International Journal of Engineering and Advanced Technology (IJEAT)
ISSN: 2249-8958 (Online), Volume-2 Issue-5, June 2013

Development and Validation of Performance Measures for Green Supplier Selection in Indian Industries

Samadhan P. Deshmukh, Vivek K. Sunnapwar

Abstract — An environmentally conscious supply chain, also called a green supply chain, is a new concept appearing in recent literature. The purpose of this study is to identify the critical green manufacturing factors considered during supplier selection in the Indian manufacturing sector. The approach of the research includes a literature review, in-depth interviews and questionnaire surveys. The major activities of the green supply chain; namely green design, green logistic design, green manufacturing, green costs, quality, environment performance assessment, customer co-operation are covered throughout the research. Factor analysis is done using Statistical Package for the Social Sciences (SPSS) software to help managers understand the important environmental dimensions. Factor analysis is used to evaluate the relative importance of various environmental factors. The data are analysed using "mean score".

Index Terms— Green Manufacturing, green supplier selection, environmental performance measures, factor analysis.

I. INTRODUCTION

The green supplier selection process is one of the key operational tasks for sustainable supply chain partners. The powerful supplier should enhance the performance of the supply chain with environmental, social and economical aspects [1]. Green supply chain management (GSCM) is a fastest growing concept in developing countries and having its presence both in environment management and supply chain management literature. Adding the 'green' dimension to supply chain management (SCM) involves addressing the influence and relationship between supply-chain management and the natural environment. 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 [1]. With increasing government regulation and stronger public awareness in environmental protection, firms today simply cannot ignore environmental issues if they want to survive in the global market [2]. In addition to complying with the environmental regulations for selling products in certain countries, firms need to implement strategies to voluntarily reduce the environmental impact of their products. The integration of environmental, economic and social performances to achieve sustainable development is a major business challenge for the new century.

Manuscript published on 30 June 2013.
***** Correspondence Author (s)
Samadhan Deshmukh, Pursuing M. E. in Mechanical Engineering, Mumbai University, Mumbai, India.
Vivek Sunnapwar, Principal in Lokmanya Tilak College of Engineering, Mumbai, India

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 [3].

This study explains the practices and implementation of green supply chain and environmental performance among various manufacturing industries located in India. Total seven 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

The works on the evaluation and/or selection of suppliers are abundant; those that concern environmental issues are rather limited. There are only few studies related to green supply chain management. Approaches towards green supply chain management (GSCM) practice have been identified by various researchers. Baskaran *et al*. [4] evaluated suppliers within the Indian textile and clothing industry (both garment manufacturers and ancillary suppliers) using sustainability criteria. Sample of sixty-three suppliers and six sustainability criteria including discrimination, abuse of human right, child labour, long working hours, unfair competition, and pollution were examined. Bhateja *et al*. [5] 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 and procurement, green manufacturing, green warehousing, green distribution, green packaging, and green transportation were covered throughout the research. Deif [6] 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.

Wu *et al*. [7] used the fuzzy decision making trial and evaluation laboratory (DEMATEL) method to find influential factors in selecting GSCM criteria.

Awasthi *et al*. [8] presented a fuzzy multi criteria approach for evaluating environmental performance of suppliers. The approach proposed consisted of 12 criteria. Hua *et al*. [9] 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. A framework was presented for integrating environmental factors into the supplier selection process [10]. Subsequently, a framework of the supplier selection process which incorporated environmental performance was developed. Chen *et al*. [11] proposed a network to clarify managerial levels and firm-related content. It derived four business functions from product life-cycle management: design, purchasing, manufacturing, and marketing and service. It also associated their related activities with greenness.

Yeh and Chuang [12] developed an optimal mathematical planning model for green partner selection which involved different objectives. Lin *et al*. [13] 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. A model was proposed for evaluating green suppliers [2]. 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 [14]. Sarkis [15] discussed components and elements of green supply chain management. The decision framework was modelled and solved as an analytical network process (ANP). Kumar *et al*. [16] 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 study proposed that the factors like green sourcing and procurement, green manufacturing, green warehousing, green distribution, green packaging, and green transportation play important role in supplier selection.

III. RESEARCH METHODOLOGY

Based on the literature reviewed, a tentative list of the criteria for green supplier selection was developed. The task of designing the questionnaire was carried out after reviewing a variety of literature. 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 seven major criteria were finalized. Each criterion in the questionnaire was judged on a five 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. Reliability indicates the extent to which an experiment, test or any other measuring procedure yields the same results [17]. The reliability assessment was conducted on Statistical Package for the Social Sciences (SPSS) software. The methodology adopted was 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. The most common method to measure reliability is by using Cronbach's alpha, which was carried out using SPSS. The value ranges 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 criterion has 10 or less sub-criteria under it) then Cronbach's alpha values can be quite small. Here, the mean inter-item correlations were also calculated. J. Pallant [17] recommended their optimum value to be above 0.3. Item analysis was conducted for each of the 47 parameters through a mean score method. These dimensions are represented in the form of a questionnaire, for measuring the different facets of GSCM practices implementation.

IV. FACTOR ANALYSIS, RESULT ANALYSIS AND DISCUSSION

A. *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 on SPSS software. The final Cronbach's values and the range of correlation coefficient give an idea about the scale chosen. It also helps 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 shows the reliability analysis of the major criteria selected for the study.

TABLE I. Reliability analysis

Criteria	Total Items	Final Cronbach's Alpha	Range of correlation coefficients
Green design	9	0.859	0.303-0.748
Green logistic 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

Published By:
Blue Eyes Intelligence Engineering
and Sciences Publication (BEIESP)

B. 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. The study stated that if only a few correlations above the required level are found, the 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 [17]. Meanwhile Digalwar and Sangwan [18] recommended KMO value more than 0.5 as optimal. Final Cronbach's alpha value and range of correlation coefficients is calculated using reliability analysis. Also, the correlation matrix in Table I shows that a majority of the correlations are greater than 0.3. . It can be seen from the table that reliability analysis confirms all the seven major criteria are suitable for applying factor analysis. This indicates that the sub-criteria have common factors [18].

Table II shows KMO and Bartlett's test of sphericity analysis of the major criteria selected for the study. 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 ($p < 0.05$).

C. 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 Eigen value over one were extracted and the scree plot along with the unrotated factor solution analysed. Those factors with a significant slope above the bend in the scree plot were extracted [17]. A sample scree plot for green design criterion is shown in Fig.1 and sample component plot for green design is shown in Fig.2.

TABLE II. KMO and Bartlett's test of sphericity

Criteria	KMO	Bartlett's significance value (p)
Green design	0.685	0.000
Green logistic 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

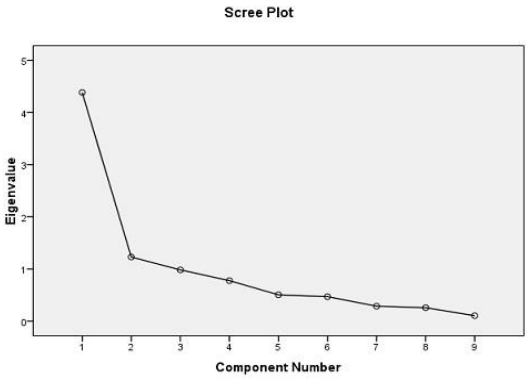

Fig.1 Sample scree plot for green design

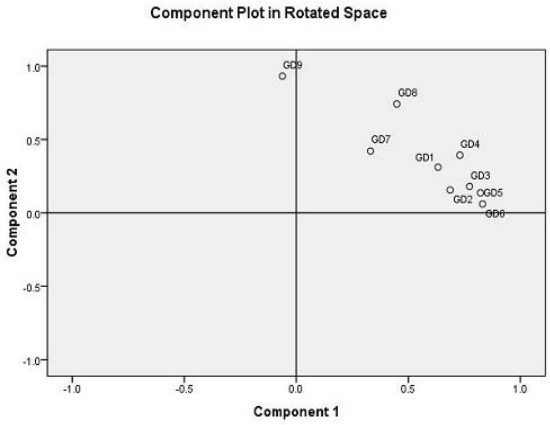

Fig.2 Sample component plot for green design

Also, the results of the factor analysis are shown in Table

TABLE III. Factor Analysis

Criteria	Eigen Value	% Variance	Factors Extracted
Green design	4.383 1.229	48.698 62.353	2
Green logistic 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

Seven green supply chain factors with 47 underlying dimensions considered in this study and each dimension has its own importance for effective green supply chain performance. Table IV to Table XI shows the mean values (M) and standard deviation (S.D) of the criteria and sub-criteria respectively obtained from various respondents. The tables show the important criteria in the descending order of their means. Higher mean values indicate more important criteria.

Published By:
Blue Eyes Intelligence Engineering
and Sciences Publication (BEIESP)

TABLE IV. Performance of main factors

Criteria	Mean	Std. Deviation
Quality (QTY)	4.04	0.879
Environment performance assessment (EPA)	3.98	0.825
Green manufacturing (GM)	3.93	0.728
Customer co-operation (CC)	3.86	0.727
Green costs (GC)	3.79	0.799
Green design (GD)	3.69	0.876
Green logistic design (GLD)	3.56	0.863

Among all seven main green supply chain factors quality (4.04) was the most important criteria for the manufacturing industry in India. Quality was followed by environment performance assessment, green manufacturing, and customer co-operation respectively.

TABLE V. Performance of green design

Sub-criteria	Mean	Std. Deviation
Design of products for optimum consumption of material/energy	4.16	.898
Co-operation & feedback with customer in developing eco-design	3.87	.718
Importance of recycling product design from supplier	3.77	.845
Products design meet environmental regulation and safety standards	3.68	.979
Degree of use of environment friendly technology by supplier	3.65	.915
Degree of use of environment friendly materials by supplier	3.65	.755
Product design and developed for ease in dismantling and remanufacturing	3.58	.923
Renewable product design of supplier	3.52	.962
Possibility of eliminating secondary processes considered.	3.35	.915

Green design which had 9 underlying dimensions was having design of products for optimum consumption of material/energy (4.16) as the most important dimension.

TABLE VI. Performance of green logistic design

Sub-criteria	Mean	Std. Deviation
Degree of Use of recycled material for packaging material considered	3.90	.790
Packaging material disposal planned	3.81	.833
Minimizing the use of packaging considered	3.58	.923
Product recycling rate	3.29	1.101
Importance of Having reverse logistic system of supplier	3.23	.669

Green logistic design which had 5 underlying dimensions was having consideration of recycled material for packaging material as the most important dimension (3.90) followed by planning of packaging material disposal (3.81).

TABLE VII. Performance of green manufacturing

Sub-criteria	Mean	Std. Deviation
Consideration of reduction in setup time	4.13	.562
Minimizing toxic/hazardous waste during manufacturing	4.10	.746
Consideration of environmental issue in selection of manufacturing process	4.06	.772
Measures taken to reduce material & energy used in manufacturing	4.03	.752
Consideration of environmental issue in production planning and control	3.97	.795
Optimum energy consumption during manufacturing process	3.87	.516
Minimizing use of natural resources during manufacturing	3.77	.447
Possibility of product being recyclable, reusable	3.48	.658

Green manufacturing which had 8 underlying dimensions was having a reduction in setup time (4.13) as the most important dimension followed by minimization of toxic/hazardous waste during manufacturing (4.10).

TABLE VIII. Performance of green cost

Sub-criteria	Mean	Std. Deviation
Increase of cost in purchasing environmentally friendly materials	4.06	.998
Degree of reduction in overall cost of the organization	3.94	.814
Degree of Reduction in transportation cost	3.84	.898
Water & air pollution treatment cost	3.58	.720
Energy consumption costs	3.55	.568

Green cost which had 4 underlying dimensions was having cost in purchasing environmentally friendly materials (4.06) as the most important dimension followed by reduction in the overall cost of the organization.

TABLE IX. Performance of quality

Sub-criteria	Mean	Std. Deviation
Acceptance rate of product by customer	4.42	.720
Capability of quality management in organization	4.39	.803
Degree of having quality -related certificates	4.10	1.076
Capability of handling abnormal quality	4.00	.775
Amount of goods delivered on time improved	3.94	.929
Extent of process improvement	3.87	1.118
Warranties and claim policies for customers	3.87	.763
Achievement in higher technological level	3.87	.885
Improvement in capability of research and development	3.87	.846

Published By:
Blue Eyes Intelligence Engineering
and Sciences Publication (BEIESP)

Quality which had 9 underlying dimensions was having an acceptance rate of product by customer (4.42) as the most important dimension.

TABLE X. Performance of environment performance assessment

Sub-criteria	Mean	Std. Deviation
Achievement of cleanser production	4.16	.860
Minimization of air emission and waste water	4.00	.931
Optimization of man-power resources in production process	3.90	.790
Degree of reduction in energy consumption	3.87	.718

Environment performance assessment which had 4 underlying dimensions was having achievement of Cleanser production (4.16) as the most important dimension.

TABLE XI. Performance of customer co-operation

Sub-criteria	Mean	Std. Deviation
Co-operation from customers for using less energy during product transportation	4.19	.543
Degree of co-operation from customers for green packaging	4.16	.779
Degree of co-operation from customers for cleaner production	4.16	.735
Degree of co-operation from customers for eco-design	3.97	.657
Encouragement in giving suggestions on environmental performance	3.87	.670
Degree of co-operation with customers for environmental procurement	3.81	.601
Degree of customers involvement in process of determining environmental goals	3.81	.980

Customer co-operation which had 8 underlying dimensions was having usage of less energy during product transportation (4.19) as the most important dimension by customers followed co-operation from customers for green packaging. To summarize, Fig. 3 shows importance of the major green supplier criteria in Indian industries.

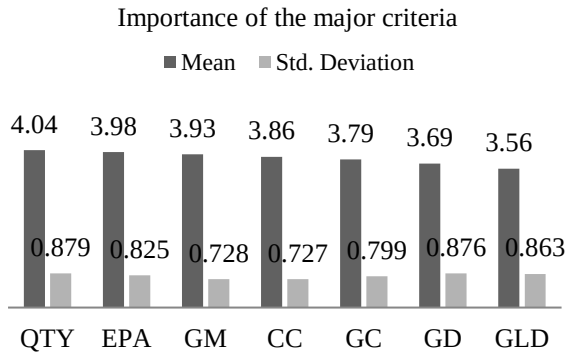

Fig.3 Importance of the major criteria in Indian industries

V. CONCLUSION

The 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. The study investigated the important performance measures for green supplier selection by "mean method".

The study shows that among all 7 main green supply chain performance measures quality is the most important criteria for the manufacturing industry in India. Quality is followed by the 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. It is seen that Indian manufacturing companies compromise on cost in order to procure and produce products of better quality and environmentally friendly. Green cost is followed by green design and green logistic design respectively. Supplier providing better service and delivery reliability should be chosen over a cheaper supplier who is weaker in these parameters.

REFERENCES

[1] G. Kannan, J. Sarkis, R. Sivakumar, M. Palaniappan, "Multi criteria decision making approaches for green supplier evaluation and selection: A literature review", *Conference on the Greening of Industry Network, GIN 2012*, Linkoping – Sweden, October 22-24, 2012.
[2] A. H. I. Lee., H-Y Kang, C-F Hsu, H-C Hung, "A green supplier selection model for high-tech industry", *Expert Systems with Applications*, vol. 36, 2009, pp. 7917–7927.
[3] J. Sarkis, "Evaluating environmentally conscious business practices". *European Journal of Operational Research*, vol. 107, 1998, pp. 159–174.
[4] V. Baskaran, S. Nachiappan, S. Rahman, "Indian textile suppliers' sustainability evaluation using the grey approach", *Int. J. Production Economics*, vol. 135, 2012, pp. 647–658.
[5] A. K. Bhateja, R. Babbar, S. Singh, A. Sachdeva, "Study of green supply chain management in the Indian manufacturing Industries: A literature review cum an analytical approach for the measurement of performance", *International Journal of Computational Engineering & Management*, vol. 13, 2011, pp. 84–99.
[6] A. M. Deif, "A system model for green manufacturing", *Journal of Cleaner Production*, vol. 19, 2011, pp. 1553–1559.
[7] K-J Wu, M-L Tseng, T. Vy, "Evaluation the drivers of green supply chain management practices in uncertainty", *Procedia - Social and Behavioral Sciences*, vol. 25, 2011, pp. 384 – 397.
[8] A. Awasthi, S. S. Chauhan, S. K. Goyal, "A fuzzy multicriteria approach for evaluating environmental performance of suppliers'', *Int. J. Production Economics*, vol. 126, 2010, pp. 370–378.
[9] L. Hua, C. Weiping, K. Zhixin, N. Tungwa, L. Yuanyuan, "Fuzzy multiple attribute decision making for evaluating aggregate risk in green manufacturing", *Tsinghua Science and Technology*, ISSN 1007-0214, vol. 19/20, 2005, pp. 627–632.
[10] P. K. Humphreys, Y. K. Wong, F. T. S. Chan, "Integrating environmental criteria into the supplier selection process", *Journal of Materials Processing Technology*, vol. 138, 2003, pp. 349–356
[11] C-C Chen, H-J Shyur, H-S Shih, K-S Wu, "A business strategy selection of green supply chain management via an analytic network process", *Computers and Mathematics with Applications*, vol. 64, 2012, pp. 2544–2557.
[12] W-C Yeh, M-C Chuang, "Using multi-objective genetic algorithm for partner selection in green supply chain problems", *Expert Systems with Applications*, vol. 38, 2011, pp. 4244–4253.
[13] C-T Lin, C-B Chen, Y-C Ting, "A green purchasing model by using ANP and LP methods", *Journal of Testing and Evaluation*, vol. 40, No. 2, 2012, Paper ID JTE104259
[14] D. Nimawat, V. Namdev, "An overview of green supply chain management in India", *Research Journal of Recent Sciences*, vol. 16, 2012, pp. 77–82.

[15] J. Sarkis, "A strategic decision framework for green supply chain management", *Journal of Cleaner Production*, Vol. 11, 2003, pp. 397–409.
[16] S. Kumar, S. Chattopadhyaya, V. Sharma, "Green supply chain management: A case study from Indian electrical and electronics industry". *International Journal of Soft Computing and Engineerin*g, vol. 1, Issue-6, 2012, pp. 275–281
[17] J. Pallant, *SPSS Survival manual*, Open University press, 2001.
[18] A. K. Digalwar, K. S. Sangwan, "Development and validation of performance measures for world class manufacturing practices in India", *Journal of Advanced Manufacturing Systems*, vol. 6, 2007, pp. 21–38.

Samadhan Deshmukh received B. E. in Mechanical Engineering from Shivaji University, Kolhapur in 2008. He is currently pursuing M. E. in Mechanical Engineering (With specialization in Manufacturing Systems) from Mumbai University. For last 4 years he is working as Assistant Professor in Watumull Institute, Worli, Mumbai-18.

Vivek Sunnapwar completed his doctoral research in the year 2004 from Amravati University. He joined Lokmanya Tilak College of Engineering, Navi Mumbai in the year 2005 as a Professor. He is currently working as a Principal in Lokmanya Tilak College of Engineering, Navi Mumbai. He has published number of research papers in journals and proceedings of national and international seminar/ conferences.

Published By:
Blue Eyes Intelligence Engineering and Sciences Publication (BEIESP)