Major Project

Dissertation on

Comparative study of AHP and TOPSIS in Green Supply Chain Management

Submitted by:

Mohit Deswal

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Under the guidance of:

Mr. N. Yuvraj

Assistant Professor,

Department of Mechanical Engineering

Department of Mechanical Engineering

DELHI TECHNOLOGICAL UNIVERSITY

(Formerly Delhi College of Engineering)

Bawana Road, New Delhi

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CERTIFICATE

This is to certify that the report entitled **"Comparative study of AHP and TOPSIS in Green Supply Chain Management"** submitted by **Mohit Deswal** (Roll No.:07/PRD/2010) in partial fulfillment for the award of Masters of Technology in Production Engineering from Delhi Technological University, is a record of bonafide project work carried out by him under my supervision and guidance.

Mr. N. Yuvraj
Assistant Professor
Department of Mechanical Engineering
Delhi Technological University, Delhi

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Mohit Deswal

(07/PRD/2010)

M.Tech (Production Engineering)

Delhi Technological University

ABSTRACT

Green supply chain management (GSCM) is defined as the process of using environmentally friendly raw materials and manufacturing products which can be reused, remanufactured, recycled or easily disposed so as to have sustainable supply chain. GSCM aims in reducing waste, reducing emission, preserving the quality of natural resources, decrease of consumption of hazardous and harmful materials, better product life cycle, usage of environmentally friendly materials etc. The growing importance of GSCM is driven mainly by the escalating deterioration of the environment, e.g. diminishing raw material resources, overflowing waste sites and increasing level of pollution. However, it is not just about being environment friendly; it is about good business sense and higher profit. Green supply chain aims to balance marketing performance with environmental issues. Since GSCM is a fast growing concept, two Multiple criteria decision making (MCDM) methods have been compared in the parameters related to green concept for different chairs to get the best alternative. MCDM refers to making decisions in the presence of multiple, usually conflicting criteria. Analytic Hierarchy Process (AHP) and Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) are methods of MCDM. In this project, AHP and TOPSIS methods have been applied to get the best alternative among different chairs having different environmental performance parameters. After getting the preference order from both AHP and TOPSIS, best alternative was found with respect to environmental performance parameters. Since result was almost the same in AHP as well as TOPSIS, so it is suggested that AHP model should be used because of its simplicity in use and easiness in understanding as compared to TOPSIS.

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CHAPTER 1

1. INTRODUCTION: GSCM

In the eighteenth century natural resources were abundant, but there was no way to utilize them efficiently. The industrial revolution, which began about the middle of that century, increased labor productivity to many fold. Industrialization gained momentum and automation provided mechanical innovation thinking, which supported the idea of human substitution by machine. The benefits of industrialization are a shift from rural and agrarian economy to an urban and industrial economy. The mass production technique increased the consumption, as it supplied goods at cheaper price and made society perceive luxurious as well as necessary goods. The demand for goods also increased with improvement in the standard of living and increased population. It leads to natural resources depletion on one hand and the environmental degradation by dumping pollutants on the other.

Deepening environmental concerns and perceptions of increased risk to health and safety of community residents from industrial activities have led to a significantly increase in interest in research at the interface of environmental management and operations of industries. From the last decade, the concept of sustainable development (SD) had gained significant attention from the research. So, keeping in mind the environmental protection, sustainable development is introduced which may be defined as the Development that meets the needs of the present generation without compromising the ability of future generations to meet their own needs. To overcome the problems associated with climate change, unsustainable consumption of natural resources and very high rate of energy consumption, a new technology named Green supply chain management (GSCM) is emerging as a lifesaver by decreasing the harmful effects of modernization and industrialization (Sarkis, 2003).

GSCM aims in reducing waste, reducing emission, preserving the quality of natural resources, decrease of consumption of hazardous and harmful materials, better product life cycle, usage of environmentally friendly materials etc. GSCM is a fast growing concept in India but it has proven to be a successful tool for modern world. The green supply chain management is a sort of management mode which would comprehensively consider the environmental influence and resource utilization efficiency in the whole supply chain and how to implement the green supply chain management in special industrial operation at present has become one of hotspot problems. In other words, it is optimal decision making during supply chain activities by considering the environmental influence. The issue of green supply chain management has received attention among manufacturing practice and research. GSCM initiates deliver bottom line benefits. Companies are trying to greener their supply chain to reduce the cost of production so as to have the competitive advantage. They are also trying to make their production process eco-friendly.

The scope of green supply chain management ranges from reactive monitoring of the general environment management programmes to more proactive practices implemented through various Rs (Reduce, Re-use, Rework, Refurbish, Reclaim, Recycle, Remanufacture, Reverse logistics etc.). Eco-efficiency and remanufacturing process have become important in achieving sustainable supply chain (Ashley, 1993; Srivastava, 2007). GSCM is gaining interest among researchers and practitioners of operations and supply chain management. The growing importance of GSCM is driven mainly by the escalating deterioration of the environment, e.g. diminishing raw material resources, overflowing waste sites and increasing level of pollution. However, it is not just about being environment friendly; it is about good business sense and higher profit. Green supply chain aims to balance marketing performance with environmental issues. Greening the supply chain is increasingly a concern for many business enterprises and a challenge for logistic management. Increasing pressures from a variety of directions have caused the supply chain managers to think and start implementing the green supply chain management practices to improve both their economic and environmental performance. One of the key aspects to green supply chains is to improve both economic and environmental performance simultaneously throughout the chains by establishing long-term buyer-supplier relationships. Green supply chain can not only generate environmental benefits, but also business benefits. In India, the diversity in the adoption rates has seen some manufacturing supply chain companies proactively implementing environmental strategies such as green purchasing and eco-design. Many manufacturing supply chain enterprises considered or initiated some GSCM practices such as investment recovery, eco-design and internal environmental management. However, investment recovery and development of recycled material markets in India have not received much attention. That is to say the maturation of the manufacturing product market is still progressing and has yet to create a critical mass to be economically worthwhile for development of the used parts market. However, a regulated manufacturing product take-back system has been in operation in India. These take-back system forces manufacturers to consider environmental effects in the whole life cycle, and thus providing motivation for organizations to further pursue GSCM practices and closing the manufacturing supply chain loop. Thus, GSCM practices have emerged as a systematic approach within the manufacturing industry in India to balance the economic and environmental sustainability of firms. A hierarchy of strategies was given by Carter and Ellram in which 4 different stages of strategies, to be adopted by GSC managers, are given as shown in fig 1.1.

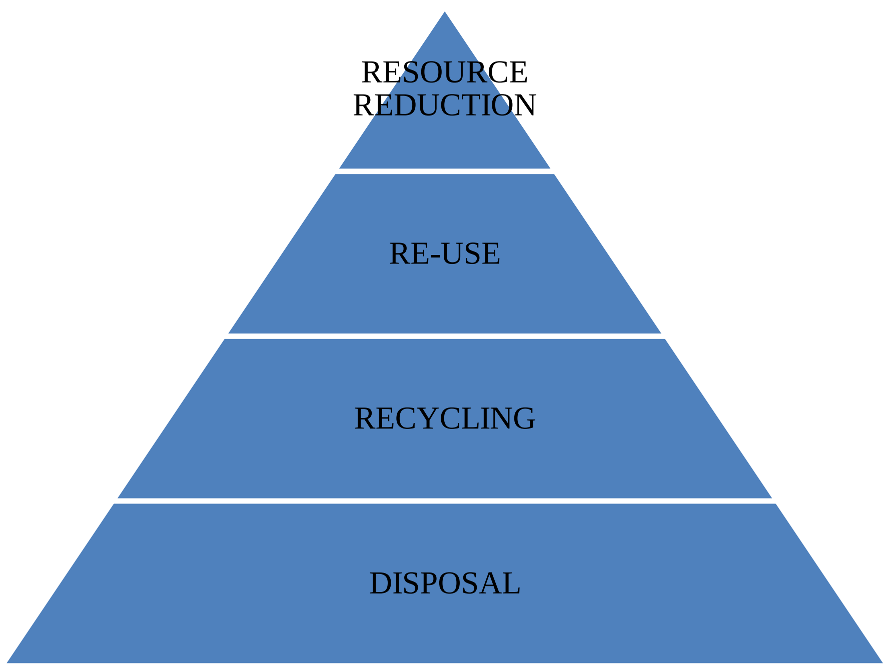

Figure 1.1: Hierarchy of strategies (Carter and Ellram, 1988)

Difference between conventional SCM and Green SCM:

A Supply chain consists of all parties involved, directly or indirectly, in fulfilling a customer request. The supply chain includes not only the manufacturer and suppliers, but also transporters, warehouses, retailers, and even customers themselves. Within each organization, such as manufacturer, the supply chain includes all functions involved in receiving and filling a customer request. These functions include, but are not limited to, new product development, marketing, operations, distribution, finance, and customer service.

A supply chain is dynamic and involves the constant flow of information, product, as well as pricing and availability information, to the customer. In fact, the primary purpose of any supply chain is to satisfy customer needs and, in the process, generate profit for itself. The term supply chain conjures up images of product or supply moving from suppliers to manufacturers to distributors to retailers to customers along a chain. This is certainly part of the supply chain, but it is also important to visualize information, funds, and product flows along both directions of this chain. The term supply chain may also imply that only one player is involved at each stage. In reality, a manufacturer may receive material from several suppliers and then supply several distributors. Thus, most supply chains are actually networks.

It may be more accurate to use the term supply network or supply web to describe the structure of most supply chain as shown in fig below:

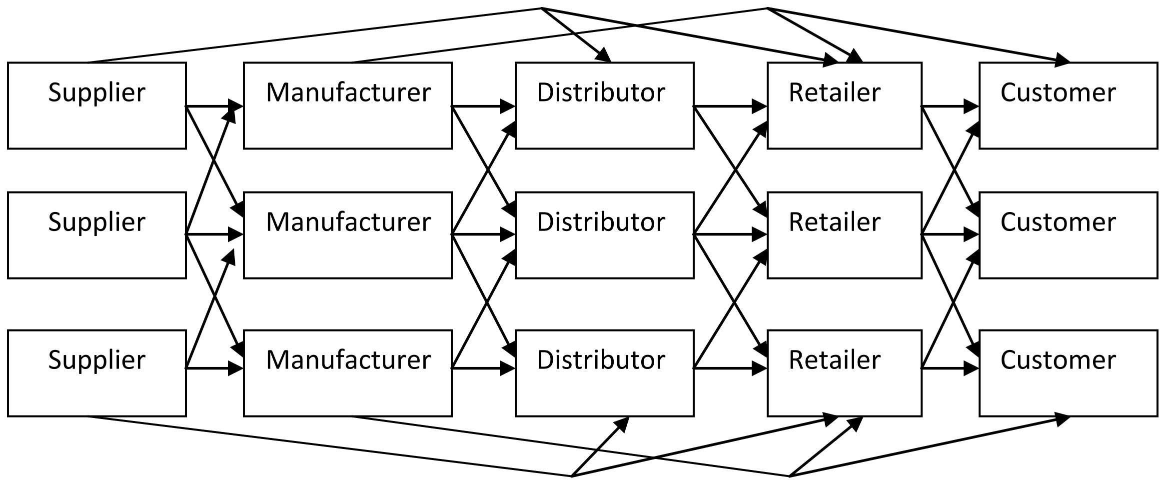

Fig 1.2: Supply chain stages

So, a typical supply chain may involve a variety of stages. These supply chain stages include:

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

Each stage in a supply chain is connected through the flow of products, information, and funds. These flows often occur in both directions and may be managed by one of the stages or an intermediary. Each stage as shown in fig 1.2 above need not be present in a supply chain. The appropriate design of the supply chain depends on both the customer's needs and the roles played by the stages involved.

Conventional SCM (Supply chain management) usually concentrated on economy and control of the final product but seldom considers its ecological effects. In comparison, GSCM is green, integrated ecologically optimized and takes into consideration of human toxicological effects as well. Companies put ecological requirements as the main criteria for products and productions and ensure economic profitability and sustainability. Some characteristics differences between conventional SCM and GSCM have been shown in table 1.1.

Difference between convention SCM and GSCM are summarized in table below:

S.No	Characteristics	Conventional SCM	Green SCM
1	Objectives value	Economic	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

Table 1.1: Conventional vs Green SCM

1.1 DEFINITION:

GSCM (Green supply chain management) is defined as the process of using environmentally friendly raw materials and manufacturing products which can be reused, remanufactured, recycled or easily disposed so as to have sustainable supply chain.

GSCM's definition has ranged from green purchasing to integrated supply chain flowing from supplier to manufacturer, to customers and reverse logistics. Some of the definitions given by different scholars are as follows:

- Hervani et al., 2005 defined green chain management(GSCM) = Green purchasing + Green manufacturing/materials management + Green distribution/marketing + Reverse logistics)
- Srivastava, 2007 defined GSCM as an integrating environment thinking into supply chain management, including product design, material sourcing and selection, manufacturing processes, delivery of the final product to the consumers, and end-of-life management of the product after its useful life.
- Lee, 2004 defined GSC initiative as the programmes striving to transfer and disseminate environmental management, in particular advanced environmental management practices, through its entire supply chain, by using the relationships between large-sized buying firms and their suppliers.
- Shukla et al., 2009 defined GSCM as all encompassing, strategic set of actions taken by collaborating partners and stakeholders of an ultimate supply chain to mitigate and /or eliminate the detrimental impacts of all business activities, spanning across the chain, on the environment and thereby ensuring the sustainability.
- Vachon and Klassen, 2006 defined two sets of green supply chain practices:

Activities using markets or arm's length transactions conducted by the buying organization in order to evaluate and control its suppliers (environmental monitoring) and Activities comprising a direct involvement of the buying organization with its suppliers to jointly develop environmental solutions (environmental collaboration).

1.2 OBJECTIVES OF GSCM:

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

1.3 GREENING THE SUPPLY CHAIN:

Protection of environment becomes a basic principle for a green company business, even at the expense of profit. Greening is a process of developing green technologies and products for sustainable development. The future of sustainable industrialization depends on the degree to which the firms are greened and being environment friendly. Greening resulted in win-win alliance with regulatory, community and consumer. In the win-win perspective, the industries that are innovative can simultaneously realize improvements in productivity and environmental performance. Reasons for industries being greened are:

- Industries consider greening as a potential source of opportunity instead of burden.
- Greening not only reduces the environmental impact, but also improves efficiency and competitive advantage.
- Most of the industries have the concept to follow the leader strategy. Environmentally conscious competitors make their industries greener and it attracts other industries to do the same.
- The natural environment is being treated as an internal factor to create positive image or good reputation among the society. This goodwill is an intangible asset for the industry.
- Industry managers believe that they have to become socially responsible by moving beyond compliance to promoting best practice.

Figure 1.3 shows the sustainable supply chain framework providing methods and benefits of having sustainable supply chain and figure 1.4 shows economy, society and environmental effect of having sustainable green logistics

Figure 1.3: Sustainable Supply Chain Framework:

Walk the Talk Stakeholders	Leadership	*Knowledge Sharing with
Get “outside the box”	Innovation	*Sustainable product and process development
Align with Corporate Strategy	Integration	*Supply chain operations *Procurement *Supplier Management
Measure and Improve results	Continuous Improvement	*Supplier engagement *Pollution prevention *Environmental Mgmt. System
Meet or exceed requirements	Compliance	*Price of entry *A given

There are some major stakeholders, who are currently driving the industry to become greener:

a) Inter-organizational: consumers, suppliers and employees directly related to an organization’s profitability.

b) Intra-organizational: community stakeholders (community groups and environmental organizations) and

c) Regulatory stakeholders (government, trade associations, informal networks, and a given organization’s competitors). Regulatory stakeholders other than government may have the power to convince government to intervene for the environmental protection.

During the greening process, an enterprise should move from lower end solution to higher, such as from reduce to disposal. The waste minimization is a process of increasing resource utilization or reduction of waste and extracting maximum from the waste stream before final disposal or recycling. As globalization leads to raising standards of knowledge and capability, it is possible to achieve high quality of life and living standards through waste minimization without long-term harm to the environment. Green supply chain help in elimination of wastes, optimize utilization of resources, sustain the environment, provides competitive advantage, impress customers and create social responsibility.

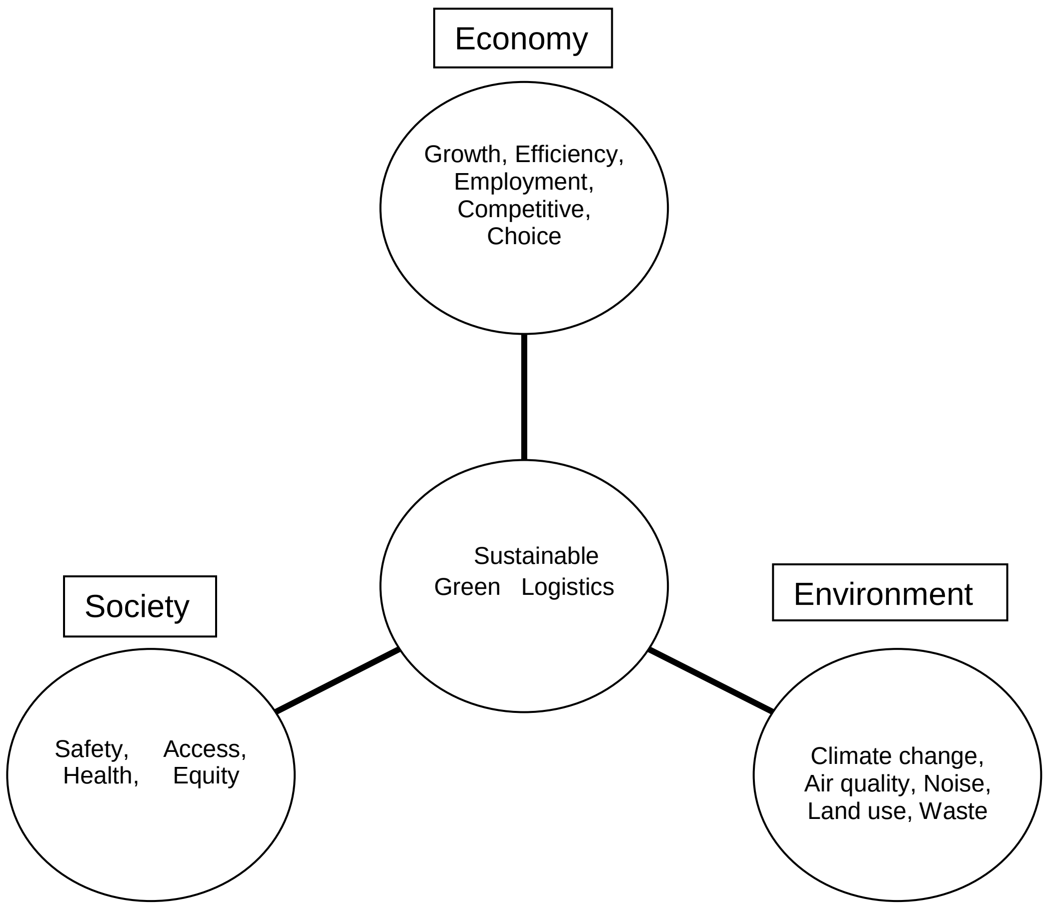

Fig 1.4: Sustainable green logistics diagram

1.4 VARIOUS INDUSTRIES RELATED TO GSCM:

GSCM is emerging a fast-growing field in various industries due to its long-term benefits. There are many fields where green supply chain is used like automobile, power generating, chemical/petroleum, electrical, electronics, textile, steel, food processing, pharmaceutical, mining, agriculture, printing etc.

Now, the food industry can be divided into two processing sectors, i.e. manufacturing and packaging of food, and the retail sector, i.e. distribution and selling. So, while talking about food industry, there is discussion about the whole supply chain, i.e. from manufacturing to customers selling of food. So there is need to green our whole supply chain to make it environmental friendly. The Indian food market is estimated at $91.7 billion, with the processing segment accounting for $29.4 billion. Although it is the fifth largest country in the country, it is still in inception. Processed food makes up only 2 percent of total agriculture and food produce in the country. The government has put food processing and retail high on its agenda and is both easing legislation and increasing investments in the sector (Food biz daily). Considering the immense potential for growth, multinationals have already entered the market. Unilever, Nestle, Pepsi and Cadbury are presently the most important actor. Today, small retailer accounts for 97 percent of sales. With twelve million shops, India has the largest density of groceries in the world. Big corporations plan to bring their 3 percent share to 15-20 percent within a few years. Investments are planned not only by foreign corporations, but also by domestic firms like Reliance, Tata, and Birlas (India Fdi watch).

With regards to the situation in China, the membership of WTO has exerted more environmental pressures on Chinese enterprises, which have led their supply chains to become more complex and diverse. Large Chinese enterprises, like Guitang Group and Shuanghui Group, have been the pioneers in embracing the concept of GSCM and the focused of a number of surveys (Zhu and Sarkis, 2004; 2006, and Zhu, et al., 2007). However, the situations within the Chinese small and medium-sized enterprises (SMEs) are unclear. With the integration of the global economy, the formation and development of industry chain and industry integration, GSCM of Chinese SMEs had become a very important weight in the market competition. However, SMEs, due to their various constraints – finance, infrastructure, human resources and so on, have found that it is significantly challenging to adapt GSCM effectively into their corporate strategies.

In China, Zhu and Sarkis, 2004 studied the relationships between GSCM practices and performance among those early adopters of Chinese enterprises. They compared the automobile, power plants and electronic industries in the Chinese context and found the three industries differ in GSCM practices adoption. Chung-Hsiao in 2008 studied the Green supply chain management in the electronic industry in which they mentioned that there are various approaches for implementing green supply chain management practices. Fengfei Zhou in 2009 study on the Implementation of Green Supply Chain Management in Textile Enterprises in which according to the author the green supply chain management is a sort of modern management mode which could comprehensively consider the environmental influence and resource utilization efficiency in the whole supply chain and how to implement the green supply chain management in special industrial operation at present has become into one of hotspot problems.

1.5 GSCM ISSUES AND CHALLENGES:

The production of goods from the raw materials for the consumption is the goal of all industries. But the whole process of manufacturing and consumption of goods is not so simple. It's the whole supply chain which should be successful at every stage. The supply chain includes the whole process of planning, organizing, manufacturing, distribution, consumption. At every stage there is some consumption of resource which can be economical like the consumption of electricity, water, chemicals etc for getting the finished products or it can be non-economical as if it is producing a lot of wastes affecting our environment. Since the company tries to be economical but beside this they should reduce the non-economical part as much as possible for reducing the pressure on the environment. Because it has become necessary to prevent the environmental pollution and global warming while producing and consuming the goods. So, nowadays, a concern has grown among the manufacturers to eliminate the generation of waste as much as possible to have the whole supply chain environment friendly and also increase its productivity and revenue. So to achieve this we use the concept of 3 R's namely reuse, recycle, and replenishment of available resources in our supply chain so that we can have sustainable development and that's why we have targeted to use green supply chain management so that we can reduce the thrust on the available resources and help in retrieving the used resources for recycling purposes. Green supply chain management has its roots both in environmental management and supply chain management literature. Challenges for sustainable supply chain managers are:

- Ecological challenge
- Social challenge
- Economic challenge
- Integration challenge

Present scenario of unsustainable development disturbs the patent form of the nature. It shows a man-centric effort to conquer nature and ultimately over-power it. The economy that is built up by man to protect him and prosper is stressed. The important factors that are responsible for environment deterioration are population growth, continuous depletion of non-renewable sources, frequent fluctuations in consumption pattern, increase in per capita income and industrialization. Nature is a cycle of production process, which circulates matter continuously and generates no waste. Conventionally, the industrial process is linear i.e. from input to output; waste is also generated. Nature's finite capacity is capable of absorbing limited quantity of residual waste from the economy or providing limited quantity of resources to the economy. Current scenario natural throughput is less than anthropogenic throughput. This endangered the need to maintain the long run carrying capacity of the earth.

As the twenty-first century begins, humanity is being squeezed between deserts expanding outward and rising seas encroaching inward. Physical production has an unavoidable environmental impact, which leads to environmental damage if the impact exceeds the carrying capacity.

Currently global production expands at around 3 percent per year, while technology development only reduces the specific footprint by around 2 percent per year. The ecological footprint is a tool to measure the carrying capacity and defined as a total land required to support resources consumed and waste generated by a company. The per capita footprint is a biologically productive land and water area required to support the resource consumption and waste output per person. Redefining, Progress is a non-profit public policy institute working to develop more accurate measures of economic welfare and discourage the waste and pollution generation and the resource consumption. It reported that in the late 1970s humanity's collective ecological footprint breached the sustainability mark for the first time and has remained unsustainable ever since. By the year 2000, the ecological deficit reached nearly 1 acre per person, or 9 million square miles (23 million square kilometers). Three main geo-chemical reservoirs (atmosphere, biosphere and hydrosphere) on which humankind depends for survival are polluted. The world's oceans are absorbing an unprecedented amount of CO_2, increasing their acidity and threatening the long-term survival of many marine species. The magnitude of absorbing is three times greater than those experienced between ice ages. The ocean has taken approximately 120 billion tons of carbon generated by human activities since 1800. Some 20 million to 25 million tones of CO_2 are being added to the oceans each day. By 2050, the world's population could grow to about 10 billion. At present, CO_2 absorption limit of the atmosphere is about 10 billion tonnes a year. This would mean that each person on the planet could sustainably generate a tone of CO_2 each year. While per capita emissions of CO_2 currently stand at almost 19.9 tonnes in the USA, 9 tonnes in the Britain and 0.9 tonnes in India.

Solid wastes are heterogeneous mass of throwaways from human, industrial and commercial activities that are normally non-flowing in nature. Industries in USA may drive progress but they also saddle the nation about 7.6 billion tonnes of industrial solid waste each year. These industrial wastes are growing in quantity and becoming more difficult to dispose or degrade. Cities in developing countries typically produce about 0.5 kg to 1 kg of solid waste per day per capita. Solid waste management usually accounts for 30 percent to 50 percent of municipal operational budgets and cost about US$ 5 per capita per year. Cost of acquiring land for disposal is expensive and highly political due to community resistance.

Altruism aside, regulatory is necessary such as the European Union's restrictions on hazardous substance and electronic equipment increasingly require companies to use greener practices. These laws have business decision makers examining both their own operational processes and those of their suppliers. Firms can be held liable for the ecologically irresponsible actions of their suppliers in a court of law, the court of public opinion, or both. Moreover, suppliers with lax environmental policies are likely targets for government prosecutions and even shutdowns, which can impede their ability to fill your orders. "The bottleneck in your supply chain and the customer isn't going to be peeved with the supplier. They're going to be peeved with you for not delivering them the product on time", says Andrew Armstrong, a director at the consulting firm WSP Environmental in London. For one, a greener supply chain is usually a more efficient one. “Any pollution is waste, and waste costs money,” says Sarkis, 2003.

1.6 DRIVERS TO ADOPT GSCM:

- Target marketing
- Employee morale.
- Brand reputation
- Lowered cost
- Product differentiation
- Increased efficiency
- Adapting to regulation and reducing risk
- Sustainability of resources
- Competitive and supply chain pressures
- Customer pressures
- Expected business benefits
- Social responsibility
- Community pressures
- Competition
- Supplier pressures
- Market demand

1.7 ACTIVITIES IN GREEN SUPPLY CHAIN MANAGEMENT:

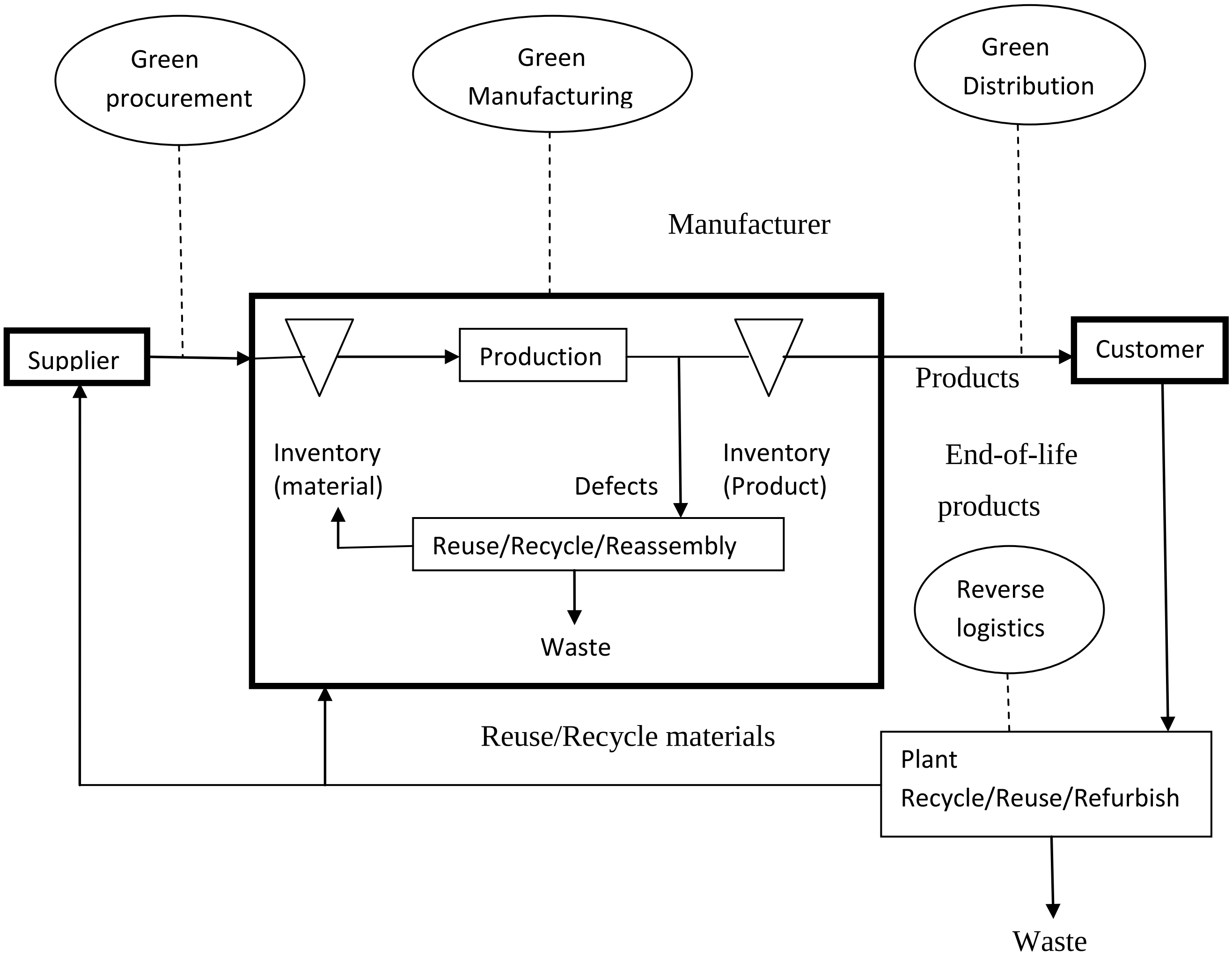

Fig 1.5: Activities in Green supply chain management (Ninlawan et al., 2010)

The green activities can be revealed as shown in fig 1.5:

A. Green procurement: Green procurement is defined as an environmental purchasing consisting of involvement in activities that include the reduction, reuse and recycling of materials in the process of purchasing. Besides, green procurement is a solution for environmentally concerned and economically conservative business and a concept of acquiring a selection of products and services that minimizes environmental impact (M.A. Salam, 2008).

B. Green manufacturing: Green manufacturing is defined as production processes which use inputs with relatively low environmental impacts, which are highly efficient, and which generate little or no waste or pollution. Green manufacturing can lead to lower raw material costs, production efficiency gains, reduced environmental and occupational safety expenses, and improved corporate image (M.Atlas, 1998).

C. Green distribution: Green distribution consists of green packaging and green logistics. Packaging characteristics such as size, shape, and materials have an impact on distribution because of their affect on the transport characteristics of the product. Better packaging, along with rearranged loading patterns, can reduce materials usage, increase space utilization in the warehouse and in the trailer, and reduce the amount of handling required (J.C. Ho, 2009).

D. Reverse Logistics: Reverse logistics is the process of retrieving the product from the end consumer for the purpose of capturing value or proper disposal. Activities include collection, combined inspection/selection/sorting, re-processing/direct recovery, redistribution, and disposal.

Function	Initiatives	Outcome
Product Development	*Design for environment *Redesign packaging *Identify and use less hazardous or recyclable materials *Provide waste management solutions for products at the end of their life-cycle	*Offer environmental friendly products and drive competitiveness *Reduce product size and weight *Improve waste management and reduce solid waste
Procurement	*Conduct green sourcing for indirect and direct materials *Collaborate with suppliers for their green initiatives *Localize sourcing for JIT	*Utilize environmental friendly materials *Cost reduction benefits from suppliers' improved efficiency *Short procurement distance and reduced raw material inventory
Production	*Improve factory layout *Improve production process from straight push to pull, push-pull, or postponement strategy *Utilize fuel efficient tools and machines *Recycle materials	*Reduce in-house traffic movements *Reduce finished goods inventory and warehouse space *Improve fuel efficiency
Distribution	*Strategically place warehouse and distribution centers *Improve warehouse layouts *Utilize fuel efficient tools and machines	*Achieve least total costs, while minimizing carbon footprint *Improve fuel efficiency
Transportation	*Consolidate milk-run for both inbound and outbound *Use more environmentally friendly logistics providers *Reroute fleet vehicles *Optimize truckloads *Utilize rail or intermodal *Utilize back-haul	*Reduce waste of empty trailer space *Incentivize logistics providers to be "greener" *Reduce miles and improve fleet utilization *Reduce carbon emissions caused by transportation

Table 1.2: Different function's outcome

Table 1.2 shows different functions of supply chain. For these functions some initiatives are needed and are shown the positive environmental effects of adopting green supply chain management.

1.8 ISO 14000 SERIES: CERTIFICATE TO GREENING OPERATION:

1. Introduction:

Organizations of all kinds are increasingly concerned to achieve and demonstrate sound environmental performance by controlling the impact of their activities, products or services on the environment, taking into account their environmental policy and objectives. They do so in the context of increasingly stringent legislation, the development of economic policies and other measure to foster environmental protection, and a general growth of concern from interested parties about environmental matters including sustainable development.

In 1996, International Organization for Standards adopted ISO 14000 series as its international specification standards for Environmental Management Systems with the following objectives:

- Encouraging an internationally common approach to environmental management.
- Strengthening company's abilities to improve and measure environmental performance through continual system audits.
- Improving international trade and removing trade barriers.

Figure 1.6 shows the environmental management system model which shows the continuous improvement by having good planning, action taken and implementation and improvement needed.

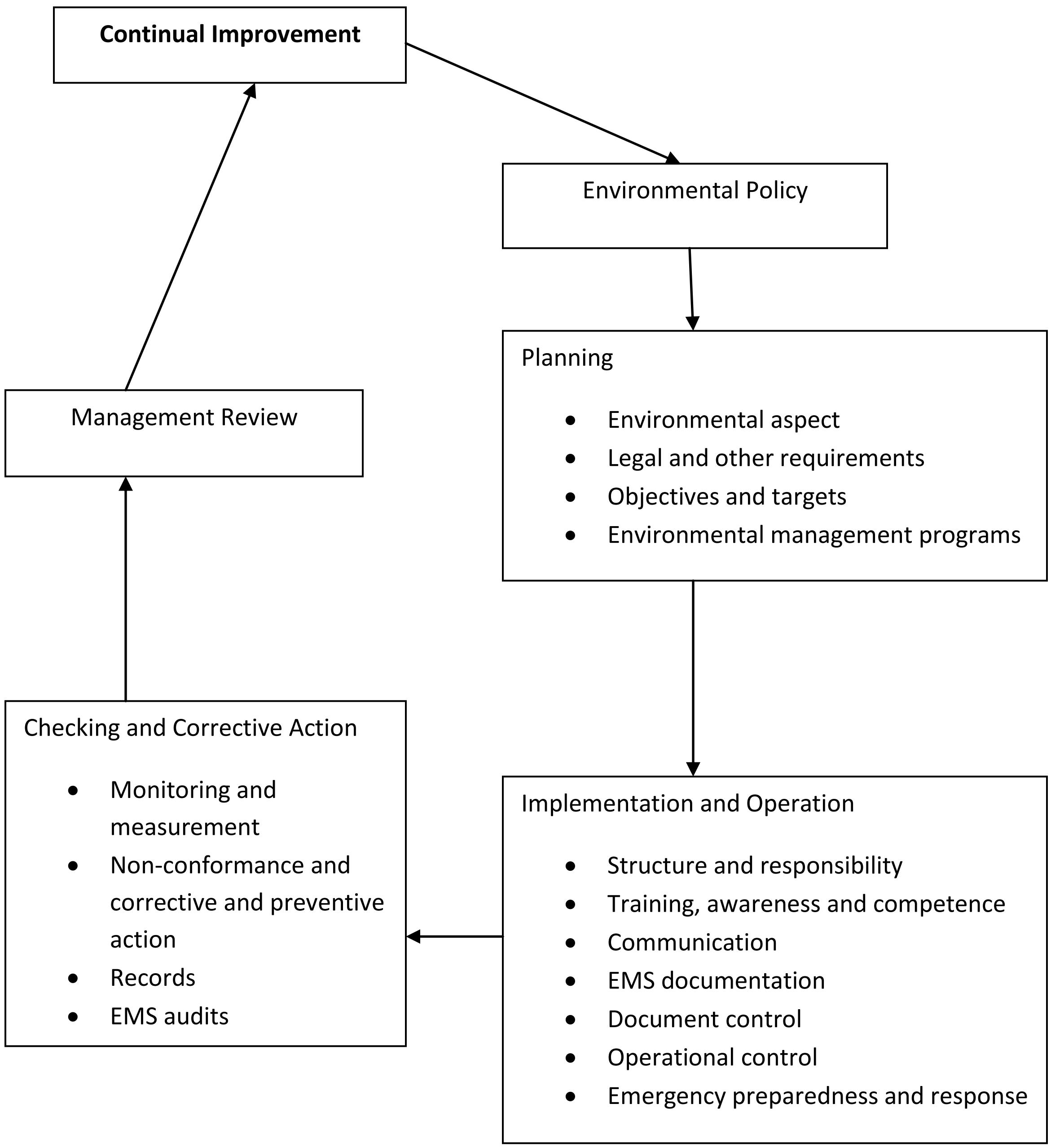

Fig 1.6: Environmental management system model (Quazi H.A. et al., 2001)

Many organizations have undertaken environmental "reviews" or "audit" to assess their environmental performance. On their own, however, these "reviews" and "audits" may not be sufficient to provide an organization with the assurance that its performance not only meets, but will continue to meet, its legal and policy requirements. To be effective, they need to be conducted within a structured management system and integrated with overall management activity.

International environmental management standards are intended to provide organizations with the elements of an effective environmental management system which can be integrated with other management requirements, to assist organizations to achieve environmental and economic goals. These standards, like other international standards, are not intended to be used to create non-tariff trade barriers or to increase or change an organization's legal obligations. This International Standard specifies the requirements of such an environmental management system. It has been written to be applicable to all types and sizes of organizations and to accommodate diverse geographical, cultural and social conditions. The success of the system depends on commitment from all levels and functions, especially from top management. A system of this kind enables an organization to establish, and assess the effectiveness of, procedures to set an environmental policy and objectives, achieve conformance with them, and demonstrate such conformance to others. The overall aim of the standard is to support environmental protection and prevention of pollution in balance with socio-economic needs. It should be noted that many of the requirements may be addressed concurrently or revisited at any time.

There is an important distinction between these specifications which describes the requirements for certification/registration and/or self-declaration of an organization's environmental management system. Environmental management encompasses a full range of issues including those with strategic and competitive implications. Demonstration of successful implementation of the standard can be used by an organization to assure interested parties that an appropriate environmental management system is in place.

Supply chain management is one of the systems operated in every company. "Greening the supply chain" refers to buyer companies requiring a certain level of environmental responsibility in core business practices of their suppliers and vendors. Many companies have internal standards, policies, and/or environmental management systems that govern their own environmental performance and efficiency. If suppliers do not abide by these same standards, the buyer company may be not buying and using products that do not meet their own standards.

For international companies, re-integrating and redesigning their global production network to serve the emerging market for "sustainable" products has become a major concern. Regulations such as WEEE (Waste of electrical and electronic Equipment) or RoHS (Restrictions on Hazardous Substances), passed in Europe, are one of the most important pressures. Many international companies, including Sony, Cannon, Espon, IBM, and HP have started their own green supply chain management (GSCM) programs that focus on different aspects of environmental performance, especially in conformity with RoHS. By correct GSCM, a company can handle all the green information from their suppliers, improve their product to meet the demands from the customers, and prevent loss of business.

2. Basic Requirements:

The ISO 14001 standards defines the requirements that an organization must incorporate into its environmental management system (EMS) to meet internationally recognized standards for sound environmental performance. The standard itself does not establish absolute requirements for environmental performance beyond an organization's commitment to achieve conformance with applicable legislation and regulation and to continually improve the EMS. The standard applies to those environmental aspects which an organization can control and over which it can be expected to have an influence, and contains only those requirements that can be objectively audited for the registration and/or self declaration purposes. Figure 1.7 shows the influence of adopting ISO 14001 certification.

The ISO 14001 standard is applicable to any organization wanting to:-

- Implement, maintain and improve an EMS.
- Assure itself of its conformance with its stated environmental policy.
- Demonstrate such conformance to others.
- Seek certification/recognition of its EMS by an external organization and /or
- Make a self determination and declaration of conformance with the standard

Fig 1.7: The sphere of influence and interest surrounding ISO 14001 certification (Quazi H.A. et al., 2001)

The extent to which this standard is applied is dependent upon such factors as the organization's environmental policy, the nature of its activities and the conditions in which it operates. It is intended that the implementation of an environmental management system described by the specification will result in improved environmental performance. The specifications are based on the concept that the organization will periodically review and evaluate its environmental management system in order to identify opportunities for improved and their implementation. Improvements in its environmental management system are intended to result in additional improvements in environmental performance.

The environmental management system provides a structured process for the achievement of continual improvement, the rate and extent of which will be determined by the organization in the light of economic and other circumstances. Although some improvement in the environmental performance can be expected due to the adoption of systematic approach, it should be understood that the environmental management system is a tool which enables the organization to achieve and systematically control the level of environmental performance that it sets itself. The establishment and operation of an environmental management system will not, in itself, necessarily result in an immediate reduction of adverse environmental impact.

3. Future of Green process implementation:

A firm has the choice and flexibility to define its boundaries and may choose to implement this International Standards with respect to the entire organization, or to specific operating units or activities of the organization. If this international standard is implemented for a specific operating unit or activity, policies and procedures developed by other parts of the organization can be used to meet the requirements of this International Standard, provided that they are applicable to the specific operating unit or activity that will be subjected to it. The level of detail and complexity of the environmental management system, the extent of documentation and the resources devoted to it will be dependent in the size of an organization and the nature of its activities. This may be the case in particular for small and medium sized organizations.

Integration of environmental matters with the overall management system can contribute to the effective implementation of the environmental management system, as well as to efficiency and clarity of roles. This International Standards contains management system requirements, based on the dynamic cyclical process of "Plan, Implement, Check and Review".

The environmental policy should be

- A public statement of the organization's environmental commitment
- Visible evidence of the support of the organizations top management for the environment.
- Possible far reaching in its business implications.
- A relatively long lived document.
- One of the foundations of the EMS and a reference / baselines for an organizations strategies, plans and actions.

In this way, the policy will clearly state how the organization will respond to all of its current and anticipated environmental issues and sets the parameters and boundaries within which it can take action. The policy must provide confidence to stake-holders that the organization has adopted a responsible approach to its environmental affairs. The actual role of the policy in this regard might defer slightly depending on the type of stakeholders involved, but in general the environmental policy should:

- Assure bankers, insurers and shareholders that the organization is in compliance with environmental legislation;

- Seek to reassure its employees that the organization has adopted a responsible approach to the environment and inform them about their own environmental responsibilities;
- Attract investment from environmentally concerned investors;
- Reduces the fear and concerns of local communities and environmental campaigners.

The far reaching business implications of the policy require that the top management initiates, develop, supports and takes responsibility for the policy. Their commitment, ownership and leadership for the policy are fundamental to its success. They are ultimately accountable for it and as an evidence of their commitment, should be signed by them.

4. Vital features and principles to be included in the green policy

An environmental policy provides a set of values for the organization to follow. Some policies take the form of a few bullet points or a short statement of environmental commitment. Others are lengthy documents that specify specific objectives and targets. The length of the policy is not as important as the policy's appropriateness to the nature of scale and culture of the organization. The policy should serve as the framework for setting the environmental objectives and targets. The policy should keep the following key commitments which are considered as the pillars of any environmental policy:

- Compliance with applicable environmental laws and regulations.

- Continual improvement- the step by step process of enhancing the environmental management system so as to achieve improvements in the overall environmental performance and
- Adoption of pollution prevention strategies.

This does not mean that an organization has to improve in all areas at once, but the policy should be able to drive the overall efforts for continually improving the organizations environmental management.

The ISO 14000 series is based on five principles that guide in its implementation. These are as follows:

- ISO 14001: Specifies minimum requirements for achieving ISO 14000 certification.
- ISO 14004: Sets guidelines for developing an environmental management system.
- ISO 14010: Establishes the general principles of environmental auditing.
- ISO 14011: Establishes auditing procedures for the auditing of environmental management systems.
- ISO 14012: Establishes qualification criterion for environmental auditors (Aspan H., 2000).

From the above discussion, it has become clear that the development of an Environmental Management System is quite necessary for the survival of the industries. Until and unless the companies do not have an environmental management system, they cannot get the ISO 14000 certification and without this, they cannot survive for a long time. Similarly, some basic requirements of the ISO 14000 is also been discussed. It is important to see that EMS is meant for continuous improvement and not the one time set-up programme. Hence the companies that do not have an environmental management system should develop one. It is not necessary that it should develop for the whole plant but it should be developed for some portion that has major contribution in degrading the environment.

1.9 BENEFITS OF GREEN SUPPLY CHAIN MANAGEMENT:

Organizations can be benefited by green supply chain as discussed below:

- Lowered costs and increased efficiency:

If there is effective management of suppliers, then transaction costs can be reduced and also recycling and reuse of raw materials can be done. Also, the wastes and the emission of hazardous substances can be reduced a lot preventing corporations from being fined as a result of violating environmental regulations. Consequently, operational cost of the whole cycle can be reduced and also the efficiency of using our resources will improve.

- Adaptation to regulation and reducing risk:

If green supply chain management is adopted then chances of being prosecuted for anti-environmental and unethical practices will get reduced.

- Product differentiation and competitive advantage:

Green supply chain management helps the organization to be benefited in the competitive world because now-a-days consumers are aware of the environmental sustainability of the product. So not only the organization will get benefit of attracting new profitable customers but also give them competitive advantage in market. It will provide them good reputation in the market and a brand image.

- Sustainability of resources:

If the organization is using green supply chain management, then they will purchase green input resources for environmental friendly production process to produce environmentally friendly goods helping in proper and effective utilization of resources.

- Improves agility:

Green SCM helps mitigate risks and speed innovations.

- Increased adaptability:

Green supply chain analysis often leads to innovative processes and continuous improvements.

- Promotes alignment:

Green SCM involves negotiating policies with suppliers and customers, which results in better alignment of business processes and principles.

So, GSCM helps in getting the sustainability of resources which helps in increasing efficiency, lowered costs and improving quality and products. Also, there is product differentiation which helps in getting competitive advantage. By adapting to regulation, risk has been reduced, there is effective management of suppliers and also there is positive impact on financial performance. There is better control of product safety and quality which leads to increased sales. There is more investment and risk sharing activities among partners in the chain, so our supply chain has become transparent. Also, beneficial uses for waste have been found.

There is improved quality of products due to green supply chain implementation. The products will be environment friendly and technologically advanced while adopting green supply chain management. Besides there are other advantages as follows:

- Positive impact on financial performance
- Effective management of suppliers
- Dissemination of technology, advanced techniques, capital and knowledge among the chain partners
- Transparency of the supply chain
- Large investments and risks are shared among the partners in the chain
- Better control of product safety and quality
- Increasing of sales
- Find beneficial uses for waste

Environmental practices are being more acceptable in the world of business. The number of organizations contemplating the integration of environmental practices into their strategic plans and daily operations is continuously increasing (Sarkis J, 2003). Environmental issues in the supply chain and operations management are significantly growing, as part of the wider debate on how industry meets the challenges of sustainability (Frankel, C., 1998). There is an extensive body of literature on reverse channels, which extends supply chain analysis to include the "take-back process for used goods (Krikke et al., 2004). Hence, the aspect of the greening of supply chains has become a central concern (Rao, 2002) and achieving sustainability through operations management is often seen as a key challenge (Yeung et al., 2003). Angell (ACMA, 2005) argues that operations managers are facing internal and external pressure to apply environment-friendly measure to their daily activities. This includes the return of the end-of-life and used products to the producer as well as the eco-friendly handling of these returns, either through recovery (recycling, remanufacturing, re-use), or through adequate waste disposal. The logistical and operational implications of reverse channels provide new challenges within logistics and supply chain management research. While the body of knowledge on reverse logistics (the process of product take-back) is well developed, the area of closed-loop supply chain management has, so far, evolved less. Closed-loop supply chain management, a fairly new area of supply chain management research, deals with a conventional forward supply chain and a reverse supply chain which is concerned with the take-back and recovery of returned products (Handfield et al., 2002). However, academic research on closed-loop supply chains is largely determined by quantitative research on individual aspects of the chain, such as product acquisition (Ferrer G., 2001, Toktay et al., 2003) or product recovery and control (Kiesmu Ller et al., 2003, Inderfurth et al., 2003).

Business organizations are facing increasing pressure of balancing the marketing and environmental performance (Khoo H.H. et al., 2001). Businesses succeed because they respond to external and internal changes and adjust in an effective manner. Beamon, 1999 highlights that the current state and trend of environmental degradation from regulatory, consumer and moral standpoints indicate a need for a change in manufacturing philosophy. The new logic on competition is based on the supply chains and new trends in the market can help in the implementation of greening the supply chains (Scavarda et al., 2003). With regard to the environmental movement, businesses can be motivated to embrace change brought about by consumers, government, competition, and ethical responsibility. To achieve business goals and objectives, a company must respond to increasing consumer demand for "green" products comply with ever tightening environmental regulations, and implement environmentally responsible plans as a good corporate citizen. The impact on business decision making is both short and long term. Short-term responses may involve reactions to accidents or compliance with regulations or liability triage; long-term response involves recognition that the environment is a major factor in decision making, with company-wide implications (Bucholz R., 1993).

Leading edge firms will take proactive steps to incorporate environmental management principles in every aspect of their value-adding activities. A 1992 survey of 500 German firms regarding motive for environment management found that ecological responsibility, adherence to government regulation, and safeguarding corporate viability were the leading factors (Fisher et al., 1994).

The roles of government in preserving the environment are as regulator, facilitator, and buyer. First, the government sets various mandates and policies such as vehicle emission standards, noise control, and recycling requirements in federal, state and local levels. Governments in Europe and Canada have also set stringent standards on source reduction, material reuse, and waste recycling (Stock J., 1998). The classic examples of product take-back and recovery legislation are the European End-of-life Directive (ELV directive) and the Directive on Waste of Electrical and Electronic Equipment (WEEE directive) (Margerete and PETER, 2006). Both Directives demand that the producers of these goods take care of the return and recovery of the products at the end of their useful lives. Second, the government supports research and provides investment and regulatory incentives for businesses to develop new environmental technologies. Specific to logistic, the government is a major agency in the development of transport infrastructure and regulation, including high-speed rail and alternative fuels. Third, since the government is often the single largest buyer of goods and services in many countries, it can use its power to buy "green", thus providing monetary incentives for government contractors.

Businesses can cut costs by conserving energy, reducing resources used, and reusing and recycling useable materials. For example, total quality management programs can be seen as a part of the integrated environmental management programme because they save money by reducing scraps and defects in the transportation process. When a firm's objectives are cost minimization and profit maximization, continuous improvement of the process to reduce end-of-pipe contamination and focusing on pollution prevention makes sense (Cairncross F., 1992).

Private organizations such as Hewelett-Packard, IBM, Xerox and Digital Equipment Corporation have introduced some form of initiative for greening their supply chains including the integration of suppliers, distributors and reclamation facilities (Sarkis J., 2003). Organizations are including environmental issues in their negotiation with suppliers to maintain their market share and sometimes even just to survive (Hwa T.J., 2001). Increasing consumer awareness has encouraged businesses to introduce environmentally friendly products and services. Firms such as Church and Dwight, Tom's of Maine, and Patagonia have taken a proactive approach by developing their corporate strategies and new products and services with an environmental focus (Ottman J., 1994). Being environmentally responsible means improving operational efficiency by conserving resources and reusing them as much as possible.

Greening the supply chain is the process of incorporating the environmental criteria or concerns in the organizational purchasing decisions and long term relationships with suppliers. Indeed, there are three approaches involved to Green Supply Chain: environmental, strategy and logistics (Gilbert S., 2001).

Concept of Green Productivity (GP) shows that for any development strategy to be sustainable, it needs to have a focus on environment, quality and profitability, which form the triple focus of GP (Hwa T.J., 2001). Working with Green supply chain means to work in the interface of those areas because the GSC is totally linked to environmental protection, which is its main objective, strategy because it approaches procurement, material handling, distribution, storage, material recovery and disposition (Breno Torres Santiago et al., 2004).

The interface between logistics and the environment is embedded in the value adding functions a firm performs. As resources are used to create desired utilities, pollutants are implicitly produced as byproducts during each step of the integrated supply chain process. For example, packaging is used to protect the products from damage and is an undesired item once they are consumed. Proper management and awareness of the environmental implications of logistics activities can significantly reduce the negative impact.

Traditional logistics systems do not encompass environmental issues and stress too narrowly the need to minimize costs and maximize profits in the private sector (Daskin M.S., 1985). An environmentally responsible logistics approach expands the manager's horizon by adding another objective to the system: minimizing total environmental impact.

CHAPTER 2

2. LITERATURE REVIEW:

- Yang et al., 2011 proposed some strategies to advance cooperation satisfaction among enterprise based on low carbon supply chain management in order to enhance the competence of the whole supply chain. They brought the concept of low carbon supply chain management. They found that only with good cooperation satisfaction among enterprises based on low carbon supply chain management can the whole supply chain run quickly and effectively.
- Bettina et al., 2011 developed Green Brewery Concept to demonstrate the potential for reducing thermal energy consumption in breweries, to substantially lower fossil CO2 emissions and to develop an expert tool in order to provide a strategic approach to reach this reduction. They took 3 breweries and found that it is preferable to develop a tool instead of a simple guideline where a pathway to a CO2 neutral thermal energy supply is shown for different circumstances. He gave methodology which includes detailed energy balancing, calculation of minimal thermal energy demand, process optimization, heat integration and finally the integration of renewable energy based on exegetic considerations.
- Miriam et al., 2010 analyzed the application of eco-design for the redesign of components in the footwear industry(e.g. the stiffener) investigating the factors that influence its use, the benefits, the difficulties and the results in terms of environmental and costs advantages. Regarding the redesigned product, the main gains were cost savings of about 10 % and a reduction in non-recyclable materials,

using natural fibers and polymers in the composition (31% of biomass and 69% of fossil material). The use of toxic materials were completely eliminated and reduction of energy consumption during the injection process. The scraps and channels for injection of the stiffener were completely recycled and reused leading to reduction of amount of wastes.

- Wang et al., 2011 divided the supply chain network of manufacturing enterprises into the following three types, the centralized type, the decentralized type and the adaptive type. They provided basis for strategic planning of environmental protection in different types of the supply chain networks. They established a green supply chain network to make the most advantages of cooperation and the scale effect, achieve the unify of cost control in upstream and downstream firms to reduce or eliminate the hazards of environmental costs and eventually establish the “environment-friendly society” considering green procurement, cleaner production and green marketing for environmental cost analysis.
- Tania et al., 2011 proposed model for the planning and design of supply chain structures for annual profit maximization, while considering environmental aspects through eco-indicator methodology. They balanced profit and environmental impacts using an optimization approach adapted from symmetric fuzzy linear programming, while the supply chain is modeled as mixed integer linear programming optimization problem using the resource-task-network methodology. Their proposed model and optimization approach allow complex systems to be represented in a very simple way.

- Chun-Jen et al., 2010 developed an integrated production inventory model with short life-cycles which considers the greening operation processes over a finite planning horizon and reduction design is considered in the supplier's forward and remanufacturing processes. Their study incorporates inspection cost, transportation cost, cost of less flexibility, green-component life-cycle value design, green design cost of reducing gas emission and reverse remanufacturing.
- Balan et al., 2010 examined the carbon footprint across supply chain and presented an initial analytical model that measures carbon emission from both stationary and non-stationary supply chain processes. Their model helps to understand the heat flux and carbon wastages at each node of the supply chain and allows to calculate the total heat (and hence carbon) transferred from one stage of the supply chain to another.
- Toshi et al., 2010 estimated the effects of ISO 14001 certification on the promotion of GSCM. They showed that facilities with environmental management systems certified to ISO 14001 are 40% more likely to assess their suppliers' environmental performance and 50% more likely to require that their suppliers undertake specific environmental practices. So government programs increase the probabilities that facilities will assess their suppliers' environmental performance and require suppliers to undertake specific environmental practices by 7% and 8% respectively.
- Ming-Lang et al., 2010 identified the appropriate environmental and non environmental GSCM criteria for the case of a printed circuit board manufacturer in Taiwan for selecting a green supplier and ranking suppliers using a grey relational

analysis. Their study proposed a hybrid MCDM approach to deal with the alternatives problem in linguistic preferences, quantitative data and incomplete information and can be applied to evaluate and determine the criteria weights and reduce management risks.

- Emel kizilkaya aydogan, 2010 presented a conceptual performance measurement framework that takes into account company level factors for a real world application problem. In order to use the conceptual framework for measuring performance for Turkish aviation firms, a methodology that takes into account both quantitative and qualitative factors and the interrelation between them should be utilized. For this reason, an integrated approach of analytic hierarchy process (AHP) improved by rough sets theory (Rough-AHP) and fuzzy TOPSIS method is proposed to obtain final ranking.
- Manki Chandra das et al., 2011 developed a framework to evaluate performance and ranking of seven IIT's in respect to stakeholder's preference using an integrated model consisting of fuzzy AHP and COPRAS. Findings based on 2007-2008 data show that performance of two IITS's need to be improved.
- Sadeghzadeh et al., 2010 reviewed the guidelines resulting in the strategic technologies of fuel cells as converters in the automotive industry and considered the capabilities and attractions of strategic technology and tried to find the development solutions of fuel cell strategic technologies by technical economical appropriate fields of attention and investment. Therefore, the purpose of the paper was to rank the attractiveness and importance of the stack of fuel cells as a sub-system, as well as determine the amount of knowledge, specialized manpower and

equipment needed in two industrial and laboratory scales and from among multi-criteria decision making methods, TOPSIS approach has been dealt with. In order to selecting required information in the evaluation stages of method by asking professional experts views, questionnaire method for data gathering was chosen. The results of the paper included ranked essential solutions for the development of technologies for fuel cells as the power systems for vehicles for allocating attention and investment in the sub-system of stacks of fuel cells by using the multi-criteria decision making selected method (TOPSIS)

- Rong et al., 2009 considered the important role of representation element in an interval-valued fuzzy set for decision analysis, the concepts of three parameters interval-valued fuzzy set and three parameters interval-valued fuzzy value was proposed, and some operators on three parameters interval-valued fuzzy values were given, and a new distance between three parameters interval-valued fuzzy values was defined. Based on the proposed distance, a TOPSIS decision-making method was shown for a multi-criteria decision-making model on three parameters interval-valued fuzzy sets.

GSCM is fast growing concept in this decade. So there are many literature related to green supply chain. Also there is vast use of AHP and TOPSIS model for decision making problem. Since there are few journals related to application of AHP and TOPSIS model in green supply chain management and there is need to get the best decision when we have different attributes. So AHP and TOPSIS methods have been applied in this context. Since these methods are the most widely used methods now-a-days, we have compared both the models in the context of the case discussed. So, a comparative study between two models (AHP and TOPSIS) has been done.

CHAPTER 3

3. INTRODUCTION: AHP MODEL

The Analytic Hierarchy Process (AHP) is a structured technique for organizing and analyzing complex decisions. Based on mathematics and psychology, it was developed by Thomas L.Saaty in the 1970's (often referred to, eponymously, Saaty method) and has been extensively studied and refined since then. AHP allows user to access the relative weight of multiple criteria or multiple options against given criteria in an intuitive manner. In case quantitative ratings are not available, policy makers or assessors can still recognize whether one criterion is more important than another. Therefore pair-wise comparisons are appealing to users. Saaty established a consistent way of converting such pair-wise comparisons(X is more important than Y) into a set of numbers representing the relative priority of each of the criteria.

It has particular application in group decision making and is used around the world in a wide variety of decision situations; in fields such as government, business, industry, healthcare and education.

Rather than prescribing a "correct" decision, the AHP helps decision-makers find on that best suits their goal and their understanding of the problem. It provides a comprehensive and rational framework for structuring a decision problem, for representing and quantifying its elements, for relating those elements to overall goals, and for evaluating alternative solutions.

Decision situations to which the AHP can be applied include:

- Choice-The selection of one alternative from a given set of alternatives, usually where there are multiple decision criteria involved.
- Ranking- Putting a set of alternatives in order from most to least desirable.
- Prioritization-Determining the relative merit of members of a set of alternatives as opposed to selecting a single one or merely ranking them.
- Resource allocation-Apportioning resources among a set of alternatives
- Benchmarking- Comparing the processes in one's own organization with those of other best-of-breed organizations.
- Quality management- Dealing with the multidimensional aspects of quality and quality improvement.
- Conflict resolution- Settling disputes between parties with apparently incompatible goals or portions.

AHP strengths and weaknesses:

Strengths:

- The advantages of AHP over other multi-criteria methods are its flexibility, intuitive appeal to the decision makers and its ability to check inconsistencies (Ramanathan, 2001). Generally, users find the pair-wise comparison form of data input straight forward and convenient.
- Additionally, the AHP method has the distinct advantage that it decomposes a decision problem into its constituent parts and builds hierarchies of criteria. Here the importance becomes clear (Macharis et al., 2004).

- AHP helps to capture both subjective and objective evaluation measures while providing a useful mechanism for checking the consistency of the evaluation measures and alternatives. AHP reduces bias in decision making.
- The AHP method supports group decision-making through consensus by calculating the geometric mean of the individual pair-wise comparisons (Zahir, 1999).
- AHP is uniquely positioned to help model situations of uncertainty and risk since it is capable of deriving scales where measures ordinarily do not exist (Millet and Wedley, 2002).

Weakness:

Despite the popularity of the AHP, many authors have expressed concern over certain issues in the AHP methodology.

- Many researchers have long observed some cases in which ranking irregularities can occur when the AHP or some of its variants are used. This rank reversal is likely to occur e.g. when a copy or a near copy of an existing option is added to the set of alternatives that are being evaluated. Triantaphyllou, 2001 proved that rank reversal is not possible when a multiplicative variant of the AHP is used. According to Belton, 1986 and Belton and Gear, 1997 a key issue for the AHP ranking reversals is the interpretation of the criteria weights. However, the AHP and some of its variants are considered by many as the most reliable MCDM method.
- The AHP method can be considered as a complete aggregation method of the additive type. The problem with such aggregation is that compensation between

good scores on some criteria and bad scores on other criteria can occur. Detailed, and often important, information can be lost by such aggregation.

- With AHP the decision problem is decomposed into a number of subsystems, within which and between which a substantial number of pair-wise comparisons need to be made, may become very large (n(n-1)/2), and thus becomes a lengthy task (Macharis et al. 2004).
- Another important disadvantage of the AHP method is the artificial limitation of the use of the 9-point scale. Sometimes, the decision maker might find difficult to distinguish among them and tell for example whether one alternative is 6 or 7 times more important than another. Also, the AHP method cannot cope with the fact that alternative A is 25 times more important than alternative C (Murphy, 1993; Belton and Gear, 1983; Belton 1986). Due to the discussion on the scale's restrictions, Hajkowicz et al., 2000 modified the procedure in their study by using a 2-point-scale, due to time constraints placed on decision makers. So the decision makers only indicated whether a criterion was more or less important or equally to its partner.

3.1 **AHP FORMULATION**:

The AHP method consists of three steps:

Step 1: Making hierarchy structure

Step 2: Comparison of alternatives and criteria

Step 3: Prioritization of different alternatives based on relative weights

Step 1: Making hierarchy structure: I

n this, objective, attributes and alternatives of a complex decision problem is structured as a hierarchy. In the hierarchical structure, there are 3 levels: in the uppermost level we have objectives or goal, in the middle we have criteria or attributes that define the alternatives, and in the lowest level we put decision alternatives.

Step 2: Comparison of alternatives and criteria:

In this we determine the relative importance of different attributes with respect to the objective and a pair-wise comparison matrix of the alternatives and attributes using a scale of relative importance is constructed. In AHP, pair-wise comparisons are done on the basis of nine-point intensity of standardized comparison scale given by Saaty (also known as Saaty rating scale). This can be shown in table given below.

Intensity of importance	Definition	Explanation
1	Equal importance	Two factors contribute equally to the objective
3	Somewhat more important	Experience and judgement slightly favour one over the other
5	Much more important	Experience and judgement strongly favour one over the other
7	Very much more important	Its importance is demonstrated in practice
9	Absolutely more important	The evidence favouring one over the other is of the highest possible validity
2,4,6,8	Intermediate values	When compromise is needed

Table 3.1: The Saaty rating scale

A basic, but very reasonable, assumption is that if attribute X is much more important than attribute Y and is rated as 5, then Y must be much less important than X and is valued as 1/5 or we can say a_{ij}=a_{ji} and such a matrix is said to be a reciprocal matrix.

Assuming M attributes, the pair-wise comparison of attribute i with attribute j yields a square matrix B_{M*M} where a_{ij} denotes the comparative importance of attribute i with respect to attribute j. In the matrix, b_{ij}=1 when i=j and b_{ij}=1/ b_{ji}

$$
B_{M*M} = \begin{array}{c} \\ B_1 \\ B_2 \\ B_3 \\ - \\ - \\ B_M \end{array}
\begin{array}{c} \begin{array}{cccccc} B_1 & B_2 & B_3 & - & - & B_M \end{array} \\
\begin{bmatrix} 1 & b_{12} & b_{13} & - & - & b_{1M} \\ b_{21} & 1 & b_{23} & - & - & b_{2M} \\ b_{31} & b_{32} & 1 & - & - & b_{3M} \\ - & - & - & - & - & - \\ - & - & - & - & - & - \\ b_{M1} & b_{M2} & b_{M3} & - & - & 1 \end{bmatrix} \end{array}
$$

Then relative normalized weight(w_j) of each attribute by calculating the geometric mean of the i-th row and normalizing the geometric means of rows in the comparison matrix. This can be represented as:

$$GM_j = \left[\prod_{j=1}^{M} b_{ij} \right]^{1/M}$$

And

$$w_j = GM_j / \sum_{j=1}^{M} GM_j$$

The geometric mean method of AHP is commonly used to determine the relative normalized weights of the attributes, because of its simplicity, easy determination of the maximum Eigen value, and reduction in inconsistency of judgements.

Then calculate matrices A3 and A4 such that A3 = A1*A2 and A4 = A3/A2, where A2 = [w1,w2, …….., wj]^T

Then determine the maximum Eigen value λ_{max} that is the average of matrix A4.

Then calculate the consistency index CI = (λ_{max} - M)/(M-1). The smaller the value of CI, the smaller is the deviation from the consistency.

Then obtain the random index (RI) for the number of attributes used in decision making. Refer to table 3.2 for details.

Then calculate the consistency ratio CR= CI/RI. Usually, a CR of 0.1 or less is considered as acceptable, and it reflects an informed judgement attributable to the knowledge of the analyst regarding the problem under study.

Step 3: Prioritization of different alternatives based on relative weights:

The next step is to compare the alternatives pair-wise with respect to how much better (i.e. more dominant) they are in satisfying each of the attributes, number of alternatives, then there will be M number of N x N matrices of judgements, since there are M attributes. Construct pair-wise matrices using a scale of relative importance. The judgements are entered using the fundamental scale of the AHP method. The steps are the same as those suggested above.

In the AHP model, both the relative and absolute modes of comparison can be performed. The relative mode can be used when decision makers have prior knowledge of the attributes for different alternatives to be used, or when objective data of the attributes for different alternatives to be evaluated are not available.

The absolute mode is used when data of the attributes for different alternatives to be evaluated are readily available. In the absolute mode, CI is always equal to 0, and complete consistency in judgements exists, since the exact values are used in the comparison matrices.

Then next step is to obtain the overall or composite performance scores for the alternatives by multiplying the relative normalized weight (w_j) of each attribute(obtained in step 2) with its corresponding normalized weight value for each alternative(obtained in step 3), and summing over the attributes for each alternative. This step is similar to the SAW method. Or as proposed by Barzilai and lootsma (1994) and Lootsma (1999) proposed a multiplicative version of the AHP. In this MAHP method, the normalized weight value for each alternative is raised to the power of the relative normalized weight (w_j) of each attribute, with multiplication over the attributes for each alternative. This step is similar to WPM.

M	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
RI	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49	1.51	1.58	1.56	1.57	1.59

Table 3.2: Random index (RI) for factors used in the decision-making process (Saaty, 1980)

CHAPTER 4

4. INTRODUCTION: TOPSIS MODEL

TOPSIS is a multi-criteria method to identify solutions from a finite set of alternatives based upon simultaneous minimization of distance from an ideal point and maximization of distance from a nadir point. TOPSIS can incorporate relative weights of criterion importance (Olson D.L., 2003). There is a variety of multi-criterion techniques to aid selection in conditions of multiple criteria. The acronym TOPSIS stands for technique for preference by similarity to ideal solution (Yoon K., 1980). TOPSIS was initially presented by Hwang and Yoon, 1981, Lai et al., 1994, and Yoon and Hwang, 1995. TOPSIS is attractive in that limited subjective input is needed from decision makers. The only subjective input needed is weights. According to TOPSIS, the best alternative would be the one that is nearest to the positive-ideal solution and farthest from the negative ideal solution (Ertugal and Karasoglu, 2007). The positive ideal solution is a solution that maximizes the benefit criteria and minimizes the cost criteria, whereas the negative ideal solution maximizes the cost criteria and minimizes the benefit criteria (Wang and Elhag, 2006). In short, the positive ideal solution is composed of all best values attainable from the criteria, whereas the negative ideal solution consists of all worst values attainable from the criteria (Wang, 2007, Mohammadi et al., 2010).

4.1 TOPSIS FORMULATION:

The TOPIS (Technique for Order Preference by Similarity to Ideal Solution) method was developed by Hwand and Yoon, 1981. This method is based on the concept that the chosen alternative should have the shortest Euclidean distance from the ideal solution, and the farthest from the negative ideal solution. The ideal solution is a hypothetical solution for which all attribute values correspond to the maximum attribute values in the database comprising the satisfying solutions; the negative ideal solution is the hypothetical solution for which all attribute values correspond to the minimum attribute values in the database. TOPSIS thus gives a solution that is not only closest to the hypothetically best, that is also the farthest from the hypothetically worst. The main procedure of the TOPSIS method for the selection of the best alternative from among those available is described below:

Step 1: The first step is to determine the objective, and to identify the pertinent evaluation attributes.

Step 2: This step represents a matrix based on all the information available on attributes. This matrix is nothing but the decision table. Each row of this matrix is allocated to one alternative, and each column to one attribute. Therefore, an element m_{ij} of the decision table 'D' gives the value of the j-th attribute in original real values, that is, non-normalized form and units, for the i-th alternative.

In the case of a subjective attribute (i.e., objective value is not available), a ranked value judgement on a scale is adopted. Table 4.1 may be used for the purpose.

Subjective measure of the attribute	Assigned value
Exceptionally low	0.0
Extremely low	0.1
Very low	0.2
Low	0.3
Below average	0.4
Average	0.5
Above average	0.6
High	0.7
Very high	0.8
Extremely high	0.9
Exceptionally high	1.0

Table 4.1: Value of attribute

Once a subjective attribute is represented on a scale, then the normalized value of the attribute assigned for different alternatives are calculated in the same manner as that for objective attributes. m^2_{ij}

Step 3: Obtain the normalized decision matrix, R_{ij}. This can be represented as

$R_{ij} = m_{ij}/[\sum_{j=1}^{M} m^2_{ij}]^{1/2}$

Step 4: Decide on the relative importance (i.e., weights) of different attributes with respect to the objective. A set of weights w_j (for j=1,2, …., M) such that $\Sigma w_j = 1$ may be decide upon.

Step 5: Obtain the weighted normalized matrix V_{ij}. This is done by the multiplication of each element of the column of the matrix R_{ij} with its associated weight w_j. Hence, the elements of the weighted normalized matrix V_{ij} are expressed as:

$V_{ij} = w_j R_{ij}$

Step 6: Obtain the ideal (best) and negative ideal (worst) solutions in this step. The ideal (best) and negative ideal (worst) solutions can be expressed as:

$V^+ = \{(\sum_i^{max} V_{ij}/j \in J), (\sum_i^{min} Vij/j \in J')/i=1,2,\ldots,N\},$

$= \{V_1^+, V_2^+, V_3^+, \ldots, V_M^+\}$

$V^- = \{(\sum_i^{mIN} V_{ij}/j \in J), (\sum_i^{max} Vij/j \in J')/i=1,2,\ldots,N\},$

$= \{V_1^-, V_2^-, V_3^-, \ldots, V_M^-\}$

Where J= (j=1,2,…..,M)/j is associated with beneficial attributes, and

J'= (j=1,2,…..,M)/j is associated with non-beneficial attributes.

V_j^+ indicates the ideal (best) value of the considered attribute among the values of the attribute for different alternatives. In the case of beneficial attributes (i.e., those of which higher values are desirable for the given application), V_j^+ indicates the higher value of the attribute. In the case of the non-beneficial attributes (i.e., those of which lower values are desired for the given application), V_j^+ indicates the lower value of the attribute. V_j^- indicates the negative ideal (worst) value of the considered attribute among the value of the attribute for different alternatives. In the case of beneficial attributes (i.e., those of which higher values are desirable for the given application), V_j^-indicates the lower of the attribute. In the case of non-beneficial attributes (i.e., those of which lower values are desired for the given application), V_j^- indicates the lower value of the attribute.

Step 7: Obtain the separation measures. The separation of each alternative from the ideal one is given by the Euclidean distance in the following equations.

$$S_i^+ = \{\sum_{j=1}^{M} (V_{ij} - V_j^+)^2\}^{0.5}, \qquad i = 1,2,\ldots\ldots.,N$$

$$S_i^- = \{\sum_{j=1}^{M} (V_{ij} - V_j^-)^2\}^{0.5}, \qquad i = 1,2,\ldots\ldots.,N$$

Step 8: The relative closeness of a particular alternative to the ideal solution, P_i can be expressed in this step as follows.

$$P_i = S_i^- / (S_i^+ + S_i^-)$$

Step 9: A set of alternatives is generated in the descending order in this step, according to the value of P_i indicating the most preferred and least preferred feasible solutions. P_i may also be called the overall or composite performance score of alternative A_i.

CHAPTER 5

5. CASE STUDY AND RESULT:

A case study of furniture industry in Norway has been taken in which different environmental performance parameters have been taken for 6 different chairs (Michelsen et al., 2005). They identified nine different environmental performance indicators based on suggestions from WBSCD (World Business Council for Sustainable Development) and one value performance indicator which was measured as inverse life cycle cost. They calculated the eco-efficiency of 6 different chairs and showed the relative values graphically which provided information about the relative performance of the products. They defined LCC of a product as the price of the product (defined as recommended retail price minus taxes), the average costs in the use phase (cleaning, repair etc.) and the average disposal costs. They used eco-efficiency indicators to compare products. They used GaBi 3v2 software for studying life cycle assessment. They used four of the nine environmental performance indicators to calculate a single score of environmental performance because of the limitation of the software. The weighing model was immature because only 4 indicators were included. So there was need to develop a weighing procedure which can include all the indicators and which can be commonly accepted within the furniture industries having green supply chain. So in this project, AHP and TOPSIS methods were applied which included all the parameters and provided the best result.

So modifying the data for 6 chairs having different environmental performance parameters, we have following table 5.1(Michelsen et al., 2005):

Chair →	**1**	**2**	**3**	**4**	**5**	**6**	**Unit**
Parameter ↓							
EC	1109	1216	933	1265	869	901	MJ
MC	4.36	6.61	8.04	6.81	6.98	4.47	Kg materials
ODSE	1.12×10^{-6}	1.08×10^{-6}	1.41×10^{-6}	9.34×10^{-7}	1.50×10^{-6}	7.48×10^{-7}	Kg R11-equiv
WC	393	430	328	426	279	24	Kg water
GGE(110Y)	23.2	33.8	29.3	35.7	27.3	30.1	Kg CO_2-equiv
AETA	6.93×10^{-2}	6.23×10^{-2}	7.82×10^{-2}	5.94×10^{-2}	7.98×10^{-2}	8.87×10^{-3}	Kg SO_2 -equiv
TW	12.91	13.27	13.89	14.47	13.47	6.90	Kg waste
EOHM(EI95)	3.00×10^{-4}	3.00×10^{-4}	3.98×10^{-4}	2.59×10^{-4}	4.16×10^{-4}	3.02×10^{-4}	Kg Pb-equiv
EOPOS	0.09	0.16	0.16	0.16	0.13	0.16	Kg ethen -equiv
LCC	1093	1958	2123	2903	1989	1805	NOK

Table 5.1: Absolute value for environmental and value performance

Where parameters stands for:

EC - Energy consumption

MC - Material consumption

ODSE - Ozone depleting substance emissions

WC - Water consumption

GGE - Greenhouse gas emissions

AETA - Acidification emission to air

TW - Total waste

EOPOS - Emission of photochemical oxidizing substances

EOHM - Emission of heavy metals

LCC - Life cycle cost

Chair →	1	2	3	4	5	6
Parameter ↓						
EC	0.784	0.715	0.931	0.687	1	0.965
MC	1	0.659	0.542	0.640	0.625	0.975
ODSE	0.603	0.693	0.530	0.800	0.498	1
WC	0.061	0.056	0.073	0.056	0.086	1
GGE	1	0.686	0.792	0.649	0.849	0.771
AETA	0.128	0.142	0.113	0.148	0.111	1
TW	0.534	0.520	0.497	0.477	0.512	1
EOHM	0.863	0.863	0.666	1	0.622	0.858
EOPOS	1	0.562	0.562	0.562	0.692	0.562
LCC	1	0.558	0.515	0.376	0.549	0.605

Table 5.2: Normalized data table for selection of chairs

AHP method:

Now, AHP method is used to determine the weights of the attributes and prepared the following matrix A1:

A1 =

	EC	MC	ODSE	WC	GGE	AETA	TW	EOHM	EOPOS	LCC
EC	1	5	1/3	7	1/3	1/5	1/5	1/7	1/5	1/7
MC	1/5	1	1/9	3	1/9	1/9	1/9	1/9	1/9	1/9
ODSE	3	9	1	3	1	1/3	1/3	1/5	1/3	1/5
WC	1/7	1/3	1/3	1	1/9	1/9	1/9	1/9	1/9	1/9
GGE	3	9	1	9	1	1	1	1/3	1	1/3
AETA	5	9	3	9	1	1	1	1/3	1	1/3
TW	5	9	3	9	1	1	1	1/3	1	1/3
EOHM	7	9	5	9	3	3	3	1	3	1
EOPOS	5	9	3	9	1	1	1	1/3	1	1/3
LCC	7	9	5	9	3	3	3	1	3	1

So, now calculating the geometric means we get,

GM_{EC} = 0.4789

GM_{MC} = 0.2041

GM_{ODSE} = 0.8089

GM_{WC} = 0.1768

GM_{GGE} = 1.3903

GM_{AETA} = 1.6330

GM_{TW} = 1.6330

GM_{EOHM} = 3.4364

GM_{EOPOS} = 1.6330

GM_{LCC} = 3.4364

Now, let us calculate the weights of the parameters:

w_{EC} = 0.03229

w_{MC} = 0.0137619

w_{ODSE} = 0.05454

w_{WC} = 0.01192

w_{GGE} = 0.09374

w_{AETA} = 0.11010

w_{TW} = 0.1101

w_{EOHM} = 0.2317

w_{EOPOS} = 0.1101

w_{LCC} = 0.2317

So matrix A2 = $\begin{bmatrix} 0.3229 \\ 0.0137 \\ 0.0545 \\ 0.0119 \\ 0.0937 \\ 0.1101 \\ 0.1101 \\ 0.2317 \\ 0.1101 \\ 0.2317 \end{bmatrix}$ A3 = A1 x A2 = $\begin{bmatrix} 0.366013 \\ 0.160586 \\ 0.606446 \\ 0.137467 \\ 0.960899 \\ 1.134559 \\ 1.134559 \\ 2.465387 \\ 1.134559 \\ 2.465387 \end{bmatrix}$

Now, A4 = A3 / A2 = $\begin{bmatrix} 11.3351 \\ 11.6688 \\ 11.1192 \\ 11.5325 \\ 10.2506 \\ 10.3048 \\ 10.3048 \\ 10.6404 \\ 4.89667 \\ 10.6404 \end{bmatrix}$

Now, λ_{max} = Avg of A4 = 10.0269356

CI = (10.0269356 – 10)/(10 – 1) = 0.029928

CR = 0.029928/1.49 = 0.020085906

Now, since CR is less than 0.1, so whatever matrix A1, have been decided, is correct i.e. there is good consistency in the judgements made. Also, there is no contradiction in the judgements.

So now by using multiplicative AHP, we get

W_1 = 0.671439543

W_2 = 0.402960897

W_3 = 0.483436548

W_4 = 0.502954187

W_5 = 0.499423927

W_6 = 0.785650226

Since $W_6 > W_1 > W_4 > W_5 > W_3 > W_2$

So, order of preference of chairs is

6 > 1 > 4 > 5 > 3> 2

TOPSIS:

Now, after AHP, we will apply TOPSIS model for the data in table 5.1 for getting the preference for the chairs.

So, using TOPSIS, we can calculate and find the following normalized decision matrix using data from table 5.2:

	1	2	3	4	5	6	weights (from AHP)
EC	0.3739	0.3410	0.4440	0.3272	0.4769	0.4602	0.0322
MC	0.53614	0.3533	0.2905	0.3431	0.3351	0.5227	0.0137
ODSE	0.3474	0.3992	0.3053	0.4609	0.2869	0.5761	0.0545
WC	0.06031	0.0553	0.0772	0.0554	0.0850	0.9888	0.0119
GGE	0.5107	0.3503	0.4044	0.3314	0.4335	0.3937	0.0937
AETA	0.1229	0.1374	0.1085	0.1422	0.1066	0.9606	0.1101
TW	0.3527	0.3434	0.3282	0.3150	0.3382	0.6605	0.1101
EOHM	0.4285	0.4285	0.3306	0.4965	0.3088	0.4260	0.2317
EOPOS	0.6038	0.3393	0.3393	0.3393	0.4178	0.3393	0.1101
LCC	0.6473	0.3612	0.3333	0.2434	0.3554	0.3916	0.2317

After this, we can get the following matrix:

	1	2	3	4	5	6
EC	0.01207	0.01101	0.01433	0.01056	0.01539	0.01485
MC	0.00731	0.00486	0.00399	0.00472	0.00461	0.00719
ODSE	0.01894	0.02177	0.01665	0.02513	0.01564	0.03142
WC	0.00071	0.00065	0.00086	0.00066	0.00101	0.01178
GGE	0.04787	0.03283	0.0379	0.03106	0.04063	0.03690
AETA	0.01353	0.01501	0.01194	0.01565	0.01173	0.10576
TW	0.03888	0.03780	0.03613	0.03468	0.03723	0.07272
EOHM	0.09928	0.09928	0.0766	0.11503	0.07154	0.09870
EOPOS	0.06647	0.03735	0.03735	0.03735	0.04600	0.03741
LCC	0.14997	0.08369	0.07722	0.05639	0.08234	0.09073

So,

$V_{EC}^{+} = 0.010560$ $\quad V_{EC}^{-} = 0.015390$

$V_{MC}^{+} = 0.003997$ $\quad V_{MC}^{-} = 0.007313$

$V_{ODSE}^{+} = 0.015647$ $\quad V_{ODSE}^{-} = 0.031420$

$V_{WC}^{+} = 0.000659$ $\quad V_{WC}^{-} = 0.011786$

$V_{GGE}^{+} = 0.031065$ $\quad V_{GGE}^{-} = 0.047870$

$V_{AETA}^{+} = 0.011736$ $\quad V_{AETA}^{-} = 0.105760$

$V_{TW}^{+} = 0.034687$ $\quad V_{TW}^{-} = 0.072721$

$V_{EOHM}^{+} = 0.071548$ $\quad V_{EOHM}^{-} = 0.115039$

$V_{EOPOS}^{+} = 0.037350$ $V_{EOPOS}^{-} = 0.066470$

$V_{LCC}^{+} = 0.056390$ $V_{LCC}^{-} = 0.149979$

So, now we get

$S_1^{+} = 0.02470012$ $S_1^{-} = 0.1325690$

$S_2^{+} = 0.03970435$ $S_2^{-} = 0.1290051$

$S_3^{+} = 0.04569103$ $S_3^{-} = 0.1049391$

$S_4^{+} = 0.04469188$ $S_4^{-} = 0.1401748$

$S_5^{+} = 0.02950485$ $S_5^{-} = 0.1319413$

$S_6^{+} = 0.01263361$ $S_6^{-} = 0.0688602$

After that, we get

$P_{N1} = 0.84294425$

$P_{N2} = 0.76465845$

$P_{N3} = 0.69666730$

$P_{N4} = 0.75808578$

$P_{N5} = 0.81724669$

$P_{N6} = 0.84497469$

So,

$P_{N6} > P_{N1} > P_{N5} > P_{N2} > P_{N4} > P_{N3}$

So, preference of chairs is

6 > 1 > 5 > 2 > 4 > 3

Both AHP and TOPSIS are the methods of MCDM (Multiple criteria decision making). For getting the preference order for different chairs having different parameter's value, we applied both AHP and TOPSIS model. Using AHP, preference order 6 > 1 > 4 > 5 > 3> 2 was obtained. So according to AHP, table 6 is the most preferred chair to be used.

Then TOPSIS was applied for the given data. So TOPSIS provided the preference order 6 > 1 > 5 > 2 > 4 > 3 for 6 different chairs. So, TOPSIS also suggested to use chair 6 for the given parameters value. Finally it showed that chair 6 is the best attribute to be used.

CHAPTER 6

6. CONCLUSIONS AND SCOPE FOR FUTURE RESEARCH:

For getting multi-criteria decisions, AHP and TOPSIS models were developed. In this study, AHP and TOPSIS methods were used to deal with MCDM problems for getting the decision related to choose the best chair having different environmental performance parameters. Because green supply chain is the emerging field, so a case study of furniture industry having green supply chain is included. In the case study different chairs having different environmental performance parameters were taken. Since both the methods AHP and TOPSIS may or may not provide same result, both methods were compared. Since it is desired to get the best alternative, i.e. decision maker always looks for the best alternative for the given parameters, in our result it was found that chair 6 is the best alternative to be used for the given parameters related to greening concept. AHP and TOPSIS models provided almost the same ranking order of the alternatives and both methods showed that table 6 is the most preferred chair.

Since, AHP method is probably the most used method for MCDM. Also, there is less effort to get preference order and even it involves less complicated procedure while getting results for the given parameters. In this study, the best known AHP method yielded almost the closed results to TOPSIS method (which is much more complicated than AHP). As it is shown from the formulation of both the methods that AHP involves much simpler and fast computation than TOPSIS, so it suggested that it is more suitable for applying AHP model in the context of chairs for the environmental concerned parameters. So it is suggested to use AHP method in furniture industries having green supply chain because of the easiness in applying the method.

In future, for determining the preference order, MCDM methods like VIKOR or DAEMETAL methods can be used and further results can be compared to get best alternatives.

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