EMERGING SUPPLIER SELECTION CRITERIA IN THE CONTEXT OF TRADITIONAL VS GREEN SUPPLY CHAIN MANAGEMENT

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ABSTRACT

Supply chain management used to be widely understood as an integrated one-way manufacturing process, in which the raw material is converted to the finished product and then delivered to the customer. It merely centered around the procurement of raw material to make the final product. With increasing concern towards environmental protection, organizations have become more and more responsible for their products and overall sustainability. For companies to maintain their sustainability and competitiveness in the market, green supply chain management (GSCM) considers a systematic and integrated approach. It has been found from the literature that the green supplier selection is an important issue in improving environmental related performance. This study attempts to find out what the traditional supply chain is and how to redefine the basic structure of traditional supply chain. It also explores major factors included in green supply chain along with the criteria for supplier selection process.

KEYWORDS

Supplier selection, Supplier selection methods, Supplier selection criterion, Green supply chain management (GSCM).

1. INTRODUCTION

In a competitive business environment, selection of suppliers represents one of the most critical issues faced by manufacturing firms. The cost of raw materials comprises a major portion of the product's final cost and the selection of appropriate suppliers significantly reduces the purchasing costs in manufacturing firms. Two types of supplier selection are prominent in practice today. In the first type (single sourcing), one supplier can satisfy the buyer's entire requirements and the buyer needs to make only one decision: finding the best supplier. In the second and more common type (multiple sourcing), more than one supplier must be selected, because no single supplier can satisfy all the buyer's requirements. Hence, for effective supply chain management, firms need to select both the best set of suppliers and find as to how much quantity should be allocated among them for creating a constant environment of competitiveness (Alyanak and Armaneri, 2009). Moreover, with the changing environmental requirements, affecting the manufacturing operations, increasing attention is also required to be given to develop effective environmental management (EM) strategies for the supply chain.

Environmental management or Green supply refers to the way in which innovations in supply chain management and industrial purchasing are considered in the context of the environment.

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Activities included in Green Supply Chain management (GSCM) are re-use, recycle, remanufacture and reverse logistics etc. Among various issues in GSCM, green supplier selection is a crucial problem to be addressed for improving the environmental performance. This is because, a good supplier helps with the supply of material that comply with the regulations and further assists in green design, affecting the performance of the entire supply chain. Carvalho *et. al.* (2010), Rao and Holt (2005) and Van Hoek and Erasmus (2000) expressed that "GSCM" is an important organizational philosophy, which plays a significant role in promoting efficiency and synergy between partners. It facilitates environmental performance, minimizes waste and saves cost in order to achieve corporate profit and to set market-share objectives. It also improves the ecological efficiency of organizations and their partners.

This study is an attempt to compare traditional supply chain and green supply chain and to explore the importance of green supply chain management in the current context in India. It also lists out various criteria in supplier selection and is structured in the following manner. In section 2, an elaborate survey is included to explore the literature pertaining to traditional and green supply chain management. In section 3, the difference between traditional SCM and Green SCM is covered. Section 4 gives the overall information about the traditional supply chain. In section 5, the basic structure of a traditional supply chain is redefined by accommodating the environmental concerns. Section 6 gives a basic idea about what is green supply chain management. Section 7 explains various criteria for supplier selection in the traditional and green supply chain and Section 8 ends with the conclusion.

2. LITERATURE REVIEW

In recent years, several proposals for supplier- related problems have been reported in the literature. For traditional and green supply chain, the supplier selection methods are divided into two clusters of single model and combined models as illustrated below in Fig. 1.

2.1. Traditional Supply Chain

Extensive single model approaches have been proposed for supplier selection, such as the Analytical Hierarchical Process (AHP) by Bayazit, O. (2005). The Author proposed dependencies and interaction among various criteria in a decision making model, pointing that the analytical network process is a more appropriate methodology. Bhutta, K.S., Huq, F. (2003) analysed as to how AHP provides a framework to cope up with multiple criteria situations, involving supplier selection, while total cost of ownership is a methodology and philosophy. Chan, F. T. S. (2003) proposed a model using AHP for interactive supplier selection as a contribution to development of supply chain management. Satty, T. H. (1994) showed as to how to make a decision in multi-criteria decision making situation, using the Analytical Hierarchical Process (AHP). Analytic Network Process (ANP) is used as a decision tool to solve multi criteria decision making tool as also proposed by O Bayazit (2006) and Gencer C, Gürpinar D., (2007). Difference between managers rating is examined by Verma and Pullman (1998) using discrete choice analysis (DCA) to perceive the importance of different supplier attributes and their actual choice of suppliers in an experimental setting.

R. Verma *et.al*. (2008), provided directions for designing and executing discrete choice studies for services and discussed several examples for a number of industries including health care, financial services, retail, hospitality and online services. Interpretive structural model (ISM) to

show levels of importance in supplier selection process and the inter-relationship of different criteria were developed by Mandam A. and Deshmukh, S.G. (1994). Kannan and Haq (2007) used an interpretive modeling methodology to understand the interactions among the criteria, which influences the supplier selection. Kannan *et. al*. (2010), developed a structure to analyze the interactions among the criteria such as buyer- suppler relationship, evaluation and certification system, inert-organizational communication, supplier commitment, competitive pressure, supplier performance, long-term strategic goals, supplier development program, purchasing performance, joint action, trust, top management support and supplier strategic objective for the supplier development using ISM. To select the best third party reverse logistics provider for summarizing and identifying the relationship among attributes Govindan *et. al*. (2012a), applied an interpretive structural modeling methodology.

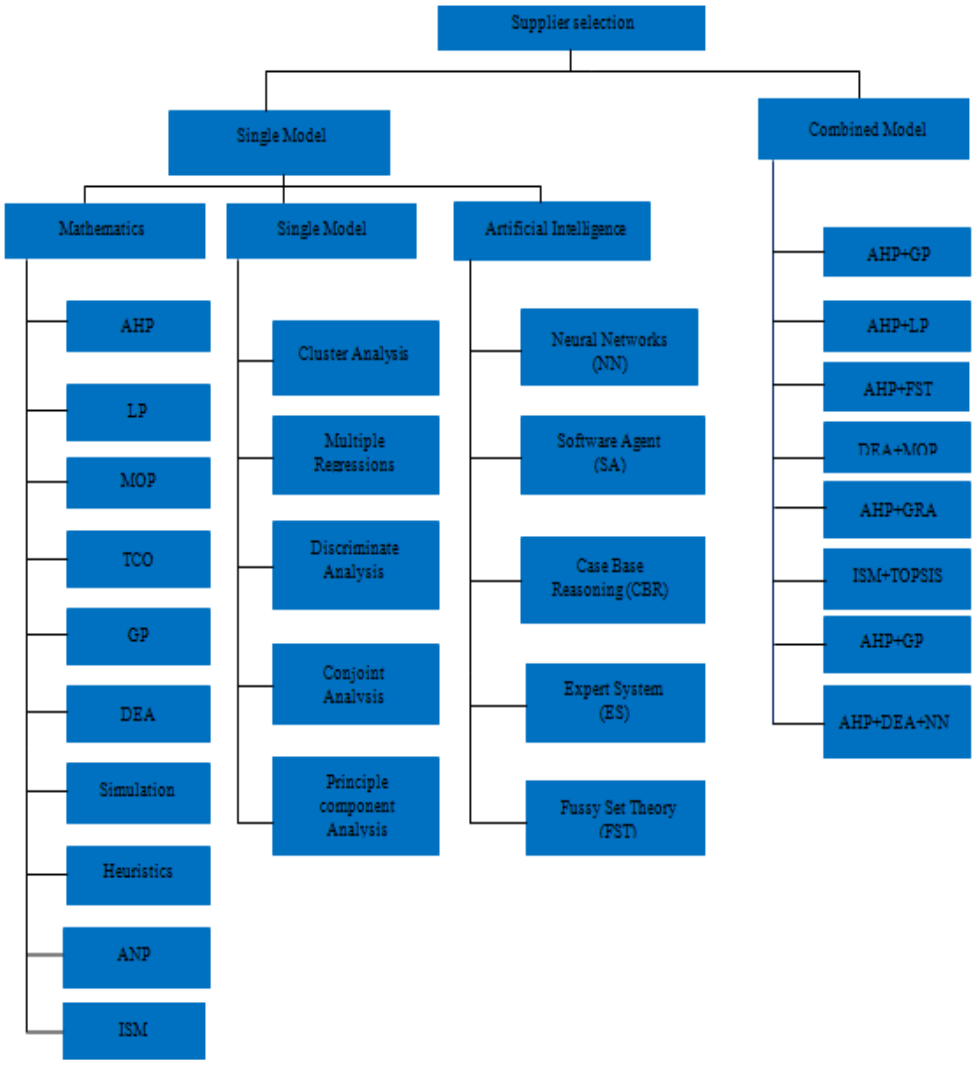

Figure 1. Existing analytical methods for supplier selection

Case-based reasoning (CBR) by Paul Humphreys, *et.al*. (2003) developed a knowledge-based system (KBS) which integrates the environmental factors into the supplier selection process. Artificial neural network (ANN) and intelligent supplier selection relationship management system (ISRMS) using hybrid case base reasoning (CBR) was applied by Choy *et. al*. (2003a, b) to select and benchmark a potential supplier. K. Zhao (2011) summarized particular characteristics of the supply chain of Chinese petroleum enterprises and analyzed the limitations of the traditional methods of supplier selection and brought forward the method based on a case based reasoning system (CBR). Liu *et.al.* (2000) proposed and demonstrated the application of Data Envelopment Analysis (DEA) in evaluating the overall performances of suppliers in a manufacturing firm. Wu *et. al.* (2007) proposed an approach that included three stages. Firstly, DEA and CCR model are used to calculate pair-wise efficiency and proposes a cross- evaluation DEA model,. Secondly, the pair-wise efficiency scores were then utilized to construct the consistent fuzzy preference relation. Thirdly, the row wise summation technique was used. M. Toloo, (2011) used cardinal and ordinal data to identify the most efficient supplier.

A Genetic algorithm (GA) was proposed by Ding *et. al.* (2005) and Neural networks were proposed by Choy *et. al.* (2003c). Fuzzy TOPSIS was used by Chen-Tung Chen *et.al.* (2006) and in this study, linguistic values were used to assess the ratings and weights. Triangular or trapezoidal fuzzy numbers are used to express linguistic ratings. To deal with the selection of a supplier problem in SCM, a Multi-criteria decision making (MCDM) model based on fuzzy set theory was proposed. To guide the supplier selection process for whom, the best third party reverse logistics provider (3PRLP) is relevant, Kannan *et. al.* (2009b) applied a multi-criteria group decision-making (MCGDM) model in a fuzzy environment. Fuzzy extent analysis by Kannan and Murugesan, (2011), proposed a structured model for the selection of a 3PRLP, under fuzzy environment for the battery industry, which established the relative weights for attributes and sub-attributes.

In multiple sourcing, many researchers have applied different methods of mathematical programming. For a multiple-criteria supplier selection scenario, Ng, W.L. (2008) proposed a weighted linear program. Mixed integer LP used by Hong *et. al.* (2005) established formal methods for reasoning about first order programs, including a sound and complete lifted inference procedure for integer first order programs. Multi-objective programming (MOP) was proposed by Rezaei and Davoodi, (2011) and goal programming (GP) by Lee *et. al.* (2009b) and Jolai *et. al.* (2011). Hong *et. al. (*2005) proposed a mathematical programming model, with the objective function being to maxmise or minimize the decision variables. In his review work, Ho *et. al.* (2010) mentioned that there are several hybrid techniques that have been used for solving supplier selection in multiple sourcing environments and order allocation, such as DEA and MOP. Talluri *et. al.* (2008) effectively considered multiple factors and interrelationships among them for assisting in buyer supplier negotiation, proposing an optimization model.

Ghodsypour and O'Brien (1998) proposed AHP and LP together to choose the best supplier by considering tangible and intangible factors so that the total value of purchasing (TVP) becomes maximum. Using ISM and TOPSIS, Kannan *et. al.* (2009a) proposed a multi-criteria group decision-making (MCGDM) model in a fuzzy environment to develop a guide in the selection process of best 3PRLP. Authors analyzed the interactions between criteria before arriving at the decision. The analysis was done through Interpretive Structural Modeling (ISM) and fuzzy technique for order preference by similarity to ideal solution (TOPSIS). AHP and Grey Relational Analysis (GRA) were used by Ching-Chow Yang, (2004), Haq and Kannan, (2006b) and

Jianliang Peng, (2012). Kull and Talluri, (2008) used AHP and GP for product life cycle consideration and risk measurement as decision tools in supplier selection process.

AHP, DEA and neural networks were used by Ha and Krishnan (2008) and ANP & GP were used by Demirtas and Ustun (2009) and S. M. Gupta (2006). Many authors have proposed several types of MOP approaches for the supplier selection and order allocation problem, including Ghodsypour and O'Brien (2001), Narasimhan *et. al.*(2006),Wadhwa and Ravindran (2007), Demirtas and Ustun (2008), Kannan *et. al.* (2009c), Amid *et. al.,* (2011), Jolai *et. al.* (2011), Amin *et. al.* (2012) and Liao & Kao (2012). Amin and Zhang (2012) have summarized the models used for a supplier selection and order allocation problem and is widely available in the contemporary literature.

2.2. Green Supply Chain

The GSCM literature has focused on encouraging existing suppliers to improve their environmental performance by requiring these suppliers to acquire certifications or to introduce green practices. Supplier selection in GSCM has been identified as significant in making purchasing decisions. In order to meet the environmental regulations, many scholars have studied the indicators of a green supplier evaluation. For example, Roy and Whelan (1992) showed a model for reducing waste coming out from electronics without harming and affecting the environment. Noci (1997) applied an AHP model to design a green supplier rating system. Sarkis (1998) categorized five major components for green business practices and that are analysis of life cycle, total envornmental management quality, ISO1400 certification for green supply chain and green design. Handfield *et. al*. (2002) utilized the Delphi method to collect environmental experts' opinions from different companies and proposed an environmentally conscious purchasing decision based on AHP. Sarkis (2003) utilized ANP to develop a six-dimension strategic decision framework for GSCM. Amy H.I. Lee (2009) proposed a model for manufacturers to have a better understanding of the capabilities that a green supplier must possess that can evaluate and select the most suitable green supplier for cooperation and accordingly used Delphi and fuzzy extended AHP.

Hsu and Hu (2009) presented ANP as a new criterion of supplier selection to hazardous substance management including green purchasing, green materials coding & recording, capability of green design, inventory of hazardous substances, management for hazardous substances, legal-compliance competency and environmental management systems. Lee *et. al*. (2009a) proposed quality, technology capability, pollution control, environment management, green products and green competencies for green supplier selection in the high-tech industry. Awasthi *et. al*. (2010) presented a fuzzy multi criteria approach for evaluating the environmental performance of suppliers and mentioned that the availability of clean materials, environmental efficiency, green image, environmental costs, green products, environmental & legislative management and green process management as the most commonly referred criteria in green supplier evaluation literature. Bai and Sarkis (2010) used a grey system and rough set methodologies to integrate sustainability into supplier selection and summarized environmental metrics as pollution controls, pollution prevention, environmental management system, and resource consumption and pollution production. Gulcin Buyukozkan (2011) compared a novel hybrid MCDM approach based on fuzzy DEMATEL, fuzzy ANP & fuzzy TOPSIS to evaluate green suppliers.

Yeh and Chuang (2011) developed two multi-objective genetic algorithms for green partner selection, which involved four objectives such as cost, time, product quality and a green appraisal

score. They offered green image, product recycling, green design, green supply chain management, pollution treatment cost and environment performance assessment criteria for green supplier selection. Alireza Iirajpour (2012) used Technique for order preference by similarity to ideal solution (TOPSIS) method for selection of a supplier. Govindan et al. (2013) proposed a fuzzy multi criteria approach for measuring sustainability of a supplier and considered pollution production, resource consumption, eco-design and environmental management system as environmental criteria. K.Mathiyazhagan *et.al.* (2013) used an Interpretive Structural Modeling (ISM) to understand the mutual influences amongst the twenty-six barriers by conducting a survey. A study by Lixin Shenc (2013) examined GSCM to propose a fuzzy multi criteria approach for green suppliers' evaluation. Authors translated subjective human perceptions into solid crisp by fuzzy set theory and the overall performance score for each supplier was generated through fuzzy TOPSIS.

3. DIFFERENCE BETWEEN TRADITIONAL AND GREEN SCM

Traditional Supply chain management (SCM) usually concentrated on cost and control of the final product, but hardly considered its ecological effects. In comparison, GSCM is green, integrated and ecologically optimized and takes into consideration the human toxicological effects as well. Companies considered ecological requirements as the most important criteria for products and production, to ensure economic profitability and sustainability. Some characteristic differences between traditional SCM and green SCM are shown in table 1.

Table 1. Traditional SCM vs Green SCM

Sr.No.	Characteristics	Conventional SCM	Green SCM
1	Objectives and values	Economic	Economic and Ecological
2	Ecological optimization	Integrated Approach High	Ecological Impacts
3	Supplier Selection Criteria	Price Switching Supplier Short Term Relations	Ecological Aspects Long Term Relations
4	Cost prices	Low	High
5	Speed and Flexibility	High	Low

4. TRADITIONAL SUPPLY CHAIN MANAGEMENT

These supply chain stages include:

- Component/ raw material suppliers
- Manufacturers
- Wholesalers/distributors
- Retailers
- Customers

A traditional supply chain is defined as an integrated manufacturing process, wherein the Supplier supplies raw materials or semi finished goods to the manufacturer and are manufactured or

assembled into final products, and then the finished goods are sent to the wholesaler, to retailer and finally delivered to customers. Figure 2 illustrates structure of a traditional supply chain. Each stage in a supply chain is connected, on one side by physical flow of goods i.e. from top to bottom on left hand side and on the other side by the information flow i.e. from customer to supplier. The appropriate design of the supply chain depends on both the customer's needs and the roles played by the stages involved. Traditional SCM has usually concentrated on economy and control of the final product, but hardly considered its ecological effects.

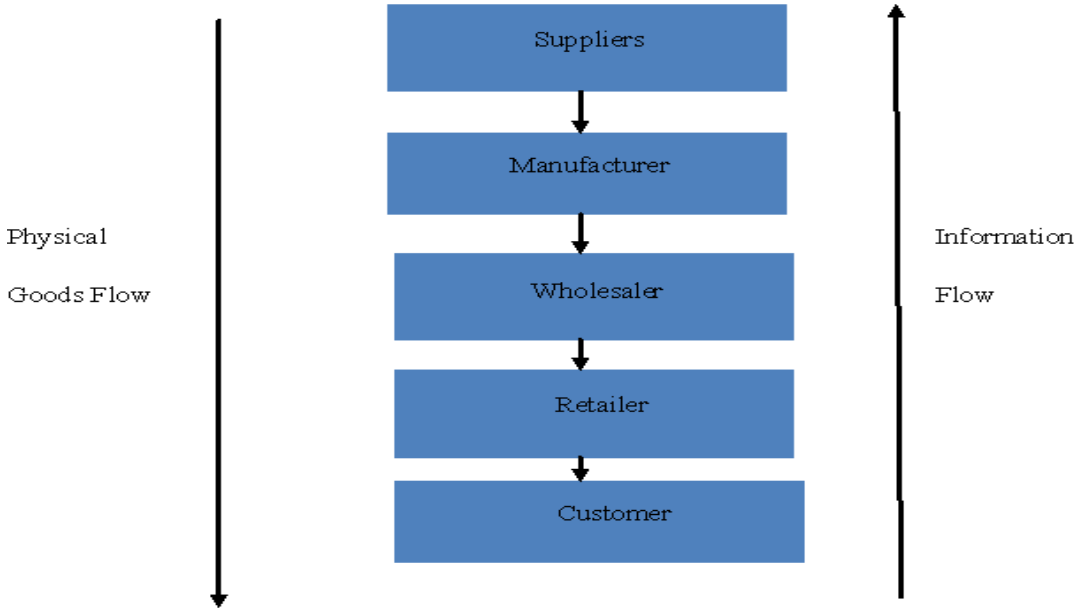

Figure 2: Traditional supply chain structure

5. REDEFINED STRUCTURE OF TRADITIONAL SUPPLY CHAIN MANAGEMENT

The concept of Green supply chain management faces new challenges in the context of manufacturing and production enterprises worldwide. The main challenge is to develop ways that finds an optimum between industrial development and environmental protection. The first step in meeting this challenge is to redefine the basic structure of a traditional supply chain and accommodate the environmental concerns associated with reduce waste and resources as shown in Fig. 3.

Traditional supply chain also includes a supplier, manufacturer, wholesaler, retailer and customer. But the main objective of extending the traditional supply chain is to consider the in between and eventual environmental effects of all products and processes known as stewardship. The stewardship concept is shown in figure 3 below. After the life cycle of the product gets over, the product is finally collected from customer and after the collection, if some components are found to be good enough to use, it is directly sent to the retailer and those are not further forwarded for dismantling. In final dismantling of the product, if some parts are found to be used are forwarded directly in manufacturing process and finally those, which are not of any use are disposed off or recycled such that it is used as raw material.

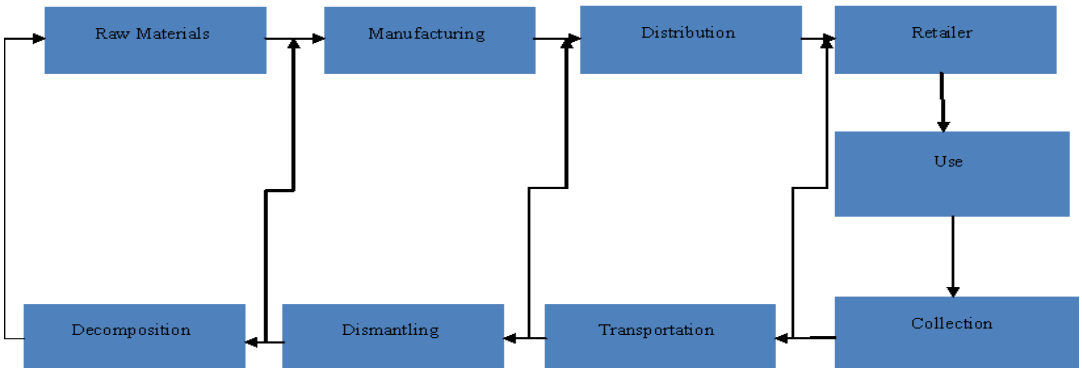

Figure 3. Redefined basic structure of traditional supply chain

6. GREEN SUPPLY CHAIN MANAGEMENT

The economic advancements and development in a society consumes a lot of energy and other resources and these contribute to a lot of environmental issues and also results in depletion of natural resources. In view of this, it has become increasingly imperative for organizations facing competitive, regulatory and community pressures to search for a balance between economic and environmental performance. Currently, many of the organizations are attempting to go green in their businesses, because of the concern for environmental sustainability. They have realized that the green technology adoption benefits them in their business operation, which also affects the suppliers and customers. Environmental regulations and directives in advanced economies such as US, the European Union (EU) and Japan have become important concerns for manufacturers. Green Supply Chain Management (GSCM), therefore emerges as a new systematic environmental approach in supply chain management as it considers factors such as eco-design & design for environment, industrial ecology, environmental management systems, product stewardship & extended product responsibility and life cycle analysis as shown in Fig. 4.

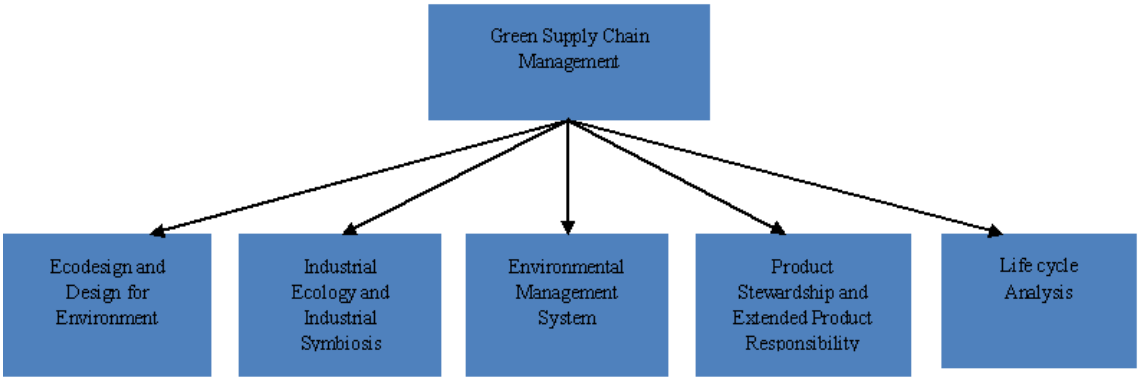

Figure 4. Systematic environmental approach in supply chain management

Eco-design is an approach in the design of a product with special consideration for the environmental impacts of the product during its whole lifecycle. In assessment of life cycle of the product, the whole life cycle is divided into procurement, manufacture, use and disposal. Eco-design is a growing responsibility and understanding of our ecological footprint on the planet. It is imperative to search for building new solutions that are environmentally friendly and lead to a reduction in the consumption of materials and energy.

Industrial ecology is the study of energy and material flows through industrial systems. The global industrial economy can be modeled as a network of industrial processes that extract resources from the Earth and transform those resources into commodities, which can be bought and sold to meet the needs of humanity. Industrial symbiosis is a branch of industrial ecology, whose main focus is material and energy exchange.

Environmental management system (EMS) refers to a comprehensive, planned, systematic and documented organizational environmental program management. It includes the organizational structure, planning and resources for developing, implementing and maintaining policy for environmental protection. EMS is "a database and system, which integrates process for training of personal and procedures, summarize, monitor and reporting of specialized environmental performance information to external and internal stakeholders of a firm." EMS is typically reported using International Organization of Standards (ISO) 14001 to help understand the EMS process.

Extended producer responsibility, also known as Product Stewardship is a strategy to place a shared responsibility not only of end user, but all of them, who are involved in product chain for end life of product management. This is done while encouraging product design changes that minimize a negative impact on human health and the environment at every stage of the product's lifecycle. It is the primary responsibility of brand owner or producer, who makes the marketing and design decision to incorporate the treatment and disposal cost into the cost of product. It also creates a setting for markets to emerge that truly reflect the environmental impacts of a product, and to which producers and consumers respond.

Life-cycle analysis (LCA) is a technique to assess the environmental impacts associated with all the stages of a product's life from material processing, manufacturing, distribution, use, maintenance, repair and recycling. LCAs can help avoid a narrow outlook on environmental concerns by compiling an inventory of relevant energy and material inputs & environmental releases. This is done by evaluating the potential impacts associated with identified inputs & releases, interpreting the results to help make a more informed decision.

6.1 Objectives of green supply chain management

Main focus of GSCM is to make business orientation eco-friendly:

- To achieve competitive advantage and high performance through GSCM practices.
- To integrate the green supply chain into corporate policies and strategies for smooth operation.
- To make a significant difference in its approach.
- To show how important it is to conserve environment and sustain the natural resources and show to what extent is the business activities dependent on environment.

7. CRITERIA FOR SUPPLIER SELECTION

7.1 Traditional supplier selection criteria

Since 1960s, supplier selection criteria and suppliers performance have been a focal point of many researchers. While the traditional supplier evaluation methods primarily considered financial measures in the decision making process, more recent emphasis points to the incorporation of multiple suppliers criteria into the evaluation process (Talluri and Narasimhan, 2007).

It was observed that the price or cost is not the most widely adopted criterion. Instead, quality, followed by delivery, cost etc. are the most popular criteria used in supplier selection process. It proves that in contemporary SCM traditional approach single criteria i.e. cost is not supportive and robust. The traditional cost-based approach cannot guarantee that the selected supplier is global optimal, because the customer-oriented criteria (quality, delivery, flexibility, and so on) are not considered (Ho *et. al.,* 2009).

Location, additional value added capability, scope of resources, quality, cost, flexibility in contracts, on time delivery, reputation, culture and existing relationship are the top10 factors considered in supplier selection according to a survey (Shu and Wub, 2009). 23 criteria were identified for supplier selection based on a survey of 273 purchasing managers by Dickson (1966). The Author observed that quality was perceived to be the most important criterion followed by delivery and performance history (Chaudhry *et. al*. 1993;Talluri and Narasimhan, 2003).

Weber *et. al*. presented a review of 74 articles that represented the supplier selection literature available since the year 1966. They also characterized each article according to the criteria used, purchasing environment assumed and techniques or analytical methods employed. Capacity, quality, on time delivery and net price, were the criteria that appeared most often in articles (Weber *et. al.,* 1991). Ho *et. al.* (2009), suggested that flexibility, finance, risk, research & development, manufacturing capability, technology, management, service, relationship, reputation, price, delivery, safety and environment are followed after quality management, safety and environment.

7.2 Green supplier selection criteria

Supplier selection is a multi-criteria decision making process and mostly the data type is qualitative and quantitative in nature. Supplier selection problem involves tangible and intangible criteria. Variations in the criteria mostly depend upon products and also include lots of judgmental facts. Various criteria that are important for green supplier selection, as evident in literature and gathered from discussions with experts include:

Design criteria: In the development of a new product, mostly design criteria is considered and the design criteria includes, reuse of the components, reduction of waste coming out of product as well as cost, design according to changeability of product/processes, design for proper utilization of material, dismantling of the component makes easy, design for utilization of resources efficiently, design according to remanufacturing is done afterwards.

Manufacturing criteria: Minimize the amount of hazardous material used in production of product, Measures taken to reduce material, water and energy used in manufacturing, Reduced setup time, Minimizing use of natural resources during manufacturing, Minimizing toxic/hazardous waste during manufacturing, Production schedule, Close loop manufacturing/Remanufacturing, Backup system, Quality level, Supply chain information sharing.

Technology criteria**:** Technology level ability of R&D, Cleaner technology (water, air, energy used), Technical expertise.

Green logistics criteria: Sustainable transportation Handling and storage of hazardous material, Control on inventory, Warehousing, Packaging and Facility Allocation.

Customer service criteria: Technical support, Re-design, Complaint response time, Storage frequency, Warranty, Certification.

Environmental management criteria: Raw material, reuse recovery; Recycle of waste, Emission, ISO 14000 certification.

Procurement management criteria: Requirement of green purchasing, Green material coding and recording, Inventory of substitute material, suppler management.

R&D management criteria: Capability of green design, Inventory of hazardous substance, legal compliance competency.

Process management criteria: Management of hazardous substance, Prevention of mixed material, Process auditing, Pre-shipment inspection.

Operational performance criteria: Inventory level has to reduced, Reduction in percentage of scrap, Promote to use only for environmental quality products, Optimization of maximum capacity utilization, Percentage goods delivered on time, Monitoring the environmental and implementation for improvement with industry, Conduct the program to promote and track the reduction of waste, Waste management program for compliance with all applicable regulations, Selection of energy efficient equipment as for mechanical, electrical, and lightning applications, Development of prevention program to identify and eliminate sources of pollution.

Customer co-operation criteria: Customer's co-operation for eco-design, Customer co-operation for cleaner production (air, water and energy), Insisting form customer for green packaging, Co-operation for using less energy during transportation of product, Co-operation with customer for environmental procurement.

8. CONCLUSION

The concept of traditional supply chain management is becoming more complex and competitive day by day; as it was considered earlier as the process of converting raw material into final product and finally delivered it to the end user. In the current era, the analysis of each individual stage in the supply chain is equally important. Thus the concept of supply chain has emerged in all production process, ranging from raw material acquisition to final delivery of the product.

Changes in the state of environment, subsequent public pressure and environmental logistics have come to enforce the shift in manufacturing and business practices. Now it has become most important to analyze the entire life cycle effect of all processes and products. Therefore, the structure of traditional supply chain is to be extended further and included with the product recovery mechanism. Presence of this extension has created an additional level of complexity in the analysis and design of supply chain.

Upon reviewing the extant literature, it can be concluded that the concept of SCM needs to be remodeled in the green context. The difference between traditional supply chain management and green supply chain management points to the need to address the ecological aspect, through there exists a tradeoff with the cost, speed and flexibility. The addition of the product recovery mechanism gives rise to numerous issues affecting strategic and operational supply chain decisions. Subsequently, the extension of the traditional supply chain requires the establishment and implementation of new performance measurement systems. In view of this, the supplier selection criteria have to be redesigned as per the need and the context. These new measurement systems developed will serve as the centerpieces of environmentally conscious implementation plans, based on continuous improvement, that will enable organizations to become and remain more competitive, while achieving sustainable processes and development.

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