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Article

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Performance Appraisal for Green/Environmental Friendliness of a Supply Chain Department

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Abstract:

Purpose: This paper aims at proposing a method for evaluating the environmental friendliness of a supply chain department in any organization. Supply chain involves activities that could affect the natural environment and if these activities are not properly evaluated and monitored, it could affect the natural environment and also generate ecological performance change.

Design/methodology: The model for the appraisal consists of 5 criteria and 30 subcriteria. The method is applied at 3 levels; beginning with finding the relative weight of the subcriteria under each criterion using Analytic Hierarchy Process (AHP), followed by computing the value associated with each level descriptor in a scale. Some subcriteria have 5 level descriptors (very strong/moderate /weak/very weak / no), some subcriteria have 3 level descriptors (always / sometimes/ never) and some have 2 levels descriptor (yes/no). Finally, the method is concluded by the means of an additive model, whereby the weight associated with each subcriteria is multiplied by the corresponding level descriptor and summed up to get the limit/state. This methodology is called the weighing multiplication and additive model (WMAAM).

Findings: Supply chain (SC) involves operational activities and for these activities to be environmental friendly, they have been categorized under criteria namely; green design, green procurement, green manufacturing, environmental management and green marketing. These criteria which consist of 30 subcriteria are evaluated in order to compute the overall environmental friendly appraisal of the SC department.

Practical implications: The study plays important role in understanding various areas to be monitored and considered during supply chain activities in order to achieve a green supply chain management or an environmental friendly supply chain.

Originality/value: The main contribution of this work is to propose an effective methodology that guides SC practitioners on carrying out green performance appraisal of a SC department in any organization.

Keywords: Analytic hierarchy process (AHP), environmental management, green supply chain management, performance appraisal

1. Introduction

Although the supply chain function of any organization is an important element of modern business, one must also consider the implication of these activities to the environment we live in. Supply chain management involves various activities starting from procurement of raw materials, design of products, manufacturing of products, marketing of products, down to the logistics involved in getting the product to the consumer. Each of these activities, if not operated from the perspective of environmental sustainability, could cause threat to the ecosystem. For example, a company that involves in the creation of manufactured products that uses processes that are polluting and do not conserve energy or natural resources, poses threat to the environment. On the other hand, a company that involves in the creation of manufactured products using processes that are non-polluting, conserve energy and natural resources are economically sound and safe for the environment and consumers. This process is called green manufacturing. Other environmental friendly supply chain processes are green procurement, green design, environmental management and green marketing. (Odeyale, Alamu & Odeyale, 2013).

Supply chain involves activities that could affect the natural environment and also generate environmental performance change. This is why there is a need to audit supply chain department based on environmental sustainability. Every organization should know their current status and aim at developing or improving its sustainable and environmental friendly supply chain operations. Green or environmental friendly supply chain generally refers to supplier product and environmentally related management, or to incorporating environmental protection principles into supplier management systems, the purpose of which is to enhance market competence by implanting more environmental protection concepts (Lin & Juang, 2008).

This study proposes an appraisal to detect/monitor the state of green operation of any supply chain department. The improvement developed can be quantitatively measured and translated into a qualitative value that provides a general state of the environmental friendliness of the

supply chain department. In this paper, an environmental friendliness appraisal has been developed using an additive multicriteria methodology. The appraisal has been able to identify the current state of a supply chain department and compare this state with the highest and lowest possible state.

2. Literature review

The appraisal process starts with the identification of the set of criteria to be used for evaluation. The criteria are listed as follows;

The decision criteria used for the evaluation of green supply chain management based on different sections of industrial operation are listed below and briefly explained (Odeyale et al., 2013).

- **Green Design (GD):** This is also known as sustainable design or environmental design. It involves the designing of 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 through 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 etc.
- **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, resource recovery and 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.

To obtain the information from the company under study, a questionnaire was prepared. This questionnaire is a general questionnaire and can therefore be applied to any company or enterprise. Each criterion includes different subcriteria; each subcriterion has a descriptor associated and constructed with the levels that describe plausible impacts of the alternatives with respect to each subcriterion. The subcriteria included inside the 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?
- 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?

The subcriteria included inside the criterion environmental management are presented below:

- How would you rate your emission control level?
- What level of natural raw materials are used?
- How are unwanted waste disposal operations?
- Are training courses provided and/or updating of technical knowledge on environmental sustainability?
- How often does the management carry out environmental impact assessment?
- Are the products of this company biodegradable?

Based on the literature review of green supply chain management, there have been several researches which involve green, environmental or sustainable concepts to traditional supply chain management. Few works on evaluation of supply chain management are highlighted as follows; Webb (1994) emphasized that product manufacturing had to use environmental criteria to select appropriate raw materials while also paying attention to recycling and the green purchasing concept as well. Beamon (1999) proposed that environmental factor must be introduced to the supply chain model to put forward wider supply chain design methods. Kuo et al. (2004) pointed out that, in the entire process of supply chain management, the combination of the process; the products, the packaging, and the distribution have to take environmental problems into account, not only by reducing the social burden on the environment, but also by meeting environmental laws, and lowering green trading barriers. Lai (2004) suggested that building green supply chains has become a major challenge, but that the trend of providing green products can allow us to advance towards a sustainable society. Lin and Juang (2008) used AHP methodology to select green suppliers for a biotechnology industry. Ali and Kannan (2010) developed a model of the drivers affecting the implementation of green supply chain management using an Interpretive Structural Modeling (ISM) framework. The various drivers of green supply chain management (GSCM) were identified based on the GSM literature and on consultations with experts in the industry. The model developed was validated on a case study involving a manufacturing firm in southern India. Ru-Jen, Rong-Huei and Thi-Hang (2011) explored the criteria that influence the performance of the automobile manufacturing industry, using the fuzzy set theory and Decision Making Trial and Evaluation Laboratory. The method was used to evaluate its performance and find key criteria in improving the manufacturers' green performance. Kuo-Jui, Ming-Lang and Truong (2011) used the fuzzy Decision Making Trial and Evaluation Laboratory (DEMATEL) method to find influential factors in selecting GSCM criteria. They evaluated suppliers' performance to find key factor criteria to improve performance and provide a novel approach of decision-making information in GSCM implementation. Chan, He, Chan and Wang (2012) proposed and empirically tested a model delineating the relationship among environmental orientation, green supply chain management (GSCM) activities (green purchase, customer cooperation and investment recovery) and corporate performance. Chiau-Ching, Hsu-Shih, Huan-Jyh and Kun-Shan (2012) designated green supply chain management (GSCM) strategies to effectively direct business functions and activities in a leading Taiwanese electronics industry. Yao-Fen, Su-Ping, Yi-Ching and Chen-Tsang (2013) established a green management standard with GrSCM that green restaurants can implement. They combined GrSCM for food and beverage management to develop green restaurant standards, and primarily adopted the Delphi Technique to develop green standards of restaurant management. Payman and Cory (2013) identified and analyzed the published definitions of green supply chain management (GSCM) and sustainable supply chain management (SSCM) and later proposed a new definition for SSCM. Ming-Lang, Ru-Jen, Yuan-Hsu, Rong-Hui and Kimhua (2013) explored the differences between close-loop and open hierarchical structures, which are used in the analytical network process (ANP) analysis of

green supply chain management (GSCM) under uncertainty. They examined the interdependence among the proposed aspects and criteria used to assess GSCM in two hierarchical structures and compared the results to those of a real situation. Odeyale et al. (2013) proposed a Fuzzy-AHP model for the evaluation and selection of an effective green supply chain management strategy.

3. Methodology

The green appraisal or performance appraisal of the environmental friendliness is developed by the means of an additive model known as weighing multiplication and additive model (WMAAM). Scores are multiplied by weights and the products summed. The formula is represented in equation 1 below; Let v_{ij} represent the value associated with the value of option i on criterion j . Let w_j represent the weight assigned to criterion j . Then, the overall value of option i is simply;

$$V_i = \sum_j w_j v_{ij} \quad (1)$$

$$V_i = \sum v_i$$

In words, the scores assigned to the states of an option on all the criteria is derived by multiplying the respective weights assigned to the subcriteria and the value of the corresponding level descriptor, and those products summed across all the criteria. This methodology allows a hierarchical representation of objectives and criteria by clustering them under 'parent' nodes (Carnero, 2008).

3.1 Weighing process

Step 1. Finding the weights of subcriteria using AHP

Converting decision criteria into numerical values could be very intricate, however the decision maker should be able to categories each criteria according to their importance. This can be done by a process called method called Analytical Hierarchy Process. AHP is a multi-criteria decision-making method developed by Saaty (Saaty T. and Vargas L., 1982). AHP aims at quantifying relative weights for a given set of criteria on a ratio scale. Two features of AHP differentiate it from other decision-making approaches. One, it provides a comprehensive structure to combine the intuitive rational and irrational values during the decision making process. The other is its ability to judge the consistency in the decision-making process. To make a decision in an organised way to generate priorities we need to decompose the decision into the following steps.

- 1) Define the problem and determine the kind of knowledge sought.
- 2) Structure the decision hierarchy from the top with the goal of the decision, then the objectives from a broad perspective, through the intermediate levels (criteria on which subsequent elements depend) to the lowest level (which usually is a set of the alternatives).
- 3) Construct a set of pairwise comparison matrices. Each element in an upper level is used to compare the elements in the level immediately below with respect to it.
- 4) Use the priorities obtained from the comparisons to weigh the priorities in the level immediately below. Do this for every element. Then for each element in the level below add its weighed values and obtain its overall or global priority.

One of the most crucial steps in many decision-making methods is the accurate estimation of the pertinent data. This is a problem not bound in the AHP method only, but it is crucial in many other methods which need to elicit qualitative information from the decision-maker. Very often qualitative data cannot be known in terms of absolute values. For instance, "what is the worth of specific computer software in terms of a user adaptivity criterion?" Although information about questions like the previous one are vital in making the correct decision, it is very difficult, if not impossible, to quantify them correctly. Therefore, many decision-making methods attempt to determine the relative importance, or weight, of the alternatives in terms of each criterion involved in a given decision-making problem. An approach based on pairwise comparisons which was proposed by Saaty has long attracted the interest of many researchers. Pairwise comparisons are used to determine the relative importance of each alternative in terms of each criterion. In this approach the decision-maker has to express his opinion about the value of one single pairwise comparison at a time. Usually, the decision-maker has to choose his answer among 10-17 discrete choices. Each choice is a linguistic phrase. Some examples of such linguistic phrases are: "A is more important than B", or "A is of the same importance as B", or "A is a little more important than B", and so on (Table 1).

Intensity of Importance	Definition	Explanation
1	Equal importance	Two activities contribute equally to the objective
3	Weak importance of one over another	Experience and judgment slightly favour one activity over another
5	Essential or strong importance	Experience and judgment strongly favour one activity over another
7	Demonstrated importance	An activity is strongly favoured and its dominance demonstrated in practice
9	Absolute importance	The evidence favouring one activity over another is of the highest possible order of affirmation
2, 4, 6, 8	Intermediate values between the two adjacent judgments	When compromise is needed
Reciprocals of above nonzero	If activity 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.	

Table 1. Scale of Relative Importance (Saaty, 1980)

Pairwise comparisons are quantified by using a scale. Such a scale is a one-to-one mapping between the set of discrete linguistic choices available to the decision maker and a discrete set of numbers which represent the importance, or weight, of the previous linguistic choices. The scale proposed by Saaty is depicted in Table 1. In Saaty's scale, 9 is established as the upper limit, 1 as the lower limit and a unit difference between successive scales values. The values of the pairwise comparisons in the AHP are determined according to the scale introduced by Saaty (1980). According to this scale, the available values for the pairwise comparisons are members of the set: $\{9, 8, 7, 6, 5, 4, 3, 2, 1, 1/2, 1/3, 1/4, 1/5, 1/6, 1/7, 1/8, 1/9\}$ (see also Table 1).

The criteria and subcriteria are organized in a tree structure as shown in Figure 1. The weighing process of the subcriteria is computed by hierarchical ranking carried out by application of AHP. For example under the criterion green design, there are four subcriteria namely; Energy savings (GD1), increasing innovation capabilities (GD2), complying with the Dfddr principles (GD3) and abstaining from utilizing toxic substances (GD4). These subcriteria are ranked in such a way that the highest ranking has the highest relevancy to attain the criterion goal by pairwise comparison (Table 1).

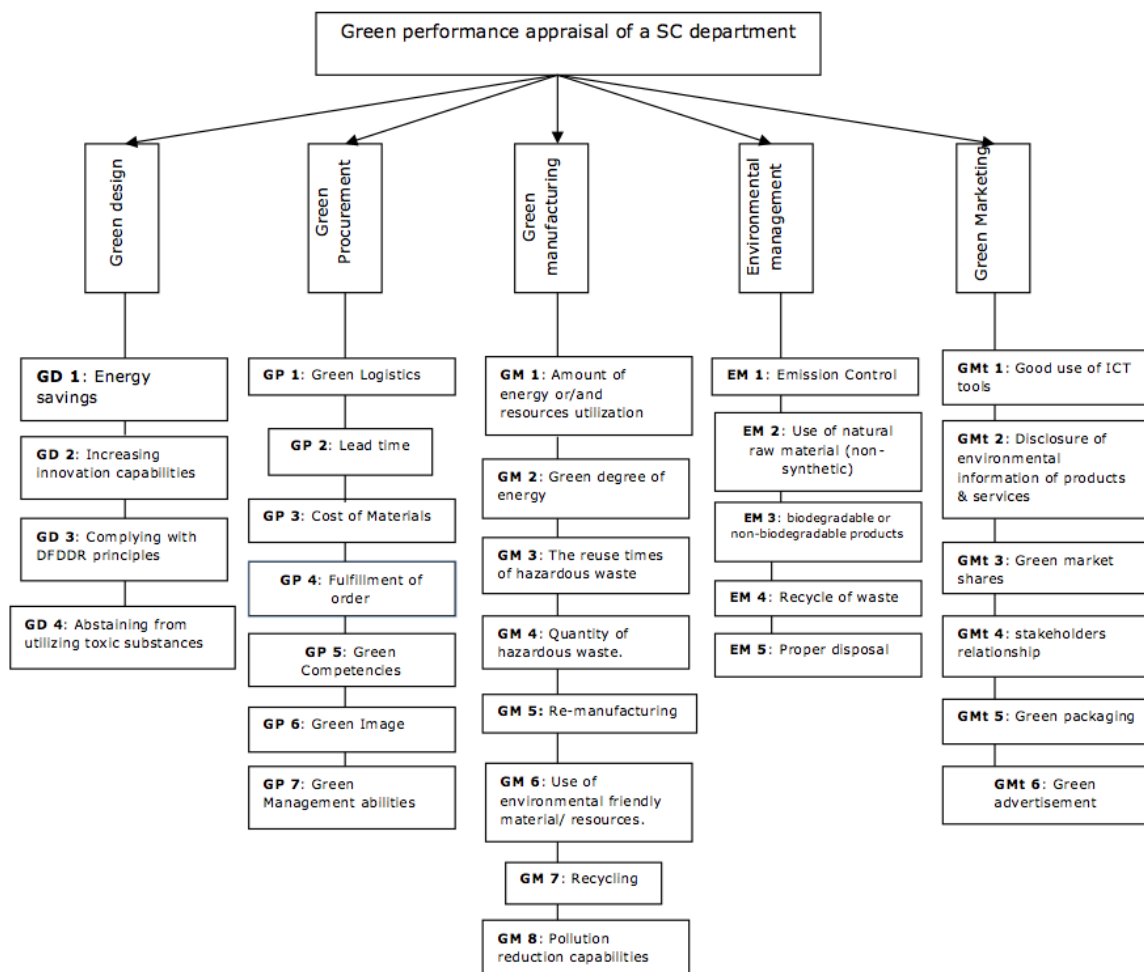


Figure 1. The hierarchical and appraisal tree

Step 2. Computing the value of the level descriptor of subcriteria

The green appraisal is composed of 5 criteria and 30 subcriteria have shown in Figure 1. The level descriptor is basically the corresponding value associated with the response to each subcriterion. As explained earlier in the introduction, each criterion includes different subcriteria; each subcriterion has a descriptor associated and constructed with the levels that describe plausible impacts of the alternatives with respect to each subcriterion. The subcriteria included inside the 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?
- 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?

The degree of the answers to these questions is what is referred to as level descriptor. The subcriteria have questions embedded in them in which their responses to the questions are in 5, 3 or 2 levels. There are some subcriteria with only two levels in the scale i.e. L1_{100%} and L2_{0%} (answers to yes/no questions) as shown in Figure 2, while some subcriteria have three levels in the scale i.e. L1_{100%}, L2_{50%} and L3_{0%}, (answers to always/sometimes/never questions) as shown in Figure 3 and some subcriteria with the five level scale i.e. L1_{100%}, L2_{75%}, L3_{50%}, L4_{25%} and L5_{0%} (answers to very strong/strong/moderate/weak/no). For example there are four subcriteria under the criterion green design namely; Energy savings (GD1), increasing innovation capabilities (GD2), complying with the Dfddr principles (GD3) and abstaining from utilizing toxic substances (GD4); have questions in the questionnaire such as; *how often do you engage in energy savings during product design?*, *Rate your organizations based on complying with the disassembly, reuse and recycling (DfDRR) principles?*, *How often does your organization use toxic substances during product design?* and so on. The response to these questions could be sometimes, never, strong, weak, yes, no etc. whatever the response is, the associated value is the level descriptor. Note that under criterion green manufacturing, evaluating response from the questionnaire on questions such as *What is the reuse time of hazardous waste?*, *How can you quantify the amount of hazardous waste during and after manufacturing process?* and so on, gives higher level descriptor when the numbers are lower and lower level descriptor when the numbers are higher. This is due to the facts that an organization that has a smaller number of reuse times of hazardous waste or amount of

hazardous waste during and after manufacturing process is more environmental friendly while organizations that have higher number are less environmental friendly.

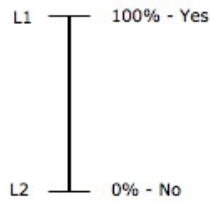


Figure 2. Level descriptor of a subcriterion with two levels

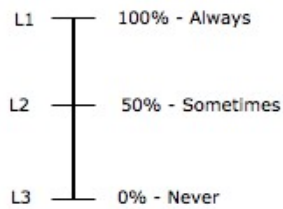


Figure 3. Level descriptor corresponding to the subcriterion with three levels descriptor

Step 3. Computing the score of the state

The score of the state is computed by multiplying the weight of the subcriteria with its corresponding level descriptor. The flowchart for all the 3 steps is illustrated in Figure 4 below.

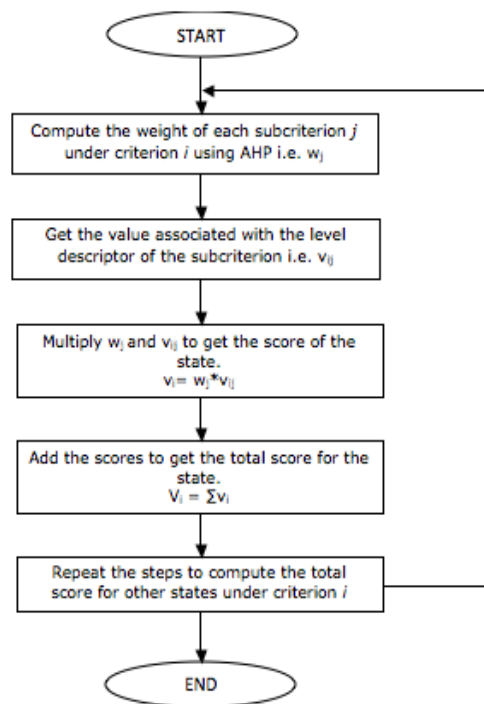


Figure 4. Flowchart showing the steps involved in the performance appraisal process

States

The alternative states considered in this paper are excellent state, excellent / satisfactory state limit, satisfactory/acceptable limit, acceptable / alert limit, alert / catastrophic limit and totally catastrophic state. This model was used to evaluate the present state of the environmental friendliness of the supply chain department of an organization, and the alternative state is called current state/status using Equation 1.

Limits between states

The limit between each state values were obtained by analyzing the level in which each subcriterion should be considered, once that criterion is in a specific state. For example, under the green manufacturing criterion:

- The excellent state is obtained with all the subcriteria at the best level i.e. L1 (100%)
- The excellent / satisfactory limit is obtained when subcriteria GM1, GM2, GM6 and GM 8 are at the second best level i.e. L2 (75%) and the subcriteria GM3, GM4, GM5 and GM7 are at the best level.
- The satisfactory / acceptable limit is computed by considering the subcriteria GM1, GM2, GM4 at second best level, GM5, GM7 at best level and the subcriteria GM3, GM6, GM8 at the third best level L3 (50%).
- The acceptable/alert limit corresponds with the subcriterion GM4 at the second best level, GM1, GM2, GM3, GM6, GM8 at the third best level and GM5, GM7 are the fourth best level.
- The alert / catastrophic limit is evaluated with the subcriteria GM3 at the third best level and the rest subcriteria at the fourth best level.
- The totally catastrophic limit is computed with all subcriteria at the worst level. L5 (0%)

Subcriteria (weight)	a	b	c	d	e	f
GM1 (10.96)	L1 _{100%}	L2 _{75%}	L2 _{75%}	L3 _{50%}	L4 _{25%}	L5 _{0%}
GM2 (12.49)	L1 _{100%}	L2 _{75%}	L2 _{75%}	L3 _{50%}	L4 _{25%}	L5 _{0%}
GM3 (15.48)	L1 _{100%}	L1 _{100%}	L2 _{50%}	L2 _{50%}	L2 _{50%}	L3 _{0%}
GM4 (15.48)	L1 _{100%}	L1 _{100%}	L2 _{75%}	L2 _{75%}	L4 _{25%}	L5 _{0%}
GM5 (9.23)	L1 _{100%}	L1 _{100%}	L1 _{100%}			L2 _{0%}
GM6 (13.15)	L1 _{100%}	L2 _{75%}	L3 _{50%}	L3 _{50%}	L4 _{25%}	L5 _{0%}
GM7 (9.13)	L1 _{100%}	L1 _{100%}	L1 _{100%}			L2 _{0%}
GM8 (14.07)	L1 _{100%}	L2 _{50%}	L2 _{50%}	L2 _{50%}		L3 _{0%}
	100	83	69	45	21	0

Table 1. Limits between state for green manufacturing criterion

As seen in Table 1 above, the score for each state was computed by multiplying the value of the level descriptor by the corresponding weight of the subcriterion, and summing it up;

$$c \text{ (acceptable state)} = [(0.75 \times 10.96) + (0.75 \times 12.49) + (0.50 \times 15.48) + (0.75 \times 15.48) + (1 \times 9.23) + (0.5 \times 13.15) + (1 \times 9.13) + (0.5 \times 14.07)] = 69$$

Similar procedures as stated above were applied to all the criteria to set limits between states, for example under criterion Green design which has 4 subcriteria;

- a) The excellent state is obtained with all the subcriteria at the best level i.e. L1 (100%)
- b) The excellent / satisfactory limit is obtained when subcriteria GD2 and GD3 are at the second best level i.e. L2 (75%) and the subcriteria GD1 and GD4 are at the best level.
- c) The satisfactory / acceptable limit is computed by considering the subcriteria GD3 and GD4 at second best level, GD1 at best level and the subcriteria GD2 at the third best level L3 (50%).
- d) The acceptable/alert limit corresponds with the subcriterion GD3 and GD4 at the second best level, GD1 at the third best level and GD 2 are the fourth best level.
- e) The alert / catastrophic limit is evaluated with the subcriteria at the fourth best level.
- f) The totally catastrophic limit is computed with all subcriteria at the worst level. L5 (0%)

Subcriteria (weight)	a	b	c	d	e	f
GD1 (32.41)	L1 _{100%}	L1 _{100%}	L1 _{100%}	L2 _{50%}	L3 _{0%}	L3 _{0%}
GD2 (13.57)	L1 _{100%}	L2 _{75%}	L3 _{50%}	L4 _{25%}	L3 _{50%}	L5 _{0%}
GD3 (17.96)	L1 _{100%}	L2 _{50%}	L2 _{50%}	L2 _{50%}	L2 _{50%}	L3 _{0%}
GD4 (36.06)	L1 _{100%}	L1 _{100%}	L2 _{50%}	L2 _{50%}	L2 _{50%}	L3 _{0%}
	100	88	66	46	33	0

Table 2. Limits between state for green design criterion

Hence, the limits between states for all the criteria are presented in Table 3-7 below. To obtain the limit between states for global audit as shown in Table 8, the mean/average limit of each state were computed. For the performance appraisal of any organization, in our case a supply chain department, a level of descriptor should be associated with each subcriterion. As explained earlier, there are some subcriteria with only two levels in the scale i.e. L1_{100%} and L2_{0%} (results of yes/no questions), while some subcriteria have three levels in the scale i.e. L1_{100%}, L2_{50%} and L3_{0%} (answers to always/sometimes/never questions) and some subcriteria with the five level scale.

Limits	Value
Excellent	88%-100%
Satisfactory	66%-87%
Acceptable	46%-65%
Alert	33%-45%
Catastrophic	0%-32%

Table 3. Limit values between states in green design criterion

Limits	Value
Excellent	86%-100%
Satisfactory	71%-85%
Acceptable	44%-70%
Alert	33%-43%
Catastrophic	0%-32%

Table 4. Limit values between states in green procurement criterion

Limits	Value
Excellent	83%-100%
Satisfactory	69%-82%
Acceptable	45%-68%
Alert	21%-44%
Catastrophic	0%-20%

Table 5. Limit values between states in green manufacturing criterion

Limits	Value
Excellent	79%-100%
Satisfactory	66%-78%
Acceptable	52%-65%
Alert	31%-51%
Catastrophic	0%-30%

Table 6. Limit values between states in environmental management criterion

Limits	Value
Excellent	73%-100%
Satisfactory	63%-72%
Acceptable	27%-62%
Alert	17%-26%
Catastrophic	0%-16%

Table 7. Limit values between states in green marketing criterion

Alternatives	Limits between states
Excellent State	82%-100%
Satisfactory State	67%-81%
Acceptable State	43%-66%
Alert State	26%-42%
Catastrophic State	< 26%

Table 8. Limit values between states considering the global audit

4. Results

The questionnaire with the information about the current state of the supply chain department was completed by an independent person to the organization. Thus, from the previous semantic values stated in the methodology above, the current state of the supply chain department is computed to be 71.7 (Satisfactory / Acceptable limit) on the 0-100 scale as shown in Table 8. In the area of green design, the department scored 71.9 (Acceptable), under the criterion green procurement it scored 81.3 (Satisfactory). Other appraisals are; green manufacturing, environmental management and green marketing are 61.9 (Acceptable), 67 (Acceptable) and 76.4 (Excellent) respectively. From the performance appraisal, it is seen that the organization had the lowest score under green manufacturing. This is majorly due to the fact that the organization does not have provision for recycling processes as shown in Figure 8. There is also need to improve on some subcriteria (such as pollution reduction capabilities, recycling, and hazardous waste management) under this criterion. The organization scored low under these subcriteria which in turn affected the overall score of the green manufacturing criterion.

The graphical representation of the current state based each criterion is shown in Figure 5 (to prevent ambiguity only green design criterion is shown) and the overall status is also computed by calculating the average score of the appraisal on the criteria (Figure 6).

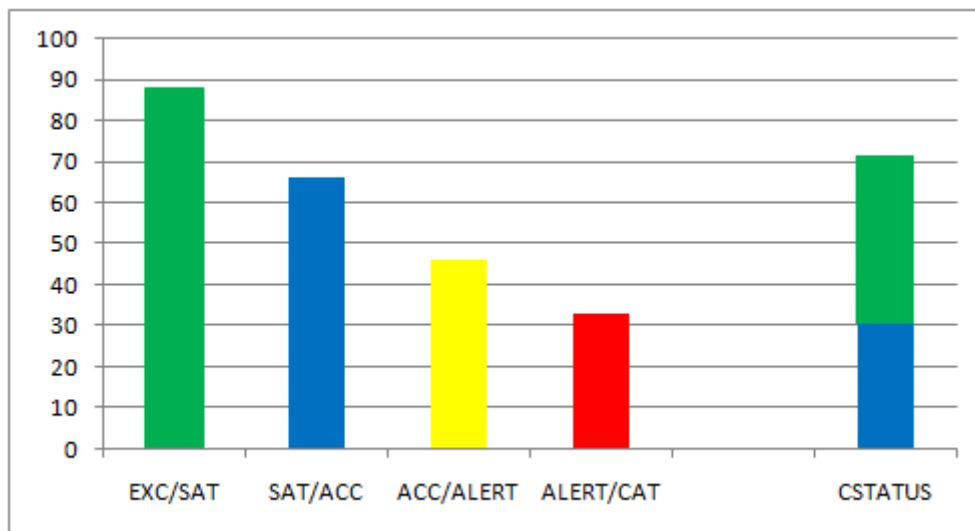


Figure 5. Current status of the department under the green design criterion

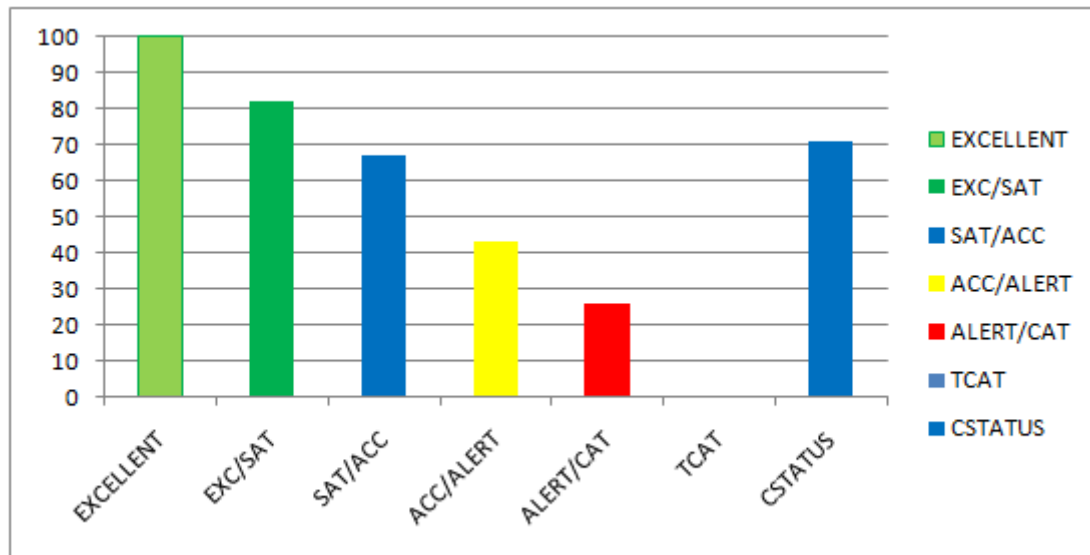


Figure 6. Overall current status of the department

5. Concluding remark

A WMAAM multicriteria technique has been used to perform a green appraisal of a supply chain department. The appraisal is objective and can be distinguished for any organization by the means of establishing the specified limits between weights and state. This performance appraisal can be used from time to time to evaluate the current environmental friendly status of the SC department. It is essential to monitor the status of the SC department. The objective of this study is to create a model for evaluation of a supply chain department from the perspective of environmental friendliness. Key criteria of green supply chain management were used for the appraisal. Being green and ethical is no longer an option; it is a necessity in supply chain management. As mentioned earlier, supply chain involves activities that could affect the natural environment and also generate environmental performance change thus organizations need to be environmentally conscious in all their activities. This study gives any supply chain organization an insight on how to monitor and evaluation their supply chain activities in order to aid environmental sustainability.

An excel application has been developed using this methodology in order to make it easier for organizations to carry out their own performance appraisal. As shown in figure 7 and 8 below.

		RESPONSES
Green Design		
GD 1: Does your organization participate in energy saving activities?		YES WEAK ALWAYS SOMETIMES
GD 2: How can you rate your level of increasing innovation capabilities?		
GD 3: Does the organization comply with Df4dr principles?		
GD 4: Does the organization abstain from utilization of toxic substances?		
Environmental Management		
EM 1: How would you rate your emission control level?		MODERATE SOMETIMES YES YES SOMETIMES
EM 2: Does the organization use natural raw materials during production?		
EM 3: Are the products of the organization biodegradable?		
EM 4: Is there provision for recycling of waste?		
EM 5: How often do you ensure proper disposal of waste?		
Green Manufacturing		
GM 1: How would you rate the amount of energy resource utilization?		VERY STRONG STRONG SOMETIMES MODERATE YES STRONG NO SOMETIMES
GM 2: What is the degree of green energy utilization?		
GM 3: How often do you prevent the reuse of hazardous waste?		
GM 4: What is the quantity of non-hazardous waste after manufacturing process?		
GM 5: Is there provision for remanufacturing process?		
GM 6: How would you rate the quantity of environmental friendly materials/resources used for manufacture?		
GM 7: Are there provisions for recycling operations?		
GM 8: Does the management embark on pollution reduction capabilities?		

Figure 7. The input section of the performance appraisal application

			GREEN DESIGN				
STATE	Range	Indicator	Subcriteria	Level Descriptor	Score	Summary	
Excellent	88 - 100		GD 1: Energy Savings	100	32.41	SCORE	71.7925
Satisfactory	66 - 87		GD 2: Increasing Innovation Capacity	25	3.3925	STATE	SATISFACTORY
Acceptable	46 - 65		GD 3: Complying with DFFDR principles	100	17.96	INDICATOR	
Alert	33 - 45		GD 4: Abstaining from utilizing toxic substance	50	18.03		
Catastrophic	0 - 32		Score		71.7925		
			ENVIRONMENTAL MANAGEMENT				
STATE	Range	Indicator	Subcriteria	Level Descriptor	Score	Summary	
Excellent	79 - 100		EM 1: Emission Control	50	12.825	SCORE	66.565
Satisfactory	66 - 78		EM 2: Use of natural raw materials	50	9.31	STATE	SATISFACTORY
Acceptable	52 - 65		EM 3: Biodegradable products	100	14.01	INDICATOR	
Alert	31 - 51		EM 4: Recycling of waste	100	19.12		
Catastrophic	0 - 30		EM 5: Proper disposal	50	11.3		
			Score		66.565		
			GREEN MANUFACTURING				
STATE	Range	Indicator	Subcriteria	Level Descriptor	Score	Summary	
Excellent	83 - 100		GM 1: Amount of energy utilization	100	10.96	SCORE	61.945
Satisfactory	69 - 82		GM 2: Green degree of energy	75	9.3675	STATE	ACCEPTABLE
Acceptable	45 - 68		GM 3: Reuse times of hazardous waste	50	7.74	INDICATOR	
Alert	21 - 44		GM 4: Quantity of hazardous waste?	50	7.74		
Catastrophic	0 - 20		GM 5: Re-manufacturing	100	9.24		
			GM 6: Use of env. friendly raw materials	75	9.8625		
			GM 7: Recycling	0	0		
			GM 8: Pollution Reduction capabilities	50	7.035		
			Score		61.945		

Figure 8. Application showing appraisal results based on the input/response

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