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Environmental and Social Conscious Green Supplier Selection in Tamilnadu Textile Industry

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Abstract: ***Green and human rights are becoming important criteria for industry to achieve global standards. In this paper, we concentrated on the textile industry, which is considered as the base industry across the globe. Environmental load is increased because of the waste from the textile industry. Maximum waste is generated while converting the fiber into raw material for the textile industry. Textile companies are keen in selecting suitable and Green suppliers in their supply chain to increase their environmental performance and decrease their hazardous effects on the environment. For selecting suitable and Green suppliers a performance evaluation system is necessary. Thus, in our study, a model for evaluating the traditional performance along with a Green and social performance of suppliers is proposed using Grey approach. The criteria required for the evaluation are obtained through a brainstorming session. The identified criteria are evaluated using the grey approach. Finally to validate the weights of the criteria a sensitivity analysis was conducted.***

Keywords: Supply Chain, Green Supplier Selection, Textile Industry, Grey Approach.

1. Introduction

The process of transforming raw materials into final products and then delivered to the end-customer is called as a traditional supply chain process [1][2]. In this process the natural resources are extracted and exploited. Because of this serious environmental problems, like global warming and acid rain are caused mainly due to the waste and emission by the supply chain [3]. Environmental sustainability has been an important issue in recent times. To obtain environmental sustainability, Green supply chain has become an important and interesting area in which most of the researches are researching. Green supply chain management includes Green purchasing, Green manufacturing, Green distribution and Reverse logistic. In Green supply chain, Green supplier selection plays a vital role. In an organization the suppliers' selection has become the most critical activity and a strategic purchasing decision that commits significant resources (40-80 percent of total product cost), impacts the total performance of the organization, image of the organization and organization environmental performance [4]. Therefore, organizations have to establish close and integrated relationships with their supplier to develop their environmental performance [5]. Green supplier selection is the best way to maintain the environmental standards. For this every organization has to evaluate Green performance of their suppliers.

Along with the Green performance, Social performance of an organization is also important. The countries where the sustainability reporting is mandatory, the multinational firms in these countries outsources their products the developing nations where there is no essential requirement to adhere the various aspects of sustainable development. The importance of sustainability issues in business can be understood through the recent experiences of three multinational companies: Reebok, Satyam Computer Services, and Coco-Cola. Reebok India have done corporate's fraud of Rs. 870 crore. Some of its officials and employees have defected a systematic "mismanagement" in the business planning and the running. The governance and operations were mismanaged. The bills were inflated and not recorded correctly. In 2009, Satyam computer Service (India) have manipulated the firm's account for more than seven year to attract businesses. The manipulation was done by the founder and the members of senior management at Satyam Computer Services (India). This led to the firm's involvement in an US$1.47 billion fraud case. Similarly, in 2005, several new plants of Coco-Cola in India was on the brink of closing down its operations for non-compliance of environmental issues.

These three examples demonstrate that though there are many aspects of industry sustainability, there are some that are critical; these include workforce practices, social issues such as corruption, and environmental issues such as pollution. The work force aspect includes consideration of criteria such as discrimination, abuse of human rights, child labor, long working hours, corruption, and pollution. The rest of the paper is organized as follows. A literature review was conducted on criteria and methods for selection and evaluation of the suppliers are presented in section 2. In section 3, presents the research design. We presented a Gray approach methodology for evaluating and selecting the Green supplier in section 4. Section 5, presents a numerical application of the proposed approach. In section 6, we presented the conclusions and future work.

2. Literature Review

Supplier selection and evaluating their performance is not new. But Selection of suitable suppliers and evaluating his performance is the most important strategies for enhancing the quality and reputation of the organization [6]. In the traditional selection process, environmental criteria are added to make the supplier more conscious about the environment. Important literatures on Green supplier evaluation criteria and methods used to evaluate the environmental performance of the supplier are described in the coming paragraphs.

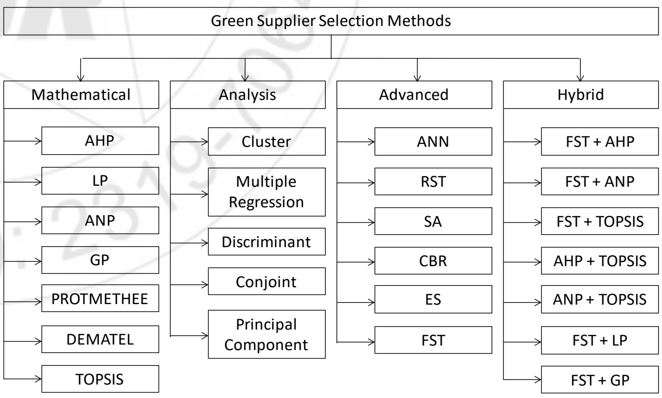
For a proactive Green strategy Green Competence, Current Environmental Efficiency, Supplier's Green Image, and Net Life Cycle Cost are the four major criteria used by an organization in supplier evaluation and selection process [7]. Greening the supplier selection process is an important activity to be carried out by the organization improving their image in the market. Environmental Costs due to pollutant effects, Environmental Costs for improvement, Management Competencies, Green Image, Design for Environment, Environmental Management Systems, and Environmental competencies are the seven major criteria that will play a vital role in supplier evaluation and selection process using the multistage framework [8]. Five stages are there in the lifecycle of products and they are pre manufacturing, manufacturing, distribution/packaging, use/maintenance and end of life. Materials, energy consumed, solid residue, liquid residue, gaseous residue and technology are vital environmental criteria in this five lifecycle stage using multi-objective decision analysis [9]. Six criteria are vital for the assessment of environmental performance of a supplier. And the criteria are Pollution Control, Environmental and legislative management, Green Product, Green Image, Environmental costs and Green Process management using hybrid fuzzy multicriteria decision approach [10]. Similar to Tuzkaya et. Al., Lee et al. identified six major criteria like quality, technology capability, pollution control, environment management, Green Product, Green Competence with comprehensive sub-criteria for evaluation of supplier's environmental performance using the Delphi method and fuzzy extended analytic hierarchy process [11].

Use of environmental friendly technology, Use of environmental friendly material, Green market share, Partnership with Green organization, Management commitment, Adherence to environmental policies, Green R&D projects, Staff Training, Lean process planning, Design for environment, Environment certification, and Pollution control initiatives are the twelve criteria used to assess the environmental performance of the supplier using Fuzzy TOPSIS was identified [12]. Kuo et al. proposed Delphi method to identify supplier selection criteria which had six dimensions like quality, cost, delivery, service, environment and corporate social responsibility [13]. Baskaran et al. proposed new criteria such as discrimination, abuse of human rights, child labor, long working hours, and society/unfair competition for evaluating the social responsibility of the supplier using the grey approach [14]. Green Technology Capabilities, Green Purchasing Capabilities, Green Design, Life Cycle Assessment, Internal Green Production Plans, Green Production, Green Certificates, the Reduction of Hazardous Materials in the Production Process, and Environmental Management Systems are the ten criteria considered in selecting the supplier based on linguistic preferences and gray-fuzzy theory [15].

Shaw et al. identified Greenhouse gas emission as a constraint while selecting a supplier with traditional criteria like cost, quality rejection percentage, late delivery percentage and demand using fuzzy AHP and fuzzy multi-objective linear programming [16]. From Table 1 it is clear that availability of Clean Materials, environmental management systems, Technology capability, Green competence and Life Cycle Assessment are the most commonly referred criteria in supplier evaluation. Figure 1 shows the various techniques used to evaluate and select Green suppliers. The selection method is broadly classified as four such as mathematical analysis, advanced and hybrid.

Table 1: Generally used criteria for environmental performance assessment of suppliers

Criteria	*References*
Green Competence	[7], [8], [11]
Current Environmental Efficiency	[7]
Supplier's Green Image	[7]
Life Cycle Assessment	[7], [9], [15]
Environmental Costs	[8], [10]
Green Image	[8], [10]
Design for Environment	[8], [15]
Environmental Management Systems	[8], [10], [11], [15]
Green Process management	[10]
Green Product	[10], [11]
Technology capability	[9], [11], [12], [15]
Clean Material	[9], [12], [15]
Green market share	[12]
Partnership with Green organization	[12]
Management commitment	[12]
Adherence to environmental policies	[12]
Green R&D projects	[12]
Human resource development for Environmental performance	[12]
Lean process planning	[12]
Human Rights	[19], [21]
Green certifications	[12], [15]
Greenhouse gas emission	[9], [16]



AHP – Analytic Hierarchy Process LP – Linear Programming
ANP – Analytic Network Process GP – Goal Programming
PROTMETHEE – Preferred Rank Organization Method for Enrichment Evaluation Network RST – Rough Set Theory
DEMATEL – Decision Making Trail and Evaluation
TOPSIS – Technique for Order Preference by Similarity to Ideal Solution
ANN – Artificial Neural Network SA – Software Agent
CBR – Case Based Reasoning ES – Expert System
FST – Fuzzy Set Theory

Figure 1: Green Supplier Selection Methods

3. Research Design

India is the second largest fiber producer in the world and the major fiber produced is cotton along with silk, jute, wool, etc. The textile industry is a base industry as everybody needs clothing. We conducted this study in a cluster of textile industry located in Tirupur, Coimbatore and Erode District of Tamil Nadu. These Districts have approximately 700 ancillary units which provide the raw material for the garment manufactures. The conversion of fiber into the raw material required for textile industry creates more loads to the environment. To reduce these loads Greening the supplier is important.

In supplier selection criteria along with traditional criteria some important environmental performance assessment and social performance assessment criteria are added and evaluated. In our work we have considered Gray approach for selecting and evaluating the supplier. Linguistic terms for alternatives ratings and linguistic terms for criteria weightings respectively are given in Table 2 and Table 3. The methodology for evaluation is described in the next section of the paper.

Table 2: Linguistic terms for supplier ratings

Linguistic Term		Membership Function
Poor	P	(0,1)
Fair	F	(1,3)
Average	A	(3,5)
Good	G	(5,7)
Excellent	E	(7,9)

Table 3: Linguistic terms for criteria weights

Linguistic Term		Membership Function
Not Important	NI	(0,0.1)
Somewhat Important	SI	(0.1,0.3)
Important	IM	(0.3,0.5)
Very Important	VI	(0.5,0.7)
Extremely Important	EI	(0.7,0.9)

4. Grey Approach Methodology

The proposed Grey approach for evaluating supplier's environmental performance consists of eight steps and these steps are presented in detail as follows [20].

Step 1: Selection of evaluation criteria

In this methodology one of the most significant parts is to identify the criteria and measuring indicators. Criteria and sub-criteria affecting on suppliers' selection processes differ based on their objectives of the organization. Criteria are identified by brainstorming session with experts for their strategic goals.

Step 2: Assignment of weight to criteria and rating for the suppliers

Let l be number of supplier called S = (S_1, S_2, S_3, … , S_l) and m be number of criteria called C = (C_1, C_2, ….., C_m). The criteria weights are denoted by w_m (m=1, 2, ……, i). The performance ratings of each decision maker D_k(k=1, 2,….., K) for each supplier is denoted by d_l (l=1,2,…,j). In this step the decision maker will evaluate the criteria and supplier and determine the linguistic term for them. With reference to the linguistic term from the table 2 and 3 the grey rating for the supplier and grey weight for the criteria is assigned.

Step 3: Calculate aggregate grey weight for criteria and rating for the supplier. Determine the Decision matrix.

If the grey weights for criteria and grey rating for suppliers of all decision makers is described R_k = (x_k, y_k), k= 1,2 ,…, K, then the aggregated grey weight for criteria and rating for suppliers is given by R = (x, y), k=1,2,.., K where

$$x = \frac{1}{K}\sum_{k=1}^{K} x_k \qquad y = \frac{1}{K}\sum_{k=1}^{K} y_k \tag{1}$$

The aggregate grey weight for the criteria and aggregate grey rating for the supplier is determined using the equation 1. The fuzzy decision matrix (DM) is determined for the supplier S and the criteria C are constructed.

Step 4: Calculated the weighted normalized matrix

The data are normalized using linear scale transformation to bring the various criteria scales into a comparable scale. The normalized grey decision matrix R is give by

$$R = [r_{ml}]_{i \times j} \quad m=1,2,\dots, i \quad l=1,2,\dots, j \tag{2}$$

Where

$$r_{ml}=\left(\frac{x_{ml}}{y_l^*}, \frac{y_{ml}}{y_l^*}\right) \text{ and } y_l^* = \max_m y_{ml}$$

The weighted normalized matrix V for criteria is calculated by multiplying the weights (w_l) of the evaluation criteria with normalized fuzzy decision matrix r_{ml}

$$V = [v_{ml}]_{i \times j} \quad m=1,2,\dots, i \quad l=1,2,\dots, j \tag{3}$$

Where $v_{ml} = (w_l)\,(r_{ml})$

Step 5: Set ideal supplier alternative as referential supplier

From m possible supplier set S the ideal referential supplier S^{max} = (G_1^{max}, G_2^{max},…, G_i^{max}) is obtained using

$$S^{max}=\{[\max_l(\bar{v}_{1l},\underline{v}_{1l})], [\max_l(\bar{v}_{2l},\underline{v}_{2l})], \dots\dots, [\max_l(\bar{v}_{il},\underline{v}_{il})]\} \quad l=1,2,\dots, j \tag{4}$$

Step 6: Calculate the Grey possibilities

Compare suppliers set S to the ideal referential supplier S^{max}

$$P\{S_m \le S^{max}\} = 1/m \sum_{m=1}^{i} P(v_{ml} \le G_m^{max}) \tag{5}$$

Lower is best

Step 7: Ranking the suppliers.

In this step the based on $P\{S_l \leq S^{max}\}$ value the supplier is ranked.

Step 8: Conduct sensitivity analysis to determine the influence of criteria weights on decision making.

Sensitivity analysis is useful in situations where uncertainties exist in the definition of the importance of different factors. It is conducted to see the importance of criteria weights in evaluating the environmental performance of supplier.

5. Numerical Illustration

To identify the criteria with regards to their strategic goals a brainstorming session was conducted with the main player in the Tamil Nadu textile industry. In the brainstorming session we have identified 10 criteria in which 6 are traditional criteria, 2 are environmental performance criteria and 2 are social responsibility criteria.

The identified criteria are presented in the Table 4. Traditional criteria describe the financial performance, quality assured, on time delivery, technology used for fiber conversion, and flexibility. Environmental performance criteria describe the clean production capability of the supplier and their environment management system. Social responsibility criteria describe the concern for the human resource work there and responsibility towards society.

Table 4: Identified Criteria

Id	*Criteria*	*Id*	*Criteria*
C_1	Cost	C_6	Technology
C_2	Quality	C_7	Clean Production
C_3	Reliability	C_8	Environment Management System
C_4	Flexibility	C_9	Human Rights
C_5	Delivery	C_{10}	Corporate Social Responsibility

For illustration we have described the method using 4 suppliers and 4 expert evaluating 10 criteria. Decision makers have investigated all the criteria and supplier, respective weights and ratings in linguistic term has provided in the Table 5 and Table 6.

Table 5: Linguistic assessments for 10 criteria

Criteria	*Decision Makers*			
	D_1	D_2	D_3	D_4
C_1	SI	IM	VI	SI
C_2	IM	SI	IM	VI
C_3	NI	SI	NI	IM
C_4	IM	NI	SI	NI
C_5	VI	EI	VI	VI
C_6	VI	VI	VI	EI
C_7	EI	VI	EI	EI
C_8	VI	EI	VI	VI
C_9	EI	VI	IM	EI
C_{10}	SI	IM	IM	SI

Table 6: Linguistic assessments for four suppliers

Criteria	*Supplier*							
	S_1				S_2			
	D_1	D_2	D_3	D_4	D_1	D_2	D_3	D_4
C_1	G	A	F	A	G	A	G	F
C_2	E	G	A	A	G	E	G	A
C_3	A	G	G	E	E	E	A	G
C_4	G	G	E	G	G	A	E	E
C_5	G	A	A	A	A	G	G	A
C_6	E	A	A	G	G	E	G	G
C_7	G	A	F	F	G	G	A	F
C_8	G	G	A	G	E	G	E	A
C_9	F	A	P	F	P	F	F	F
C_{10}	G	F	A	G	F	A	A	G
Criteria	*Supplier*							
	S_3				S_4			
	D_1	D_2	D_3	D_4	D_1	D_2	D_3	D_4
C_1	G	F	A	A	A	F	F	G
C_2	A	G	E	G	G	F	A	E
C_3	G	A	A	G	E	G	A	A
C_4	A	A	G	E	E	E	G	A
C_5	G	A	F	A	A	G	A	G
C_6	E	G	G	E	E	G	G	G
C_7	F	G	A	F	G	G	F	A
C_8	G	G	A	E	A	A	G	E
C_9	A	A	F	P	P	P	F	A
C_{10}	A	F	G	A	G	G	A	F

Using the linguistic assessments provided the decision makers their grey membership function is obtained from Table 2 and Table 3. For these grey weights an aggregate grey weights are computed using the equation (1) for the criteria and rating for the supplier and shown in the Table 7 and Table 8 respectively

Table 7: Aggregate Grey Criteria Weights

Criteria	*Aggregate grey weight*	
C_1	0.25	0.45
C_2	0.30	0.50
C_3	0.10	0.25
C_4	0.10	0.25
C_5	0.55	0.75
C_6	0.55	0.75
C_7	0.65	0.85
C_8	0.55	0.75
C_9	0.55	0.75
C_{10}	0.20	0.40

Table 8: Aggregate Grey Decision Matrix for Suppliers

Criteria	*Suppliers*							
	S_1		S_2		S_3		S_4	
C_1	3.0	5.0	3.5	5.5	3.0	5.0	2.5	4.5
C_2	4.5	6.5	5.0	7.0	5.0	7.0	4.0	6.0
C_3	5.0	7.0	5.5	7.5	4.0	6.0	4.5	6.5
C_4	5.5	7.5	5.5	7.5	4.5	6.5	5.5	7.5
C_5	3.5	5.5	4.0	6.0	3.0	5.0	4.0	6.0
C_6	4.5	6.5	5.5	7.5	6.0	8.0	5.5	7.5
C_7	2.5	4.5	3.5	5.5	2.5	4.5	3.5	5.5
C_8	4.5	6.5	5.5	7.5	5.0	7.0	4.5	6.5
C_9	1.3	3.0	0.8	2.5	1.8	3.5	1.0	2.5
C_{10}	3.5	5.5	3.0	5.0	3.0	5.0	3.5	5.5

From the aggregate Grey decision matrix for supplier the normalized Grey decision matrix is determined using equation (2) and shown in the Table 9. Calculate weighted normalized suppliers matrix using equation (3) as shown in the Table 10.

Table 9: Normalized Grey decision matrix for suppliers

Criteria	*Suppliers*							
	S_1		S_2		S_3		S_4	
C_1	0.40	0.67	0.47	0.73	0.38	0.63	0.33	0.60
C_2	0.60	0.87	0.67	0.93	0.63	0.88	0.53	0.80
C_3	0.67	0.93	0.73	1.00	0.50	0.75	0.60	0.87
C_4	0.73	1.00	0.73	1.00	0.56	0.81	0.73	1.00
C_5	0.47	0.73	0.53	0.80	0.38	0.63	0.53	0.80
C_6	0.60	0.87	0.73	1.00	0.75	1.00	0.73	1.00
C_7	0.33	0.60	0.47	0.73	0.31	0.56	0.47	0.73
C_8	0.60	0.87	0.73	1.00	0.63	0.88	0.60	0.87
C_9	0.17	0.40	0.10	0.33	0.22	0.44	0.13	0.33
C_{10}	0.47	0.73	0.40	0.67	0.38	0.63	0.47	0.73

Table 10: Normalized Weighted Grey decision matrix for suppliers

Criteria	*Suppliers*							
	S_1		S_2		S_3		S_4	
C_1	0.10	0.30	0.12	0.33	0.09	0.28	0.08	0.27
C_2	0.18	0.43	0.20	0.47	0.19	0.44	0.16	0.40
C_3	0.07	0.23	0.07	0.25	0.05	0.19	0.06	0.22
C_4	0.07	0.25	0.07	0.25	0.06	0.20	0.07	0.25
C_5	0.26	0.55	0.29	0.60	0.21	0.47	0.29	0.60
C_6	0.33	0.65	0.40	0.75	0.41	0.75	0.40	0.75
C_7	0.22	0.51	0.30	0.62	0.20	0.48	0.30	0.62
C_8	0.33	0.65	0.40	0.75	0.34	0.66	0.33	0.65
C_9	0.09	0.30	0.06	0.25	0.12	0.33	0.07	0.25
C_{10}	0.09	0.29	0.08	0.27	0.08	0.25	0.09	0.29

Using equation (4) from m possible supplier set S the ideal referential supplier S^{max} is selected and listed below.

S^{max} = {(0.12, 0.33), (0.20, 0.47), (0.07, 0.25), (0.07, 0.25), (0.29, 60), (0.41, 0.75), (0.30, 0.62), (0.40, 0.75), (0.12, 0.33), (0.09, 0.29)}

Using equation (5) grey possibility for comparing the suppliers set S with ideal referential supplier S^{max}

$$P(S_1 \leq S^{max}) = 0.57$$
$$P(S_2 \leq S^{max}) = 0.52$$
$$P(S_3 \leq S^{max}) = 0.60$$
$$P(S_4 \leq S^{max}) = 0.56$$

From the Grey possibility for supplier 2 has the lowest value so the supplier 2 is ranked 1. Supplier 4, supplier 1 and supplier 3 take rank 2, 3, and 4 respectively. 15 Experiments were conducted to check the reliability of the method and weight assigned.

Table 11 shows the result of sensitivity analysis. Out of 15 experiments supplier 2 got rank 1 11 time, supplier 1 got rank 1 2 times and supplier 4 got rank 1 twice. It shows that the reliability of the method is 73%.

Table 11: Sensitivity Analysis

Exp No	*Definition*	*Grey possibility*				*Ranking*
		S_1	S_2	S_3	S_4	
1	C_1- C_{10} = (0, 0.1)	0.52	0.51	0.54	0.52	$S_2 > S_4 = S_1 > S_3$
2	C_1- C_{10} = (0.1,0.3)	0.54	0.51	0.56	0.54	$S_2 > S_4 = S_1 > S_3$
3	C_1- C_{10} = (0.3, 0.5)	0.56	0.51	0.60	0.56	$S_2 > S_4 = S_1 > S_3$
4	C_1- C_{10} = (0.5, 0.7)	0.57	0.53	0.62	0.57	$S_2 > S_4 = S_1 > S_3$
5	C_1- C_{10} = (0.7, 0.9)	0.58	0.53	0.63	0.58	$S_2 > S_4 = S_1 > S_3$
6	C_1 = (0.7, 0.9), C_2- C_{10} = (0, 0.1)	0.53	0.51	0.55	0.53	$S_2 > S_4 = S_1 > S_3$
7	C_2 = (0.7, 0.9), C_1,C_3- C_{10} = (0, 0.1)	0.53	0.51	0.54	0.53	$S_2 > S_4 = S_1 > S_3$
8	C_3 = (0.7, 0.9), C_1,C_2,C_4- C_{10} = (0, 0.1)	0.53	0.51	0.56	0.53	$S_2 > S_4 = S_1 > S_3$
9	C_4 = (0.7, 0.9), C_1-C_3,C_5- C_{10} = (0, 0.1)	0.52	0.51	0.55	0.51	$S_{4\,=}\ S_2 > S_1 > S_3$
10	C_5 = (0.7, 0.9), C_1-C_4,C_6- C_{10} = (0, 0.1)	0.51	0.52	0.55	0.52	$S_1 > S_4 = S_2 > S_3$
11	C_6 = (0.7, 0.9), C_1-C_5,C_7- C_{10} = (0, 0.1)	0.53	0.52	0.55	0.51	$S_4 > S_2 > S_1 > S_3$
12	C_7 = (0.7, 0.9), C_1-C_6,C_8- C_{10} = (0, 0.1)	0.53	0.51	0.55	0.52	$S_2 > S_4 > S_1 > S_3$
13	C_8 = (0.7, 0.9), C_1-C_7,C_9- C_{10} = (0, 0.1)	0.53	0.51	0.55	0.53	$S_2 > S_4 = S_1 > S_3$
14	C_9 = (0.7, 0.9), C_1-C_8,C_{10} = (0, 0.1)	0.53	0.53	0.54	0.51	$S_1 = S_2 > S_2 > S_3$
15	C_{10} = (0.7, 0.9), C_1- C_9 = (0, 0.1)	0.52	0.51	0.55	0.52	$S_2 > S_4 = S_1 > S_3$

6. Conclusions

In this paper, Grey approach is applied to evaluate traditional performance of suppliers along with the environmental performance and social performance for Tamilnadu textile industry. In the proposed approach a brainstorming session was conducted and 10 criteria were selected for evaluation of the supplier performance. Six criteria describe the traditional performance like cost, quality, reliability, flexibility, delivery and technology. Two criteria describe the environmental performance like clean production and environment management system while the other two criteria describe the social responsibility like human rights and corporate social responsibility. For the selected criteria and suppliers, expert consultant investigates and assigns the weights and rating respectively. These weights are processed in the Grey approach and ranking is given to the supplier. Finally a sensitivity analysis was conducted to determine the influence of the criteria weights in the decision making process.

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