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Validation of Performance Measures for Green Supplier Selection in Indian Industries

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Abstract: *An environmentally conscious supply chain, also called a green supply chain, is a new concept appearing in recent literatures. The purpose of this study is to identify the critical green manufacturing factors considered during supplier selection in the Indian manufacturing sector. The relationship between green supplier selection management practices and environmental performance is studied. The criteria are differentiated for evaluating traditional suppliers and green suppliers. The major activities of the green supply chain; namely green procurement, green manufacturing, green costs, quality, green packaging, customer co-operation are being covered throughout the research. From these above factors best factors for green supplier selection are selected and which can be implemented in any individual manufacturing industry. In this study, factor analysis is done using Statistical Package for the Social Sciences (SPSS) software to help decision makers understand the important environmental dimensions. The study demonstrates use of factor analysis to evaluate the relative importance of various environmental performance measures. This study also aims to develop a decision support tool which should help companies to integrate environmental criteria into their green supplier selection process.*

Keywords: *Green manufacturing; green supplier selection, environmental performance, factor analysis*

I. INTRODUCTION

The Green Supplier selection process is one of the key operational tasks for sustainable supply chain partnership. The powerful supplier should enhance the performance of the supply chain with environmental, social and economical aspects [1]. Due to the current awareness in the environmental aspects, the assortment of the supplier has turned their way and made focus on the green criteria base more than a habitual way [2]. With increasing government regulation and stronger public awareness in environmental protection, firms today simply cannot ignore environmental issues if they want to survive in global market. In addition to complying with the environmental regulations for selling products in certain countries, firms need to implement strategies to voluntarily reduce the environmental impacts of their products. The integration of environmental, economic and social performances to achieve sustainable development is a major business challenge for the new century. Environmental management is becoming more and more important for corporations as the emphasis on the environmental protection by organizational stakeholders, including stockholders, governments, customers, employees, competitors and communities, keeps increasing. Programs such as design for the environment, life cycle analysis, total quality environmental management, green supply chain management and ISO 14000 standards are popular for environmentally conscious practices. A green supplier evaluation system is necessary for a firm in determining the suitability of a supplier as a partner in the green supply chain [3].

This study explains the practices and implementation of green supply chain and environmental performance among various manufacturing industries located in India. Total 7 practices namely green design, green logistic design, green manufacturing, green costs, quality, environment performance assessment, and customer co-operation are considered with 47 sub factors. The study consists of five sections. After this introduction, in section II, review of the relevant literature is given. It helps in establishing a link between green supply chain management and environmental performance measures. Section III contains research methodology. The result and comparative analysis of various factors of green supply chain management by calculating 'mean score' are presented in section IV. Finally, the conclusion is presented in section V.

II. LITERATURE REVIEW

In this work, the articles were studied keeping in mind multi criteria green supplier evaluation and selection approaches ranging from year 2006 to 2012. Based on number of articles studied the following issues were examined - (i) Application of Multi Criteria Decision Making (MCDM) tool (ii) evaluation of green supplier selection criteria.

A literature review of Green Supply Chain Management (GSCM) yielded studies linking green, environmental, or sustainable concepts. Most studies emphasized reduction, re-manufacturing, recycling product design, process design, manufacturing practices, procurement, and some mixture of items across managerial levels. Integrating environmental concepts into these business functions ameliorated environmental pollution. However, a more elaborate and organized analysis will allow efficient implementation of GSCM strategy. Bhateja *et al.* [4] conducted study of various activities of the supply chain processes of various Indian Manufacturing Industries. The six major activities of the supply chain; namely green sourcing & procurement, green manufacturing, green warehousing, green distribution, green packaging, green transportation were covered throughout the research. Deif [5] presented a system model for the new green manufacturing paradigm. An open mixed architecture for the design, planning and control of green manufacturing activities was developed. The model captured various planning activities to migrate from a less green into a greener and more eco-efficient manufacturing.

Agarwal *et al*. [6] presented a methodology to evaluate suppliers using portfolio analysis based on the analytic network process (ANP) and environmental factors. The study introduced green criteria into the framework of supplier selection criteria. A set of criteria covering a wide range of parameters was submitted in the form of table and opinion of expert was taken to select pertinent criteria for vendor selection. The study consisted of four main criteria clusters or dimensions as operational life, environmental friendly, overall performance, and process management. There were 21 sub criteria under the main four dimensions. Buyukozkan and Cifci [7] examined GSCM and GSCM capability dimensions to propose an evaluation framework for green suppliers. The identified components were integrated into a novel hybrid fuzzy multiple criteria decision making (MCDM) model combining the fuzzy Decision Making Trial and Evaluation Laboratory Model (DEMATEL), the Analytic Network Process (ANP), and Technique for Order Performance by Similarity to Ideal Solution (TOPSIS) in a fuzzy context. The combined fuzzy ANP and fuzzy DEMATEL approaches used in the study offered a more precise and accurate analysis by integrating interdependent relationships within and among a set of criteria.

Kumar *et al*. [8] investigated the green supply chain management practices likely to be adopted by the manufacturing industry of electrical and electronics products in India. The relationship between green supply chain management practices and environmental performance was studied. The data were analyzed using "mean score". The results indicated the performance of eco procurement, eco accounting, eco logistics design, eco product design, eco manufacturing, and economic performance, its practices in response to the current wave of national & international green issues. Kuo *et al*. [9] developed a green supplier selection model which integrated artificial neural network (ANN) and two multi-attribute decision analysis (MADA) methods: data envelopment analysis (DEA) and analytic network process (ANP). It also discovered that ANN – MADA had better power of discrimination and noise- insensitivity in evaluating green suppliers' performances. The final green supplier selection had six dimensions including quality, cost, delivery, service, environment and corporate social responsibility. Toke *et al*. [10] gave details on the investigation, practice and evaluation of green supply chain management. The research included various functions like purchasing and inbound logistics, production, distribution and out-bound logistics, and reverse logistics. A number of integration issues potentially affecting each of these functional areas were then presented.

Wu *et al*. [11] used the fuzzy Decision Making Trial and Evaluation Laboratory (DEMATEL) method to find influential factors in selecting GSCM criteria. Awasthi *et al*. [12] presented a fuzzy multi criteria approach for evaluating environmental performance of suppliers. The proposed approach consisted of 12 criteria. Hua *et al*. [13] developed a fuzzy multiple attribute decision-making (FMADM) method with a three-level hierarchical decision-making model to evaluate the aggregate risk for green manufacturing projects. Humphreys *et al*. [14] presented a framework for integrating environmental factors into the supplier selection process. Subsequently, a framework of the supplier selection process which incorporated environmental performance was developed. Chen *et al*. [15] proposed a network to clarify managerial levels and firm-related content. It derived four business functions from product lifecycle management: design, purchasing, manufacturing, and marketing and service. It also associated their related activities with ''greenness''.

Yeh and Chuang [16] developed an optimal mathematical planning model for green partner selection which involved different objectives. Lin *et al*. [17] modelled a green purchasing system by applying the analytic network process (ANP) and linear programming (LP) methods. The ANP provided the solution for green supplier selection. It consisted of criteria like energy saving, pollution reduction, social responsibility etc. Lee *et al.* [2] proposed a model for evaluating green suppliers. The Delphi method was applied first to differentiate the criteria for evaluating traditional suppliers and green suppliers. The major four activities of the green supply chain management; namely green purchasing, green manufacturing, green marketing and reverse logistics were covered throughout the study by Nimawat and Namdev [3]. Sarkis [18] discussed components and elements of green supply chain management. The decision framework was modelled and solved as an analytical network process (ANP).

III. OBJECTIVES OF STUDY

The objective of this study is to investigate the practices and implementation of green supplier selection in Indian industries. The objective is to select best factors for supplier selection with the green manufacturing approach, which can be implemented in individual manufacturing industry. The task of designing the questionnaire was carried out after reviewing a variety of literature. Based on the literature reviewed, a tentative list of the criteria for green supplier selection was developed. In the pre-testing phase of the questionnaire, practicing industry representatives were consulted for their view on the criteria selected and whether all the relevant criteria were covered in the questionnaire. Based on their feedback, the criteria list was modified and put into a structured form, with each sub-criteria falling under their respective criteria/major criteria. At the end of the pre - testing stage, 47 sub-criteria under the heading of 7 major criteria were finalized. Each criterion in the questionnaire was judged on a 5 point Likert Scale, where, 1 = very low, 2 = low, 3 = moderate, 4 = high and 5 = very high. Likert scale is a tried and tested scale has been successfully used in many cases, including supplier selection. Pallant J. [19] stated that the reliability of a scale indicates how free it is from random error. It indicated the extent to which an experiment, test or any other measuring procedure yields the same results. The reliability assessment was conducted on Statistical Package for the Social Sciences (SPSS) software. The methodology adopted is similar to the one described by Pallant J. in her book on SPSS. The responses were obtained from various manufacturing firms, chemical industries, pharmaceutical Industries, automobile industries, small workshops, and chemical laboratories. Managers/ higher level authority in different level of organizations were interviewed. This was made to obtain accurate information and data to help in the formulation of the important green evaluation measures.

Pallant J. stated in her book that reliability can be measured in various ways [19]. The most common method to measure reliability is by using Cronbach's alpha, which was carried out using SPSS. This statistic indicated the correlation of the items that make up the scale. The values ranged from 0 to 1, with higher values indicating greater reliability. Nunnally (1978) recommended a minimum value of 0.7. Cronbach's alpha values are dependent on the number of items on the scale. If the number of items in the scale is less than 10 (as in this study, where each criteria has 10 or less sub-criteria under it) then Cronbach's alpha values can be quite small. Here, the mean inter-item correlations were calculated. J. Pallant recommended their optimum value to be above 0.3.

IV. COMPARATIVE FACTOR ANALYSIS

4.1 RELIABILITY ANALYSIS

Reliability indicates the extent to which an experiment, test or any other measuring procedure yields the same results. Reliability analysis was carried out using total 47 criteria using SPSS software. The final Cronbach's values and the range of correlation coefficients will give an idea about the scale chosen, which should be free from random error. It will also help to find that the sub-criteria have been properly assigned to their respective criteria or not. The final Cronbach's Alpha values should be more than 0.7.

TABLE I. *RELIABILITY ANALYSIS*

Criteria	Total number of Items	Final Cronbach's Alpha	Range of correlation coefficients
Green Design	9	0.859	0.303-0.748
Green Logistics Design	5	0.749	0.370-0.737
Green Manufacturing	7	0.738	0.158-0.688
Green Costs	5	0.861	0.568-0.998
Quality	8	0.774	0.336-0.599
Environment performance assessment	4	0.847	0.529-0.717
Customer Co-operation	6	0.728	0.207-0.587

A visual inspection of the range of correlation coefficients column in Table I reveal that a majority of the correlations are greater than 0.3. Also Cronbach's alpha values are more than a minimum required value of 0.7. The final Cronbach's values and the range of correlation coefficients prove that the scale chosen is free from random error and that the sub-criteria have been properly assigned to their respective criteria. This indicates that the sub-criteria have common factors (Digalwar and Sangwan, 2007).

4.2 KMO AND BARTLETT'S TEST OF SPHERICITY

The next appropriateness for factor analysis was determined by examining the strength of relationships among the sub-criteria. This was conducted by three measures, the coefficients in the correlation matrix, the Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy and Bartlett's test of sphericity. Tabachnick and Fidell recommended an inspection of the correlation matrix for evidence of coefficients greater than 0.3. He stated that if only a few correlations above this level are found, then factor analysis may not be appropriate. The Bartlett's test of sphericity should be significant ($p < 0.05$) in the factor analysis to be considered appropriate. The KMO index ranges from 0 to 1 with 0.6 recommended as the minimum value [19]. Meanwhile Digalwar and Sangwan, (2007) recommended KMO value more than 0.5 as optimal. Final Cronbach's Alpha value and range of correlation coefficients is calculated using reliability analysis. Table I shows the reliability analysis of the major criteria selected for the study.

TABLE II. *KMO AND BARTLETT'S TEST OF SPHERICITY*

Criteria	KMO	Bartlett's significance value (p)
Green Design	0.685	0.000
Green Logistics Design	0.622	0.000
Green Manufacturing	0.654	0.000
Green Costs	0.761	0.000
Quality	0.604	0.000
Environment performance assessment	0.759	0.000
Customer Co-operation	0.604	0.000

Analysis of the KMO measure using SPSS in Table II reveals that all the measures meet the required standard. The Bartlett's test indicates that all the criteria are significant i.e., $p < 0.05$.

4.3 FACTOR ANALYSIS

Factor analysis was conducted on each criterion. The components were extracted in SPSS using principal component analysis with varimax rotation. Initially, factors with an Eigen value over 1 were extracted and the scree plot along with the unrotated factor solution analyzed. Those factors with a significant slope above the bend in the scree plot were extracted. A sample scree plot for green design criteria is shown in Fig.1 and sample component plot for green design is shown in Fig.2.

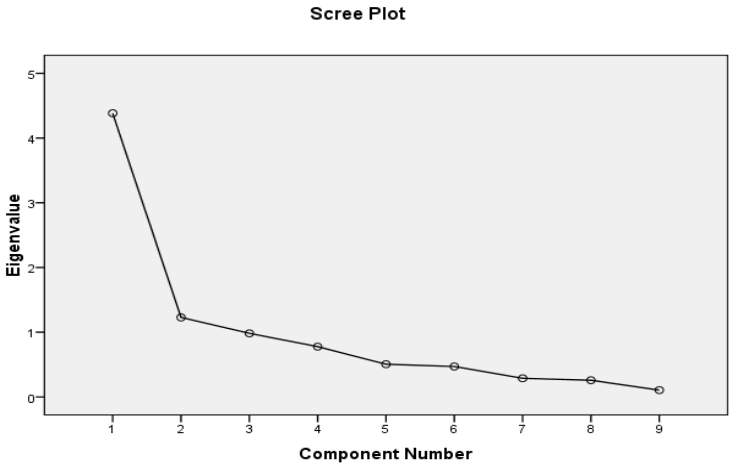

Fig.1 Sample Scree plot for green design

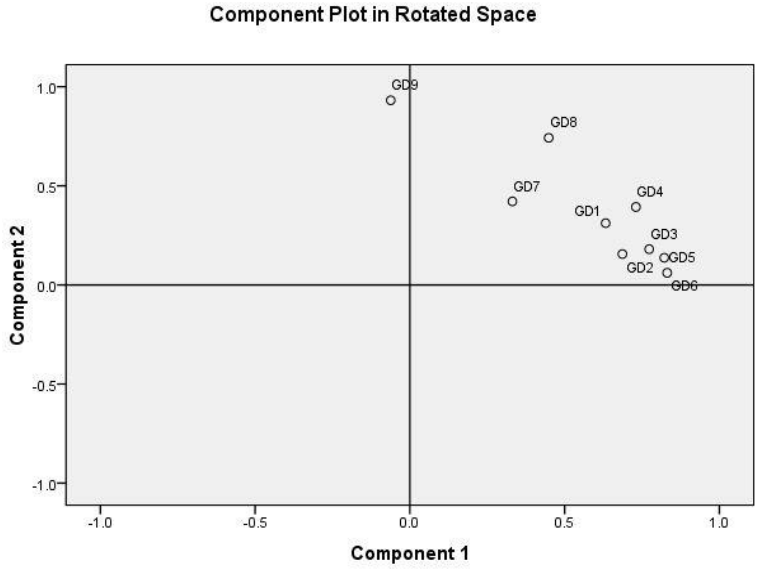

Fig.2 Sample Component plot for green design

The results of the factor analysis are shown in Table III.

TABLE III. *FACTOR ANALYSIS*

Criteria	Eigen value	% variance	Factors extracted
Green Design	4.383 1.229	48.698 62.353	2
Green Logistics Design	2.624 1.286	52.472 78.184	2
Green Manufacturing	2.999 1.196 1.071	37.485 52.441 65.831	3
Green Costs	3.354	67.089	1
Quality	2.647 1.220	52.945 77.350	2
Environment performance assessment	2.768	69.190	1
Customer Co-operation	2.497 1.173	41.615 61.158	2

4.4 IMPORTANCE OF MAIN CRITERIA FROM MEAN VALUE

In order to find out which criteria were considered important by the Indian manufacturing sector an analysis of the mean values was carried out using SPSS. Table IV shows the mean values (M) and standard deviation (S.D) of the criteria and sub-criteria respectively obtained from various respondents. The table shows the important criteria in the descending order of their means. Higher mean values indicate more important criteria. Higher mean values indicate more important criteria.

TABLE IV. *IMPORTANCE OF THE MAJOR CRITERIA*

Criteria	Mean	Std. Deviation
Quality	4.035	0.879
Environment Performance Assessment	3.984	0.825
Green Manufacturing	3.927	0.728
Customer Co-operation	3.863	0.727
Green Costs	3.794	0.799
Green Design	3.692	0.876
Green Logistics Design	3.561	0.863

Fig.3 shows importance of the major criteria in Indian Industries. Mean value gives an indication of the important criteria to be considered in supplier selection using green manufacturing approach.

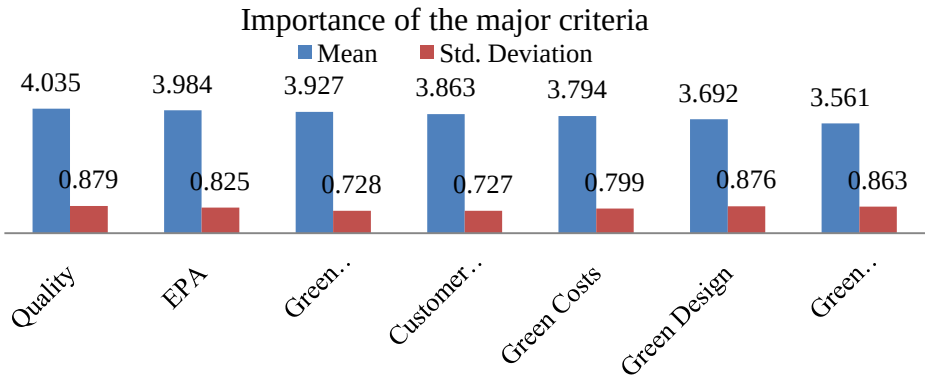

Fig.3 Importance of the major criteria in Indian Industries

V. CONCLUSION

This research presents practitioners with a 1 to 5 item measurement scale for evaluating the different facets of their green supply chain practices implementation. Green supply chain management (GSCM) is a relatively new green issue for the majority of Indian industries. The present empirical study investigated the GSCM practices adopted by different industries in Maharashtra, India. An analysis of the results indicated that quality is the most important criteria for the manufacturing industry in India. Quality was followed by environment performance assessment, green manufacturing, and customer co-operation. Surprisingly green cost, which is generally, regarded the only parameter considered for supplier selection occupies fifth place. This showed that Indian manufacturing companies compromise on cost in order to procure and thus produce products of better quality and environmentally friendly. Supplier providing better service and delivery reliability is chosen over a cheaper supplier who is weaker in these parameters.

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