,0.3795	0.031,0.0585,0.1176	0.0128,0.0246,0.0416

Note. APC= Average priority of criteria APS= Average priority of scores

Table 10

Final Ranking of Strategies and Crisp Scores

Alternatives	Final ranking	Crisp scores
RB	[0.0569,0.1058,0.2019]	0.1215
EB	[0.0702,0.1362,0.285]	0.1638
IB	[0.1679,0.3247,0.6318]	0.3748
CL	[0.2284,0.4341,0.7881]	0.4835

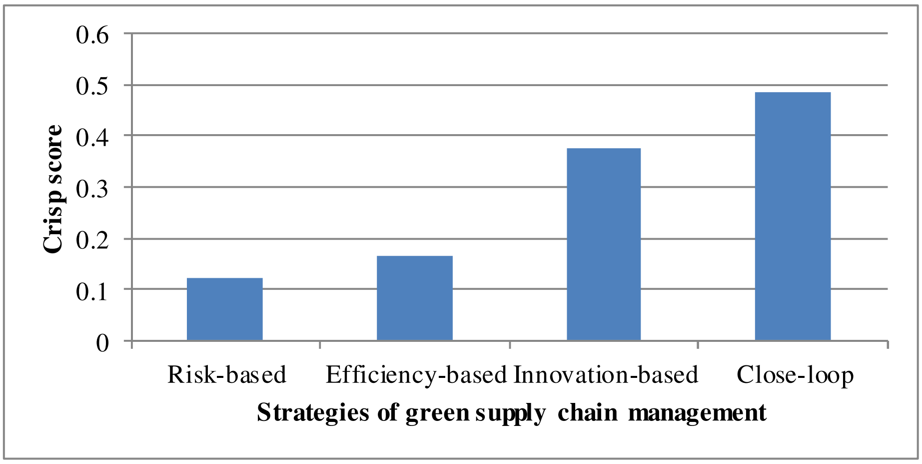

*Figure 4***.** Priority of Strategies after defuzzification

4. Conclusion and recommendations

In this paper, evaluation and selection of GSCM strategy in Cement manufacturing industry is illustrated by incorporating fuzzy sets in Saaty's priority theory. As "importance" is normally expressed in subjective/ linguistic terms, "intensity of importance" scale is fuzzified and expressed in the form of TFN. Four strategies and five decision criteria are determined and then priority theory is used. Priority theory estimates the weights (priorities) of green supply chain criteria using triangular pair-wise comparison method. The four strategies were also compared in pair-wise manner under each decision criterion. Adjusted average score of the normalized row and the column sum is suggested to confirm the priorities. The final scores of each of strategies were evaluated by multiplying (fuzzy arithmetic) the priorities and then adding them.

Based on this result, Close-Loop strategy A_4 was selected as the best supply chain strategy for the cement industry, followed by Innovation Based A_3, Efficiency Based A_2, and Risk Based A_1 as shown in Figure. 4. Thus, in order to save the environment and ecosystem, it is highly recommendable to inculcate a green supply chain management in all manufacturing industry, this helps to protect the environment and at the same time integrates corporate functional strategies to a achieve effective and profitable green management.

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