Green Supplier Assessment in Environmentally Responsive Supply Chains through Analytical Network Process

Gopal Agarwal and Lokesh Vijayvargy

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Abstract— **Suppliers' assessment is a critical function within supply chain management. Green supplier assessment is also necessary for sustainable supply chain management. The purpose of this paper is to present a methodology to evaluate suppliers using portfolio analysis based on the analytical network process (ANP) and environmental factors. Since environment protection has been concern to public in recent years, and the traditional supplier selection did not consider about this factor; therefore, this paper introduces green criteria into the framework of supplier selection criteria. The paper discerns various characteristics of the suppliers and also produces recommendations on supplier management for an exemplary case scenario. It also provides insight into the role of intangible factors in decisions related to supply chain. The methodology generates decision rules relating the various attributes to the performance outcomes.**

Index Terms— **Supply Chain, Logistics, and Optimization Model**

I. Introduction

With increase in environmental concerns during the past decade, a consensus is growing that environmental pollution issues accompanying industrial development should be addressed together with supply chain management, thereby contributing to green supply chain management (GSCM).

"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.

Green supply chain management (GSCM) is generally understood to involve screening suppliers based on their environmental performance and doing business only with those that meet certain environmental regulations or standards. The green supply chain known at present refers to supply chain effect brought about by green products proposed by European Community in the 21st century. Some companies, especially, small and medium enterprises, started to build cooperative corporations with supply chain partners, with the hope of promoting propagation of environment management initialization and designing new green products

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Decision making in supply chain is crucial as it involves multi-criteria, multi- level, multi-objective and multi-personal decisions. The emphasis on higher co-operation and co-ordination among the partners of supply chain is key issue, which requires strategies suitable to system-optimal performance where the point of focus shifts from local to global optimal. Decisions at the interface between supplier and manufacturer depend on trade-offs between various factors. Some of the factors are tangible and general in nature, while some other are situation specific and intangible in nature. Multi-criteria decision making tools like AHP and ANP are gaining wide applicability and attempt has been made to make use of them in issues related to inbound supply chain. The priority coefficients thus found by these techniques are used in optimization techniques to get desired results. Application of supply chain concepts has been made in service industry as no such work has been attempted earlier.

The uninterrupted supply of auto components and packaging material and fresh materials to scattered outlets all across the country is biggest challenge faced by XYZ Automobile Company. There is large number of items in inventory list, a big supplier base and fluctuating demand with long duration of realization of paybacks as small quantities of raw material are consumed in each unit sale. The pressure on supply line is enormous due to JIT environment of supply with weekly supply schedule, small storage space at outlets and short life cycles of ingredients. Vendor selection plays significant role in the future relations and capability to work in supply chain environment

The green suppliers can be the biggest assets to the organization but poor choice can make them biggest liability also. This paper, thus deals with issues related to supply. For select items vendor selection model based on ANP is proposed to show procedure involved and steps in software "super decisions" are shown using windows for easy understanding. There is no vendor rating system presently in order at XYZ Company and thus a suitable, easy to comprehend and yet simple in nature vendor rating model based on decision matrix is proposed for existing vendors. A brief theoretical orientation of each issue is presented to show the work already done and to justify the selection of prioritizing model.

The remainder of this paper is organized as follows. Section 2 discusses literature on selection criteria and methodology for suppliers in GSCM in terms of various companies. Next, Section 3 debates the ANP M approach. Section 4 then presents an illustrative case study which used for supplier selection using the ANP model. Finally, Section 5 presents procedure and result and section 6 presents conclusions and limitations.

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II. LITERATURE REVIEW

The following papers have strengthen the methodology aspect and provided insights into the selection of correct model.

Green supplier management, has captured significant interest in the current literature (Lee et al., 2009; Hsu and Hu, 2009). Sphere of influence theory states that greening a supply chain is influenced greatly by focal companies that can effectively influence suppliers to engage in the GSC projects and act as better performers (Hall, 2001). The extant literature of supplier management in GSCs recognizes that differentiated supplier management approaches exist in GSC projects (Forman and Jørgensen, 2004; Kogg, 2003; Hamprecht et al., 2005; Goldbach et al., 2003; Zhu et al., 2008). Supplier selection is a multi-criteria problem which include analytic hierarchy process (AHP) (Akarte, (2001), Chan (2003)), Fuzzy analytic hierarchy process (FAHP) (Kuo(2007), Kahraman (2003)), case based ANP (Bayazit (2006), Gurpinar(2007)). Agrawal et al. (2003) analyzed trust building using Analytic Network Process (ANP). They explained the trust as most important enabler of buyer-supplier relationship, in the context of e-enabled supply chain. Agrawal et al. (2002) have also applied ANP framework for analyzing alternatives for improvement in supply chain performance. Lee and Kim (2000) have used the integrated approach of ANP and Goal Programming for interdependent information system project selection. Meade and Sarkis (1999) have used the ANP approach for analyzing the organizational project alternatives for agile manufacturing process. This paper has explored the methodology in great detail and provided good insight into the development of ANP model. Saaty et al. (2003) have used model of AHP and LP for allocation of intangible resources.

From the literature we can develop a broad supplier assessment process model in the context of greening a supply chain that can be separated into three managerial decision phases: indentified suppliers, classifying criteria's and evaluating suppliers' based environmental performance, and select the best supplier.

III. THE METHODOLOGY

A set of criteria covering wide range of parameters is submitted in the form of table and opinion of expert is taken to select pertinent criteria for vendor selection in the context of XYZ Automobile Company. Apart from this an unstructured opinion is also sought. Cost being one of the most important parameters has not been included in this analysis as the alternatives chosen are cost competitive and thus a detailed analysis is required to select one of them on the basis of comprehensive analysis of various other factors and ultimately the priorities obtained with ANP can be seen in the context of cost parameter and an appropriate decision can be taken. The priorities obtained from the ANP can be directly used in linear programming model as the coefficients in the objective function to get the required distribution of the demand among the suppliers which can satisfy a set of constraints related to lead time, plant capacity of supplier etc. Since XYZ Company is buying the Gear box from a single source, as the demand is not very high, there is no need of applying the optimizing tool here.. 1-5 scale is used for comparison.

A. The ANP Methodology

ANP is a generalized form of the widely used multi-criteria decision making technique of AHP (Saaty, 1980). ANP offers several advantages over other evaluation techniques such as data envelopment analysis (DEA), expert systems, goal programming etc. (Sarkis and Sundarraj, 2006).

It is one of the most comprehensive frameworks for corporate decisions, that is available today to the decision-maker. It is a process that allows one to include all the factors and criteria, tangible and intangible, those have bearing on making best decision. The Analytic Network Process allows both interaction and feedback within clusters of elements (inner dependence) and between clusters (outer dependence). Such feedback best captures the complex effects of interplay in corporate world, especially when risk and uncertainty are involved.

The ANP, developed by Saaty, provides a way to input judgments and measurements to derive ratio scale priorities for the distribution of influence among the factors and groups of factors in the decision. Because the process is based on deriving ratio scale measurements, it can be used to allocate resources according to their ratio-scale priorities. The well-known decision framework, the Analytic Hierarchy Process (AHP) is a special case of the ANP. Both the AHP and the ANP derive ratio scale priorities for elements and clusters of elements by making paired comparisons of elements on a common property or criterion. Although many decision problems are best studied through the ANP, one may wish to compare the results obtained with it to those obtained using the AHP or any other decision approach with respect to the time it took to obtain the results, the effort involved in making the judgments, and the relevance and accuracy of the results.

ANP models have two parts: the first is a control hierarchy or network of objectives and criteria that control the interactions in the system under study; the second are the many sub-networks of influences among the elements and clusters of the problem, one for each control criterion. The ANP has been applied to a large variety of decisions: marketing, medical, political, social, forecasting and prediction and many others. Its accuracy of prediction is impressive in applications that have been made to economic trends, sports and other events for which the outcome later became known.

The ANP utilizes the idea of a control hierarchy or a control network to deal with different criteria, eventually leading to the analysis of benefits, opportunities, costs, and risks. By relying on control elements, the ANP parallels what the human brain does in combining different sense data as for example does the thalamus.

Software "SUPER DECISIONS" is available for solving ANP problem and is used in this project.

IV. A CASE STUDY

The Indian Automobile industry has witnessed major changes in the past few years. After liberalization of the market, many global automobile manufacturers such as Ford, General Motors, Suzuki, Honda, Mercedes (in the car segment) and Piaggio, Suzuki, Honda, Yamaha, Kawasaki (in the motorbike segment) have established manufacturing bases or international purchase centres in India (Shukla 2009).

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To detail the proposed supplier management process model, we provide an illustrative example. We use India as our context, since it is a region of the world where significant supply chain pressures exist. The illustrative example is not an actual application of a real world situation, but it is based on interview of various manager of XYZ Automobile Company. The values used in the illustrative example are composites based on the authors' knowledge and observations.

To set the stage, we assume that Company XYZ is an assembler of Bike in Delhi, India. Pressures from its target market, Europe, include environmental regulations such as RoHS (The Restriction of the use of certain Hazardous substances in Electrical and Electronic Equipment). Company XYZ is working on a project aiming to restrict certain hazardous substances in its Gear Box. The company has to deal with such environmental issues along whole supply chains, and thus concerns GSCs. Senior managers of Company XYZ are considering a comprehensive supplier management decision.

We can assume that a filtering process, which is used to reduce the number of suppliers in our sample has been completed. The application of the ANP model presented in this study is assessed for the case of a XYZ Automobile Company.

This company is interested in incorporating green initiatives into supplier evaluation and selection for GSCM practice. In relation to the increased environmental regulations, the case study company wanted to implement a systematic method of selecting appropriate suppliers based on competency. The proposed decision model for supplier selection in GSCM was implemented for 21 criteria under four main criteria clusters. The relative importance of criteria for supplier selection is determined based on expert opinion as determined by sampling the company's GSCM team. The expert group consists of five people from the case company who are responsible for the planning of green initiatives, evaluating the suppliers' performance and maintaining the list of the approved suppliers with respect to the capability of management of hazardous substance. The case experience provided assistance in understanding how to establish the decision model for supplier selection and selecting appropriate suppliers in GSCM. The application and analysis of ANP methodology is presented in the following steps.

The first step in ANP method implementation is to construct the decision structure of the supplier selection problem and to identify the relevant criteria and alternatives developed based on the literature. This model has four levels (see Fig. 1). The second level consists of four main criteria clusters or dimensions, they are Operational Life (D1), Environmental friendly (D2); Overall performance (D3), and Process Management (D4). There are 21 criteria under the above-mentioned five dimensions. The fourth level is the alternatives they are Supplier A, Supplier B, Supplier C, and Supplier D in the illustrated case.

V. Procedure

Step 1 Formation of network with goal, clusters and subnets: The problem is first designed in the software by making clusters and the corresponding nodes and connections. The vendor selection problem is designed as hierarchical network with the goal as the topmost cluster. This is linked to another cluster containing logistics, technological, business and relationship criteria as its nodes (fig. 2).

Step 2 The clusters and nodes under all 4 subnets, Each subnet consists of two clusters i.e. Attributes and Alternatives.

Step 3 Node Comparisons: This involves comparison of nodes with respect to a control criterion.

Step 4 Generation of weighted and limiting supermatrix: In this step the generation of the weighted and the limiting supermatrices for all the four sub networks.

Step 5 The Values obtained at the subnet level are raised to the goal level and limit matrix (fig. 3) is obtained for goal.

Step 6: The values obtained from the synthesis are taken at the level of the goal and overall synthesis for the model is achieved as shown in Figure 4.

Step7 Sensitivity analysis: In this the variations in the priority of the alternatives with respect to change in the wieghtage of the control criteria can be observed. One such graph is presented in Figure 5 to show the variations in the priorities of the alternative with respect to business criteria.

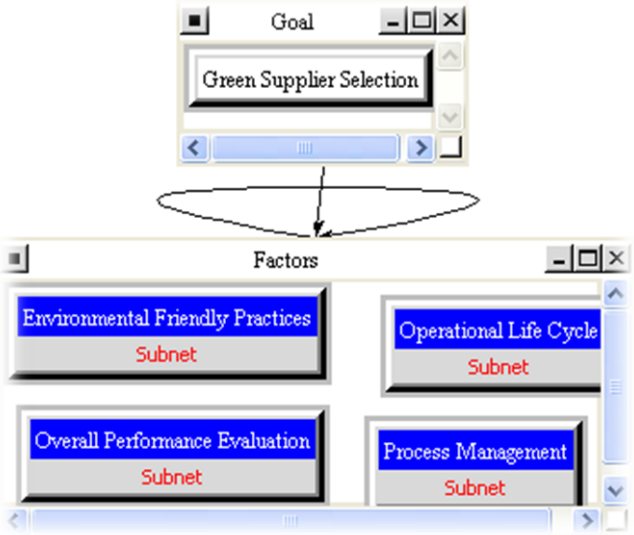

Fig. 2: The design of the problem:

Super Decisions Main Window: Lakshya.mod: Limit Matrix

Cluster Node Labels		Factors				Goal
		Environmental Friendly Practices	Operational Life Cycle	Overall Performance Evaluation	Process Management	Green Supplier Selection
Factors	Environmental Friendly Practices	0.237151	0.237151	0.237151	0.237151	0.237151
	Operational Life Cycle	0.189265	0.189265	0.189265	0.189265	0.189265
	Overall Performance Evaluation	0.290890	0.290890	0.290890	0.290890	0.290890
	Process Management	0.282694	0.282694	0.282694	0.282694	0.282694
Goal	Green Supplier Selection	0.000000	0.000000	0.000000	0.000000	0.000000

Done

Fig. 3: Limited matrix for goal

A. *Result of ANP modeling*

Based on the priorities obtained from ANP, supplier D has highest priority coefficient of 0.313 followed by supplier C and supplier B with 0.239 and 0.236 and last placed is supplier A with overall priority of 0.21. Clearly supplier D is best choice. The vendor D is also the present supplier and is also supplying to famous brands like TV Motor, Bajaj etc. and the case company is more or less in good touch with this supplier. The results are indicators of the personal preferences which the analysts have as the pair-wise

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Based on the response of experts on the attributes following hierarchy has been formed and used in ANP software "SUPER DECISIONS"

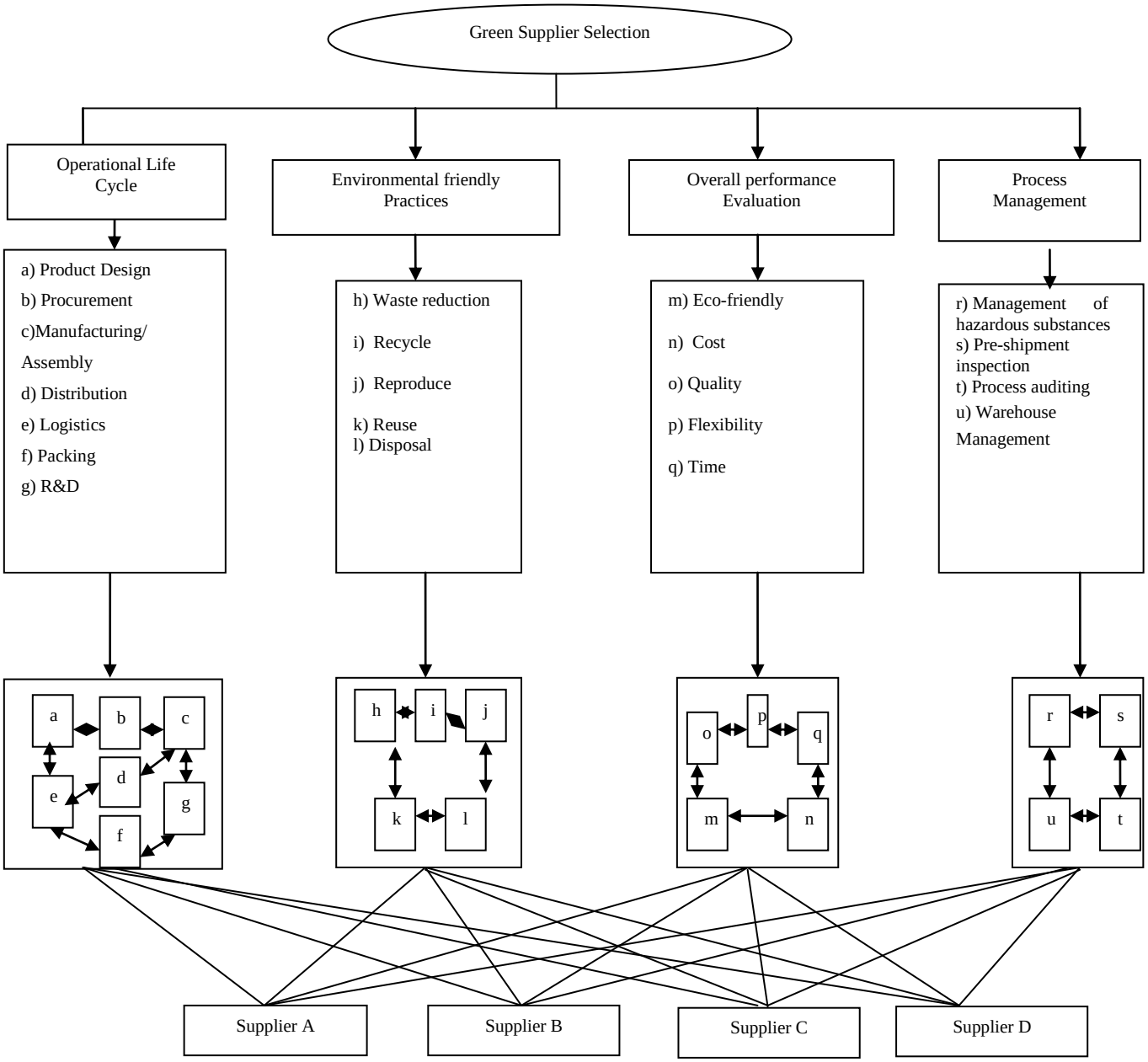

Figure 1: ANP-Based model for selecting green supplier

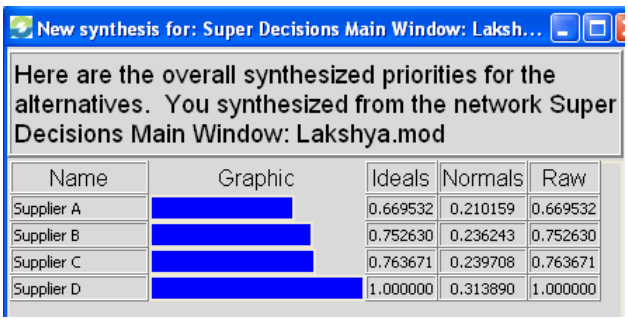

Fig.4: Synthesis for the Goal

Comparison (See in appendix A) is based on his knowledge, word of mouth information available to him and judgments. One of reasons could be the first hand experience of the present supplier, which the analysts have in comparison to the here-say, and written details of other two alternatives. One more important point is that the supplier D is located very close to Delhi as compare to other vendors.

VI. Conclusion

The GSCM based conceptual framework and operational model to incorporate environment into supplier selection have been presented. By identifying the related criteria of purchasing activities form the proposed framework, an ANP methodology has applied to an automobile company. Compared with the previous investigations, the

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previous method may have contributions to performance and cost criteria. But new model for selecting suppliers with emphasis on environmental issues has been incorporate to assess the performance of green supplier. ANP can capture both quantitative and qualitative criteria and reflect more realistic results among decision attributes and alternatives owing to the existence of interdependent relationships in the real supplier selection and evaluation environment. Therefore, ANP modeling can serve as a new method and offer insights to managers in selecting green suppliers systematically.

If a company wants to incorporate environmental factor into supplier selection and evaluation in GSCM practice, the company can adopt the presented model, which includes all the criteria for understanding the competence of its suppliers and prioritizing the suppliers.

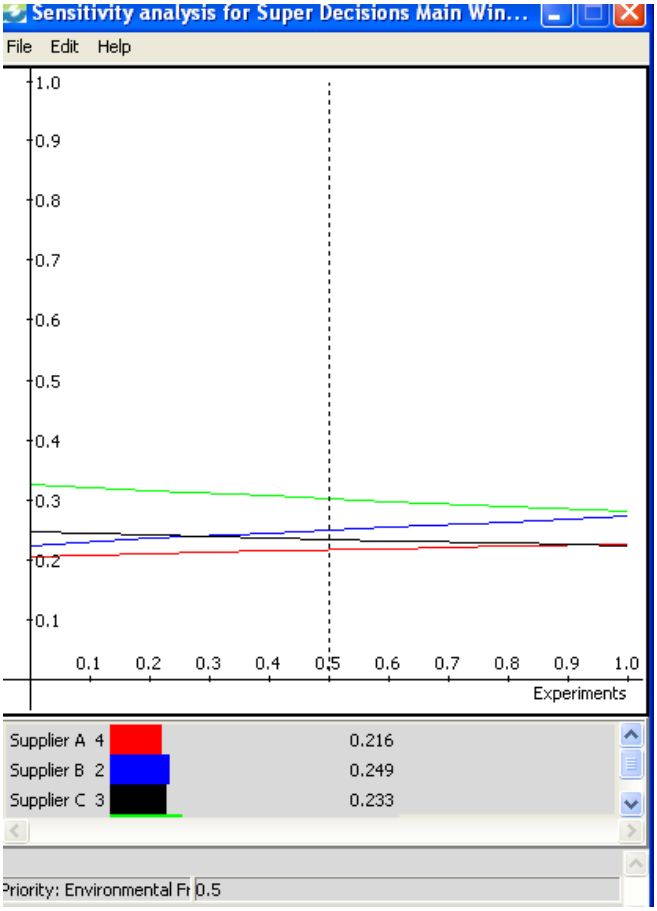

Fig. 5: Sensitivity Analysis

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Appendix A: Pair-wise comparison of dimension

Factors	Operational Life Cycle	Environmental Friendly practices	Overall Performance evaluation	Process management
Operational Life Cycle	1	3/4	2/4	3/5
Environmental Friendly practices	4/3	1	3/4	3/4
Overall Performance evaluation	4/2	4/3	1	1
Process management	5/3	4/3	1	1

Operational Life Cycle Factor	Product Design	Procurement	Manufacturing	Distribution	Logistics	R & D
Product Design	1	3/4	2/4	2/5	2/5	1
Procurement	4/3	1	3/4	3/4	3/4	2/4
Manufacturing	4/2	4/3	1	2/3	2/4	3/4
Distribution	5/2	4/3	3/2	1	1	2/5
Logistics	5/2	4/3	4/2	1	1	4/3
R & D	1	4/2	4/3	5/2	3/4	1

Environmental Friendly practices factor	Waste Reduction	Recycle	Reproduce	Reuse	Disposal
Waste Reduction	1	1	2/3	2/3	4/2
Recycle	1	1	3/2	1	4/2
Reproduce	3/2	2/3	1	2/4	4/2
Reuse	3/2	1	4/2	1	4/1
Disposal	2/4	2/4	2/4	1/4	1

Overall Performance evaluation factor	Organizational	Cost	Quality	Flexibility	Time
Organizational	1	2/3	1/4	1/3	1/3
Cost	3/2	1	3/4	3/4	3/4
Quality	4	3/4	1	1	4/3
Flexibility	3	4/3	1	1	3/4
Time	3	4/3	3/4	4/3	1

Process management factor	Management of Hazardous substances	Pre-shipment inspection	Process Auditing	Warehouse Management
Management of Hazardous substances	1	1/4	1/4	1/4
Pre-shipment inspection	4	1	5/2	5/3
Process Auditing	4	2/5	1	5/2
Warehouse Management	4	3/5	2/5	1

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