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Integrating environmental factors in the suppliers assessment using analytic hierarchy process as a decision making tool

R. Sivaprakasam[1], V. Selladurai[2] and P. Sasikumar[3]
1 Associate Professor, Karpagam College of Engineering, Coimbatore, India,
2 Principal, Coimbatore Institute of Technology, Coimbatore, India.
3 Professor, KPR Institute of Engineering and Technology, Coimbatore, India.

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Corresponding Author E-mail: rspkarpagam@gmail.com

Abstract
Green production has become an important factor in recent years influencing the sustainability of the manufacturing sector. With increasing concern toward environmental protection, it has been found from the literature that the Green Supplier Selection is one of the approaches in solving environmental related issues. Supplier selection is a multi-criteria decision making problem involving both qualitative and quantitative criteria. In this study, Analytic Hierarchy Process (AHP) method is used to compute the relative weights for each criterion and to determine the best supplier according to the overall aggregating score of each supplier. The effectiveness of the AHP model is illustrated using a case study in a textile manufacturing company in the southern part of India.

Keywords: Green suppliers, Analytic Hierarchy Process (AHP) and Green Supply Chain Management (GSCM)

1. Introduction
Due to the increasing awareness among people on environmental issues and to survive in the global market, it is mandatory for the firms to find ways to incorporate environmental aspects into their supply chain management. In order to reap the greatest benefits from environmental management, firms must integrate all members in the green supply chain [1]. Moreover, it is a pressure situation for multinational firms to survive in global market and need to realize the necessity to make their products universally accepted. As a consequence of this pressure and the efforts to address, Environmental Management (EM) issues have become more relevant to operations management researchers [2].

In order to sustain and to have competitive advantage over their competitors, the organizations must devise and execute creative strategies. Green Supply Chain Management (GSCM) is one of the management tools or techniques used to solve such issues. Srivatsava[3] highlighted that GSCM can reduce the ecological impact of industrial activity without sacrificing quality, cost, reliability, performance or energy utilization efficiency. Since the environmental sustainability and ecological performance can be demonstrated only by its suppliers, supplier selection in GSCM is a critical activity in purchasing management [4, 5]. Poor or wrong selection of suppliers will have an adverse effect and negative impact on the reputation of the manufacturer as well as the quality of the product. Selection of an appropriate supplier satisfying all requirements among various criteria is a difficult task for the decision maker. Purchasing cost can be minimized and competitive attitude of the companies can also be enhanced through better selection of supplier.

Vachon and Klassen[6] conducted a survey of the Canadian and United States package printing industry to examine the linkage between green supply chain practices and the selection of environmental technologies. Suppliers are considered to be the assets in the supply chain as their performance influencing the benefits of the company and play an important role for the success of any firm. This paper presents a structured model for selecting the Green suppliers using Analytic Hierarchy Process (AHP) for a textile manufacturing company located in the southern part of India. This paper is organized as follows: Section 2 describes the literature review for green supplier selection methods. Problems description is given in section 3. Section 4 presents the solution methodology. In Section 5, the application model (case study) is discussed. Section 6 presents the conclusion of this paper.

Since every industry recognize and realize the need for protecting the environment, GSCM is regarded as a technique for reducing costs as well as increasing customer and shareholder value. GSCM seems a promising area for trying out new operations research techniques and the core of GSCM is a decision-making problem. As selection of green suppliers is a multi-criteria decision problem, more number of multi-criteria decision making (MCDM) methodologies have been proposed by researchers in the literature. Analytic Hierarchy Process (AHP), Analytic Network Process (ANP), TOPSIS, PROMOTHEE, ELECTREE, VIKOR, Data Envelopment Analysis (DEA), Case-Based Reasoning (CBR), Mathematical Programming, Simple Multi-Attribute Rating Technique (SMART) and their hybrids are few examples of such approaches.

Saaty[7] proposed the analytical hierarchy process (AHP) to support in multi-criteria decision making problems to conquer the complexity associated with the categorical and simple linear weighted average ranking methods. Sarkis[8] developed a model using Analytical Network Process (ANP) approach for analyzing the systemic and hierarchical relationships among a number of decision and environmental factors influencing the organizations performance. Handfield et al.[9] illustrated the use of AHP in integrating environmental criteria into supplier evaluation and selection decisions. Humphreys et al.[10] proposed a framework to consider environmental aspects in the supplier selection process and developed a model comprised of quantitative and qualitative environmental criteria. Lu et al. [11] proposed a multi-objective decision making process for green supply chain management to help the supply chain manager in measuring and evaluating suppliers' performance based on an analytical hierarchy process (AHP) methodology.

Jabbour and Jabbour [12] analyzed the inclusion of environmental criteria in the supplier selection process at five companies of Brazil and emphasized the need for the selection of environmentally fit suppliers.

Arimura et al.[13] examined the effects of ISO 14001 certification on GSCM practices and concluded that ISO 14001 certified facilities play a role in reducing environmental impacts. Zhou and Li [14] developed a green supplier selection method for chemical industry using Analytic Network Process (ANP) and radial basis function(RBF) neural network. Wu et al.[15] investigated the relationships between green supply chain management drivers and GSCM practices of Taiwan's textile and apparel manufacturers. Organizational support, social capital and government involvement were considered as GSCM drivers. Green purchasing, cooperation with customers, eco- design and investment recovery were considered as GSCM practices. It was concluded that excepting the investment recovery, remaining three GSCM practices were positively affected by GSCM drivers. Kumar et al. [16] investigated the green supply chain management practices followed by the manufacturing sector of electrical and electronics products in India and concluded that the factors like green sourcing and procurement, green manufacturing and green packaging play important role in supplier selection. Kannan et al.[17] carried out an exploratory literature review of multi-criteria decision making (MCDM) approaches considering green criteria as the major part for supplier evaluation and selection. Sivaprakasam et al. [18] developed a comprehensive framework model for analyzing the criteria and sub-criteria involved in the implementation of green supply chain practices in industries. The literature study revealed that the implementation of green issue within the supplier selection process is limited as relatively lower number of papers published.

So, it is quite clear that relatively few works have been carried out considering environmental issues in supply chain management. This research work presents analytical hierarchy process (AHP) as a multi-criteria decision making tool that involves simple and efficient procedures to help the decision maker in selecting the green suppliers.

2. Environmental Factors and Methodology

As environmental awareness increases, buyers today are learning to purchase goods and services from suppliers that can provide them with low cost, high quality, short lead time, and at the same time, with environmental responsibility. In order to reap the greatest benefits from environmental management, firms must integrate all members in the green supply chain. Green supply chain management has emerged as a way for firms to achieve profit and market share objectives by lowering environmental impacts and increasing ecological efficiency [19].

In this work, textile industry is chosen for case study for the implementation of green supply chain management since textile Industry is considered as one of the most polluted sector among other industries because of the usage of huge amount of dyes and chemicals for the production of consumer textiles. Almost all the textiles have a negative impact on the environment. The key environmental impacts associated with textiles are air emissions, waste water pollutants and solid wastes. The textile industry has to boost its green credentials to ensure the safety of their supply chain. Textile manufacturers have to move ahead with environmental initiatives targeted at energy efficiency, waste recycling, green supplier selection and other green technologies. In this paper, a framework for integrating environmental factors into the supplier selection process is presented. Traditionally, companies consider factors like quality, flexibility etc. when evaluating supplier performance. However, environmental pressure is increasing, resulting in many large companies beginning to consider environmental issues and the measurement of their suppliers' environmental performance. The company chosen for this study is a textile manufacturing industry. The criteria involved in the selection of green suppliers are given in Table 1.

Table 1: Definitions of the criteria involved in the implementation of GSCM [18]

Sl.No.	Criteria	Description	References
1	Quality (Q)	Quality refers to the conformance and reliability of the product. The factors assessing quality include mainly quality systems, process quality, total quality management and rate of certified product.	2, 20, 21.
2	Cost (C)	It refers to the costs investing in environmental management of its processes or it may be a source of environmental costs because of its destructive processes.	10, 22.
3	Technology capability (T)	It refers to the availability of technical manpower, state-of-art reprocessing technology, R&D facilities, capability to perform reverse logistics function, etc.	09, 23.
4	Service (S)	The performance of the supplier in providing service to the manufacturer is the prime criteria to decide its suitability for a particular product.	20, 21, 24.
5	Pollution control (P)	It means the control of emissions and effluents into air, water or soil.	9, 10, 20.
6	Environment management System (E)	Environmental Management is the set of general management function aspects for an organization, including planning needed to develop and maintain the policy and the organization's environmental objectives.	8, 10.
7	Green Competencies (G)	The factors that show the competencies of supplier in improving green production. It includes the checking of a supplier's ability to reduce pollution effects, implement clean technology and use of environmental friendly materials	10, 20.
8	Green image (I)	Green image refers to market share changes as a result of adopting environmentally friendly products and the relationship with stakeholders /due to the change of the company's image after implementing 'green' programs.	10, 20, 22.
9	Procurement Management (M)	Defining the overall intended procurement strategies	1, 9.
10	Process Management (B)	It represents the activities of planning and monitoring the performance of a process.	9, 20, 25.
11	Risk factor (R)	It refers to the performance and past history of the suppliers, the political status of the supplier's country, rules and regulations of the government and managing both business and environmental issues effectively.	22, 26.

Analytic Hierarchy Process (AHP) is one of the MCDM method that was originally developed by Prof. Thomas L. Saaty. This is an Eigen value approach to the pair-wise comparisons. In short, it is a method to derive ratio scales from paired comparisons for the measurement of quantitative as well as qualitative performances. The scale ranges from 1/9 for 'least valued than', to 1 for 'equal', and to 9 for 'absolutely more important than' covering the entire spectrum of the comparison [27].
The application of AHP to the complex problem usually involves the following steps [2]:

Step 1: Establish the hierarchy structure.

The problem is decomposed and structured in a hierarchy of different levels constituting goal, criteria, sub-criteria and alternatives.

Step 2: Construct a pair-wise comparison matrix.

Once the hierarchy of the problem has been structured, the next step is to determine the priorities of elements at each level ('*element*' here means every member of the hierarchy). A set of comparison matrices of all elements in a level of the hierarchy with respect to an element of the immediately higher level are constructed so as to prioritize and convert individual comparative judgments into ratio scale measurements. The preferences are quantified by using a nine-point scale. The meaning of each scale measurement is explained in Table 2.

Step 3: Test the consistency of each comparison matrix by calculating the Eigen vector and maximum Eigen value.

After all matrices are developed and all pair-wise comparisons are obtained; Eigen vectors or the relative weights (the degree of relative importance amongst the elements), global weights and the maximum Eigen value (λ_{max}) for each matrix are calculated. The λ_{max} value is an important validating parameter in AHP. It is used as a reference index to screen information by calculating the consistency ratio of the estimated vector in order to validate whether the pair-wise comparison matrix provides a completely consistent evaluation [28].

Table 2: Nine point scale of preference between two elements [28]

Preference weights/ Level of importance	**Definition**	**Explanation**
1	Equally preferred	Two activities contribute equally to the objective
3	Moderately	Experience and judgment slightly favor one activity over another
5	Strongly	Experience and judgment strongly or essentially favor one activity over another
7	Very strongly	An activity is strongly favored over another and its dominance demonstrated in practice
9	Extremely	The evidence favoring one activity over another is of the highest degree possible of affirmation
2,4,6,8	Intermediate values	Used to represent compromise between the preferences listed above
Reciprocals	Reciprocals for inverse comparison	

The consistency ratio is calculated as per the following steps:

- Calculate the Eigen vector or the relative weights and λ_{max} for each matrix of order *n*
- Compute the consistency index (CI) for each matrix of order *n* by the formula

$$CI = (\lambda_{max} - n)/(n-1)$$

- Consistency ratio (CR) is then calculated using the formula

$$CR = CI/RI$$

where *RI* is a known random consistency index obtained from a large number of simulation runs and varies depending upon the order of matrix. Table 3shows the value of the Random Consistency Index (RI) for matrices of order 1–10 obtained by approximating random indices using a sample size of 500 [28].

Table 3: Average random index (RI) based on matrix size [28]

N	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.52	0.89	1.11	1.25	1.35	1.40	1.45	1.49

The acceptable *CR* range varies according to the size of matrix i.e., 0.05 for a 3 × 3 matrix, 0.08 for a 4 × 4 matrix and 0.1 for all larger matrices, $n \geq 5$ [28] .If the value of *CR* is equal to, or less than that value, it implies that the evaluation within the matrix is acceptable or indicates a good level of consistency in the comparative judgments represented in that matrix. In contrast, if *CR* is more than the acceptable value, inconsistency of judgments within that matrix has occurred and the evaluation process should therefore be reviewed, reconsidered and improved. The comparative judgments should be reconsidered with respect to the issues raised in the section of establishment of comparative judgements. The problem may also have to be more carefully restructured. An acceptable consistency property helps to ensure decision-maker reliability in determining the priorities of a set of criteria.

Step 4: Estimate the relative weights of the elements of each level.

After forming the hierarchical structure of the problem and pair-wise comparison matrix, the relative weights of the elements are determined within each level.

3. Results and discussion

The company chosen for this research study is a textile manufacturing industry located in the southern part of India. When the company was in the process of selecting the green suppliers, they were in search of a systematic approach that could be applied for the selection process. The following example illustrates the process of solving this decision making problem by AHP method.

Step1: Establishment of the hierarchy structure

The core of the AHP is to allow decision makers to structure a MCDM problem in the form of a criteria hierarchy. A hierarchy has at least three levels (Fig. 1): the focus or overall goal of the problem at the top, multiple criteria that define alternatives in the middle, and competing alternatives at the bottom. Initially, the overall goal of the decision is presented at the top level of hierarchy. Specifically, the overall goal of this application is to ‘select the green suppliers’. The second level represents factors or criteria. In this study, eleven factors are considered to constitute the second level in order to achieve the overall goal. The third level of the hierarchy represents the alternatives or choices. The decision-maker can apply this framework to structure their particular problem in selecting the best green suppliers.

Step 2: Establishment of pair-wise comparison matrix

The pair-wise comparisons generate a matrix of relative rankings for each level of the hierarchy. The number of matrices depends on the number elements at each level. The order of the matrix at each level depends on the number of elements at the lower level that it links to. The pair-wise comparisons are given in terms of how much element A is more important than element B. As the AHP approach is a subjective methodology, information and the priority weights of the elements may be obtained from a decision-maker of the company using direct questioning or a questionnaire method. The pair-wise comparison matrix for the criteria of the company obtained is shown in Table 4.

Step 3: Testing the consistency of the pair-wise comparison matrix

Once the pair-wise comparison matrix is obtained, the relative weights of the criteria is found out and checked for the consistency using the consistency ratio (CR). The consistency ratio of the criteria for the company is given in Table 5.

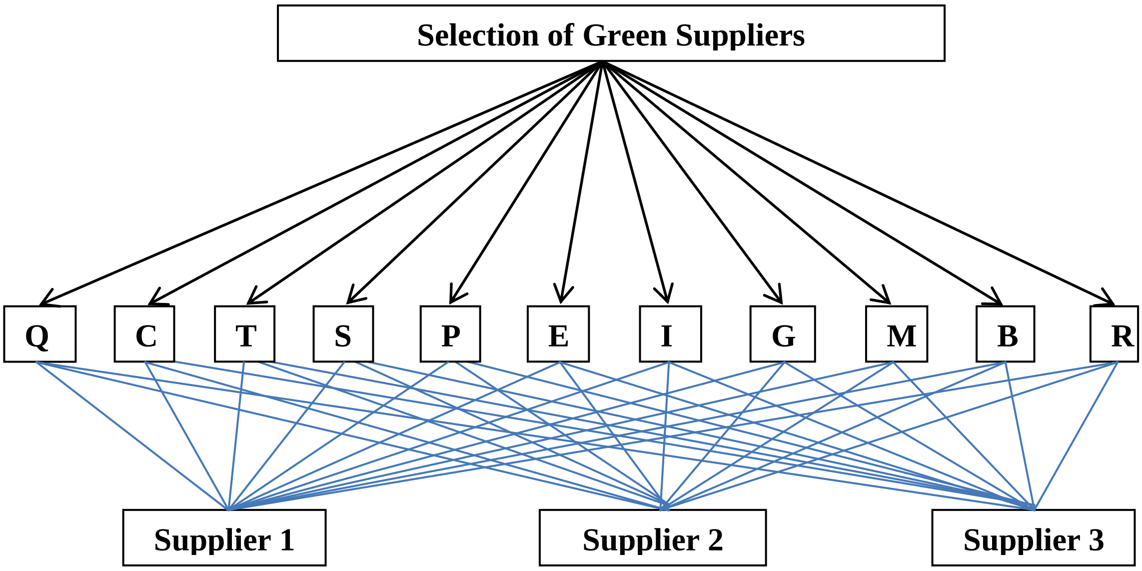

Figure 1: Hierarchy structure for the selection of green suppliers

Table 4: Pair-wise comparison matrix and relative weights of the criteria

Criteria	Q	C	T	S	P	E	I	G	M	B	R	Priority weights
1.Quality (Q)	1.000	2.000	0.333	5.000	0.200	0.143	0.166	0.143	3.000	0.333	0.250	0.0347
2.Cost (C)	0.500	1.000	0.250	4.000	0.200	0.166	0.200	0.143	3.000	0.500	0.200	0.0301
3.Technology Capability (T)	3.000	4.000	1.000	6.000	3.000	0.200	0.333	0.333	5.000	0.500	0.333	0.0742
4.Service (S)	0.200	0.250	0.166	1.000	0.143	0.125	0.143	0.111	3.000	0.200	0.166	0.0182
5. Pollution Control (P)	5.000	5.000	0.333	5.000	1.000	0.333	0.333	0.200	4.000	0.333	0.333	0.0633
6. Environment Management System (E)	7.000	6.000	5.000	8.000	3.000	1.000	1.000	0.250	7.000	3.000	3.000	0.1658
7. Green Image (I)	6.000	5.000	3.000	7.000	3.000	1.000	1.000	0.250	6.000	2.000	2.000	0.1337
8. Green Competencies (G)	7.000	7.000	3.000	9.000	5.000	4.000	4.000	1.000	9.000	4.000	3.000	0.2667
9. Procurement Management (M)	0.333	0.333	0.200	0.333	0.250	0.143	0.166	0.111	1.000	0.200	0.200	0.0154
10. Process Management (B)	3.000	2.000	2.000	5.000	3.000	0.333	0.500	0.250	5.000	1.000	0.200	0.0752
11. Risk factor (R)	4.000	5.000	3.000	6.000	3.000	0.333	0.500	0.333	5.000	5.000	1.000	0.1221

Table 5: Consistency ratio for the criteria of the company

Maximum Eigen value (λ_{max})	12.4363
Consistency Indeed (CI)	0.1436
Consistency Ratio (CR)	0.0951
Conclusion	Since $CR < 0.1$, accept the pair-wise comparison matrix

Step 4: Estimating the relative weights of the elements of each level

After finding the global weights of the criteria, local or relative weights of the three alternatives (Supplier A, B and C) are found out using the pair-wise comparisons. Global weights of the three alternatives are found out by multiplying the relative weights of the criteria and the local or relative weights of the three suppliers, and the results are shown in Table 6. Based on the global weights of the three suppliers, select the best supplier which is having the highest overall priority weights.

Table 6: Overall rating of three suppliers using AHP

Criteria	**Priority weight of criteria**	**Priority weight**	**Global weight**	**Priority weight**	**Global weight**	**Priority weight**	**Global weight**
		SUPPLIER A		**SUPPLIER B**		**SUPPLIER C**	
1. Quality (Q)	0.0347	0.0378	0.0013	0.0293	0.0010	0.0585	0.0020
2. Cost (C)	0.0301	0.0178	0.0005	0.0174	0.0005	0.0486	0.0014
3. Technology Capability (T)	0.0742	0.0689	0.0051	0.0587	0.0043	0.0349	0.0025
4. Service (S)	0.0182	0.0179	0.0003	0.0147	0.0002	0.0518	0.0009
5. Pollution Control (P)	0.0633	0.2130	0.0134	0.1154	0.0073	0.2791	0.0176
6. Environment Management System (E)	0.1658	0.1804	0.0299	0.2430	0.0402	0.1745	0.0289
7. Green Image (I)	0.1337	0.1309	0.0175	0.1980	0.0264	0.1199	0.0160
8. Green Competencies (G)	0.2667	0.1514	0.0404	0.1542	0.0411	0.1199	0.0320
9. Procurement Management (M)	0.0154	0.0260	0.0004	0.0272	0.0004	0.0258	0.00039
10. Process Management (B)	0.0752	0.0672	0.0050	0.0608	0.0045	0.0229	0.00172
11. Risk factor (R)	0.1221	0.0881	0.0107	0.0807	0.0098	0.0635	0.00776
Overall Priority		**0.12487**		**0.13629**		**0.11161**	
Rank		**2**		**1**		**3**	

Conclusion

1. Environmental factors are considered as an important issue for business and management. Also there is an increasing interest among the researchers and practitioners in both environmental management and supply chain management challenges. Traditionally, while evaluating the performance of the suppliers, criteria like quality, cost, flexibility etc. were considered.
2. In this research work, environmental factors like environmental management system, green competencies, green image and pollution control are also considered for selecting the best suppliers. AHP is used as a decision making methodology for the selection of green suppliers and case illustration is presented for textile manufacturing industry.
3. From the overall rating of three suppliers, it is identified that Supplier B is the best supplier, as it has highest overall priority weights.
4. Fuzzy approach can be included in the decision making approach as a future research.

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References

1. Hsu, C.W. and Hu A.H., *J. Clean. Prod*, 17 (2009) 255.
2. Kannan, G., Haq, A.N., Sasikumar, P., Arunachalam, S., *Int. J. Manag. Decn. Mak.* 9(2) (2008) 163.
3. Srivastava S.K, *Int. J. Manag. Rev*, 9(1) (2007) 53.
4. Lamming R and Hampson .J, *Brit. J. Manage*, 7 (1996) 45.
5. Rao P., *Int. J. Oper. Prod.* (2002) 632.
6. Vachon S. and Klassen. R. D., *Int. J. Prod. Econ.* 111 (2008) 299.
7. Saaty T. L., *The Analytic Hierarchy Process* (New York: Pergamon) (1988).
8. Sarkis J., *Eur. J. Ope. Res*, 107 (1) (1998) 159.
9. Handfield R., Steven, R., Srouft, R. Melnyk, S. A., *Eur. J. Ope. Res*, 141 (2002) 70.
10. Humphreys P. K., Wong Y. K., Chan. F. T. S., *J. Mater. Process. Technol.*, 138 (1–3) (2003) 349.

11. Lu L. Y. Y., Wu, C. H., and Kuo, T.-C., *Int. J. Prod. Res*, 45(18–19) (2007) 4317.
12. Ana Beatriz L. S. Jabbour, Charbel J. C., Jabbour., *Ind. Manage. Data. Syst* 109 (4) (2009) 477.
13. Arimura T.H., Nicole Darnall and Hajime Katayama, *J. Environ. Econ. Manag*, 61(2011) 170.
14. Zhou L.J.and Li, H., *Appl. Mech. Mater*, (84-85) (2012) 761.
15. Wu G.C., Ding, J.H. and Chen, P.S., *Int. J. Prod. Econ*, 135(2) (2012) 618.
16. Kumar S., Chattopadhyaya, Sharma. V., *Int. J. Soft Comp. Engg.*, 1, (6) (2012) 275.
17. Kannan Govindan, Joseph Sarkis, Murugesan Palaniappan, *Int .J. Adv. Manuf. Tech* (2013) 863.
18. Sivaprakasam, R., Selladurai, V., Sasikumar, P., *Ann. Oper. Res*, (2014).
19. Van Hock R. I., and Erasmus, *Logistics Solutions*, 2 (2000) 28.
20. Lee A. H. I., *Expert. Syst. Appl*, 36, (2009) 2879.
21. Chan F.T.S. and Kumar, N., *Omega-Int. J. Manage. S*, 35 (4) (2007) 417.
22. Chiou C.Y., Hsu, C.W., Hwang W.Y., *Int. Conf. IE&EM*, IEEE (8-11) (2008) 1909.
23. Choi TY, Hartley JL., *J.Oper.Manag*, 14(4) (1996) 333.
24. Muralidharan C., Anantharaman N and Deshmukh S.G., *Int. J. Environ. Sci. Te* 38 (3) (2002) 22.
25. Tuzkaya G., Ozgen, A., Ozgen, D. and Tuzkaya, U., *Int .J. Environ. Sci. Te*, 6(3) (2009) 477.
26. Min H., *Int. J. Phys. Distr Log*, 24(5) (1994) 24.
27. Vaidya,O. and Kumar, S., *Eur.J.Oper.Res.*169(1) (2006) 1.
28. Saaty T. L., *Fundamentals of decision making and priority theory*, 2nd Edition, RWS Publication, Pittsburg, (2000).