AN ANALYTIC MODEL PROPOSAL FOR ENVIRONMENTALLY CONSCIOUS SUPPLY CHAIN MANAGEMENT

(ÇEVREYE DUYARLI TEDARİK ZİNCİRİ YÖNETİMİ İÇİN ANALİTİK BİR MODEL ÖNERİMİ)

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Table of Contents

List of Symbols

AHP: Analytic Hierarchy Process

ANP: Analytic Network Process

CSCMP: Council of Supply Chain Management Professionals

DFA: Design for Assembly

DFE: Design for Environment

DFM: Design for Manufacturing

DFP: Design for Packaging

ECSC: Environmentally Conscious Supply Chain

ECSCM: Environmentally Conscious Supply Chain Management

EMS: Environmental Management System

EOF: End of Life

EPA: Environmental Protection Agency

EPR: Environmental Producer Responsibility

GL: Green Logistics Dimensions

GOA: Green Logistics Activities Dimensions

ISO: International Organization for Standardization

JIT: Just In Time

MCDM: Multi Criteria Decision Making

MP: Manufacturing Priorities

NPD: New Product Development

PWC: Pairwise Comparison

ROHS: Release of Hazardous Substances

SCM: Supply Chain Management

TMMT: Toyota Motor Manufacturing Turkey

UNEP: United Nations Environment Program

WEEE: Waste of Electrical and Electronic Equipment

List of Figures

List of Tables

ABSTRACT

Developing technology and human being's continual spend up trend act a significant role in environmental pollution. Especially in the last decade, people and social organizations are becoming more conscious of the problems that environmental pollution causes.

It's obvious that in every place that production exists, environmental affects also exist. The concept of decreasing these affects force producers to be green with legal, environmental, economic and market drivers. Today pioneering producers try to make greener their supply chain. Considering legal requirements, instead of formerly applied compulsory operations, today's numerous firms are fulfilling voluntary. Positive effects of environmental development on economic issues motivate the firms to invest more in this subject.

In this thesis, the applications that Turkish firms are performing on environmental conscious supply chain management are analyzed by a model that is based on ANP method which is one of the multi criteria decision making methods. In light of the decision makers and data acquired in interviews, firms' current supply chain management, Just in Time (JIT) and environmentally focused supply chain management systems are compared and the outcomes obtained are analyzed.

Key Words: Environmentally conscious supply chain management, Multi criteria decision making, ANP, Strategic decision making.

RESUME

Le développement technologique et la tendance de l'être humain à consommer continuellement provoquent la pollution de l'environnement. Les problèmes dérivés de cette pollution ont conduit surtout les dernières années les organisations sociales et l'humanité à prendre conscience des sujets environnementaux.

Il est évident que la production affecte l'environnement. L'ideé que les influences pernicieuses de la production peuvent être réduites, ainsi que les pressions légales, environnementales et économique et aussi les nécessités du marché obligèrent les producteurs à la production verte. De nos jours, les producteurs prééminents s'efforcent à rendre leur chaîne logistique plus sensible à l'environnement. Les travaux faits auparavant à cet effet par les entreprises en raison des obligations légales sont faits de nos jours volontairement. Les influences économique positives du développement environemental augmentèrent aussi les investissements faits à ce sujet par les entreprises.

Dans ce travail, on a étudié les travaux faits sur la gestion de la chaîne logistique sensible à l'environnement par des établissements au premier plan de la Turquie au moyen d'un modèle préparé par ANP qui est une des méthodes de décision de multicritère. A la lueur des données obtenues par suite des entrevues faites aves les décideurs, on a comparé la gestion de la chaîne logistique de ces établissements avec celle des chaînes logistiques juste-à-temps et sensible à l'environnement et on a analysé les résultats obtenus.

Les mots clés : Gestion de la chaîne logistique sensible à l'environnement, Méthode de décision de multicritère, ANP, Décision stratégique.

ÖZET

Gelişen teknoloji ve insanoğlunun sürekli tüketme eğilimi çevremizi kirletmektedir. Çevre kirliliğinin açtığı sorunlar nedeniyle, özellikle son yıllarda, çevresel konularda insanlar ve toplumsal örgütler bilinçlenmeye başladılar.

Üretimin olduğu her yerde, olumsuz çevresel etkilerin de olduğu aşikardır. Bu etkilerin azaltılabileceği fikri yasal, çevresel, ekonomik baskılar ve piyasa gereksinimleri sonucu üreticileri daha çevreci üretim yapmaya itmiştir. Bugün önde gelen üreticiler tedarik zincirlerini çevreye daha duyarlı hale sokmaya çalışmaktadırlar. Önceleri sadece yasal zorunluluklarla yapılan çalışmalar bugün bir çok firma tarafından gönüllü olarak yapılmaktadır. Çevresel gelişimin olumlu ekonomik etkileri firmaların bu konuya daha fazla yatırım yapmalarına sebep olmuştur.

Bu çalışmada, Türkiye'de üretim yapan öncü kuruluşlarda çevreye duyarlı tedarik zinciri yönetimi adına yapılan çalışmalar, çok kriterli karar verme yöntemlerinden biri olan analitik serim süreci tabanlı önerilen bir model yardımıyla incelenmiştir. Belirlenen şirket yetkilileriyle yapılan görüşmeler sonucu karar vericilerin değerlendirmeleri ile elde edilen verilerle, firmaların uygulamakta olduğu tedarik zinciri yönetimi ile tam zamanında (JIT) ve çevre odaklı tedarik zinciri yönetimi sistemleri kıyaslanmış ve elde edilen sonuçlar analiz edilmiştir.

Anahtar Sözcükler: Çevreye duyarlı tedarik zinciri yönetimi, Çok ölçütlü karar verme, Analitik serim süreci, Stratejik karar verme.

1. INTRODUCTION

During the last decades, supply chain management (SCM) has been receiving increasing scrutiny from decision makers. Market requirements, competitiveness and customer expectations and other drivers force companies to create new differences from others. Environmentally conscious supply chain management (ECSCM) helps organizations to develop 'win–win' strategies that seek to achieve profit and market share objectives by lowering their environmental risks and impacts, while raising their ecological efficiency [1]. Firms increasingly rely on their supply network to handle more complex technologies. Increasing attention is devoted to supplier's social responsibility with a particular focus on fair and legal use of natural resources. ECSCM is a new trend but it is receiving an increased attention in recent years among manufacturing practice and research. Managers use ECSCM as new opportunities for competition, and new ways, to add value to core business programs.

When this concept is started to implement, companies was focused on green production. But researchers showed that environmental impact occurs in all stages of supply chain management. With the enlargement of the concept some new activities also generated like green marketing and green design activities. Green issues have different dimensions. Different companies implementing green technologies for several reasons. Legal requirement, market pressures, customer's expectations and economic reasons are some of these. On the other hand advantages of implementing ECSCM are discussed long time by researchers. Some of them mentioned that green activities are requiring high raw material cost and operational cost. Contrary a number of researchers mention that evaluation of green activities is a strategic decision. They also add that this type of strategic decisions show their positive advantages on the long time period. More over some kind of advantages are unable to calculate. For instance creating positive image for a company is one of the most important success criteria but it is hard to identify it with an economic number.

Company's managers are responsible to take strategic decisions. Evaluation and implementation of the ECSCM also is an important strategic decision. The efficiency of the supply chain is related with the coordination between departments. The processes that will use for better performance have to be made by decision makers. These decisions will have internal and external implications for the management of an organization. ECSCM decisions are one of the latest issues facing organizations with strong internal and external linkages decision makers use some instruments for better results. Analytic Network Process (ANP) is one of these instruments. Our aim in thesis is to identify and structure the primary strategic and operational elements for a framework that will aid managers in evaluating ECSCM alternatives.

The structure that is developed in this thesis is a network hierarchy that can be used to evaluate the alternatives. The technique for analyzing the decision is based on the AHP approach first introduced by Saaty in 1980 [99]. The dynamic characteristics and complexity of our decision environment, which is true for most strategic decisions, makes the ANP technique a suitable tool. Ford Otosan, Hyundai Assan, Toyota and Arçelik are selected as case companies in this study for the evaluation of ECSCM alternatives. The supplied case studies provide additional insights for research and practical applications.

The organization of this thesis is then as follows. The thesis begins with the presentation of ECSCM. In this part drivers, performance indicators, advantages and disadvantages of the ECSCM are identified. Then, the author attempts to structure various main components of the ECSCM into an evaluation framework. The components are explained en detail and the effects of them are analyzed. After a review of ANP technique, a conceptual evaluation model based on the ANP approach is presented. The next section includes the illustration of the methodology through the cases of the firms. As a conclusion, the author gives some concluding remarks.

2. ENVIRONMENTALLY CONSCIOUS SUPPLY CHAIN MANAGEMENT

As competition has intensified and globalized over the last decades, SCM has received greater attention by manufacturing organizations. Firms increasingly rely on their supply network to handle more complex technologies and higher customer expectations. SCM aims to increase service performance while decreasing costs. SCM decrease stock levels entailing lower risk and costs, increase productivity and improve business management procedures. In other worlds, SCM involves the organization and management of activities that address the performance of materials, components, and goods and services that an organization buys and uses. SCM is an important element in competitive and logistics strategy, especially for multinational enterprises. Over the years researchers expressed SCM differently.

According to Bowersox and Closs [2] supply chain refers to all those activities associated with the transformation and flow of goods and services, including their attendant information flows, from the sources of materials to end users. Management refers to integration of all these activities, both internal and external to the firm.

Stadtler and Schönsleben [3] mentioned that SCM encompass the short and long term collaboration of a company with other companies to develop and manufacture products with the required internal and inter-company organization, planning and control of the flows of materials, financial value and information along the business processes.

According to Chan et al. [4] SCM is a continuous process, from raw materials to finished goods, via each traditional distinct function such as forecasting, purchasing, manufacturing, distribution, and sales and marketing.

Pollution Prevention World Information Network defined SCM as the oversight of material, information, and financial flows inside and outside an organization. Flows move from supplier to manufacturer to wholesaler to retailer to consumer [5].

The Council of Supply Chain Management Professionals (CSCMP) defines SCM as follows [6]:

“SCM is the systemic, strategic coordination of the traditional business functions and the tactics across these functions within a particular company and across businesses with the supply chain for the purposes of improving the long-term performance of the individual companies and the supply chain as a whole.”

The supply chain council’s SCM definition is:

“Managing supply and demand, sourcing raw materials and parts, manufacturing and assembly, warehousing and inventory tracking, order entry and order management, distribution across all channels, and delivery to the customer.”

As seen in these definitions SCM compasses a huge system and especially multi national firms enlarged their logistics operations vision to embrace SCM to further improve their cost and service performance. SCM includes managing supply and demand, sourcing raw materials and parts, manufacturing, warehousing and inventory tracking, order management, distributions across all channels, and delivery to the customer [7]. As a result procurement, production, distribution, reverse logistics and packaging are the logistics dimensions of SCM that have serious effect on it.

These steps forces managers to make coordination on logistics dimensions among suppliers, wholesalers, retailers and clients. Researchers believe that the performance of these partners is affecting the main firm’s performance. The successful management of a supply chain is also influenced by customer expectations, government regulation, competition and the environment. In some cases, social responsibilities are at least important as economic benefits. Even governmental regulations oblige firms about social assignments. Pioneering firms seems like volunteer about working in these subjects. Environmentally consciousness is also an important social assignment.

Sarkis [12] mentioned that if the supply chain contains reverse logistics than it can be named ECSCM.

Pun [8] expressed that ECSC is a method to design and/or redesign the supply chain that incorporates recycling and remanufacturing into the production process.

Hervani et al. [9] defines ECSCM as the collection of green purchasing, green manufacturing / materials management, green distribution / marketing, reverse logistics and they also mentioned that adding the “green” component to SCM involves addressing the influence and relationships of SCM to the natural environment.

Green et al. [10] defines ECSCM: Green supply refers to the way in which innovations in SCM and industrial purchasing may be considered in the context of the environment.

Srivastava [11] defined ECSCM as integrating environment thinking into SCM, 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.

Over the last years, companies are seeking to improve their environmental performance. The main reasons for these changes are regulations, customer’s expectations, international standardizations, market pressures, creating good brand image and some economic reasons. ECSCM must to embrace all steps of supply chain because that environmental impacts occur at all stages of a product's life cycle: from resource extraction, to manufacturing, use and reuse, final recycling, or disposal. In this thesis ECSCM encompasses inbound logistics, production or the internal supply chain, outbound logistics, reverse logistics, including and involving materials suppliers, service contractors, vendors, distributors and end users working together to reduce or eliminate adverse environmental impacts of their activities. For this reason, the conventional green production mentality doesn't create ocular advantages in today's competitive market. ECSCM aims to achieve profit and market share objectives by lowering their environmental risks and impacts, while raising firm's ecological efficiency. This system in not a completely open or closed system and it's characterized by some factors of energy and material is reused within the system [12].

2.1. ECSCM Drivers

ECSCM is gaining increasing interest among researchers and practitioners of operations and SCM. Three drivers drive ECSCM worldwide.

Regulations pressure is the most powerful effect that forces firms to implement ECSCM. Regulations are not voluntary requirements. Environmental regulations have provided a clear parameter of the legally acceptable level of corporate responsibility, accountability, and expectations. If markets fail to operate efficiently, either because they are uncompetitive or because it is difficult and expensive to assess environmental damage, government regulation to set environmental standards may be the only effective method of protecting the environment [13]. Regulations can be global, central governmental or regional governmental. Central governmental regulations depend on the environmental consciousness of the country. Even developed countries have solid rules, especially third-world countries rules are not sufficient. For instance in Germany, there were approximately 800 environmental laws, 2800 ordinances and 4,700 technical instructions. Some legislation that is adopted in USA can be listed: the Clean Air Act (CAA), the Clean Water Act (CWA), the Resource Conservation and Recovery Act (RCRA), the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), the Toxic Substances Act (TSCA), and the Amendment Acts to CERCLA [14]. Observing and demonstrating compliance to environmental regulation and trying to exceed the regulatory requirement to the benefit of the consumer may be perceived as a competitive advantage [16]. In this point of view environmental regulations could motivate private sector firms.

In third-world countries some other pressures force firms to be greener. Sarkis mentioned that the environmental performance of the suppliers effect hardly the environmental performance of the main firm's. Because of this reason pioneering firms that have suppliers in these countries forced them to implement ECSCM and new global standardizations. The aim of this pressure is to reduce the environmental effect of their supplier and relatively improve their SCM. For example, Bristol- Myers Squibb, IBM and Xerox have encouraged their Chinese suppliers to develop Environmental Management Systems (EMS) consistent with ISO 14001, while Ford, GM and Toyota have required their Chinese suppliers to obtain the ISO 14001 certification [17]. These types of certifications could be named as volunteer regulations. ISO 14001 and EMAS are the most prestigious of volunteer certifications. These standardizations elicit an international environmental management approach which improves international trade and removing trade barrier [14].

Accorind to Chin [18] market pressure serves as the second most important driving force for manufacturers to implement the ISO 14000-based EMS in order to maintain their competitive position in the global marketplace. ECSCM is influenced by customer's expectations. Customers are started to be more conscious about environmental problems and many organizations are making positive efforts to be more socially responsible and to meet customer expectations for more environmentally conscious products. Consequently, it may be argued that there is an expectation on the part of customers that all products offered should be environmentally safe without a need to sacrifice quality and/or having to pay higher prices for the privilege [16]. A green brand image also is an important marketing element. Carter and Ellram [15] mentioned that reverse logistics programs can improve the corporate image of the companies.

Economic reasons also force firms to be more conscious on ECSCM. Greening different phases of the supply chain should directly, or indirectly, translate into enhancement of economic or financial performance because it results in better utilization of natural resources, improved efficiency and higher productivity and reduces operating costs [19]. Firstly decrease of materials: decrease of cost for materials purchasing, decrease of cost for energy consumption, decrease of fee for waste treatment, decrease of fee for waste discharge and secondly decreases of logistics costs: decreases of inventory levels and distribution costs, and finally operational risks decrease like decrease of fine for environmental accidents are some of these economic advantages. On the other hand a number of researchers mentioned that ECSCM don't have always economic advantages. They believe that the raw materials, research and development practices that ECSCM require will decrease costs and effect negatively financial performance of the firm. Contrary to this belief, Ford-Otosan's purchasing manager that the author interviewed mentioned that green products production, reverse logistics and disposal costs are lower than others. Questionnaire what Zhu et al. [17] used for analyzing green performance of the Chinese automotive sector filled by Ford Otosan's purchasing manager could be analyzed in Appendix A. More over customers prefer green product's because they are good quality and certified.

2.2. ECSCM Performance Indicators

For the evaluation of the ECSCM measurement of the green logistic dimension activities is essential. Environmental performance indicators are described in ISO 14031. According to this environmental performance evaluation guide the following performance indicators could be listed [9]:

- Employee and participative management;
- Publicly available missions and values statements;
- Management systems pertaining to social and environmental performance;
- Magnitude and nature of penalties for non-compliance;
- Number, volume, and nature of accidental or non-routine releases to land, air, and water;
- Costs associated with environmental compliance;
- Environmental liabilities under applicable laws and regulations;
- Site remediation costs under applicable laws and regulations;
- Major awards received;
- Total energy use;
- Total electricity use;

- Total fuel use;
- Other energy use;
- Total materials use other than fuel;
- Total water use.

2.3. ECSCM Advantages and Disadvantages

ECSCM has some advantages and disadvantages. Even financial concerns affect all activities, it have a deep relations with environmental subject. Most of the firms evaluate ECSCM because of economical and financial reasons. It's obvious that conventional production systems are not efficient. Researches showed that during green activities energy, material, vehicle and natural source usage reduce. Reduction of wastes and ease of recyclability makes the supply chain more controllable. Greening the supply chain also elicit compability with the regulations and decrease environmental accidents. This averts damages and decrease fees, amends and safety costs. However greening the supply chain is not a simple organization. ECSCM requires a big capital investment, developed research and development and design departments. Especially for small and medium sized companies these economic charges are hard to support. More over green products require higher raw materials cost. However raw materials with higher prices make the product good quality.

ECSCM shows strong adjustments on environmental performance. Green products don't include hazardous materials. More over during life cycle of the products environmental impact are minimized. Even energy and material reduction has economic impacts; they also effect negatively the environment.

ECSCM may improve brand image. Green labeling and some other indicators change the customers thinking about the firms. Green image has strategic advantages and increase competitiveness of the firm. Researches shows that firms with hi brand images increase their benefit and market share. Advantages and disadvantages of the ECSCM are given in Table 2.1.a, Table 2.1.b according to their effects.

Table 2.1.a: Categorization of the advantages of the ECSCM

Advantages	Legal	Social	Commercial
Reduce of operating costs			√
Increase of access to markets			√
Easier compliance with environmental regulations	√		
Improve of environmental performance			√
Improved customer trust and satisfaction			√
Enhanced corporate image and credibility			√
Decrease of energy consumption		√	√
Increase of material cost			√
Increase of product quality			√
Increase of service quality			√
Decrease of waste production		√	√
Decrease of emissions		√	√
Decrease of risks of environmental incidents		√	√
Decrease of disposal cost			√
Decrease of raw material consumption		√	√
Decrease of noise and radiation		√	√
Decrease of use hazardous toxic		√	√
Increase of competitiveness			√
Improved worker and community health		√	
Increase of market share			√
Increase of technology development			√
Increase of operational performance			√
Support of environmental sustainability strategy and vision			√
Decrease of storing costs			√

Table 2.1.b: Categorization of the disadvantages of the ECSCM

Disadvantages	Legal	Social	Commercial
Increase of raw material costs			√
Increase of training costs			√
Increase of investment			√

3. AN EVALUATION FRAMEWORK FOR ECSCM

A detailed literature search with the concepts related to ECSCM is realized. The author found some concepts and elements which can be served as the foundation for a decision framework for prioritizing or selecting systems by the organization that will aid in managing ECSC. They are summarized as follows:

3.1. New Product Development

New product development (NPD) is the complete process of bringing a new product or service to market. Companies see NPD as the first stage in generating and commercializing new products within the overall strategic process of product life cycle management used to maintain or grow their market share.

The essence of effective NPD lies in creating products. NPD delivers the basic benefits of customers and auxiliary attributes which help to differentiate between products. NPD aims to meet the needs of customers and other internal and external stakeholders [20]. New product development is an important success factor for many companies which affect effectiveness. NPD is a complicated and time-consuming process in which several different activities are involved. The US-based Product Development and Management Association defines NPD as a disciplined and defined set of tasks and steps that describe the normal means by which a company repetitively converts embryonic ideas into saleable products or services [21].

Cooper [22] argues that NPD process requires a cross-functional team approach because that it encompass both engineering and marketing expertise. Product developers always are in a connection with marketing and marketing research, engineering, research and development, production, purchasing and finance departments.

The drivers for the NPD process can be one or more of the following three factors: Technology, market, and management. Advances in technology provide an opportunity for the improvements to an existing product. Market effects from the response of competitor's actions and/or feedback from customers through complaints about current product performance. Management is related with internal factors like the need to reduce warranty cost and external factors like new legislation with regards product performance [21].

Environmentally new product development (ENPD) is defined here as product development into which environmental issues are explicitly integrated in order to create one of the least environmentally harmful products a firm has recently produced. This also includes the redesign of existing products to reduce their environmental impact in terms of materials, manufacture, use, or disposal. The main difference between ENPD and traditional NPD is that ENPD is more focused on products post-use, and particular design for the ''Five R's'' of repair, reconditioning, reuse, recycling, and remanufacture [20].

The literature on NPD contains several alternate NPD process models. At an overall level, however, it is possible to recognize the similarities between the different models. What they have in common is that the NPD process begins with an idea to build a product that meets specific needs or create new needs for radically innovative products defined by customers and/or manufacturer, and ends with a product that is launched in the market.

The NPD process consists of several phases. The phases can be grouped into two stages. Stage I (pre-development stage) is concerned with the development of non-physical product solutions at an increasing level of detail. Stage II (development and production stage) deals with the physical embodiment of the product. Rosenthal created a four steps NPD process model. In this study the author considered the same NPD process as Rosenthal. This model consists of ideas generation and conceptual design, definition and specification, prototype and development, commercialization [23].

3.1.1. Ideas Generation and Conceptual Design

In this phase an idea for the product development is generated and the conceptual design is created according to the market needs and customers pressures. Ideas generation and conceptual design is the first stage of new product development process. Every new product and every new product development process starts with the idea generation. Idea generation is a process in which creative thinking is used to produce large amount of ideas for new products. Ideas for new products can be obtained from basic research using SWOT analysis customers, the company's research and development department, competitors, focus groups, employees, salespeople or trade shows may also be used to get an insight into new product lines or product features.

3.1.2. Definition and Specification

After creating a conceptual design, the goal of the project has to be selected in the definition and specification phase. Making studies about feasibility of the developed product to be developed and definition the performance of the product are the main steps of this phase. In this phase customer requirements, the expected costs, the expected market share of the product, the expected life cycle of the product and some other specification about the product are defined.

3.1.3. Prototype and Development

In this phase the physical embodiment of the product begins. Prototyping is simply taking the design from the virtual and imaginary realm to the physical world. Some internal tests are applied to the prototype to analysis the probable problems. In practice, most products require at least one prototyping phase. Typically, the flow is from the design phase to prototype and testing then back to design for minor changes before going to production. After obtaining a sufficient result from the development step, the product is ready for commercialization.

3.1.4. Commercialization

Commercialization is the last step of the product development. It generally includes production launch and ramp-up, marketing materials and program development, supply chain development, sales channel development, training development, training, and service and support development.

3.2. Design for Environment

An estimated 70 percent to 80 percent of product life-cycle costs are determined in the early stage of supply chain, during the design phase. Design for Environment (DFE) encompasses the process by which environmental issues are incorporated into the product realization process. DFE might be the most preferential way to improve environmentally conscious supply chain because changes in the design can cost-effectively leverage environmental effects both upstream and downstream. Valentincic [24] characterized DFE by a simultaneous design of a product and its manufacturing process in order to achieve the best outcome and consequently optimize the overall costs. Changes during design also generally yield greater returns than product modifications made later. Moreover, investments made in advanced engineering, before design begins, provide relatively low-risk, low-cost opportunities to find solutions to environmental issues. The promise DFE is to reduce the overall environmental impact of products and services through use of a life-cycle perspective. DFE is also known as eco-design green design and lifecycle design.

Poter and Linde [25] mentioned that DFE could reduce manufacturing cycle times, improve competitiveness, gain greater strategic control and meet both internal and external environmental goals and requirements. In the analytical dimension, DFE has a number of functional elements that should be included in a successful environmental strategy. The functional elements include design for recyclability, remanufacturability, reuse, disassembly, and disposal [26]. Material selection, packaging, energy use also effect directly from DFE. As a result electronic companies began to design products with joining technologies that eased disassembly and reuse of materials at the end of life by this way the amount of waste going to landfills reduce.

DFE could analyze in seven main steps: New concept development, physical optimization, optimization of material use, optimization of production, optimization of distribution, reduce of impact during product use and optimizing of end of life systems. These 7 steps compass some strategies as: Selecting environmentally low-impact materials, avoiding toxic and hazardous materials, choosing cleaner production and lean manufacturing processes, maximizing energy efficiency in manufacture and use, maximizing water efficiency in use, designing for waste minimization [27]. Moreover the success of eco-design requires internal cross functional cooperation among the entire company and the external cooperation with other partners throughout the supply chain.

3.2.1. Design for Manufacturing

There have been many definitions of Design for Manufacturing (DFM). Stoll [28] viewed DFM as a process that:

"…is concerned with understanding how product design interacts with other components of manufacturing systems and in defining product design alternatives which help facilitate "global" optimization of the manufacturing system as a whole."

In the past, products have been designed that could not be produced. Today's a rising number of manufacturing companies are therefore starting to address DFM, in order to improve the manufacturing situation by changing the product design. DFM is seen as a way to raise the productivity, virtually without any additional investments. Because of the advantages of the design stages DFM, increase the productivity significantly further than the production department can. Design for manufacturing has been used as a cost minimization and quality control [29].

Fabricius [30] argued that a number of pilot projects show that it is almost always possible to improve the manufacturability of mechanical and electro-mechanical products by implementing DFM procedure. Efficiency of this procedure could be identify by increasing of 25-30 per cent of the manufacturing costs without compromising on the product quality. O'Driscoll showed the success of the DFM as follows [31]:

- Reducing product assembly time by up to 61%;
- Reducing the number of assembly operations by as much as 53%;
- Reduction of 68% in the number of assembly defects;
- Cutting the time to market by as much as 50%.

According to Fabricius [30] DFM procedure includes the following activities:

1. DFM measurement (Production costs, quality, flexibility, risk, lead time, efficiency, environment);
2. Objectives;
3. Main functions;
4. Evaluation parameters and design ideas;
5. Generation of conceptual designs (Corporate level, family level, structural level, component level);
6. Verification and selection;
7. Detailed design.

Design automation tools are efficient to make decision and to evaluate multiple design alternatives. These design tools include computer-aided design (CAD), computer-aided engineering (CAE), solids modeling, finite element analysis, group technology (GT) and computer-aided process planning (CAPP). CAD/CAE aid the designer in cost effectively developing and analyzing design alternatives. CAD/CAE and expert system tools can utilize manufacturing guidelines to develop producible designs [32].

3.2.2. Design for Assembly

Assembly methods can be divided into three major groups: manual, fixed or hard automation and soft automation or robotic assembly. The cost of different assembly methods is different from each other. Design for Assembly (DFA) is a process by which products are designed with ease of assembly in mind. The first researches on DFA are made by Boothroyd and Dewhurst [33]. After 70's DFA approaches have been developed and a number of researches have been made. Boothroyd and Dewhurst design for assembly charts are used to estimate the assembly efficiency of an existing product based on the handling and insertion difficulties of each part. The first evaluation method was developed at Hitachi and was called the Assembly Evaluation Method. This method is based on the principle of "one motion for one part". Even though various methods have been evaluated, the basic aim is to reduce the number of the parts and ensure the ease of assembly. However, consequences of applying DFA usually include improved quality and reliability, and a reduction in production equipment and part inventory. These secondary benefits often outweigh the cost reductions in assembly. It gives the best results when used by multi-disciplined new product introduction teams. This ensures that all aspects of the product design are considered from different points of view [33].

For a better design for assembly, guides are generally focused on some important issues. The simplest way to raise the probability to produce impeccable products is to simplify the design of the product and to reduce the number of parts. For companies which produce more than one product, using common parts in different products will automatically reduce the number of parts. Consequently operation costs, stocking costs and service costs will decrease. More over easing the fabrication process will decrease costs. Designers also have to avoid of using flexible parts and interconnections in their products. Flexible parts make assembly more difficult. The materials which are hard to produce will increase costs and process time. DFA guides usually require using modular products to ease assembly with building block components and subassemblies. Some other commonly used requirement could be listed: Design for parts orientation and handling, design for efficient joining and fastening, maximize part symmetry, prefer self-locating parts [34, 35, 36, 37].

3.2.3. Design for Packaging

Design for Packaging (DFP) aim is to improve packaging issues on the early stages of production. For this purposes designers are especially focused on environmentally friendly packaging. Reusable packaging, recyclable packaging and biodegradable packaging are evaluating.

DFP main issues could be listed [38]:

- Eliminating prohibited expansion agents in packaging materials;
- Eliminating heavy metals from packaging materials;
- Minimizing toxic elements in packaging materials;
- Identifying the use of packages manufactured with recycled material content;
- Promoting the use of packaging materials which are recyclable;
- Identifying methods, processes and product and package designs to reduce the solid waste stream volume.

3.3. Green Logistics Dimensions

Green Logistics dimensions (GL) include procurement, production, distribution, reverse logistics and packaging. From procurement to reverse logistics these steps encompass whole the life cycle of the products. Although packaging is not viewed as a lifecycle element it is also affect ECSCM.

3.3.1. Procurement

The greening of business process forced managers to find new and advance methods for purchasing and SCM whereupon environmental issues acting on total quality principles. Until 70’s the importance of procurement functions was not taken seriously but especially at the last two decades argument were made that a function, which spends %50- %70 of a firm's revenue, should have more input concerning corporate strategy [39]. Today experts defined that procurement can help to identify, quantify, assess and manage the flow of environmental waste through the system with the goal of reducing waste and maximizing resource efficiency. The role of procurement is to assess the available sources of supply and provide supply strategy. Such as procurement is the first step of the supply chain, green procurement is one the most important unit of the ECSCM [9]. From this point green procurement aims to eliminate or reduce the use of hazardous substances and making efforts to reduce the environmental load generated from manufacturing and other business activities.

Purchased materials and components from suppliers heavily influence the quality, competitiveness, cost dependency, lead times, development cycles, development risks, and market availability of manufacturer's products [20]. As a result of this, firms and governments preferentially purchase materials, parts, supplies, equipment and other sources as well as services that have a lower impact on the environment.

Environmental issues are becoming a source of competitiveness. Companies know that for their customers, the greening of the product has a big role on the procurement decision. For this reason companies are using green effect for creating a difference from other competitors [40].

The win–win philosophies have created expectations that green products would be environmentally superior to traditional products but also competitive in terms of price and technical performance [41, 42, 43].

Green procurement shows its positive impacts on long- term competitiveness and profitability rather than on short terms. Procurement managers have to implement an action plan designed to achieve and enhance long-terms goals. Long term competitiveness increase efficiency, quality and cost savings [39].

Manufacturers implement green procurement to direct the selection of materials, components, products and suppliers. Industrial and consumer product manufacturers use green procurement, together with ECSCM, to manage risk, reduce costs, improve environmental performance and fulfill policy objectives. Several governments have policies in place that prescribe the use of environmental standards in procurement policies [44, 45, 46].

For instance Occupational Safety and Health Act, the Resource Conservation and Recovery Act, the Environmental Protection and Community Right to Know Act and the Clean Water Act are some of US regulatory requirements. More over there are also more voluntary environmental standards such as ISO 14000, Green Lights, some programs of the US Environmental Protection Agency (EPA) etc. [47].

There are many benefits that may be realized through implementation of green procurement. These benefits can provide significant incentive for organizations (public or private) to adopt green procurement practices. The benefits of implementing green procurement could be classified to two according to their effect like economics effects and social effects. Economic effects could be listed as follows:

- Cost avoidance: Green procurement and green product production increase the efficiency of the system so decrease costs and raise profitability. Excessive waste during manufacturing indicates possible inefficiencies in production and poor use of raw materials [44, 48, 49]. Green materials and raw materials are usually more costly than conventional alternatives but also have better quality. With the new legislations companies are responsible of their product during the life cycle even until disposal. This means, the companies has some hidden and indirect costs after selling their product like insurance costs, storage costs, waste disposal costs, permitting costs, accidental costs etc. For instance the costs of managing hazardous materials far exceed purchase costs. The firms which are implementing green systems have more production costs but lower after sales service costs. At first sight decision makers don’t pay attention to this subject because it’s difficult to calculate the cost after life cycle and disposal costs that could accrue over the next 5, 10, or

20 years. But the researches show that procurement green materials, raw materials and producing green product is not very costly as many decision makers think [17].

- Easier compliance with environmental regulations: Using green procurement in supply chain can improve company's record with environmental regulators, financiers and insurers. Adopting environmentally preferable products usage demonstrates a company's credibility and commitment to reducing environmental impacts [44].

- Support of environmental/sustainability strategy and vision: Private organizations see green procurement as a means of improving both environmental and social performance [44].

- Improved image, brand and goodwill: Green producers may also benefit from positive coverage in the media and strengthen cooperative relations with suppliers in developing alternatives. Strategic advantage, reputation and public good will are often labeled as "soft benefits" because it is difficult to estimate their financial value precisely [39].

Social effects could be listed as follows:

- Savings from conserving natural resources: Energy, water and resource efficient products, buildings and vehicles and can significantly reduce utility bills and operating costs. Rising energy prices is focusing procurement towards energy efficient green products [44].

- Reduced risk of accidents, reduced liability and lower health and safety costs: Companies who use environmentally preferable products, materials or substances can reduce health risks and liability while improving worker health and safety. Moreover reducing the risk of accidents will decrease the accidental fees [17, 44, 50].

- Improved worker and community health: Cleaner air and water, less demand for landfill and less demand for resources.

Drumwright [51] categorizes firms to two according to their reason to engage in green procurement. The first category firms engage green procurement because of the socially responsible behaviors. The first category classifies to two as: Type 1 and Type 2. For type 1 organizations green procurement is an extension of the founder's ideals and for type 2 organizations green procurement is symbolic of the corporate mission. The second category firms also classifies to two. Type 4 organizations engage green procurement just because of external restraints. For a better strategic position the second category firms must move from type 4 to type 1 or 2. Especially in developing countries where environmental regulations are not strictly enforced and where the competitive advantages of environmental management are not recognized the Type 4 organizations exists frequently [39].

Green procurement success factors could be classified to five: Success factors about suppliers, requirements, regulations, educations and the others.

Green performances of suppliers and second tier suppliers affect directly the performance of the final product and the ECSC of buyer company. In order to achieve greening at every stage and in every function, full involvement and co-operation of suppliers and business partners is essential. For this reason organizations have to determine which suppliers are best positioned to provide long term competitive advantages.

Good communication is an important success factor in supply chain. Communication between procurement personnel and other department's members and suppliers affect effectiveness of the system. Implementing DFE is a success factor for firms. More over using DFE is preferred when it is worked up with suppliers. These could be successful with a close relationship between buyers and suppliers. More over using technology to communicate, monitoring and to control could be more effective.

Sarkis [39] mentioned of some important supplier environmental performance indicators in his researches (environmental performance indicators are also described in ISO 14031). Thus could be listed like: Public disclosure of environmental records, ISO 14000 certifications, second tier supplier environmental evaluation, reverse logistics program, hazardous waste management, environmental friendly product packaging, toxic pollution management, ozone depleting substances, hazardous air emissions management, avoidance of using hazardous materials listed on EPA lists. Based on thus indicators selection and performance determination of supplier could be done. Also when the buying firm is not satisfied with the performance of a supplier or sustainability of a supplier some development program could be applied (holding awareness seminars, guiding suppliers to set up their own environmental programs, informing suppliers about the benefits of cleaner production and technologies etc...) [39].

Complying with environmental regulations is an important success factors because these regulations are not voluntary. In a case of transgressing them the production could be stopped. Usually complying with regional or central regulations are enough for companies which are doing domestic trade but companies which are exporting must to comply with export companies environmental rules. Buyers which want to engage green procurement have to implement some requirement to their supplier to enforce them to be greener. Some strategies listed below could be applied with different variations to different suppliers. For instance buyers could specify that products must have desirable green attributes or must not contain environmentally undesirable attributes. A higher effect on supplier behavior could be to require disclosure of the environmental or safety attributes of product contents. Other requirement could be about certifications of the supplier. Buyers can require suppliers to develop and maintain an EMS or to have a certificated EMS. Also buyers could ask suppliers to provide information about their environmental aspects, activities and/or management systems. Moreover buyers could develop their own standards for environmental compliance and require buyers to meet these standards. In some case buyers can take responsibility for managing the environmental effects of products throughout the product life-cycle. In high levels buyers can educate suppliers about environmental issues or can work more closely to develop a fully integrated system for recycle and re-use of materials within an industrial ecology framework [39].

Some of these strategies which use to enhance supplier performance are success factors for buyers firm when they implement these strategies themselves. For example education of buyer firms procurement managers is as important as educations of suppliers. Other success factors could be listed like: Sustainability of suppliers and implement total quality management system to green procurement.

3.3.2. Production

The most commonly perceived enemy to environmental protection is production and production operations. Environmental pollution occurs at various stages of the production. For this purpose a responsible environmental production which is named cleaner production concept developed.

Cleaner production is defined by United Nations Environment Programme (UNEP) in 1989 as continuous application of an integrated preventive environmental strategy applied to products, processes and services addressing the causes of pollution. This approach aims to elicit the sustainable development concept and to eliminate completely pollution and benefit future generations. It’s obvious that no process or product could be expected to be entirely without environmental impact. As a result the goal of cleaner production is not to produce the harmful substance at all, or to produce less of it, or a less harmful one [52].

Researches mentioned that the introduction of a “green” manufacturing strategy is a very complex issue and it has severe impacts on performance and often induces a significant modification in management procedures [53].

Cleaner production is the continuous application of an integrated preventive environmental strategy applied to processes, products, practices and services to increase eco-efficiency and reduce risks for humans and the environment. Cleaner technologies extract and use natural resources more efficiently, generate products with fewer harmful components, minimize pollutant releases to air, water and soil during manufacturing and product use, and design durable goods that can be reused or recycled [54]. In this concept eco- efficiency includes the recycling of the products and maximizing use or renewable resources cleaner production could be successful by using new technology, process update and modification, substitution of input materials, good operating practices, on-site reuse and recycling and/or product redesign [52].

Using less energy is obviously good for the environment. It is also self-evidently good for business because of economic reasons, and eventually avoids potential environmental liabilities.

Florida stated that closer bonds between suppliers and customers, which can facilitate cleaner production, are the trend in manufacturing as leading enterprises need such close relationships with suppliers to incorporate management strategies [55].

According to Rao and Holt cleaner production steps could be listed as [19]:

1. Environmentally-friendly raw materials, avoid using hazardous materials;
2. Substitution of environmentally questionable materials;
3. To be aware of environmental criteria and taking them to consideration;
4. Making environmental design for production stage;
5. Optimization of process to reduce solid waste and emissions;
6. Using cleaner technology and updating processes to make savings in energy, water, and waste;
7. Internal recycling of materials within the production phase and applying total quality management system in the production processes.

3.3.3. Distribution

CSCMP defines logistics as "The process of planning, implementing, and controlling the efficient, cost effective flow of raw materials, in-process inventory, finished goods and related information from the point of origin to the point of consumption for the purpose of conforming to customer requirements" [56].

Distribution is a sub function of the logistic operations. Researchers identify that there are two aspects of logistics activities in a firm's supply chain, i.e., inbound logistics and outbound logistics. Outbound logistics refers to physical distribution activities such as collecting, storing, and distributing products to buyers and involves warehousing, materials handling, network planning and management, order processing, and vehicle scheduling and routing. While the outbound logistics deals with finished good, and the inbound logistics is interested in raw materials. Whereas, inbound logistics considered suppliers and material for transformation purposes, outbound logistics is concerned with customer requirements and finished goods [57]. Traditional logistics systems do not encompass environmental issues and stress too narrowly the need to minimize costs and maximize profits in the private sector. In an environmentally responsible distribution approach managers have to add another objective to the system: minimizing total environmental impact. For these purpose managers need to take environmental costs and benefits into consideration while making a logistics decision or building a strategy. Researchers mentioned that distribution is one of the most effective functions that influence environmental performance. Environmentally responsible practice tends to favour fewer shipments, less handling, shorter movements, more direct routes, and better space utilization. It's obvious that these green distribution functions are cost added practices but the extended market share and competitiveness may bring more benefits. On the other hand green transportation practices have some economic advantages [57].

The impact of transport on the environment comes primarily from three sources according Wu et al.: construction of transport networks, operation of transport vehicles, and disposal of transportation vehicles and parts.

Different types of transportation are possible. Airports, harbors, rail right of ways and fills up and often pollute landfills with dismantled vehicles, parts, and toxic substances. With the efficient usage of these transports environmental effects could be decrease. For instance seaway and railway are considered greener than surface transportation. During the transportation fossil fuels is used such as oil and natural gas. More over vehicles generate noise and emit many toxic chemicals. To combat these problems, logistics managers can reduce the use of road transport, increase the use of alternative fuels of their fleets, and keep their fleets more energy efficient and less polluting. Even though it decreases the on time deliveries rate, another way to improve green transportation performance is also to reduce the number of trips by consolidating freight and balancing backhaul movements [57].

Using safer and greener alternative fuels also could be a great solution to improve transportation green performance. For instance compressed natural gas is a good alternative energy source to petrol. By using compressed natural gas in transportation machines, the environmental pollution will drastically reduce while lowering its total operating costs. Liquefied natural gas also is another alternative fuel that is cheaper and cleaner than petrol.

The maintenance and disposal of vehicles is also a major environmental problem. Proper maintenance programs help maintains vehicles in safe and efficient working condition. The improved vehicle efficiency, prolonged vehicle life, and reduced accident rates not only save operating costs but also cut the amount of environmental damage.

A good information system and innovative management ideas can also help reduce pollution and traffic congestion by allowing for more efficient loading, scheduling and routing. With a reduced number of logistical nodes in operation, logistics managers are able to run a more efficient operation at lower levels of inventories while maintaining the same, if not better, level of customer service. The results are often cost saving as well as environmentally responsible because wastes such as storage, energy and excess location are eliminated in the network. However, these savings can be mitigated by the resulting freight movements, which are not environmentally friendly.

3.3.4. Reverse Logistics

There are two major supply chains to be concerned within any distribution system: the forward chain, and the reverse supply chain. Reverse logistics is one the most developed industrial trend in the last decade. While more companies are becoming environmentally conscious, and as rigid environmental laws are being passed, goods that reach the end of their usable life are being recalled or repossessed by the manufacturer. This trend is developed with the charge for manufacturers to collect, to refurbish, and to remanufacture the used part. Reverse distribution activities embrace the removal of unavailing and environmentally hazardous products from the hands of customers.

Even there is a number of definition reverse logistics it could simply define as: an activity which forms a continuous process to treat return-products until they are properly recovered or disposed of. According to the CSCMP, Reverse Logistics is defined as:

"The process of planning, implementing, and controlling the efficient, cost effective flow of raw materials, in-process inventory, finished goods and related information from the point of consumption to the point of origin for the purpose of conforming to customer requirements [58]."

Kopicky et al. [59] defines Reverse Logistics as:

"Reverse Logistics is a broad term referring to the logistics management and disposing of hazardous or non-hazardous waste from packaging and products. It includes reverse distribution which causes goods and information to flow in the opposite direction of normal logistics activities."

There are three main drivers for reverse logistics: Economic, corporate citizenship, and legislation. Carter and Ellram [18] mentioned that the reverse logistics programs in addition to the various environmental and the cost benefits can proactively minimize the threat of government regulation and can improve the corporate image of the companies.

Economics is the most powerful driver to reverse logistics relating to all the recovery options, where the company receives both direct as well as indirect economic benefits. Reverse logistic programs elicit cost reduction because of source minimization. Moreover recovery of product and reduction of disposal costs bring economic advantages.

The legislation issue refers to the norms imposed by any jurisdiction which dictate the legal obligations of a firm. European countries are more active in this sense. For instance, Germany is the first country that implements the take-back program with its "Ordinance on the Avoidance of Packaging Waste". This law brings to manufacturer the responsibility of collecting, sorting, and recycling the packaging of their products. Several years later the European Union implemented this legislation as the "Directive on Packaging and Packaging Waste." According to this law a minimum of 50% of the waste must be recovered, 25% of the total recycled, in addition to recycling at least 15% of each material type [60]. As a result today firms implemented reverse logistics in their supply chain and force their customer and supplier for reverse logistics. Nike encourages consumers to return their used shoes, which are then shredded and made into basketballs for the less fortunate. Xerox and Hp also force their customers for reuse of cartridge of printers.

Corporate citizenship, also called "extended responsibility", refers to the search for sustainable development from an environmental and social point of view. Reverse logistics activities can lead to increase of corporate image and can bring competitive and economic advantages.

Reverse logistics consist of a complex structure. The activities and flows of reverse logistics could be seen in Figure 3.1. It's obvious what in each activity waste generation exists. The main goal in this system is to keep all materials within the operational lifecycle ant to minimize any flow into the external environment. Reduce waste is preferable to reuse, remanufacture and recycle. Even disposal is viewed as the worst option possible [61].

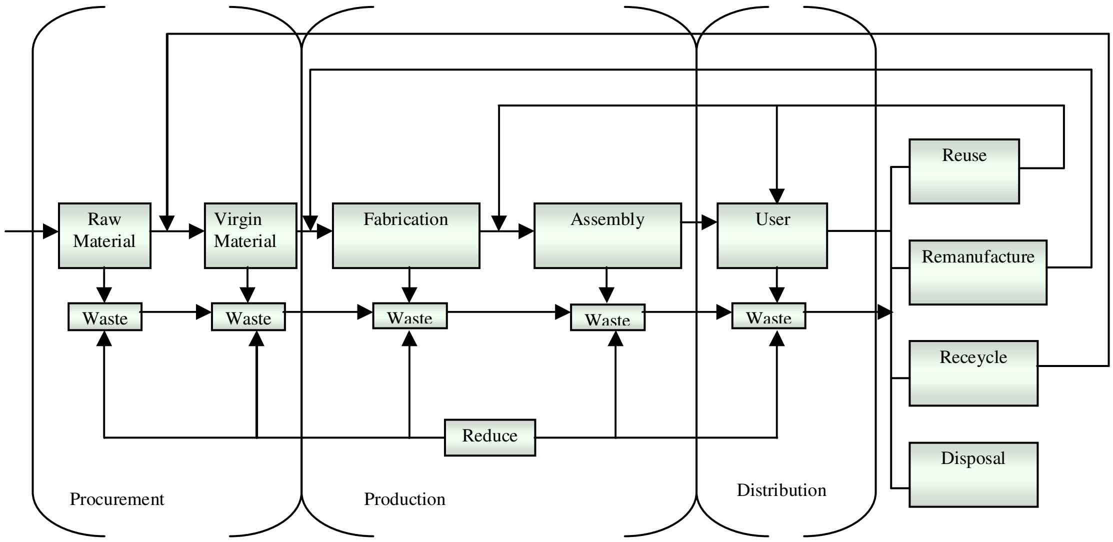

Figure 3.1 Flow of reverse logistics [61]

Reverse logistics shall become vital as service management activities and take-back for products such as automobiles, cellular handsets, lead-acid batteries, televisions, refrigerators and other white goods, personal computers.

Most quantitative models in reverse logistic literature deal with production planning and inventory control in remanufacturing, facility location, resource allocation and flows. Researchers identifies that reverse logistics consist of 3 main stages. Those are retrieval, transportation and disposition [56].

There are some causes for return products. With the new trend in the whole world the products have shorter life cycle. This means that customers don't use the products lots of time. In some cases if the quality of the product is not sufficient the customer may want to give it back to producer. The forecasting of the number of these returns good number is very complex. Even in some situation customer could give the product back without giving any reason. Damaged merchandise and incorrect shipments, product recalls also create product returns. Product recalls, inventory returns, warranty returns, end of season returns and stock adjustment returns also are some other seasons for retrieval [56].

These actions make the reverse logistics more complex. For optimal reverse logistics efficiency and effectiveness, information systems and data management must be redesigned or expanded to accommodate returns. These returned products are collecting in centers for transportation. Collection includes inspection, purchase, storage and reselling if desired. The locations of the collection centers affect the performance and efficiency of reverse logistics.

The transportation issue is the most important step of reverse logistics. Location and configuration of facilities frequently affect and are affected by the external natural environment, mainly the estimated returns. Because of the complex structure of reverse logistics many companies are unable to handle an efficient system. This situation created the need to third party logistic providers which are outsourcing all or part of the reverse logistics. Third party providers became a good opportunity for companies which are not aware of the advantages of reverse logistics. The transportation is usually made by third party providers more over they also collect customer information and track the status of returned items.

The disposition process involves decisions and actions associated with the fate of a product once a customer demonstrates product dissatisfaction. There are three types of disposition options for products returned: resell directly at the collection center; repair and refurbish; remanufacture.

3.3.5. Packaging

Generally, most products in the market come in a form of packaging that prevents the product from external damages like pressure, vibration, humidity, temperature and makes the product easy to handle. Packages display marketing information on them.

More over, they ease the handling in warehouse during transportation. Package could be made of glass, metal, paper or plastic etc…

There are typically three kinds of packaging: primary packaging, secondary packaging, and shipping packaging. Primary packaging contains the product itself and is the immediate and required container. Secondary packaging is the material that protects the primary package and is discarded when the product is about to be used. Shipping packaging refers to packaging necessary for storage, identification, and transport [57].

Researchers mentioned that packaging has strong effects on ECSCM. Wu and Dunn [57] identify that packaging is one of the most important issues in outbound logistics. Rao [62], Sarkis [63] mentioned that environment-friendly packaging might improve the environmental performance of an organization and its supply chain. For this reason regulations concerning packaging constitute an essential part of governmental policies for environmental protection. Private firms also encourage their suppliers to take back packaging is a form of reverse logistics that can be an important consideration in greening the outbound function.

In the past few decades, especially with the customer's demands, government regulations and the sense of responsibility, firms started to make development about green packaging. Today's many toxic materials have been phased out and the concepts like design for environment are becoming more common.

The main reasons for implementation of green packaging are [64]:

1. Green packaging provides economic advantages like reduction of material costs and reduction of energy costs. However, since manufacturers add the costs of packaging in their prices to the customers, the total cost of the supply, chain is reduced because recyclable packages can be used many times and the disposal costs minimized.

2. Green packaging decreases company's responsibility for negative impacts on the environment and society.

3. Green packaging increases positive image of the brand.

Researches show that packaging elements like size, shape and materials have an impact on logistics costs because they affect the transport characteristics of the good. By changing the product's size, primary and secondary packaging, and pallet patterns, companies can often realize substantial savings in packaging, warehousing and transport. Packaging environmental impacts are enclosing natural sources usage, energy usage, water pollution, air pollution, disposal and toxic material release. For these impacts reduction, researchers propose to use design for reduction, design for reuse and design for recycle, using lower impact materials and material reduction. It's obvious that reusable and recyclable packaging will increase in the future, and traditional one-way logistics will need to be adapted to handle two-way freight flows. In this situation firms compose design for packaging departments. In these departments the features that the packages must have defines. A good designed package must have these features [64]:

- Easy to open, carry and handle
- Must provide a good protection
- Must show information about the package and identification of the product.
- Must have compliance with regulations (lower impacts, reduction of toxic substances)
- Must be economic (less material, less energy)
- Designed for recycle and reuse.

Today's world pioneering firms makes different practices about packaging. For instance Amway (Thailand) delivers its detergent and other house cleaning products to customers in plastic containers. After their use, these plastic containers are collected by the Amway sales force, brought back to the company and recycled. Mc Donald's uses recyclable papers. Sony uses recycled paper instead of styrene foam. BMW equips containers for lorries and trains to carry genuine his parts and accessories without packaging. Intel made some adjustments about over packaging and reduced packaging material amount %50 for Celeron cpu's packages. Sun packaging engineers are starting to specify brown corrugated cartons instead of white, bleached cartons, which can cause emissions of chlorine compounds at the paper mill [65].

3.4. Green Organizational Activities Dimension

The major five green organization activities dimensions are reduce, reuse, remanufacture, recycle and disposal. EPR requires firms for developing these activities. The responsibility of the environmental impact of products throughout their entire life cycle embraces also the end of life effects. The principle of EPR that Thomas Lindhqvist published identifies EPR as [66]:

"EPR is a policy principle to promote total life cycle environmental improvements of product systems by extending the responsibilities of the manufacturer of the product to various parts of the entire life cycle of the product, and especially to the take-back, recycling and final disposal of the product."

Establishment of feedback loop between the downstream and the upstream is the core of EPR principle, and is instrumental in improving the design of product and product systems, with the aim of reducing the environmental impact of the product's lifecycle. Farkash and Mueller [67] described Xerox's program to reduce, recycle and ultimately reuse, remanufacture toner containers, and noted that design changes were required to facilitate reuse or recycling.

The importance of the design stage has created new formation like design for reduce design for reuse, design for remanufacture, design for recycle and design for disposal.

Governments apply requirements and regulation about end of life of the products. End-of-Life Vehicles (ELV), Release of Hazardous Substances (ROHS) or Waste of

Electrical and Electronic Equipment (WEEE) are some of these regulations which are becoming more severe today's [68]. EPR legislations hold producers responsible for meeting the costs of the collection, treatment and recovery of their products.

From a client perspective, these regulations are not much visible. Labeling is often the only sign made to customers to motivate them to choose a green product. ISO 14021 addresses environmental labeling and declaration systems to serve as a guide for customers to choose green products. Eco-labeling is a term used to refer to products (and services), which are friendlier towards the environment and the health of the consumer during their entire life cycle. The task of the labeling system is to provide information to consumers and assist consumers to judge the environmental impact of the consumption of the goods.

Today's green firms implement reuse, recycle, remanufacture and reduce strategies for several reasons. These reasons could be listed as [68]:

- Reduce raw material consumption;
- Reduced prices of products;
- Improved products;
- Improved compliance with regulations;
- Reduced cost of disposal;
- Job creation;
- Utilize expertise of product designers;
- Increased control on the second-hand market.

Private firms work on research and development projects to benefit of these advantages. For instance Canon remanufacture copying machines, replacing worn parts with new ones in the US, Europe and Japan. Parts are inspected for proper functionality, and only parts with quality compatible to new ones are reused. The Fuji Xerox DocuColor Series of photocopiers has achieved at least 45% recyclable parts and 95% reusable parts (by weight) in all models. Kodak Australia has recycled over 3 million single use cameras (of 400 million cameras recycled by Kodak worldwide) since 1990. The recycling rate in the US for Kodak single use cameras is 74%, higher than rates achieved for cans, bottles and boxes [65].

3.4.1. Reduce

The most effective method of reducing the environmental impact of construction waste is by primarily preventing its generation and reducing it as much as possible [69].

Waste reduction could be defined as the prevention of waste at source or as eliminating waste before it is created, and the term is now often inter-changed with 'waste minimization' , 'waste avoidance' or 'waste prevention'. For the efficient waste minimization the concept should be applied in whole activities of the supply chain management. Reducing the waste before they are generated is more environmental friendly and more economic. Design stages play has the most important role in waste minimization.

If waste generation could not be prevented or only prevented to a certain degree, the next step should be to ensure that the construction waste is reused, remanufactured and recycled as much as possible.

3.4.2. Reuse

Reuse is the use of a product or component part in its same form for the same use without remanufacturing. The reuse of product may be the reuse of the entire product, for example the selling of second hand cars or pc's, or it may be the reuse of components of a product, for spares for example [70]. Reuse has several economic and environmental advantages. A reusable part don't need to a new production phase. That means there is no environmental effect of the production like energy consumption, raw material use and toxic material etc. But on the other hand reusable part needs some other preparation phases. Firstly reusable part should be cleaned. More over reusable parts may be designed with more durable raw materials that are not as green as safe raw materials. Transportation of the reusable parts and the sorting of the parts also are economic and environmental disadvantages. In some cases these operations make the use inefficient. Thought it is more environmental conscious and generally more economic than remanufacture and recycling.

3.4.3. Remanufacture

Remanufacture could be identify as the production process that used products are returning at least original equipment manufacturer performance specification and giving the resultant product a warranty that is at least equal to that of a newly manufactured equivalent.

Xerox as a pioneering firm on ECSC created a remanufacturing operation flow which is accepted and used by other companies. This operation flow includes five main steps: staging, disassembly, sorting, cleaning, repair and assembly. After all of these five steps the aim of remanufacturing is that he inspected and tested products meet or exceed the quality standards of brand new products. Worn-out or out dated parts and modules are replaced and tested. Technological upgrades may also be included [71]. The unique advantage of remanufacturing is that, unlike recycling and re-use, the process of remanufacturing does not degrade the overall value of the materials used [72].

3.4.4. Recycle

After reducing, reusing and remanufacturing waste, recycling is the last choice to choose in most cases. Because the resources that went into making a part, such as labor, energy, capital equipments and manufacturing process costs, are lost in the recycling process. Almost half of the contents of our dustbins could potentially be recycled. Aluminum, glass, steel, paper, plastic are most often recycled materials. As recycling is a preferred option than disposal in a landfill for the objectives of minimization of environmental impact and perceived risk, recycling of the waste would be preferred even after it is no longer economically attractive than disposal. This would mean a delay in shift from recycling stage of hierarchy to disposal, as compared to the scenario of priority to minimization of cost.

Recycling begins with collection step. Firms and governments force customers for recycling. Governments use severe legislations on recycling. Three main categories of collection “drop-off centers", "buy-back centers" and "curbside collection" are used. After collection of the goods, different type of materials has to be separated. Separated parts use as a raw material in the production process. Although many researchers debate about the economic advantages of the recycling it’s obvious that recycling has environmental advantages.

3.4.5. Disposal

Although source reduction, reuse, remanufacturing and recycling divert large portions of waste from disposal, some waste still must be placed in landfills. For minimization of environmental impact the ideal scenario would be landfill only when it cannot be reused or recycled. The increasing shortage of landfill space and expanding regulation of waste disposal are combining to drive up the costs of waste disposal significantly in the next few years.

The disposal alternatives for firms which generate ferrous scrap as a by-product of their manufacturing process include selling to steel mills, foundries or ferrous scrap processing companies. Processors act as intermediaries in the disposition process providing a specialized service, which many plants are not otherwise capable of performing in an efficient manner [73].

3.5. Manufacturing priorities

Manufacturing priorities can be defined as a set of coordinated objectives and action programs applied to a firm’s manufacturing function and aimed at securing medium- and long-term, sustainable advantage over that firm’s competitors. Skinner argued that managers needed to give serious thought to the role that manufacturing strategy could have on a firm’s competitive abilities and the resulting effect on the firm’s performance. Moreover Skinner mentioned that while a company’s competitive strategy places specific demands on the manufacturing function, at the same time the company’s manufacturing strategy should be specifically designed to accomplish the goals of the company’s competitive strategy [74]. For the evaluation of the company measurement of these priorities are essential. A number of researchers identify different manufacturing priorities.

Responsiveness, dependability, cost, quality, delivery, flexibility, productivity, efficiency, customer satisfaction, customer service, innovativeness are some of these priorities. In this thesis manufacturing priorities are identifies as: Quality, delivery, efficiency, flexibility and customer service. Skinner mentioned that it is impossible to obtain the best results of these priorities at the same time. In this situation every firm should take his own strategic decision to give priority some of them.

3.5.1. Quality

Quality is a subjective goal. Slack et al. [75] defined quality performance as doing things right and doing the right things. The things which the operation needs to do right will vary according to the kind of operation. Also it's obvious that it chance according to the customers need and expectations. Reeves and Bednar [76] identify quality as: excellence, value, conformance to specifications, and meeting or exceeding customers' expectations.

Quality embrace low defect rates, customer perceived quality and durable products. Quality is multidimensional and that each of its dimensions can be used strategically to gain competitive advantage [77]. Quality aims to gain advantage by stabilizing the quality of the product at a predetermined level according to competition, by statistical control of supplies and production. A quality strategy that allows a firm to achieve both high design and conformance quality will lead to the attainment of a higher reputation in the market place, cost reduction, and higher productivity that can translate into higher sales growth and increased market share [74].

Quality within a supply chain may have different standards at different levels within the chain. The strategy and practices of quality in manufacturing have evolved through different stages, such as operator quality control, foreman quality control, inspector quality control, statistical quality control, total quality control, total quality management [78, 79, 80, 81].

3.5.2. Delivery

On-time delivery, throughput time, and setup time are three additional metrics used to evaluate delivery performance. On time delivery, therefore is major concern of manufacturing as well as the distribution function. In many businesses, this criterion now constitutes a qualifier and, very often, an order-losing sensitive qualifier. In some markets orders may be won through a company's ability to deliver more quickly that its competitor, or when it is able to meet the delivery date required when only some or even none of the competition can do so. The ability to meet delivery promises is also called 'delivery reliability'. Researchers argued that a company that made products to stock, using the line or continuous type of process technologies, was best equipped to compete on delivery by meeting orders from goods in stock. Contemporary researchers, however, believe that speed or reliability is achieved through fast response [74, 79, 81].

3.5.3. Efficiency

Efficiency includes low cost, rapid changes in design, quick introduction of new products. Low cost is the most important competitive function in some cases. Low manufacturing cost without failing the quality is the aim of production. A low cost strategy leads to improvements in efficiencies that a firm can use to reduce its price and all things being equal achieve an increase in sales growth and market share. Rapid changes in design will make the production stage modern and always ready to meet customer new expectations. New product and new design are preferable for customers [74, 82, 83].

3.5.4. Flexibility

Manufacturing flexibility is the speed and ease at which the production plants are able to respond to changes in demand, either introducing new products onto the market, modifying the characteristics of the current products or altering the production volumes. Flexibility is a multidimensional concept. There are various positive and negative connotations of flexibility. For example, it might mean adaptiveness, responsiveness, agility, resilience, freedom, compromise, openness, adjustment, versatility, customization, elasticity, and so on. Some of the misconceptions regarding flexibility are do as you like, freedom for all, lack of conviction, and the opposite of rigidity.

Flexibility can be defined as follows [82, 83]:

1. Changes in the product improvements, new components several variants;
2. Changes in the production system new machinery and production methods new systems new personnel;
3. Changes in demand insecurity over period fluctuations.

3.5.5. Customer Service:

Customer service includes broad product distribution, effective after-sales service, and product customization service [81].

3.6. Alternatives of ECSCM Systems

Some alternatives can be identified for improving the environmental performance of the supply chains of the organizations. These alternatives may include technological, process, or organizational characteristics. For example one such alternative might be an organizational goal to improve the just in time approach. In the application section, the author details these alternatives through the case companies.

In this thesis the author compares three alternative SCM alternatives according to the framework created for the purpose of evaluation of the ECSCM. In the framework ALT1 is identified as JIT, ALT2 as environmental focused supply chain management and ALT3 as current SCM system of the case firm. It is obvious that every SCM system has different advantages and disadvantages. In consequence they have different environmental effects.

3.6.1. System A

JIT inventory system is designed to ensure that materials or supplies arrive at a facility just when they are needed so that storage and holding costs are minimized. The goal of JIT, therefore, is to minimize the presence of non-value-adding operations and non-moving inventories in the production line. This will result in shorter throughput times, better on-time delivery performance, and higher equipment. This concept aims at continuous improvement in productivity and quality by eliminating all kinds of waste through employee participation. JIT has been shown to lower production costs, increase product and process quality, and enhance customer responsiveness. Managerial waste and environmental wastes are both addressed within JIT. Although recognizing the benefits to be gained from JIT methods of controlling inventory, the report concludes that they hurt the environment more than other techniques might.

Macdonald reported that JIT could be bad for the environment. Researches mentioned JIT approach to inventory management and manufacturing wastes fuel, pollutes the environment, and neglects procedures that would be much more environmentally sensitive. JIT requires frequent deliveries of materials and parts, increase the number of vehicles needed, result in longer truck journeys, thus generating additional traffic [84]. The trade-offs evaluated in most inventory management models are primarily inventory carrying costs and transport costs. When the reduction in inventories outweighs the increase in transport costs, as is often the case with high value parts, companies choose the JIT system. The trade-off between inventory and transport depends on many factors such as value of goods, interest rates, service level, freight rates, etc. With environmental issues considered in the inventory decisions, frequent deliveries in a JIT operation may not be favorable because they add pressure to road traffic and create demands for new roads. Researchers mentioned the problems with shipping smaller amounts between plants requiring less efficient and smaller transport vehicles, causing additional congestion and pollution and supply chain inventory requirements. In addition, Sarkis [85] mentions that there may be a requirement for additional packaging material that must also be disposed. Tyworth and Wu [86] have shown that in some cases keeping a higher level of inventory may be cheaper than keeping a low level of stock. In other words, higher inventory carrying costs associated with higher levels of inventory may be offset by transport savings because less expensive transport can be used. Most inventory decisions do not include environmental costs or potential social costs of traffic congestion in the long run. Firms need to select less congested routes, redesign delivery trucks, and consolidate shipments to improve efficiency. In the long run, firms need to re-evaluate location, partnerships, technologies and channel structure that affect the operation of JIT systems. The negative environmental impact of JIT systems can be addressed in inventory decision models by internalizing it in calculating the costs of transport. [29, 87, 88, 89]

JIT principles may require greater environmental resources for managing the quick deliveries and lower inventories than benefits from the JIT philosophy of waste reduction and elimination of waste. Implementing a severe EMS to JIT system could evaluate environmental conscious of the firms.

3.6.2. System B

The goal of the environmental focused supply chain management is to reduce the environment impact of the production and to be certainly green on each step of SCM. This system has collectively been defined as an economically driven, system-wide and integrated approach to the reduction and elimination of all waste streams associated with the design, manufacture, use and/or disposal of products and materials. In environmental focused supply chain system every activity is related with environmental requirement, quality performance and customer satisfaction. The products that is produced with this system have to be eco-labeled and eco-designed, the suppliers, the distribution and reverse logistic have to be green and green certificated. One of the most important problems associated with the development and implementation of this system is that managers have difficulty assessing the impact of this supply chain investment because of the lack of appropriate measures. For this reason JIT and other supply chain system are widely preferred in most of the companies. Although this supply chain is increasing procurement and production costs, this chain enables high product quality, green production and decreases the cost of disposal. In addition, this supply chain approach combines quality with environmental responsibility, and has powerful economic incentives that can improve profitability. Moreover, this supply chain increases environmental performance and decreases the frequency of environmental accidents. This system gives importance to customer identification and satisfaction [70].

3.6.3. System C

Whole the analyzed firms' supply chains have solid rules and a technological structure. Because that these firms are world wide firms they have to implement severe quality and environmental standards for all country. For instance Ford Otosan implement Q1-2002 quality requirement which also encompass environmental requirements beginning Feb. 1, 2002. Ford Otosan require having ISO 14001 certification for his suppliers. Toyota, Hyundai Assan and Arçelik don't require having ISO 14001 certification but they prefer certified suppliers. Ford Otosan implemented the company's new logistics process of JIT supply of parts and subassemblies direct to the production line from suppliers in an adjacent industrial park. The suppliers make complex components, sequencing of parts or modular sub-assemblies including engine dress-up, seats, doors, complete instrument panels, bumper systems and body parts, in the supplier park and deliver these to Ford Otosan's plants for assembly into the Ford Otosan vehicles. Toyota's and Hyundai Assan's design stages are not administrated in Turkey but some design processes are developing in Turkey. In every department of Hyundai Assan's Korean managers and engineers are working for eliciting better connection with Korea. Arçelik modified his SCM in 2006 by IBM. With this computer based system Arçelik raised communication between departments and suppliers. More over Arçelik gives the responsibility of collection of the packages to his dealers. In Ford-Otosan, the suppliers are linked into the Ford plant's scheduling system, enabling parts to arrive not only JIT, but also 'in sequence', which means that each delivery reaches the assembly line at precisely the right time in the exact production sequence. These processes are controlled by Ford Otosan's central production control systems by electronic data links. Ford informs the suppliers about the planned sequence of construction some days in advance. Toyota’s suppliers make daily deliveries or “milk runs” to the plant and are on the kanban system, which is the key to meeting the just-in-time requirements of the Toyota Production System. Producers in Turkey use usually land transport.

4. ANALYTIC NETWORK PROCESS

Multi-Criteria Decision Making (MCDM) is a well known branch of decision making. MCDM has been one of the fastest growing areas during the last decades depending on the changing in the business sector. Decision makers need a decision aid to decide between the alternatives. Especially in the last years, where computer usage has increased significantly, the application of MCDM methods has considerably become easier for the users the decision makers as the application of most of the methods are corresponded with complex mathematics. In discrete alternative MCDM problems, the primary concern for the decision aid is the following [90]:

1. Choosing the most preferred alternative to the decision maker;
2. Ranking alternatives in order of importance for selection problems;
3. Screening alternatives for the final decision.

4.1. ANP Methodology

ANP is a more general form of AHP [93]. Whereas AHP models a decision making framework using a unidirectional hierarchical relationship among decision levels, ANP allows for more complex interrelationships among the decision levels and attributes. Typically, in AHP the top element of the hierarchy is the overall goal for the decision model [93]. The hierarchy decomposes from the general to a more specific attribute until a level of manageable decision criteria is met. ANP does not require this strictly hierarchical structure. Interdependencies may be represented by two way arrows (or arcs) among levels, or if within the same level of analysis, a looped arc. The directions of the arcs signify dependence, arcs emanate from an attribute to other attributes that may influence it. The relative importance or strength of the impacts on a given element is measured on a ratio scale similar to AHP. The structural difference between AHP and ANP is given in Figure 4.1. A priority vector may be determined by asking the decision maker for their numerical weight directly, but there may be less consistency, since part of the process of decomposing the hierarchy is to provide better definitions of higher level attributes. Similar to the traditional AHP approach, a hierarchical relationship exists within the network model. A major difference between the two techniques is the existence of a feedback relationship among the levels within this framework [93].

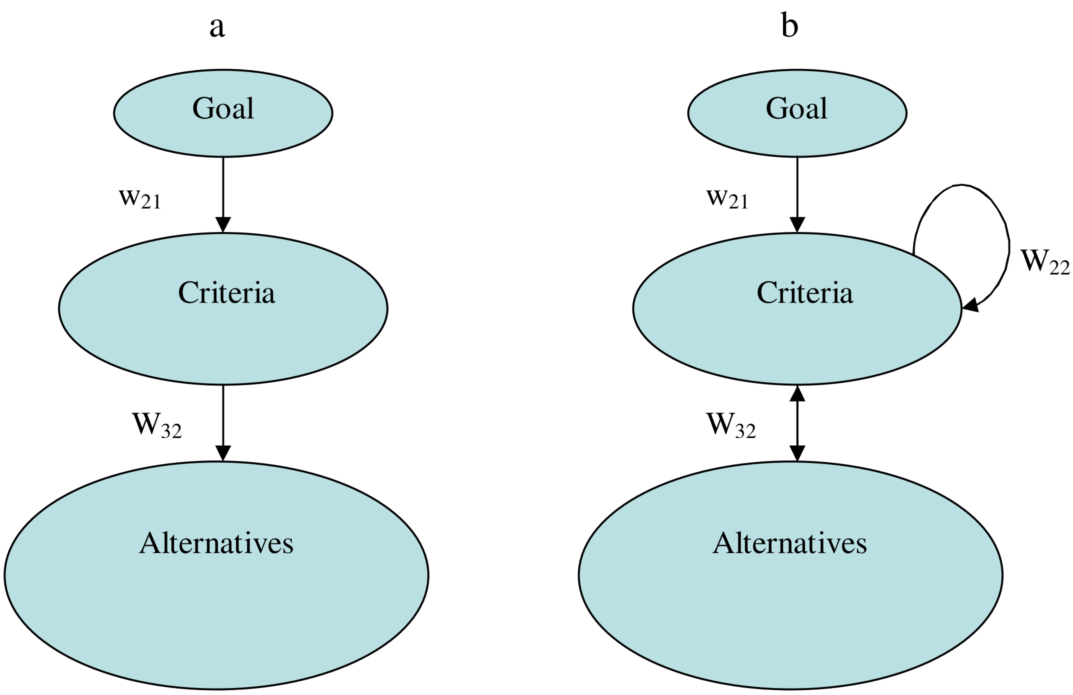

Figure 4.1: The structural difference between AHP and ANP

The ANP can be described as a system of N components (which may be part of a cluster of components) that form a network, where every component (C_n) can interact with or have an influence on itself or some or all of the other components of the system. The network, N, equals $\{C_a, C_b, C_c, \ldots, C_n\}$ and $\{\{C_a, C_a\},\{C_a, C_b\},\{C_a, C_c\},\ldots,\{Cn, C_n\}\}$ represents the set of pairwise linkage within or between components of the network. This multi-criteria decision making model derives priorities or weights for each of the ‘‘n’’ criteria or components, C_n, of the model based on their judged relative importance to the overall goal. The derivation of the ANP priority weights, which use pairwise assessment based on statistical or judgmental relevance, is quite different from more traditional methods [98, 99].

The ANP is composed of four major steps [101]:

Step 1 – Model Construction

Determine one network for each control criterion. Determine all the criteria, which affect the decision. Determine the clusters for each network. One cluster will be the alternatives. Combine the relevant criteria into same clusters. The model development will require the development of attributes at each level and a definition of their relationships [93, 100].

Step 2: Pairwise comparison matrices and priority vectors

Similar to the comparisons performed in AHP, pairs of decision elements at each cluster are compared with respect to their importance towards their control criteria. The clusters themselves are also compared pairwise with respect to their contribution to the objective. Decision-makers are asked to respond to a series of pairwise comparisons of two elements or two clusters to be evaluated in terms of their contribution to their particular upper level criteria. In addition, interdependencies among elements of a cluster must also be examined pairwise; the influence of each element on other elements can be represented by an eigenvector. The relative importance values are determined with Saaty's 1–9 scale, where a score of 1 represents equal importance between the two elements and a score of 9 indicates the extreme importance of one element (row cluster in the matrix) compared to the other one (column cluster in the matrix). Saaty's 1-9 scale for AHP preference is given in Table 4.1. A reciprocal value is assigned to the inverse comparison, that is, $a_{ij} = 1/a_{ji}$, where a_{ij} (a_{ji}) denotes the importance of the ith (jth) element. Like with AHP, pairwise comparison in ANP is performed in the framework of a matrix, and a local priority vector can be derived as an estimate of the relative importance associated with the elements (or clusters) being compared by solving the following equation:

$$A \times w = \lambda_{max} \times w \tag{4.1}$$

where A is the matrix of pairwise comparison, w is the eigenvector, and λ_{max} is the largest eigenvalue of A. Saaty proposes several algorithms to approximate w. In this thesis, Super Decision is used to compute the eigenvectors from the pairwise comparison matrices and to determine the consistency ratios [99, 101].

Table 4.1: Saaty's 1-9 scale for AHP preference

Intensity of importance	Definition	Explanation
1	Equal importance	Two activities contribute equally to the objective
3	Moderate importance	Experience and judgment slightly favor one over another
5	Strong importance	Experience and judgment strongly favor one over another
7	Very strong importance	Activity is strongly favored and its dominance is demonstrated in practice
9	Extreme importance	Importance of one over another affirmed on the highest possible order
2,4,6,8	For compromise between the above values	Use to represent compromise between the priorities listed above

Step 3: Supermatrix formation:

To obtain global priorities in a system with interdependent influences, the local priority vectors are entered in the appropriate columns of a matrix. A supermatrix, W, is a complete system matrix of components, {C_a, C_b, C_c,. . ., C_n}, and their linkages or system weights, W_{ij}, where C_i={e_{i1}, e_{i2}, . . ., e_{in}} is the subcomponent elements of the criterion component ''i.'' ANP allows interaction and feedback

$$
w= \begin{array}{c} \\ C_a \\ C_b \\ \vdots \\ C_n \end{array} \begin{array}{c} \begin{array}{cccc} C_a & C_b & \cdots & C_n \end{array} \\ \left[\begin{array}{cccc} w_{aa} & w_{ab} & \cdots & w_{an} \\ w_{ab} & w_{bb} & \cdots & w_{bn} \\ \vdots & \vdots & \vdots & \vdots \\ w_{na} & w_{nb} & \cdots & w_{nn} \end{array} \right] \end{array}
$$

Figure 4.2:The supermatrix of a network

within clusters, C_i, which is known as inner dependence, and between clusters, which is known as outer dependence. To make this more concrete, if there is no linkage between, say component C_b and C_c, then W_{bc} would be 0. However, if there is some relationship, then the entry would be nonzero, suggesting an outer dependence. An inner dependence would exist if there is a linkage within the components of a cluster, {e_{i1}, e_{i2},. . ., e_{in}}. The supermatrix of a network is given in Figure 4.2 [98].

Note that any zero value in the supermatrix can be replaced by a matrix if there is an interrelationship of the elements within a cluster or between two clusters. Since there usually is interdependence among clusters in a network, the columns of a supermatrix may sum to more than one. However, the supermatrix must be modified so that each column of the matrix sums to unity. An approach recommended by Saaty involves determining the relative importance of the clusters in the supermatrix, using the column cluster as the controlling cluster. That is, row clusters with non-zero entries in a given column cluster are compared according to their impact on the cluster of that column cluster. An eigenvector is obtained from the pairwise comparison matrix of the row clusters with respect to the column cluster, which in turn yields an eigenvector for each column cluster. The first entry of the respective eigenvector for each column cluster, is multiplied by all the elements in the first cluster of that column, the second by all the elements in the second cluster of that column and so on. In this way, the cluster in each column of the supermatrix is weighted, and the result, known as the weighted supermatrix, is stochastic [98, 101].

Raising the supermatrix to the power $2k + 1$, where k is an arbitrarily large number, allows convergence of the interdependent relationships and provides the long-term impacts of the components on each other. The new matrix is called the limit supermatrix. The limit supermatrix has the same form as the weighted supermatrix, but all the columns of the limit supermatrix are the same. The final priorities of all elements in the matrix can be obtained by normalizing each cluster of this supermatrix. Additionally, the final priorities can be calculated using matrix operations, especially where the number of elements in the model is relatively few. Matrix operations are used in order to easily convey the steps of the methodology and how the dependencies are worked out. [91, 101].

Step 4: Selection of the best alternatives: If the supermatrix formed in Step 3 covers the whole network, the priority weights of the alternatives can be found in the column of alternatives in the normalized supermatrix. On the other hand, if a supermatrix only comprises clusters that are interrelated, additional calculations must be made to obtain the overall priorities of the alternatives. The alternative with the largest overall priority should be selected, as it is the best alternative as determined by the calculations made using matrix operations [101].

4.2. Literature Survey of ANP on ECSCM

Multifunctional groups within organizations and external stakeholders have a role in decisions related to organizations and the natural environment. When organizational environmental decisions are to be made they will necessarily be strategic and usually more complex for this reason. These decisions will have internal and external implications for the management of an organization. ECSC decisions are one of the latest issues facing organizations with strong internal and external linkages. One approach to model the dynamic nature of business and its relationship to the natural environment into a decision framework is a technique that is capable of considering the multidimensional qualitative and strategic characteristics. This thesis is one that addresses this issue. The aim is to identify and structure the primary strategic and operational elements for a framework that will aid managers in evaluating ECSC alternatives [70].

A number of studies about organizational environmental decision making exist. Sarkis [91] integrated design for the environment, total quality environmental management, life cycle analysis, ECSCM, and ISO 14000 standards their attributes into a strategic assessment and decision tool using the systems with feedback or ANP technique. In this study Sarkis modified environmentally conscious business practices components as DFE, life cycle analysis, total quality environmental management, ECSCM and ISO 14001 EMS requirements. More over he determined sub-components of these components and made a multi decision making among alternative systems [91].

McIntyre [92] developed decision making process which allows more environmentally conscious decisions to be made. With the model that they described, researchers provide a method for comparing different supply chain scenarios and for understanding where in a supply chain the environmental “hot spots” are and they implemented the model to Xerox supply chain.

Meade and Sarkis [93] developed a model for helping to structure complexity by evaluating alternative logistics strategies by utilizing a systemic multi attribute analytical technique, known as the ANP. The overall objective of the model is to determine the optimum strategic logistics system or alternative for a given organization based on a logistics strategy. They evaluated the logistics system on three different levels; the organizational supply chain relationship involved, the principles of logistics required, and the attributes of principles of logistics.

Pun [94] studied about the critical decision criteria, sub criteria and benefits of ISO 14001 EMS by using an AHP, and K. F Pun (2002) developed an EMS planning framework for environmental management practices [94].

Chin [18] developed a model by using AHP for decision making of implementation of ISO 14001 based EMS in Hong Kong.

Sarkis [95] used the synthesis of the ANP and data envelopment analysis for the evaluation of environmentally conscious manufacturing programs. He used cost, quality, recyclability, process waste reduction, packaging waste reduction and regulatory compliance as decision factors for selecting or ranking environmental conscious manufacturing alternatives.

Krumwiede and Sheu [56] developed a reverse logistics decision-making model to guide the process of examining the feasibility of implementing reverse logistics in third-party providers such as transportation companies.

Meade and Sarkis [61] involved in reverse logistics service provider evaluation and the roles they play as partners set the foundation for an ANP decision model. The researchers argued some ideas about developing, selecting and maintaining third-party logistic partnership.

Sarkis [12] identified and structured the primary strategic and operational elements for a framework that will aid managers in evaluating green supply chain alternatives. He used analytical network process for analyzing the system. The most complicated set of relationships in his model was the existence for the operational life cycle cluster. There was a two-way dependency between the operational and product life cycles. The relative importance of each operational life cycle element will be dependent on what stage of the product life cycle is being considered.

Ravi et al. [96] presented ANP based decision model structures the problem related to options in reverse logistics for EOL computers in a hierarchical form and links the determinants, dimensions, and enablers of the reverse logistics with alternatives available to the decision maker. In the proposed model, the dimensions of reverse logistics for the EOL computers have been taken from four perspectives derived from balanced scorecard approach.

Efendigil et al. [97] determined the ‘‘most appropriate’’ third-party reverse logistics provider using a two-phase model based on artificial neural networks and fuzzy logic in a holistic manner. They also included in the study to demonstrate the steps of the proposed mode AHP with its fuzzy extension.

Büyüközkan and Çapan [70] used a framework for the aim of evaluating green supply chain management. They used the ANP for decision making and implemented the proposed model in a case of Ford-Otosan.

5. STRATEGIC ANALYSIS OF THE ECSCM FRAMEWORK

5.1. Brief Presentation of the Analyzed Firms

In the strategic analysis of the ECSCM Framework Arçelik, Hyundai Assan, Toyota and Ford-Otosan are analyzed. These firms are selected because they are world wide firms and they have severe applications on ECSCM. In the electronic and automotive sectors, some green activities that the author indicated are especially implementing. For instance white good firms are conscious about reverse logistics. Automotive firms are making design practices for emission reduction. Deniz Külahlıoğlu (Hyundai-Assan), Vedat Okyar (Ford-Otosan), Serdar Aydın (Ford-Otosan), Mustafa Diker (Toyota), Çağla Karaali (Arçelik), Ayfer Gül (Arçelik) and Deniz Karabulut (Arçelik) offered guidance for the strategic analysis of the ECSCM framework.

5.1.1. Arçelik

Arçelik is one of the biggest white good and electronic producers. Arçelik household appliances output increased by 23% over the previous year, reaching almost ten million units. Also last year, the consolidated international household appliances sales volume reached 6.5 million units, reflecting a 24% growth over 2005 figures. The production target for 2007 is 11 million units. In October of 2006, Arçelik held an opening ceremony for its refrigerator, washing machine and television plants in Russia. In all, the company invested € 90 million in these plants, which will produce 900,000 refrigerators and washing machines annually. The target is to reach a market share of 10% and revenues of over € 100 million in washing machine production. In the next three years, the company aims to become one of the three largest brands in the Russian market.

In white goods and electronical products, the company strengthens its leadership in the domestic market with the brand names of Arçelik, Beko and Altus and continues to grow abroad with Beko and Blomberg. The company's branded sales have an 80% share in the overall international sales revenue. According to an analysis by the independent research company, covering 27 nations including European countries, Turkey and Russia, the company has garnered a 10% market share in the region.

Arçelik not only exports its products but also its sales and distribution model, which it has developed in Turkey. Consequently, from Serbia to Mongolia and Ukraine to Lebanon, the company has almost 200 "Exclusive Shops" selling only Beko products. It aims to increase the number of these shops to 500 within the next three years [103].

5.1.2. Toyota

Toyota Motor Manufacturing Turkey (TMMT) is one of Toyota's vehicle production bases in Europe. Located in Adapazarı – Turkey, TMMT manufactures Corolla Verso and Auris models. Majority of the production is exported to over 30 countries, which are located mainly in Europe.

TMMT, owned by Toyota Motor Europe NV/SA (%90), and Mitsubishi Co., Ltd. (%10), has a total investment of € 850 million, and currently employs more than 3,000 people.

Dedicated to best quality production with the contribution of all members, TMMT applies the Toyota production system to its manufacturing processes from the very first day of the start of its operation.

Today, with an annual production capacity of 150,000 units, TMMT is one of the ten biggest overseas manufacturing operations of Toyota, and one of the biggest manufacturing companies of Turkey. TMMT established in July 1990 and started to production in September 1994. TMMT has a € 1 billion investment. In Adapazarı plant 3,545 workers are working [104].

5.1.3. Ford-Otosan

Ford Motor Company is an American multinational corporation and the world's third largest automaker which is based on worldwide vehicle sales. In 2006, Ford was the second-ranked automaker in the US with a 17.5% market share, behind General Motors

(24.6%) but ahead of Toyota (15.4%) and Daimler Chrysler (14.4%). In the 2007 Fortune 500 list, Ford was the seventh-ranked American-based company based on global revenues of $160.1 billion. In 2006, Ford produced approximately 6.6 million automobiles, and employed about 280,000 employees 100 plants and facilities worldwide [105].

Otosan started its production process in 1965. Otosan occupied a major role in the development of Turkish automotive industry. In 1997, Ford Motor Company and Koç Holding signed an agreement and created Ford Otosan as a joint venture. Each company is holding a 41% share in the venture. Today Ford Otosan's capital is 500 Million YTL. Ford Otosan has 3 foundations in Turkey in which 8008 people are working. In 2006, Ford Otosan sold 113.857 vehicles just in Turkey. Moreover Ford Otosan has been the market leader since last 5 years. In 2006, Ford Otosan was the market leader with a 17.1% market share [106]. Ford Otosan's plant, located in Kocaeli, is named as "Best Plant in the World" having the best scores in 2002, 2003, 2004 and 2005 among European Ford Plants.

5.1.4. Hyundai-Assan

Hyundai group is one of the world biggest companies. Hyundai include 45 worldwide firms. Hyundai is not only an automotive company; Hyundai also has activities on electronic and building sectors. Hyundai international works in Turkey since 1990. The hand over all the right of Hyundai international to Hyundai Assan is occurred in 1997. In 1997, Hyundai Motor Company and Kibar Holding signed an agreement and created Hyundai Assan as a joint venture. Each company is holding a 50% share in the venture. Hyundai Assan is working in İzmit Plant which has 150.000 car production capacities. In Hyundai Assan there are 1900 employees. This plant has 125.000 units of car and light commercial vehicle production capacity. Today in İzmit plant 6 different car model is producing. In 2005, Hyundai Assan is rewarded with "Think Marketing" award. [107]

5.2. Strategic Analysis of the ECSCM Framework to Analyzed Firms

The first step in any ANP approach is the development of a network decision framework. An initial network decision framework is shown in Figure 5.1 and Figure5.2.

Figure 5.1 shows a higher level or a generalized relationship amongst the clusters of factors. The ultimate goal in this situation is to evaluate ECSCM by selecting from three given alternatives.

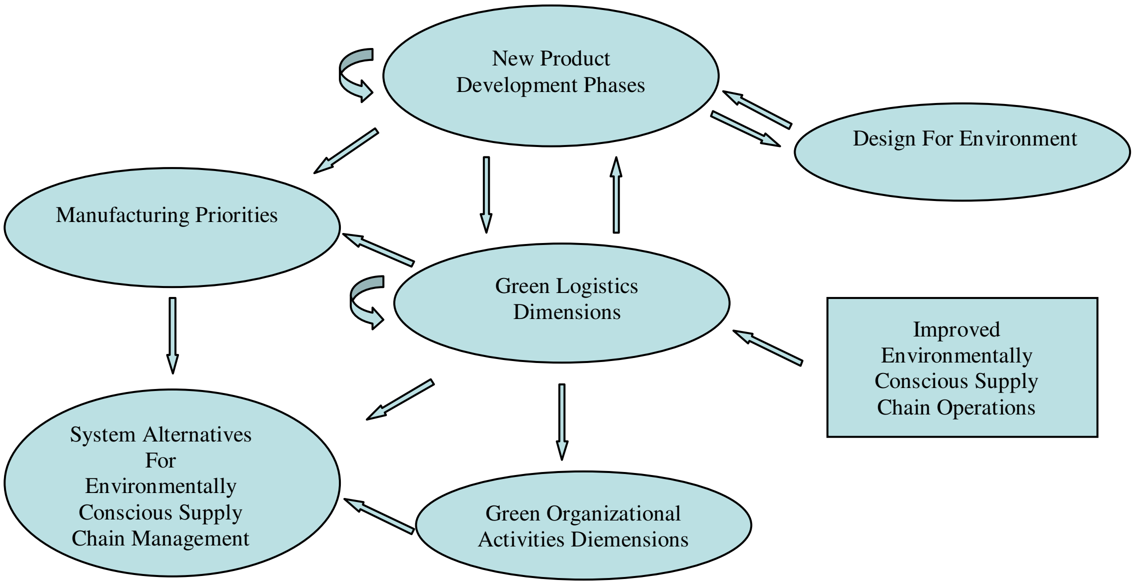

Figure 5.1: High level graphical representation of clusters and influence relationship of decision framework for evaluating ECSCM.

The arcs represent controlling relationships among the factors. The arc with is figured like a hook symbolize the relation of the sub elements of the cluster between them.

In Figure 5.2, it is shown details of the factors within each of the clusters.

The pairwise comparison questions used to elicit decision maker and managerial preferences for this ANP network decision framework are shown in Table 5.1. Decision makers are asked to provide their preferences for one factor when compared to another with respect to a third controlling factor. This elicitation process is the same as the standard approach used for the AHP technique.

Figure 5.3 shows general sub-matrix notation for supermatrix associated with the first set of questions in Table 5.1. The scale ranges from 1 (equal importance) to 9 (extremely more important), and in the other direction, from a 1 (equal importance) to 1/9 (extremely less important) [108].

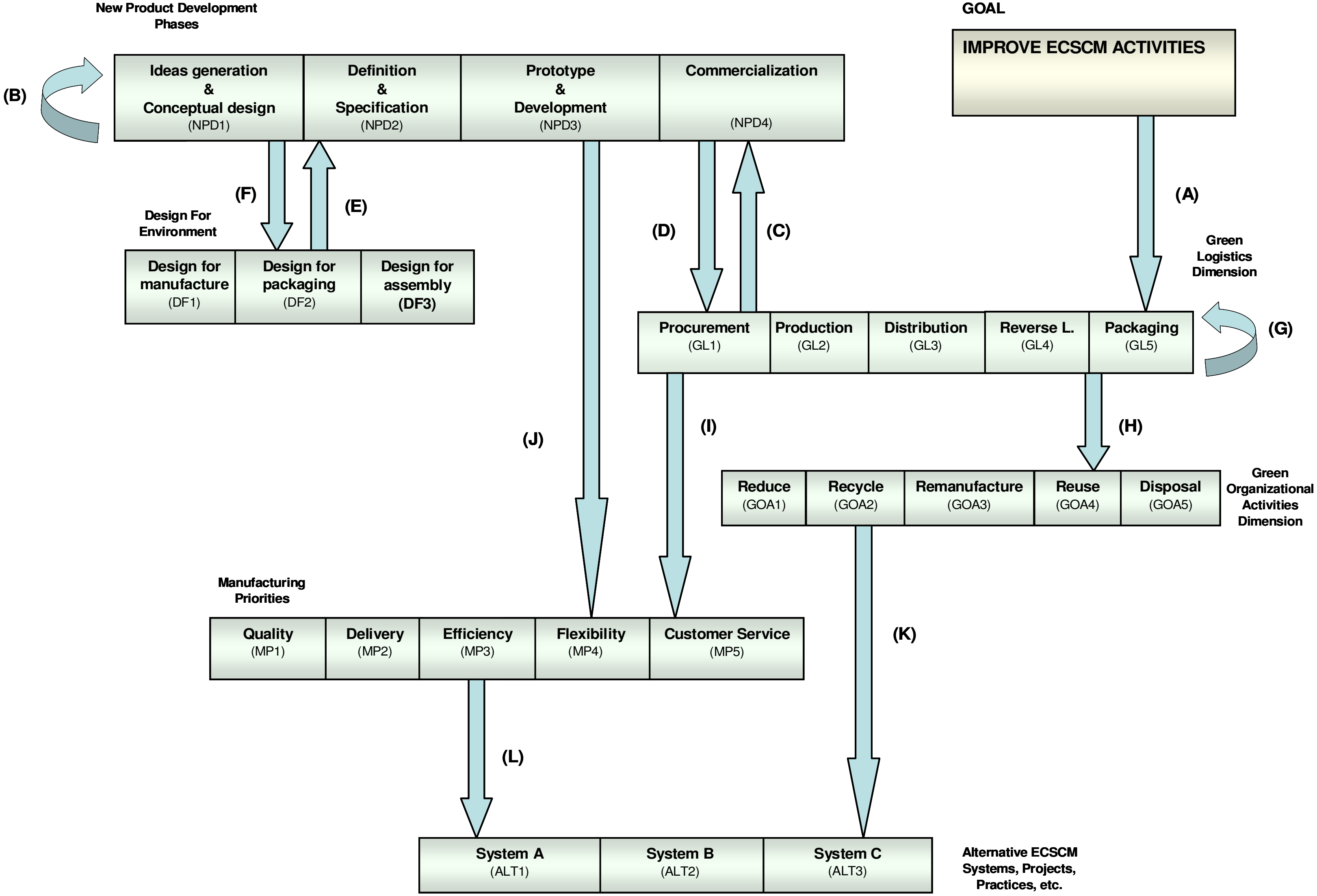

Figure 5.2: Graphical representation of relationships for the ECSCM evaluation framework

Table 5.1: Listing PWC's and example questions

Pairwise Comparasion	With respect to	Example Question
GOAL	GL	With respect to the GOAL, how much more important is the GL1 when compared to GL2?
NPD	NPD	With respect to the NPD, how much more important is the NPD1 when compared to NPD2?
GL	NPD	With respect to the GL, how much more important is the NPD1 when compared to NPD2?
NPD	GL	With respect to the NPD, how much more important is the GL1 when compared to GL2?
DF	NPD	With respect to the DF, how much more important is the NPD1 when compared to NPD2?
NPD	DF	With respect to the NPD, how much more important is the DF1 when compared to DF2?
GL	GL	With respect to the GL, how much more important is the GL1 when compared to GL2?
GL	GOA	With respect to the GL, how much more important is the GOA1 when compared to GOA2?
GL	MP	With respect to the GL, how much more important is the MP1 when compared to MP2?
NPD	MP	With respect to the NPD, how much more important is the MP1 when compared MP2?
GOA	ALT	With respect to the GOA, how much more important is the ALT1 when compared to ALT2?
MP	ALT	With respect to the MP, how much more important is the ALT when compared to ALT2?

	ALT	DF	GL	GOA	GOAL	MP	NPD
Alternatives	0	0	0	K	0	L	0
Design For Environment	0	0	0	0	0	0	F
Green Logistics Dimension	0	0	G	0	A	0	D
Green Organizational Activities Dimension	0	0	H	0	0	0	0
GOAL	0	0	0	0	0	0	0
Manufacturing Priorities	0	0	I	0	0	0	J
New Product Development	0	E	C	0	0	0	B

Figure 5.3: General Sub-matrix notation for supermatrix

The final relative importance weights for the model are determined by initially normalizing the supermatrix so that it is "column stochastic" – column values need to sum to one. In the case of a factor whose cluster is controlled by only one other cluster, the column corresponding to that factor can be rendered column stochastic by simple column averaging. The normalization process, however, is slightly more complex in the case of a factor whose cluster is influenced by more than one cluster. In such cases, a relative importance scheme must be determined for such a cluster with respect to its controlling cluster [108].

The supermatrix (M) is formed from a number of sub-matrices that are used to model Figure 5.1 and Figure 5.2 in matrix notation. In this supermatrix there will be 12 sub-matrices (A,B,C,D,E,F,G,H,I,J,K,L) that will be formed using the priority vectors.

After all the pairwise comparisons are complete, the relative importance weight for each component has to determine. The formation of sub-matrix G will require the determination of the relative impact of each green logistics dimension on each green logistics dimension for Ford-Otosan case. The formation of sub-matrix H will require the determination of the relative impact of each green logistics dimension on each green organizational activities dimension for Ford-Otosan case. Determination of the importance weight of one set of priority weight of each sub-matrices of G and H are shown in the final column of Table 5.2, Table 5.3.

G:

Table 5.2: Pairwise comparison matrix for green logistics dimension elements relative importances on green logistics dimension elements

GLl	GL1	GL2	GL 3	GL4	GL5	W
GL1	1	1	7	1	4	0.35
GL2	1	1	5	1	3	0.25
GL3	1/7	1/5	1	1/5	½	0.05
GL4	1	1	5	1	3	0.25
GL5	¼	1/3	2	1/3	1	0.10

H:

Table 5.3: Pairwise comparison matrix for green logistics dimension elements relative importances on green organizational activities dimension elements

GL1	GOA1	GOA2	GOA3	GOA4	GOA5	W
GOA1	1	1	1	1	1	0.20
GOA2	1	1	1	1	1	0.20
GOA3	1	1	1	1	1	0.20
GOA4	1	1	1	1	1	0.20
GOA5	1	1	1	1	1	0.20

Other pairwise comparison matrix could be analyzed in Appendix B.

The next step is to arrive at a set of converged weights for the supermatrix. These weights are determined by raising the supermatrix to a sufficiently large power that is, the final set of weights W_F is given by [108]:

$$W_F = \lim_{p \to \infty} (W_I)^p \qquad (5.1)$$

where W_I is the initial supermatrix.

The vector of G begins in the seventh column and row of the initial matrix. The vector of H begins in the twelfth column and row of the initial matrix, which appears in bold lettering in Table 5.4.

Table 5.4: A part of initial supermatrix (M) for improvement of ECSCM

	GL1	GL2	GL3	GL4	GL5	GOA1	GOA2	GOA3	GOA4	GOA5
GL1	**0.350**	0.400	0.050	0.200	0.200	0	0	0	0	0
GL2	**0.250**	0.450	0.200	0.150	0.200	0	0	0	0	0
GL3	**0.050**	0.050	0.500	0.050	0.050	0	0	0	0	0
GL4	**0.250**	0.050	0.050	0.400	0.050	0	0	0	0	0
GL5	**0.100**	0.050	0.200	0.200	0.500	0	0	0	0	0
GOA1	**0.200**	0.250	0.800	0.200	0.250	0	0	0	0	0
GOA2	**0.200**	0.250	0.050	0.250	0.250	0	0	0	0	0
GOA3	**0.200**	0.250	0.050	0.250	0.200	0	0	0	0	0
GOA4	**0.200**	0.200	0.050	0.250	0.250	0	0	0	0	0
GOA5	**0.200**	0.050	0.050	0.050	0.050	0	0	0	0	0

Whole weighted form of initial supermatrices could be analyzed in Appendix C. The relative influences of the alternatives on the objective of improving the ECSCM are shown in the “Goal” column. The results are obtained by using Superdecision 1.6.0 software. The author used 50 pairwise comparison matrices to obtain the results for each case firm.

The results for Ford-Otosan show that ALT 2 has a higher priority value (with score of 0.406) than the current situation (with score of 0.354) which is better than the ALT1 (with scores of 0.240).

JIT System: 0,240	Environmentally Focused Supply Chain System: 0.406	Ford- Otosan Supply Chain: 0.354

Figure 5.4: ANP priority results according to proposed model for Ford-Otosan

The results for Hyundai-Assan show that ALT 2 has a higher priority value (with score of 0.434) than the current situation (with score of 0.294) which is better than the ALT1 (with scores of 0.272).

JIT System: 0.272	Environmentally Focused Supply Chain System: 0.434	Hyundai-Assan Supply Chain System: 0.294

Figure 5.5: ANP priority results according to proposed model for Hyundai-Assan

The results for Toyota show that ALT 2 has a higher priority value (with score of 0.400) than the current situation (with score of 0.344) which is better than the ALT1 (with scores of 0.255).

JIT System: 0.255	Environmentally Focused Supply Chain System: 0.400	Toyota Supply Chain System: 0.344

Figure 5.6: ANP priority results according to proposed model for Toyota

The results for Arçelik show that ALT 2 has a higher priority value (with score of 0.350) than the current situation (with score of 0.336) which is better than the ALT1 (with scores of 0.314).

JIT System: 0.314	Environmentally Focused Supply Chain System: 0.350	Arçelik Supply Chain System: 0.336

Figure 5.7: ANP priority results according to proposed model for Arçelik

In the Figure 5.8 comparison of the Alternative SCM systems of the automotive sector firms according to the proposed evaluation model is given.

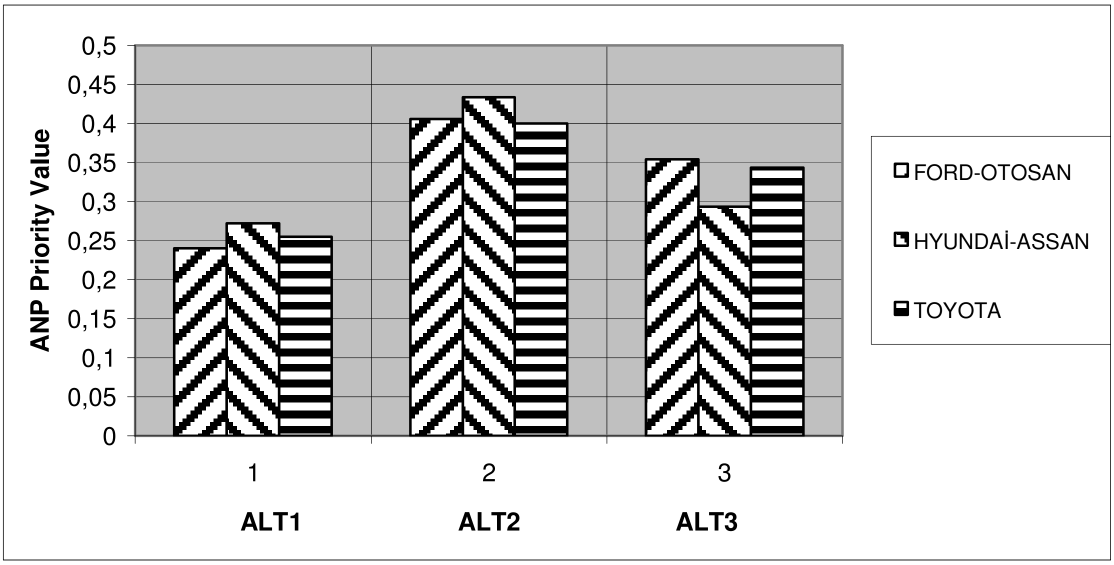

Figure 5.8: Comparison of the alternative SCM systems of the automotive sector firms according to the proposed evaluation model

The results shows that analyzed firms SCM systems are more environmentally conscious than JIT system. On the other hand it's obvious that case firms have to implement some adjustments to improve their environmental performance. Figure 5.8 shows that Hyundai-Assan gives the highest ANP priority value to JIT system when it is compared with other automotive sector firms. More over Hyundai-Assan's SCM system takes the lowest ANP priority value when it is compared with other automotive sector firms. According to the proposed model, Hyundai-Assan has to show more effort to improve his current SCM system. On the other hand it's remarkable that Ford-Otosan's and Toyota's current SCM systems take close ANP priority values. Even though the author believes that comparison of the different sector firms is not much rational Arçelik's current SCM system's ANP priority value is the biggest value according to ideal ranking.

6. CONCLUSION AND FURTHER RESEARCH

This thesis addresses the need for a strategic analysis model to assist management in evaluating a number of alternatives for improving ECSCM initiatives. Through this line, an evaluation model is developed based on a literature survey and refined with industrial experts. The proposed model is implemented in automotive, electric and electronic sector and it provides some insights. Even green issues may apply in several different sectors, automotive and electric and electronic sectors are the most influenced sectors because that some important activities are wildly used. More over every sector has different application on ECSCM. For instance packaging is not used on the final product of the automotive sector. On the other hand white good producers are very sensitive about collection and the reverse logistics of the package. This kind of different application are also exists in every stage of supply chain. In the application of the proposed model Arçelik, Hyundai Assan, Toyota and Ford-Otosan are analyzed. to Deniz Külahlıoğlu (Hyundai-Assan), Vedat Okyar (Ford-Otosan), Serdar Aydın (Ford-Otosan), Mustafa Diker (Toyota), Çağla Karaali (Arçelik), Ayfer Gül (Arçelik) and Deniz Karabulut (Arçelik) offered guidance for the case studies. These firms are selected because they are world wide firms and they have severe applications on ECSCM. More over these firms have production line in Turkey and import their product to foreign countries.

In the proposed model the following clusters are included:

- New Product Development Phase;
- Design for Environment;
- Green Logistics Dimensions;
- Green Organizational Activities Dimension;
- Manufacturing Priorities

As mentioned before on the literature review similar models are created by many researchers. But according to author, they did not use a detailed model because some reasons. The first reason is that ANP approach is the large amount of decision-maker input required, even for rather simple networks. More over decision makers are not experienced to answer this type of questions. An other reason is that SCM is a very wide subject and one decision maker is unable to answer all this questions. For this reasons the author selected the decision makers carefully.

Unfortunately in Turkey theoretical and practical truth show a big difference variously to other countries. The author determined that some practices for the environment don't implement seriously. These problems occur because governmental regulations are not contemporary and punitive sanctions are not sufficient.

On the analyze part the author observe that case firms has ECSCM. However "to be green" is not a countable term and it is dependent. ANP results that ALT2 which is environmentally focused supply chain management system is greener that current SCM systems. As a result firms may improve their SCM systems.

While the author believes that the presented model provides value, there are also further points that can be included. The proposed model did not consider all possible factors and criteria. Possible extensions include the consideration of other strategies and greening reasons (such as customers or the government) and weighting of them in the model. The model used in this study did not consider all possible interactions, either. Additional interactions between and within the decision levels could have been included.

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APPENDICES

APPENDIX A

Major questionnaire items

[a]1= not at all important; 2= not important; 3= not thinking about it; 4= important; 5= extremely important.

[b]1= not considering it; 2= planning to consider it; 3= considering it currently; 4= initiating implementation; 5= implementing successfully.

[c]1= not at all; 2= a little bit; 3= to some degree; 4= relatively significant 5= significant.

- General Information
  Ford-Otosan
- Your company is (a) state-owned; (b) a joint venture;
- (c) a FDI enterprise; (d) a private sector
  Joint venture,FDI enterprise, private sec
- Number of employees:
  7108(gölcük)
- GSCM drivers/pressure[a]
- External factors
- Regulations

-	Central governmental environmental regulations	5
-	Regional environmental regulations	5
-	Export countries’ environmental regulations	5
-	Products potentially conflict with laws	5

- Market

-	Export	5
-	Sales to foreign customers	5

- Consumers' environmental awareness 3
- Establishing company's green image 4
- • Suppliers
- Supplier's advances in developing environmentally friendly goods 4
- Environmental partnership with suppliers 4
- Supplier's advances in providing environmentally friendly packages 5
- Making sure that suppliers will remain in business (business continuity) 4
- • Internal factors
- Company's environmental mission 4
- Internal multinational policies 5
- Potential liability for disposal of hazardous materials 4
- Cost for disposal of hazardous materials 5
- Cost of environmental friendly goods 5
- Cost of environmental friendly packages 5
- • GSCM Practices[b]
- • If your company has carried out some activities in the below, please indicate how long it was done?
- • Internal management
- Commitment of GSCM from senior managers 5
- • Support for GSCM from mid-level managers 5
- Cross-functional cooperation for environmental improvements 4
- Total quality environmental management 4
- Environmental compliance and auditing programs 5
- ISO 14000 certificate 5
- Environmental Management Systems exist 5
- Eco-labeling of products 4
- • Green purchasing
- Providing design specification to suppliers that include environmental requirements for purchased items 5
- Cooperation with suppliers for environmental objectives 4
- Environmental audit for suppliers' inner management 5
- Suppliers' ISO14000 certification 5

- Second-tier supplier environmentally friendly practice evaluation 4
- • Cooperation with customers including environmental requirements
- Cooperation with customer for eco-design 4
- Cooperation with customers for cleaner production 4
- Cooperation with customers for green packaging 4
- Cooperation with customers for using less energy during product transportation 4
- • Investment recovery
- Investment recovery (sale) of excess inventories/ materials 4
- Sale of scrap and used materials 4
- Sale of excess capital equipment 3
- • Eco-design
- Design of products for reduced consumption of material/ energy 4
- Design of products for reuse, recycle, recovery of material, component parts 4
- Design of products to avoid or reduce use of hazardous of products and/or their manufacturing process 5
- • Performance[c]
- • Environmental performance
- Reduction of air emission 4
- Reduction of waste water 4
- Reduction of solid wastes 4
- Decrease of consumption for hazardous/harmful/toxic materials 4
- Decrease of frequency for environmental accidents 5
- Improve a company's environmental situation 4
- • Positive economic performance
- Decrease of cost for materials purchasing 4
- Decrease of cost for energy consumption 4
- Decrease of fee for waste treatment 4
- Decrease of fee for waste discharge 4
- Decrease of fine for environmental accidents 4
- • Negative economic performance

-	Increase of investment	2
-	Increase of operational cost	2
-	Increase of training cost	3
-	Increase of cost for purchasing environmentally friendly material	2
•	Operational performance	
-	Increase amount of goods delivered on time	5
-	Decrease inventory levels	4
-	Increase scrap rate	2
-	Promote products' quality	5
-	Increased product line	5
-	Improved capacity utilization	4

APPENDIX B

AHP PAIRWISE COMPARISON OF FORD OTOSAN

A:

Pairwise comparison matrix for green logistics dimension elements relative to Goal (A)

GOAL	GL1	GL2	GL 3	GL4	GL5	W
GL1	1	3	5	3	9	0.50
GL2	1/3	1	2	1	4	0.18
GL3	1/5	1/2	1	1	2	0.11
GL4	1/3	1	1	1	3	0.15
GL5	1/9	1/4	1/2	1/3	1	0.05

B:

Pairwise comparison matrix for new product development phase elements relative importances during ideas generation and conceptual design element of the new product development phases.

NPD1	NPD1	NPD2	NPD3	NPD4	w
NPD1	1	7	7	7	0.70
NPD2	1/7	1	1	1	0.10
NPD3	1/7	1	1	1	0.10
NPD4	1/7	1	1	1	0.10

Pairwise comparison matrix for new product development phase elements relative importances during definition and specification element of the new product development phases.

NPD2	NPD1	NPD2	NPD3	NPD4	w
NPD1	1	1/3	1	2	0.19
NPD2	3	1	3	5	0.53
NPD3	1	1/3	1	2	0.19
NPD4	1/2	1/5	1/2	1	0.10

Pairwise comparison matrix for new product development phase elements relative importances during prototype and development element of the new product development phases.

NPD3	NPD1	NPD2	NPD3	NPD4	w
NPD1	1	2	1/3	2	0.20
NPD2	1/2	1	1/6	1	0.10
NPD3	3	6	1	6	0.60
NPD4	1/2	1	1/6	1	0.10

Pairwise comparison matrix for new product development phase elements relative importances during commercialization element of the new product development phases.

NPD4	NPD1	NPD2	NPD3	NPD4	w
NPD1	1	1	1/6	1/9	0.06
NPD2	1	1	1/6	1/9	0.06
NPD3	6	6	1	1/2	0.32
NPD4	9	9	2	1	0.56

C:

Pairwise comparison matrix for new product development phase elements relative importances during procurement element of the green logistics dimension

GL1	NPD1	NPD2	NPD3	NPD4	w
NPD1	1	1/5	1/3	1	0.10
NPD2	5	1	2	5	0.52
NPD3	3	1/2	1	3	0.28
NPD4	1	1/5	1/3	1	0.10

Pairwise comparison matrix for new product development phase elements relative importances during production element of the green logistics dimension

GL2	NPD1	NPD2	NPD3	NPD4	w
NPD1	1	1/4	1/4	1	0.10
NPD2	4	1	1	4	0.40
NPD3	4	1	1	4	0.40
NPD4	1	1/4	1/4	1	0.10

Pairwise comparison matrix for new product development phase elements relative importances during distribution element of the green logistics dimension

GL3	NPD1	NPD2	NPD3	NPD4	w
NPD1	1	1	1	1	0.25
NPD2	1	1	1	1	0.25
NPD3	1	1	1	1	0.25
NPD4	1	1	1	1	0.25

Pairwise comparison matrix for new product development phase elements relative importances during reverse logistics element of the green logistics dimension

GL4	NPD1	NPD2	NPD3	NPD4	w
NPD1	1	1	1	1	0.25
NPD2	1	1	2	1	0.30
NPD3	1	1/2	1	1	0.21
NPD4	1	1	1	1	0.25

Pairwise comparison matrix for new product development phase elements relative importances during packaging element of the green logistics dimension

GL5	NPD1	NPD2	NPD3	NPD4	w
NPD1	1	1/5	1/3	1	0.10
NPD2	5	1	2	5	0.52
NPD3	3	1/2	1	3	0.28
NPD4	1	1/5	1/3	1	0.10

D:

Pairwise comparison matrix for green logistics dimension elements relative importances during ideas generation and conceptual design element of the new product development phases.

NPD1	GL1	GL2	GL3	GL4	GL5	W
GL1	1	1	1	1	1	0.20
GL2	1	1	1	1	1	0.20
GL3	1	1	1	1	1	0.20
GL4	1	1	1	1	1	0.20
GL5	1	1	1	1	1	0.20

Pairwise comparison matrix for green logistics dimension elements relative importances during definition and specification element of the new product development phases.

NPD2	GL1	GL2	GL3	GL4	GL5	w
GL1	1	1	2	1	2	0.25
GL2	1	1	2	1	2	0.25
GL3	½	1/2	1	1	1	0.15
GL4	1	1	1	1	1	0.20
GL5	½	1/2	1	1	1	0.15

Pairwise comparison matrix for green logistics dimension elements relative importances during prototype and specification element of the new product development phases.

NPD3	GL1	GL2	GL3	GL4	GL5	W
GL1	1	1	2	1	2	0.25
GL2	1	1	2	1	2	0.25
GL3	½	1/2	1	1	1	0.15
GL4	1	1	1	1	1	0.20
GL5	½	1/2	1	1	1	0.15

Pairwise comparison matrix for green logistics dimension elements relative importances during commercialization element of new product development phases.

NPD4	GL1	GL2	GL3	GL4	GL5	W
GL1	1	1	1	1	1	0.20
GL2	1	1	1	1	1	0.20
GL3	1	1	1	1	1	0.20
GL4	1	1	1	1	1	0.20
GL5	1	1	1	1	1	0.20

E:

Pairwise comparison matrix for new product development phase elements relative importances during design for manufacture element of the design for environment.

DF1	NPD1	NPD2	NPD3	NPD4	w
NPD1	1	1/2	1/2	1	0.17
NPD2	2	1	1	2	0.33
NPD3	2	1	1	2	0.33
NPD4	1	1/2	1/2	1	0.17

Pairwise comparison matrix for new product development phase elements relative importances during design for packaging element of the design for environment.

DF2	NPD1	NPD2	NPD3	NPD4	w
NPD1	1	2	1/2	1/3	0.16
NPD2	1/2	1	1/3	1/5	0.09
NPD3	2	3	1	1/2	0.27
NPD4	3	5	2	1	0.48

Pairwise comparison matrix for new product development phase elements relative importances during design for assembly element of the design for environment.

DF3	NPD1	NPD2	NPD3	NPD4	w
NPD1	1	1	1	3	0.30
NPD2	1	1	1	3	0.30
NPD3	1	1	1	3	0.30
NPD4	1/3	1/3	1/3	1	0.10

F:

Pairwise comparison matrix for design for environment elements relative importances during ideas generation and conceptual design element of the new product development phases.

NPD1	DF1	DF2	DF3	w
DF1	1	2	2	0.50
DF2	1/2	1	1	0.25
DF3	1/2	1	1	0.25

Pairwise comparison matrix for design for environment elements relative importances during definition and specification element of the new product development phases.

NPD2	DF1	DF2	DF3	w
DF1	1	2	1	0.40
DF2	1/2	1	1/2	0.20
DF3	1/2	2	1	0.40

Pairwise comparison matrix for design for environment elements relative importances during prototype and development element of the new product development phases.

NPD3	DF1	DF2	DF3	w
DF1	1	3	1	0.43
DF2	1/3	1	1/3	0.14
DF3	1	3	1	0.43

Pairwise comparison matrix for design for environment elements relative importances during commercialization element of the new product development phases.

NPD4	DF1	DF2	DF3	w
DF1	1	1	1	0.33
DF2	1	1	1	0.33
DF3	1	1	1	0.33

Pairwise comparison matrix for green logistics dimension elements relative importances during procurement element of the green logistics dimension

GLl	GL1	GL2	GL 3	GL4	GL5	W
GL1	1	1	7	1	4	0.31
GL2	1	1	5	1	3	0.27
GL3	1/7	1/5	1	1/5	1/2	0.05
GL4	1	1	5	1	3	0.27
GL5	¼	1/3	2	1/3	1	0.09

Pairwise comparison matrix for green logistics dimension elements relative importances during production element of the green logistics dimension

GL2	GL1	GL2	GL 3	GL4	GL5	W
GL1	1	1	8	8	8	0.41
GL2	1	1	9	9	9	0.44
GL3	1/8	1/9	1	1	1	0.05
GL4	1/8	1/9	1	1	1	0.05
GL5	1/8	1/9	1	1	1	0.05

Pairwise comparison matrix for green logistics dimension elements relative importances during distribution element of the green logistics dimension

GL3	GL1	GL2	GL 3	GL4	GL5	W
GL1	1	1/4	1/9	1	1/4	0.05
GL2	4	1	1/3	4	1	0.19
GL3	9	3	1	9	3	0.51
GL4	1	1/4	1/9	1	1/4	0.05
GL5	4	1	1/3	4	1	0.19

Pairwise comparison matrix for green logistics dimension elements relative importances during reverse logistics element of the green logistics dimension

GL4	GL1	GL2	GL 3	GL4	GL5	W
GL1	1	1	4	1/2	1	0.19
GL2	1	1	3	1/3	1	0.16
GL3	¼	1/3	1	1/8	1/4	0.05
GL4	2	3	8	1	2	0.41
GL5	1	1	4	1/2	1	0.19

Pairwise comparison matrix for green logistics dimension elements relative importances during packaging element of the green logistics dimension

GL5	GL1	GL2	GL 3	GL4	GL5	W
GL1	1	1	4	4	1/3	0.19
GL2	1	1	4	4	1/3	0.19
GL3	¼	1/4	1	1	1/9	0.05
GL4	¼	1/4	1	1	1/9	0.05
GL5	3	3	9	9	1	0.51

H:

Pairwise comparison matrix for green organizational activities dimension elements relative importances during procurement element of the green logistics dimension

GL1	GOA1	GOA2	GOA3	GOA4	GOA5	W
GOA1	1	1	1	1	1	0.20
GOA2	1	1	1	1	1	0.20
GOA3	1	1	1	1	1	0.20
GOA4	1	1	1	1	1	0.20
GOA5	1	1	1	1	1	0.20

Pairwise comparison matrix for organizational activities dimension elements relative importances during production element of the green logistics dimension

GL2	GOA1	GOA2	GOA3	GOA4	GOA5	W
GOA1	1	1	1	1	5	0.24
GOA2	1	1	1	1	5	0.24
GOA3	1	1	1	1	5	0.24
GOA4	1	1	1	1	4	0.23
GOA5	1/5	1/5	1/5	1/4	1	0.05

Pairwise comparison matrix for organizational activities dimension elements relative importances during distribution element of the green logistics dimension

GL3	GOA1	GOA2	GOA3	GOA4	GOA5	W
GOA1	1	9	9	9	9	0.69
GOA2	1/9	1	1	1	1	0.07
GOA3	1/9	1	1	1	1	0.07
GOA4	1/9	1	1	1	1	0.07
GOA5	1/9	1	1	1	1	0.07

Pairwise comparison matrix for organizational activities dimension elements relative importances during reverse logistics element of the green logistics dimension

GL4	GOA1	GOA2	GOA3	GOA4	GOA5	w
GOA1	1	1	1	1	4	0.23
GOA2	1	1	1	1	5	0.24
GOA3	1	1	1	1	5	0.24
GOA4	1	1	1	1	5	0.24
GOA5	¼	1/5	1/5	1/5	1	0.05

Pairwise comparison matrix for organizational activities dimension elements relative importances during packaging element of the green logistics dimension

GL5	GOA1	GOA2	GOA3	GOA4	GOA5	w
GOA1	1	1	1	1	5	0.24
GOA2	1	1	1	1	5	0.24
GOA3	1	1	1	1	4	0.23
GOA4	1	1	1	1	5	0.24
GOA5	1/5	1/5	1/4	1/5	1	0.05

I:

Pairwise comparison matrix for manufacturing priorities elements relative importances during procurement element of the green logistics dimension

GL1	MP1	MP2	MP3	MP4	MP5	w
MP1	1	4	1	4	4	0.36
MP2	¼	1	1/4	1	1	0.09
MP3	1	4	1	4	4	0.36
MP4	¼	1	1/4	1	1	0.09
MP5	¼	1	1/4	1	1	0.09

Pairwise comparison matrix for manufacturing priorities elements relative importances during production element of the green logistics dimension

GL2	MP1	MP2	MP3	MP4	MP5	w
MP1	1	3	1	2	3	0.31
MP2	1/3	1	1/3	1/2	1	0.10
MP3	1	3	1	2	3	0.31
MP4	½	2	1/2	1	2	0.18
MP5	1/3	1	1/3	1/2	1	0.10

Pairwise comparison matrix for manufacturing priorities elements relative importances during distribution element of the green logistics dimension

GL3	MP1	MP2	MP3	MP4	MP5	w
MP1	1	1/6	1	1	1	0.10
MP2	6	1	6	6	6	0.60
MP3	1	1/6	1	1	1	0.10
MP4	1	1/6	1	1	1	0.10
MP5	1	1/6	1	1	1	0.10

Pairwise comparison matrix for manufacturing priorities elements relative importances during reverse logistics element of the green logistics dimension

GL4	MP1	MP2	MP3	MP4	MP5	w
MP1	1	1	3	3	2	0.31
MP2	1	1	3	3	2	0.31
MP3	1/3	1/3	1	1	1/2	0.10
MP4	1/3	1/3	1	1	1/2	0.10
MP5	½	1/2	2	2	1	0.18

Pairwise comparison matrix for manufacturing priorities elements relative importances during packaging element of the green logistics dimension

GL5	MP1	MP2	MP3	MP4	MP5	w
MP1	1	4	1	4	1/4	0.24
MP2	¼	1	1	1	1	0.13
MP3	1	1	1	4	4	0.31
MP4	¼	1	1/4	1	1	0.09
MP5	4	1	1/4	1	1	0.23

J:

Pairwise comparison matrix for manufacturing priorities elements relative importances during ideas generation and conceptual desing element of the new product development phases.

NPD1	MP1	MP2	MP3	MP4	MP5	w
MP1	1	4	1	8	8	0.40
MP2	¼	1	1/4	2	2	0.10
MP3	1	4	1	8	8	0.40
MP4	1/8	1/2	1/8	1	1	0.05
MP5	1/8	1/2	1/8	1	1	0.05

Pairwise comparison matrix for manufacturing priorities elements relative importances during definition and specification element of the new product development phases.

NPD2	MP1	MP2	MP3	MP4	MP5	w
MP1	1	4	1	8	8	0.40
MP2	¼	1	1/4	2	2	0.10
MP3	1	4	1	8	8	0.40
MP4	1/8	1/2	1/8	1	1	0.05
MP5	1/8	1/2	1/8	1	1	0.05

Pairwise comparison matrix for manufacturing priorities elements relative importances during prototype and development element of the new product development phases.

NPD3	MP1	MP2	MP3	MP4	MP5	w
MP1	1	3	1	1	3	0.27
MP2	1/3	1	1/3	1/3	1	0.09
MP3	1	3	1	1	3	0.27
MP4	1	3	1	1	3	0.27
MP5	1/3	1	1/3	1/3	1	0.09

Pairwise comparison matrix for manufacturing priorities elements relative importances during commercialization element of the new product development phases.

NPD4	MP1	MP2	MP3	MP4	MP5	w
MP1	1	1	1	2	2	0.24
MP2	1	1	1	3	3	0.28
MP3	1	1	1	3	3	0.28
MP4	½	1/3	1/3	1	1	0.10
MP5	½	1/3	1/3	1	1	0.10

K:

Pairwise comparison matrix for alternative green supply chain systems elements relative importances during reduce element of the green organizational activities dimension

GOA1	ALT1	ALT2	ALT3	w
ALT1	1	1/6	1/3	0.10
ALT2	6	1	2	0.60
ALT3	3	1/2	1	0.30

Pairwise comparison matrix for alternative green supply chain systems elements relative importances during recycle element of the green organizational activities dimension

GOA2	ALT1	ALT2	ALT3	w
ALT1	1	1/6	1/3	0.10
ALT2	6	1	2	0.60
ALT3	3	1/2	1	0.30

Pairwise comparison matrix for alternative green supply chain systems elements relative importances during remanufacture element of the green organizational activities dimension

GOA3	ALT1	ALT2	ALT3	w
ALT1	1	1/3	1/2	0.17
ALT2	3	1	1	0.44
ALT3	2	1/2	1	0.39

Pairwise comparison matrix for alternative green supply chain systems elements relative importances during reuse element of the green organizational activities dimension

GOA4	ALT1	ALT2	ALT3	w
ALT1	1	1/6	1/3	0.10
ALT2	6	1	2	0.60
ALT3	3	1/2	1	0.30

Pairwise comparison matrix for alternative green supply chain systems elements relative importances during disposal element of the green organizational activities dimension

GOA5	ALT1	ALT2	ALT3	w
ALT1	1	1/3	1/2	0.17
ALT2	3	1	1	0.44
ALT3	2	1	1	0.39

L:

Pairwise comparison matrix for alternative green supply chain systems elements relative importances during quality element of the manufacturing priorities

MP1	ALT1	ALT2	ALT3	w
ALT1	1	1/2	1/2	0.20
ALT2	2	1	1	0.40
ALT3	2	1	1	0.40

Pairwise comparison matrix for alternative green supply chain systems elements relative importances during delivery element of the manufacturing priorities

MP2	ALT1	ALT2	ALT3	w
ALT1	1	1	1	0.33
ALT2	1	1	1/2	0.26
ALT3	1	2	1	0.41

Pairwise comparison matrix for alternative green supply chain systems elements relative importances during efficiency element of the manufacturing priorities

MP3	ALT1	ALT2	ALT3	w
ALT1	1	1	1	0.33
ALT2	1	1	1	0.33
ALT3	1	1	1	0.33

Pairwise comparison matrix for alternative green supply chain systems elements relative importances during flexibility element of the manufacturing priorities

MP4	ALT1	ALT2	ALT3	w
ALT1	1	1	1	0.33
ALT2	1	1	1/2	0.26
ALT3	1	2	1	0.41

Pairwise comparison matrix for alternative green supply chain systems elements relative importances during customer service element of the manufacturing priorities

MP5	ALT1	ALT2	ALT3	w
ALT1	1	1	1	0.33
ALT2	1	1	1	0.33
ALT3	1	1	1	0.33

APPENDIX C

Initial Supermatrix of Arçelik

A:

0.300000
0.200000
0.200000
0.200000
0.100000

B:

0.150000	0.025002	0.075000	0.037500
0.037500	0.149996	0.012500	0.012500
0.037500	0.050001	0.150000	0.050000
0.025000	0.025001	0.012500	0.150000

C:

0.087500	0.087500	0.062500	0.087500	0.025000
0.087500	0.087500	0.062500	0.087500	0.025000
0.050000	0.050000	0.087500	0.050000	0.100000
0.025000	0.025000	0.037500	0.025000	0.100000

D:

0.050000	0.062500	0.062500	0.062500
0.050000	0.087500	0.087500	0.062500
0.050000	0.050000	0.050000	0.062500
0.050000	0.012500	0.012500	0.012500
0.050000	0.037500	0.037500	0.050000

E:

0.250001	0.200003	0.250001
0.349998	0.299997	0.349998
0.250000	0.200000	0.250000
0.150000	0.300000	0.150000

F:

0.125000	0.100000	0.100000	0.083333
0.050000	0.050000	0.050000	0.083333
0.075000	0.100000	0.100000	0.083333

G:

0.112500	0.100000	0.025000	0.056818	0.050000
0.050000	0.100000	0.025000	0.022727	0.025000
0.025000	0.012500	0.112500	0.045455	0.025000
0.050000	0.012500	0.025000	0.113636	0.025000
0.012500	0.025000	0.062500	0.011364	0.125000

H:

0.087500	0.100000	0.150000	0.024999	0.075000
0.087500	0.075000	0.025000	0.112501	0.075000
0.025000	0.025000	0.025000	0.025000	0.012500
0.025000	0.025000	0.025000	0.062500	0.075000
0.025000	0.025000	0.025000	0.025000	0.012500

I:

0.083333	0.075000	0.012501	0.062500	0.062500
0.041667	0.050000	0.087496	0.050000	0.062500
0.041667	0.025000	0.025000	0.062500	0.062500
0.041667	0.075000	0.100002	0.037500	0.037500
0.041667	0.025000	0.025000	0.037500	0.025000

J:

0.062500	0.075000	0.075000	0.050000
0.012500	0.025000	0.025000	0.050000
0.062500	0.062500	0.062500	0.050000
0.062500	0.062500	0.062500	0.050000
0.050000	0.025000	0.025000	0.050000

K:

0.200000	0.200000	0.250000	0.200000	0.333333

L:

0.333333	0.350000	0.399997	0.400000	0.200000

Initial Supermatrix of Hyundai-Assan

Sub-matrix A:

0.400000
0.200000
0.100000
0.200000
0.100000

Sub-matrix B:

0.150000	0.012498	0.075000	0.062500
0.012500	0.150007	0.012500	0.025000
0.012500	0.012499	0.150000	0.012500
0.075000	0.074996	0.012500	0.150000

Sub-matrix C:

0.125000	0.075000	0.062500	0.100000	0.075000
0.075000	0.075000	0.062500	0.100000	0.075000
0.025000	0.050000	0.062500	0.025000	0.050000
0.025000	0.050000	0.062500	0.025000	0.050000

Sub-matrix D:

0.050000	0.075000	0.050000	0.100000
0.050000	0.050000	0.050000	0.050000
0.037500	0.025000	0.050000	0.050000
0.075000	0.075000	0.050000	0.025000
0.037500	0.025000	0.050000	0.025000

Sub-matrix E:

0.400000	0.400000	0.300000
0.200000	0.200000	0.300000
0.200000	0.200000	0.300000
0.200000	0.200000	0.100000

Sub-matrix F:

0.130209	0.100000	0.100000	0.062500
0.054687	0.050000	0.050000	0.125000
0.065104	0.100000	0.100000	0.062500

Sub-matrix G:

0.125000	0.075000	0.012500	0.075000	0.062500
0.037500	0.125000	0.012500	0.012500	0.012500
0.025000	0.012500	0.150000	0.012500	0.012500
0.050000	0.012500	0.012500	0.137500	0.012500
0.012500	0.025000	0.062500	0.012500	0.150000

Sub-matrix H:

0.125000	0.125000	0.200000	0.012498	0.075000
0.062500	0.050000	0.012500	0.150005	0.075000
0.012500	0.012500	0.012500	0.012499	0.012500
0.012500	0.012500	0.012500	0.049998	0.075000
0.037500	0.050000	0.012500	0.024999	0.012500

Sub-matrix I:

0.125000	0.097222	0.024999	0.075000	0.100000
0.025000	0.055556	0.075001	0.025000	0.050000
0.050000	0.027778	0.050000	0.075000	0.050000
0.025000	0.055556	0.075000	0.025000	0.025000
0.025000	0.013889	0.025000	0.050000	0.025000

Sub-matrix J:

0.062500	0.075000	0.075000	0.062500
0.012500	0.025000	0.025000	0.050000
0.150000	0.050000	0.075000	0.062500
0.012500	0.075000	0.050000	0.025000
0.012500	0.025000	0.025000	0.050000

Sub-matrix K:

0.199991	0.250000	0.250000	0.199991	0.300000

Sub-matrix L:

0.250008	0.350003	0.350003	0.200000	0.250000

Initial Supermatrix of Toyota

Sub-matrix A:

0.200002
0.299997
0.100000
0.100000
0.300000

Sub-matrix B:

0.137500	0.075002	0.034091	0.050000
0.075000	0.137498	0.045455	0.037500
0.012500	0.012500	0.136364	0.012500
0.025000	0.025000	0.034091	0.150000

Sub-matrix C:

0.075000	0.099999	0.050000	0.099999	0.050000
0.050000	0.075001	0.050000	0.075001	0.025000
0.025000	0.025000	0.075000	0.025000	0.100000
0.100000	0.050000	0.075000	0.050000	0.075000

Sub-matrix D:

0.075000	0.050001	0.062500	0.062500
0.050000	0.074999	0.087500	0.087500
0.075000	0.025000	0.025000	0.025000
0.025000	0.050000	0.037500	0.025000
0.025000	0.050000	0.037500	0.050000

Sub-matrix E:

0.399998	0.399998	0.350000
0.300002	0.300002	0.350000
0.200000	0.200000	0.200000
0.100000	0.100000	0.100000

Sub-matrix F:

0.112500	0.112500	0.083333	0.075000
0.062500	0.062500	0.083333	0.100000
0.075000	0.075000	0.083333	0.075000

Sub-matrix G:

0.125000	0.050000	0.037500	0.037500	0.050000
0.050000	0.100000	0.050000	0.037500	0.050000
0.025000	0.037500	0.100000	0.025000	0.012500
0.025000	0.025000	0.025000	0.125000	0.012500
0.025000	0.037500	0.037500	0.025000	0.125000

Sub-matrix H:

0.075000	0.075000	0.125000	0.075000	0.075000
0.050000	0.050000	0.050000	0.075000	0.075000
0.050000	0.050000	0.025000	0.050000	0.037500
0.050000	0.050000	0.025000	0.025000	0.050000
0.025000	0.025000	0.025000	0.025000	0.012500

Sub-matrix I:

0.075000	0.075000	0.050001	0.075000	0.087500
0.075000	0.075000	0.074999	0.050000	0.050000
0.050000	0.050000	0.075000	0.050000	0.062500
0.025000	0.025000	0.025000	0.025000	0.025000
0.025000	0.025000	0.025000	0.050000	0.025000

Sub-matrix J:

0.075000	0.075000	0.075000	0.062500
0.075000	0.050000	0.025000	0.050000
0.050000	0.075000	0.075000	0.050000
0.025000	0.025000	0.037500	0.062500
0.025000	0.025000	0.037500	0.025000

Sub-matrix K:

0.200000	0.200000	0.300000	0.200000	0.300000

Sub-matrix L:

0.200000	0.400000	0.200000	0.350003	0.200000

Initial Supermatrix of Ford-Otosan

Sub-matrix A:

0.500000
0.200000
0.100000
0.150000
0.050000

Sub-matrix B:

0.175000	0.050000	0.050000	0.012500
0.025000	0.125000	0.025000	0.012500
0.025000	0.050000	0.150000	0.075000
0.025000	0.025000	0.025000	0.150000

Sub-matrix C:

0.025000	0.025000	0.050000	0.050001	0.025000
0.125000	0.100000	0.050000	0.074999	0.125000
0.075000	0.100000	0.075000	0.050000	0.075000
0.025000	0.025000	0.075000	0.075000	0.025000

Sub-matrix D:

0.050000	0.062500	0.062500	0.050000
0.050000	0.062500	0.062500	0.050000
0.050000	0.037500	0.037500	0.050000
0.050000	0.050000	0.050000	0.050000
0.050000	0.037500	0.037500	0.050000

Sub-matrix E:

0.150003	0.150000	0.300000
0.349995	0.100000	0.300000
0.350001	0.250000	0.300000
0.150001	0.500000	0.100000

Sub-matrix F:

0.125000	0.100000	0.112500	0.075000
0.062500	0.050000	0.037500	0.100000
0.062500	0.100000	0.100000	0.075000

Sub-matrix G:

0.087500	0.100000	0.012500	0.050000	0.050000
0.062500	0.112500	0.050000	0.037500	0.050000
0.012500	0.012500	0.125000	0.012500	0.012500
0.062500	0.012500	0.012500	0.100000	0.012500
0.025000	0.012500	0.050000	0.050000	0.125000

Sub-matrix H:

0.050000	0.062500	0.200000	0.050000	0.062500
0.050000	0.062500	0.012500	0.062500	0.062500
0.050000	0.062500	0.012500	0.062500	0.050000
0.050000	0.050000	0.012500	0.062500	0.062500
0.050000	0.012500	0.012500	0.012500	0.012500

Sub-matrix I:

0.087500	0.075000	0.025001	0.075000	0.087500
0.025000	0.025000	0.149997	0.075000	0.025000
0.087500	0.075000	0.025000	0.025000	0.087500
0.025000	0.050000	0.025000	0.025000	0.025000
0.025000	0.025000	0.025000	0.050000	0.025000

Sub-matrix J:

0.100000	0.100000	0.075000	0.050001
0.025000	0.025000	0.025000	0.074999
0.100000	0.100000	0.062500	0.075000
0.012500	0.012500	0.062500	0.025000
0.012500	0.012500	0.025000	0.025000

Sub-matrix K:

0.100010	0.100010	0.150000	0.100010	0.150000

Sub-matrix L:

0.199992	0.333333	0.299995	0.350000	0.333333

BIOGRAPHICAL SKETCH

Alişan Çapan completed the high school in Burak Bora Anadolu Lisesi, in 2001. He received his B. Sc. degree in Electrical Engineering from Kocaeli University, İzmit, in 2005. Since 2005, he is in the M. Sc. program in Industrial Engineering of Galatasaray University.. For the completion of the program he has studied on “Environmentally Conscious Supply Chain Management”. He wrote his first academic article in 2007 with Doc. Dr. Gülçin Büyüközkan Feyzioğlu.