T.C.
BAHÇEŞEHİR ÜNİVERSİTESİ

THE GRADUATE SCHOOL OF NATURAL
AND APPLIED SCIENCES

INDUSTRIAL ENGINEERING

MODELING CLOSED LOOP SUPPLY CHAIN AND AN APPLICATION

M.Sc. Thesis

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İSTANBUL,2009

ACKNOWLEDGEMENT

I would like to express my gratitude to all those who gave me the possibility to complete this thesis. I am deeply indebted to my supervisor Prof. Dr. Hüseyin Başlıgil from the Yıldız Technical University whose help, stimulating suggestions and encouragement helped me in all the time of research for and writing of this thesis. His moral support and continuous guidance enabled me to complete my work successfully.

This thesis would not have been possible without the support Assistant Prof. Tunç Bozbura. I also want to thank Dr. Vildan Özkir for all her great help in difficult times and who guided me about the direction of my thesis from the beginning.

I am as ever, especially indebted to my lovely friends, for their love and support throughout my life.

Finally, I would like to give my special thanks to my family whose patient love enabled me to complete this work.

İSTANBUL,2009 BEDRİYE KÖKER

ABSTRACT

MODELING CLOSED LOOP SUPPLY CHAIN
AND AN APPLICATION

Köker, Bedriye

Industrial Engineering Graduate Program

Supervisor: Prof. Dr. Hüseyin Başligıl

July, 2009, 69 Pages

In the last 100 years, human civilizations have significantly altered virtually all of Earth's environments. While technological development and resource extraction have dramatically improved standards of living for many, destruction of natural ecosystems and environmental contamination have bred innumerable interrelated problems. If current rates of environmental degradation, resource consumption, and population growth continue, the well-being of future generations will be increasingly compromised.

Companies spend more time and money in fine-tuning their forward supply chains while ignoring their backward supply chains. However in today`s competitive business environment, companies can no longer ignore reverse supply chain. Closed Loop Supply Chain (CLSC) has gained an extensive importance today, in the world of increasing environmental concerns, regulations from government and social responsibilities. A CLSC consists of both the forward supply chain, and the reverse supply chain.

This work provides a model of a general closed-loop supply chain network, which includes raw material suppliers, manufacturers, retailers, customer zones and a reprocessing center. The objective of this work is selecting best place for the reprocessing centre and maximize the profit of the firm. The developed model is implemented to a real-world supply chain of an automotive fabric in Turkey. The model is run for different scenarios using different parameter setting such as used products return rate from customers for seeing the profit for the firm for each of the rates.

Keywords: Closed loop supply chain, Reverse logistics, Network design, Cost, Remanufacturing, Integer linear programming

ÖZET

KAPALI ÇEVRİM TEDARİK ZİNCİRİ MODELLEMESİ
VE BİR UYGULAMA

Köker, Bedriye

Endüstri Mühendisliği Yüksek Lisans Programı

Tez Danışmanı: Prof. Dr. Hüseyin Başlıgil

Temmuz, 2009, 69 Sayfa

Son 100 senedir insanoğlu medeniyeti dünyanın doğasını önemli bir şekilde tahrip etmektedir. Teknolojik gelişmeler ve araştırmalar yaşam standartlarını yükseltmede önemli bir rol oynasa da, aynı zamanda doğal ekosistemi tahribatla beraber çok sayıda problemi meydana getirmektedir. Eğer çevresel bozulma, doğal kaynak tüketimi ve nüfus oranındaki artış bugünkü oranıyla artmaya devam ederse, gelecek nesiller tehlikeye atılmış olur.

Şirketler tersine tedarik zincirlerini göz ardı ederken, ileriye doğru tedarik zincirlerini iyileştirerek çok zaman ve para harcamaktadırlar. Buna rağmen, şu anki rekabete dayalı ticaret ortamında şirketler tersine tedarik zincirlerini daha fazla göz ardı edememektedirler. Kapalı çevrim tedarik zinciri dünyadaki büyüyen çevresel endişe ve hükümetlerin koydukları kanunlar ve sosyal sorumluluklar neticesinde şu anda çok büyük bir önem kazanmaktadırlar. Kapalı çevrim tedarik zinciri hem tersine tedarik zinciri faaliyetlerini hem de ileriye doğru tedarik zincirlerini kapsamaktadırlar.

Bu çalışmada hammadde tedarikçilerini, üreticileri, dağıtıcıları, geri dönüşüm merkezini ve müşteri bölgelerini kapsayan genel bir kapalı çevrim tedarik zinciri oluşturulmuştur. Bu çalışmanın amacı geri dönüşüm merkezi için en iyi yerleşim yerini seçmek ve üreticinin karlılığını maksimize etmektir. Oluşturulan model Türkiye'deki otomotiv sektöründe faaliyet gösteren bir firma için gerçekleştirilmiştir. Bu model müşterilerden gelen kullanışmış ürünlerin geri dönüş oranını değiştirerek değişik senaryolar için firmanın karını gözlemlemektedir.

Anahtar Kelimeler: Kapalı Çevrim Tedarik Zinciri, Tersine lojistik, Ağ Tasarımı, Maliyet, Yeniden Üretim, Tamsayı lineer programlama

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1. INTRODUCTION

Implementation of legislation, social responsibility, corporate imaging, environmental concern, economic benefits and customer awareness are forcing original equipment manufacturers (OEM`s) not only to provide more environmental friendly products but also to take back used products at its end of life [3]. Recently, due to the increasing stringent pressures from environmental and social requirements, more and more manufacturers have adopted the practice of using returned products and incorporated product recovery activities into the production.

For most organizations, materials are returned from the field through the reverse logistics function – whether they are product returns, damaged goods or service depot returns. In most instances, the reverse logistics model employed is designed to minimize costs, allowing materials to accumulate over time and eventually be disposed of in an environmentally friendly manner. For technology companies for which the average product life cycle is measured in months, the process of recovering value from returns can be significantly improved with a timely inspection process designed to identify hidden value before recycling. Unfortunately for many firms, scrap material already sent for disposal could have become a new revenue stream.

Reverse logistics concerns the integration of used and obsolete products back into the supply chain as valuable resources. Economic, marketing, and legislative drivers increasingly are leading companies to take back and recover their products after use. The arising product flows pose novel challenges for supply chain management. [40]

In the last 100 years, human civilizations have significantly altered virtually all of Earth's environments. While technological development and resource extraction have dramatically improved standards of living for many, destruction of natural ecosystems and environmental contamination have bred innumerable interrelated problems. If current rates of environmental degradation, resource consumption, and population growth continue, the well-being of future generations will be increasingly compromised. [50] This study addresses decision making in closed loop supply chain. A CLSC consists of both the forward supply chain, and the reverse supply chain. It covers a wide range of issues, related to distribution, production, inventory, and supply chain management. For each topic, it highlights key managerial issues in real-life examples and explains which quantitative models are available for addressing them. By treating a broad range of issues in a unified way, the study offers the reader a comprehensive view on the field of closed loop supply chain.

In this study, a mathematical model for the design of closed loop supply chain is proposed. In the proposed methodology, a linear multi-objective programming model is formulated that systematically optimize the operations of both integrated logistics and corresponding used-product reverse logistics in a given closed loop supply chain. And also the model selected the best place for the reprocessing centre.

In the first part, the definition, the process and management of supply chain are represented and turning the supply chain to the closed loop supply chains. Second part is dedicated to the closed loop supply chain and needed for reverse supply chain for the today`s world. In the third part the mathematical model for the closed loop supply chain is proposed. The objective is to decide the location of the new built reprocessing centre and maximize the profit of the firm. The data which were used for the model were taken from a heating industry firm in Turkey.

An LP (Linear programming) optimization model is formulated, which is similar to a traditional network design problem. The network contains plant, value-added process center (reprocessing center), disposal centers, raw material market, retailers and customer zones.

In the conclusion the study explicates the forward and reverse supply chain networks, the strengths of the modeling closed loop supply chain for growing industry in the world and gives limitations and suggestions for further research.

2. SUPPLY CHAIN SYSTEMS

If a company makes a product from parts that purchased from suppliers, and those products are sold to customers, then this company has a supply chain. Some supply chains are simple, while others are rather complicated. The complexity of the supply chain will vary with the size of the business and the intricacy and numbers of items that are manufactured. In this part of the thesis, the evolution, definition of supply chain and definition of supply chain management have been mentioned.

2.1 DEFINITON OF SUPPLY CHAIN

A supply chain is the system of organizations, people, technology, activities, information and resources involved in moving a product or service from supplier to customer. Supply chain activities transform natural resources, raw materials and components into a finished product that is delivered to the end customer. The objective of a supply chain is customer satisfaction**.**

The supply chain, which is also referred to as the logistics network begins with ecological and biological regulation of natural resources. This is followed by the human extraction of raw material, and includes several production links (e.g., component construction, assembly, and merging) before moving on to several layers of storage facilities of ever-decreasing size and ever more remote geographical locations, and finally reaching the customer. The figure 2.1 below shows the supply chain network;

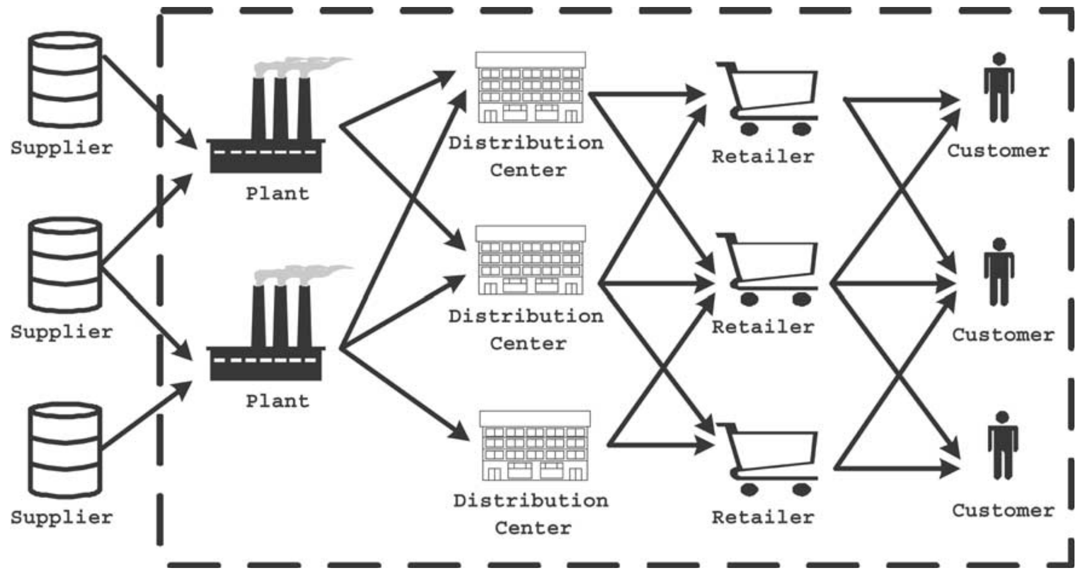

Figure 2.1: Supply chain network [58]

In a supply chain, the flow of information moves upstream, whereas the flow of material moves downstream. [26] Information flows from customers to retailers, manufacturing companies, and logistics and raw material providers. It is the way production systems have been working for decades. The difference in a supply chain is that all the partners should be informed simultaneously, and the information they receive should be sufficient for them to make their own decisions. The idea of introducing a common information system that sends the customers' information simultaneously to all the partners according to their needs is a major characteristic of the next generation of supply chains.

Material flows downstream from suppliers of raw material or components to customers. As with information, the flow of material should be coordinated among all partners. This implies that activities should be coordinated upstream and downstream. The fact that these flows should move at the lowest cost and at the highest speed should be obvious. Customer satisfaction is the ultimate goal to reach for success.

2.2 ELEMENTS OF SUPPLY CHAIN SYSTEM

Structuring the supply chain requires an understanding of the demand patterns, service level requirements, distance considerations, cost elements and other related factors. It is easy to see that these factors are highly variable in nature and this variability needs to be considered during the supply chain analysis process. [17] Moreover, the interplay of these complex considerations could have a significant bearing on the outcome of the supply chain analysis process.

A simple supply chain is made up of several elements that are linked by the movement of products along it. The supply chain starts and ends with customer;

a. Customer
b. Planning
c. Purchasing
d. Inventory
e. Production
f. Transportation
g. Customer

The following describes each of the elements

a) Customer: The customer starts the chain of events when they decide to purchase a product that has been offered for sale by a company. The customer contacts the sales department of the company, which enters the sales order for a specific quantity to be delivered on a specific date. [44] If the product has to be manufactured, the sales order will include a requirement that needs to be fulfilled by the production facility.

b) Planning: The requirement triggered by the customer's sales order will be combined with other orders. The planning department will create a production plan to produce the products to fulfill the customer's orders. To manufacture the products the company will then have to purchase the raw materials needed.

c) Purchasing: The purchasing department receives a list of raw materials and services required by the production department to complete the customer's orders. The purchasing department sends purchase orders to selected suppliers to deliver the necessary raw materials to the manufacturing site on the required date.

d) Inventory: The raw materials are received from the suppliers, checked for quality and accuracy and moved into the warehouse. The supplier will then send an invoice to the company for the items they delivered. The raw materials are stored until they are required by the production department.

e) Production: Strategic decisions regarding production focus on what customers want and the market demands. This first stage in developing supply chain agility takes into consideration what and how many products to produce, and what, if any, parts or components should be produced at which plants or outsourced to capable suppliers. [17] Based on a production plan, the raw materials are moved inventory to the production area. The finished products ordered by the customer are manufactured using the raw materials purchased from suppliers. After the items have been completed and tested, they are stored back in the warehouse prior to delivery to the customer.

f) Transportation: When the finished product arrives in the warehouse, the shipping department determines the most efficient method to ship the products so that they are delivered on or before the date specified by the customer. When the goods are received by the customer, the company will send an invoice for the delivered products.

2.3 THE EVOLUTION OF SUPPLY CHAIN

The word logistics was first associated with the military in 1905 as a branch of war that pertains to the movement and the supply for armies. [9] The evolution of the Supply chain has moved from disparate functions of logistics, transportation, purchasing and supplies and physical distribution to focus on integration, visibility, cycle time reduction and streamlined channels. The new integration has a variety of activities such as, Integrated Purchasing Strategy, Supplier Integration, Buyer-Supplier Partnerships, Supply Base Management, Strategic Supplier Alliances, Supply Chain Synchronization, and finally simply Supply chain management. The success of these activities lies in having a corporate vision that drives change throughout a firm's internal and external linkages or interface.

The activities of logistics are centuries old as discussed earlier. In early 1900s, the farm products distributors realized the importance for providing time and place utility. [1] During World War II, military forces made effective use of logistics models and forms of systems analysis to ensure that the required material was at the right place on time every time. An indication of the increased use of the term logistics during that time could be noticed in the statement of the Chief of Naval Operations, who reportedly said that he did not know what logistics was, however, he certainly wanted it to be used. The term logistics is widely used in military and military type applications even today.

Until about mid 1950's, the field of supply chain management was in a state of dormancy. The piecemeal and isolated fragmented set of activities was rampant. Production and manufacturing were given uppermost attention. [1] The inventory was the responsibility of the marketing, accounting and/or production areas and order processing was an accounting or sales responsibility. This fragmented way resulted in a great deal of friction on account of the conflicting objectives between production, marketing, accounting and finance.

This led to the assertion in the early 1960's that logistics was one of the real frontiers of opportunity for enterprises to improve their corporate efficiency. Initial focus and emphasis was on the internal front, limited to productivity within the four walls of the factory or manufacturing till the 1970's. During the Ethiopian famine relief efforts of the 1980's, the term logistics was applied to the food-supply activities. World Vision International, one of the many relief organizations at work there, produced a manual entitled *Getting It There- A Logistics Handbook for Relief and Development*. The 1980's stressed the need for quality, whereas the 1990's have seen the emergence of the supply chain management and the millennium trends on e-business or IT enabled supply chains. [1]

SCM formerly known as logistics management now includes more aspects apart from the logistics function. SCM is one of the most powerful engines of business transformation that basically means delivering the right product to the right place at the right time and at the right price. SCM is the one area wherein much operational efficiency can be gained, thereby reducing organizations costs and enhancing customer service.

Gradually, the marketing people started giving greater emphasis to distribution, giving rise to physical distribution management or in today's parlance 'outbound transportation'. This was different from the demand creation side of marketing.

In 1991, the international Council of Logistics Management (CLM), defined logistics as "the process of planning, implementing, and controlling the efficient, effective flow and storage of goods, services, and related information from the point of origin to the point of consumption for the purpose of conforming to customer requirements". Some of the terms like logistics, inbound logistics, materials management, physical distribution and supply chain management seem to be used interchangeably. Very briefly, inbound logistics covers the movement of material, components and products received from the suppliers. Materials management describes the material handling part of the movement of the material and components within the factory or firm. Physical distribution refers to the movement of the finished goods outward from the end of the assembly line from the shipping or dispatch department. Logistics describes the entire process of material and products moving into, through, and out of a firm. Finally as of today, it is the Supply Chain Management that is conceptualized as something even larger than logistics that links logistics more directly with the user's total communications network and with the firm's engineering staff. It is sufficient to know this much at the present juncture on supply chain management, as in the chapter *Process View of SCM* where we will explore different views on supply chain management. The table below show the chronological dates for supply chain.

Table 2.1: Chronological dates for supply chain management [27]

Duration	Events in SCM Evolution
Ancient Times	The Barter System evolved as an answer to the trading requirements. This was the first supply chain.
300 BC	Caesar made trading posts in East Asia to grow his trade. This was the first retailer supplier relationship. Establishment of the silk route to India.
1151	First known fire and plague insurance offered in Iceland.
1305	House of Taxis operated courier messenger service for the rich European clients. (A kind of primitive Outsourcing)
1621	Dutch West India Co. formed to trade with America and West Africa.(A pseudo third party logistics (3PL) by the Dutch Companies.)
1904	Charles S. Rolls became selling agent for cars made by F. Henry Royce. (The first traces of outsourcing).
1956	Warren Buffet started investment partnership in Omaha with money from family and friends and he went on to become a billionaire. (An overseas 3PL)
1960-1975	The essence of SCM understood. This first phase is characterized as an inventory 'push' era that focused primarily on physical distribution of finished goods.
1975-1990	The earlier approach changed. Companies began migrating from an inventory push to a customer pull channel as power began to move the downstream to the customer.

1980	In the last phase, companies realized that the productivity could be increased significantly by managing relationships, information and material flow across enterprise borders. This resulted in the present concept of supply chain management.
1981	IBM outsourced almost all of its activities and built a full computer.
1985	Wal-Mart introduced the concept of Cross Docking and replaced K-Mart as the leader in retail stores.
1985-	Cisco removed itself from the supply chain by providing to the customer directly from the vendor.
1990	Computer changed the way business is done.
1996-	Internet revolutionized the information pathway and the distribution system of the business.
1998-	The concept of e-commerce changed the definition of business itself.
2000-	Currently concepts like t-commerce and digital TV are beginning to take shape.

2.4 DEFINITION OF SUPPLY CHAIN MANAGEMENT (SCM)

Supply chain management (SCM) is the oversight of materials, information, and finances as they move in a process from supplier to manufacturer to wholesaler to retailer to consumer. Supply chain management involves coordinating and integrating these flows both within and among companies. As a solution for successful supply chain management, sophisticated software systems with Web interfaces are competing with Web-based application service providers who promise to provide part or all of the SCM service for companies who rent their service. [12]

In table 2.2 few definitions that have been used for the concept of supply chain management over the last 20 years have highlighted. And this table also showed the development of the literature in this field.

Table 2.2: Sample definitions of supply chain management

Authors	Definition
Oliver and Webber (1982)	Supply chain management covers the flow of goods from supplier through manufacturing and distribution chains to
Jones and Riley (1987)	Supply chain management techniques deal with the planning and control of total materials flow from suppliers to end-users.
Ellram (1991)	An integrative approach to dealing with the planning and control of the materials flow from suppliers to end-users.
Harland (1994)	Supply chain management is defined as the management of the flow of goods and services to end customers to satisfy their requirements.

The Supply-Chain Operations Reference-model (SCOR) is the product of the Supply Chain Council (SCC), an independent, not-for-profit, global corporation with membership open to all companies and organizations interested in applying and advancing the state-of-the-art in supply-chain management systems and practices. The SCOR-model captures the Council's consensus view of supply chain management. [57] Model scope is shown below;

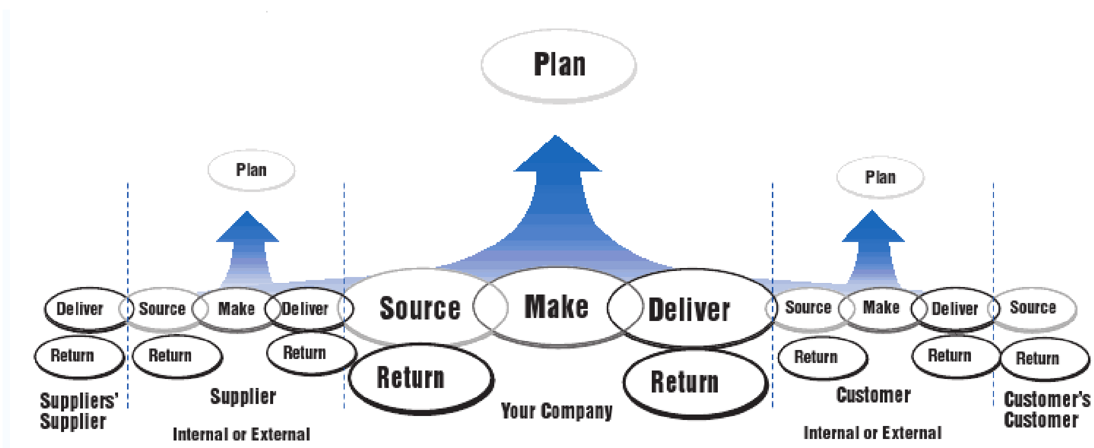

Figure 2.2: An illustration of a company's supply chain. [57]

The following are five basic components of SCM;

a) **Plan** is the strategic portion of SCM. Companies need a strategy for managing all the resources that go toward meeting customer demand for their product or service. A big piece of SCM planning is developing a set of metrics to monitor the supply chain so that it is efficient, costs less and delivers high quality and value to customers.

b) **Source** is the second component of SCM. Companies must choose suppliers to deliver the goods and services they need to create their product. Therefore, supply chain managers must develop a set of pricing, delivery and payment processes with suppliers and create metrics for monitoring and improving the relationships.(Q.LU) And then, SCM managers can put together processes for managing their goods and services inventory, including receiving and verifying shipments, transferring them to the manufacturing facilities and authorizing supplier payments.

c) **Make** is the manufacturing step. Supply chain managers schedule the activities necessary for production, testing, packaging and preparation for delivery. This is the most metric-intensive portion of the supply chain—one where companies are able to measure quality levels, production output and worker productivity.

d) **Deliver** is the part that many SCM insiders refer to as logistics, where companies coordinate the receipt of orders from customers, develop a network of warehouses, pick carriers to get products to customers and set up an invoicing system to receive payments.

e) **Return** can be a problematic part of the supply chain for many companies. Supply chain planners have to create a responsive and flexible network for receiving defective and excess products back from their customers and supporting customers who have problems with delivered products.

2.5 SUPPLY CHAIN PLANNING DECISIONS

The supply chain management issues concern activities of the firm at various levels of decision making, ranging from operational level to strategic level via tactical level. [11]

a) The strategic level: The decision making at this level is made with long term objectives and with long lasting effects. These include decisions regarding location of various facilities, including the manufacturing plant, distribution warehouses and the structure of the distribution channel.

b) The tactical level: Decision making at this level is concerned with purchasing and production functions, inventory policies and transportation strategies. These decisions will be usually updated on an annual basis.

c) The operational level: Decision making at operational level will concern day to day management of activities such as scheduling, routing and vehicle loading etc.

2.5.1 Supply Chain at a Strategic Level

The decisions at the strategic level of the supply chain lay out the framework of how the supply chain operates. The following five major activities take place within a supply chain at a strategic level:

The buy activity includes the tasks of buying raw materials, components, resources and services.

The make activity concerns creating products or services as well as ensuring maintenance and repair of resources when needed and training workers ~ in sum, performing all the tasks that are needed for production. [33]

The move activity concerns transportation of materials and personnel inside and outside the supply chain.

The store activity concerns the work-in-process (WIP) and raw material when it is waiting for transportation or transformation as well as the finished products waiting to be sent to customers.

The sell activity concerns all the market-oriented activities, including marketing and sales.
Each of these activities is linked with all other activities and with the external world. As opposed to the day-to-day decisions in each of these activities, which are covered at the tactical level, the strategic level focuses on the long term. For example, the buy activity at the strategic level focuses on developing long-term relationships with suppliers. It is not shortsighted by the near-term goal of buying from the cheapest supplier. It would identify suppliers whose strategic goals are compatible with those of the supply chain. These goals include the following:

a) Direction of technical innovation for the supplier
b) Focus on quality
c) Focus on reduction of cost
d) Focus on reduction in response time

2.5.2 Supply Chain at a Tactical Level

Tactical supply chain decisions focus on adopting measures that will produce cost benefits for a company. Tactical decisions are made within the constraints of the overarching strategic supply chain decisions made by company management. Tactical supply chain decisions take the strategic message and focus on creating real benefits for the company. These can include tactical decisions in manufacturing, logistics, suppliers and product development; [28]

Manufacturing: Tactical decisions may be made by company executives about the number and location of manufacturing sites to be operated. However, it is at a tactical level that decisions are made on how to produce the products are the lowest cost. Tactical decisions may be made as to the adoption of manufacturing methodologies such as kanban or just-in-time. Tactical decisions may be required at a regional level by using technology that is available that reduces material wastage, but cannot be exported to other manufacturing plants.

Logistics: Although tactical company decisions may require an in-house logistics function to be operational, a tactical decision may be required to use a third party logistics company in a region or country where transportation costs are high and cost benefits can be achieved by outsourcing. [23] Similarly in countries where land costs are high, construction of warehousing facilities may be cost prohibitive and despite not following the strategic vision, a tactical decision is made to use public warehousing.

Suppliers: Many companies recognize the cost benefits of using global suppliers and adopt strategic supply chain policies to take advantage. At a tactical level, management has to work within strategic guidelines to identify and negotiate the terms that will realize the greatest cost benefit across the company.

Product Development: Companies make tactical decisions on the product lines they are committed to producing. Tactical decisions have to be made as to the particular products that should be developed. If a company makes a strategic decision to introduce a new line of MP3 players in Europe, the company has to make tactical decisions regarding the specifications of the players, what countries they will be sold in and the market segment they will targeted at where the most profit can be achieved.

The tactical supply chain decisions that a company makes are not made in isolation but within the framework of the strategic supply chain decisions made at a global level, which in turn are based on the global objectives of the company.

2.5.3 Supply Chain at an Operational Level

Operational supply chain decisions are made hundreds of times each day in a company. These are the decisions that are made at business locations that affect how products are developed, sold, moved and manufactured.

Operational decisions are made with awareness of the strategic and tactical decisions that have been adopted within a company. These higher level decisions are made to create a framework within the company's supply chain operate and to the best competitive advantage. [30] The day to day operational supply chain decisions ensure that the products efficiently move along the supply chain achieving the maximum cost benefit. A number of examples of operational decisions can be identified in manufacturing, supplier relationships and logistics.

Manufacturing: Companies make tactical decisions with regards to manufacturing, such as the adoption of kanban and just-in-time. However, if the local manufacturing site is unable to rely on certain supplier's delivery times, the just-in-time method may not be suitable for some product lines. The local plant management may make an operational decision to keep certain items in stock to ensure that production is not halted. This inventory will increase costs, but a greater cost would be incurred if the production line was brought to a standstill due to a lack of items from a supplier.

Suppliers: Global suppliers and negotiated contracts are decisions made at a company level to take advantage of the company's global buying power. This offers considerable cost savings, but local sites may have to make operational decisions with suppliers to ensure an efficient supply chain. In some instances local negotiations with global suppliers are required to ensure quality of the product. [18] For example, in some countries the quality of the product produced by a supplier is not at the same level as other countries. The local management would have to make an operational decision to negotiate with the supplier for them to create a product with a higher quality to ensure the quality of the finished product.

Logistics: Strategic and tactical supply chain decisions in the logistics process often focus on the use of third party logistics companies (3PL). Many companies have identified the cost benefits of these 3PL companies and have integrated them into their supply chain. However, in some instances these 3PL companies may not operate in all regions where the company requires logistics. [21] In those cases the local management has to make operational decisions on leasing local warehousing and negotiating with regional logistics companies.

Although strategic and tactical supply chain decisions are made to bring the greatest efficiencies at the lowest cost, the daily operations of the supply chain require that local management make hundreds of operational decisions. These operational decisions are made within the framework created by the strategic and tactical processes and not made in isolation.

2.6 PROCESSES IN SUPPLY CHAIN MANAGEMENT

There are a variety of supply chain models, which address both the upstream and downstream sides.

The SCOR (Supply Chain Operations Reference) model, developed by the Supply Chain Council, measures total supply chain performance. [43] It is a process reference model for supply-chain management, spanning from the supplier's supplier to the customer's customer. It includes delivery and order fulfillment performance, production flexibility, warranty and returns processing costs, inventory and asset turns, and other factors in evaluating the overall effective performance of a supply chain.

The Global Supply Chain Forum (GSCF) introduced another Supply Chain Model. This framework is built on eight key business processes that are both cross-functional and cross-firm in nature. Each process is managed by a cross-functional team, including representatives from logistics, production, purchasing, finance, marketing and research and development. While each process will interface with key customers and suppliers, the customer relationship management and supplier relationship management processes form the critical linkages in the supply chain.

The forward supply chain processes are as follows:

Supply includes all activates connected to purchasing, transportation and storing of the raw materials and new components that are input to manufacturing system

Production/manufacturing enhances all value adding processes that transform the raw materials and components into final products according to actual customers’ demand or demand forecasts.

Distribution refers to all activities needed to provide the customers with ordered/demanded products. Distribution usually consists of transportation, storage and sales services.

2.7 FROM SUPPLY CHAIN TO CLOSED LOOP SYSTEMS

A long-term strategy for preventing exposure to hazardous industrial pollutants is to reduce their use in the first place through cleaner production. Moving toward eco-efficiency, as this goal is often defined, means that industry must reduce raw material inputs -- chemicals, natural resources, energy, water and at the same time reduce air, water, and solid pollutants for each unit of production. [20] This push toward cleaner production is typically driven by environmental an economic concerns rather than by health concerns, although it seems certain that cleaner production would benefit public health as well.

Unlike the industrialized countries, developing countries have the opportunity to leapfrog over some polluting industries and technologies into cleaner production. Recent advances in information systems, telecommunications, biotechnology, new materials, and miniaturization portend dramatic reductions in material and energy inputs. [16] Pollution monitoring and control technologies have also improved over the past 20 years. If proper incentives are in place, developing countries need not build or import yesterday's dirty technology, as all too often occurs today. The key to spurring this technological change and transfer is to send clear social, economic, and regulatory signals to companies and to ensure that markets for environmentally benign technologies will continue to grow. [20]

The potential for improved investments is enormous. The current trend toward globalization, with its accompanying investment flows, means that private companies are increasingly influencing industrial change, much more so than public investments or development assistance. Indeed, roughly 70 percent of net resource flows to the developing world now derive from the private sector. [52] Especially in the newly industrializing, fast-growth economies -- those facing the greatest risks from unchecked industrial pollution -- conditions are conducive for financing environmentally sound technology. The World Bank estimates, for example, that firms that have yet to be established will account for more than 80 percent of industrial output by 2010. [51] Indonesia has already made strides in this direction. For instance, the new pulp and paper mills being built there have pulping and bleaching technologies on par with those now being proposed as the U.S. environmental standard. [5] Although the initial costs of cleaner technologies may be higher than those of older technologies, the provision of financial and technical assistance can encourage their adoption. Such a strategy will offer economic savings and environmental and health benefits long into the future.

3. CLOSED LOOP SUPPLY CHAINS

Ideally, a zero-waste supply chain is that completely reuses, recycles, or composts all materials. However, the term can also be used to refer to corporate take-back programs, where companies that produce a good are also responsible for its disposal. The natural environment continues to be a challenging supply chain management issue. Not only does it directly impact competitiveness through traditional performance measures such as cost and quality, but also the range of stakeholders extends well outside traditional suppliers and customers. [8]

3.1 DEFINITION OF CLOSED LOOP SUPPLY CHAIN

The closed loop supply chain provides the integration of traditional 'forward' supply chain processes and 'reverse' supply chain processes. [10] Identify the common processes required by a closed-loop supply chain as: product acquisition, reverse logistics, inspection, testing and disposition, remanufacturing, and selling and distribution.

General overviews of reverse logistics and closed-loop supply chain can be found in Fleischmann [2001], Guide [2003] and Dekker et al. [2004]. The philosophy of closed loop supply chain takes in consideration also the environmental aspects by business decision making. The ideal closed loop supply chain can be defined as zero-waste supply chain that completely reuses, recycles all materials. However in real life supply chain disposal activities take place the amount of products and components being disposed should be minimized. Figure 3.1 represents the overall material flow in closed loop supply chain.

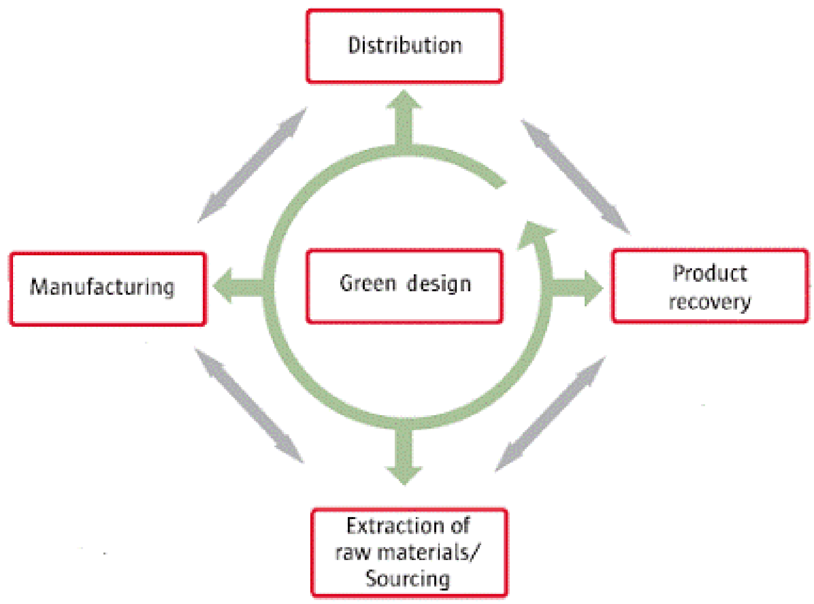

Figure 3.1: The general closed loop network structure

Reverse processes are [40] as follows:

a) Collection refers to all activities rendering used products available and physically moving them to some point for further treatment.

b) Inspection/separation denotes all operations determining whether a given product is in fact re-usable and in which way, it results in splitting the flow of used products according to distinct re-use (and disposal) options.

c) Reprocessing means the actual transformation of a used product into a usable Product/ component/ material. This transformation may take different forms including recycling, repair and remanufacturing. In addition, activities such as cleaning, replacement and re-assembly may be involved.

d) Disposal is required for products that cannot be re-used for technical or cost reasons. Disposal may include transportation, land filling and incineration steps.

e) Re-distribution refers to directing reusable products to a potential market and physically to moving them to future users. This may include sales, transportation and storage activities.

3.2 DIFFERENCE BETWEEN FORWARD AND CLOSED LOOP SUPPLY CHAIN

Closed-loop supply chains differ significantly from forward supply chains in many aspects. Interest is growing in the US because of the potential profitability and in the European Union because of legislation. [54] New business models need to be developed by joint cooperation between industry and academia that take a life-cycle approach to products.

Forward supply chain;

a) Forecasting is relatively straightforward,
b) Distributed one point to many points
c) Product quality is uniform
d) Product packaging is uniform
e) Disposition options is clear
f) Pricing is relatively uniform
g) Importance of speed is recognized
h) Forward distribution costs are easily visible
i) Inventory management is consistent
j) Product life cycle is manageable
k) Marketing methods are well known
l) Visibility of process is more transparent

Reverse supply chain;

a) Forecasting is more difficult,

b) Distributed many points to one point
c) Product quality is not uniform
d) Product packaging is often damaged
e) Disposition is not clear
f) Pricing is dependent on many factors
g) Speed is often not considered as a priority
h) Reverse costs are less directly visible
i) Inventory management is not consistent
j) Product life cycle issues are more complex
k) Marketing is complicated by several factors
l) Visibility of process is less transparent

In a forward supply chain, the customer is typically the end of the process. However, a closed loop supply chain includes the returns processes and the manufacturer has the intent of capturing additional value and further integrating all supply chain activities. Therefore, closed-loop supply chains include traditional forward supply-chain activities and the additional activities of the reverse supply chain. [37] These additional activities include product acquisition to obtain the products from the end-users, reverse logistics to move the products from the points of use to a point(s) of disposition, testing, sorting, and disposition to determine the product's condition and the most economically attractive reuse option, refurbishing to enable the most economically attractive of the options: direct reuse, repair, remanufacture, recycle, or disposal, and Remarketing to create and exploit markets for refurbished goods and distribute them.

A reverse supply chain requires careful design, planning, and control. Until researchers define the proper context for reverse supply chains, they will be different in nature from forward systems. Although we have established common activities for reverse supply chains, we do not completely understand these activities in different contexts because they vary in complexity and managerial importance from scenario to scenario. The situation is further complicated because users may return products during the product life cycle (commercial returns: a result of liberal reseller policies that permit customers to return products for any reason during a 30-, 60-, or 90-day period after purchase, warranties, repairs), at end of use, and at end of life. Each type of return requires a reverse supply chain appropriate to the characteristics. [19]

3.3 HISTORY OF CLOSED LOOP SUPPLY CHAIN

Material shortages during World War II created a need to rebuild automobile parts and started a trend that continues today. In fact, according to Rogers and Tibben-Lembke, this is now a $36 billion business that accounts for “90 to 95 percent of all starters and alternators sold for replacement are remanufactured.” [39]By the end of World War II the US Military had over 77,000,000 square feet of storage across Europe with over $6.3 billion in excess stuff requiring retrograde back to the United States. In the Pacific Theater, there was a large operation to salvage and reuse clothing and shoes to reduce the lead times for new items coming from the States. [53]

The next major date of interest in reverse logistics is the 1984 Tylenol scare. Johnson & Johnson along with McNeil Laboratories quickly responded as America watched on the evening news about the “tainted lot” of Tylenol. The rapid response by McNeil Laboratories to get the tainted products off the shelves and quickly replaced by new lots with tamper proof bottles instilled great faith in the American public and set the new standard for reverse logistics.

In 1991, The Federal Republic of Germany passed recycling ordinances that put teeth in the environmental reverse pipeline and established mandatory recycling programs. [34] Included in these ordinances were provisions for fines and prosecution for violators of the ordinances and stricter guidelines for the handling and transporting of hazardous materials and responsibilities for recovering hazardous wastes.

The German ordinances led to a 1996 United Kingdom legislation requiring shippers and manufacturers to be responsible for the return and recycling of packing materials. The European Union took this one step farther in 2001 by establishing a goal of 50-65% recovery or recycling of packaging waste. The implication for the rest of the world is that they have to be compliant if they want to do business with the EU. [46]

The US Military has experienced the same problems with reverse logistics. We alluded to General Sherman's solution after the Civil War and the problems associated with World War II. General George S. Patton, Jr. stated, "In battle, troops get temperamental and ask for things which they really do not need. However, where humanly possible, their requests, no matter how unreasonable should be answered." [36] This mentality creates a situation that is not unlike the current customer service policies of major retailers. With days of the UN Mission to Somalia in 1992 there were plane loads of "unneeded" supplies returning to Germany's Kaiserslautern Industrial Center and within days of the start of the UN Mission to Bosnia, there were items coming back as unneeded.

The August 2003 edition of Jane's Defence Weekly reported, "There is a 40 hectare (approximately 16 acres) area in Kuwait with items waiting to be retrograded to the US." Not all of that stuff was unserviceable; some of it was never even opened. In preparation for Operation Iraqi Freedom, the US Military moved the equivalent of approximately 150 Wal-Mart Supercenters into Kuwait. [48] When that much stuff is moved there is going to be excess products and supplies requiring a reverse logistics system to process them.

Although the phenomenon of Reverse Logistics was in existence for a long time, it did not gain recognition until recently. This area has intrigued many people in terms of the impact it has had and continues to have on the business world. [34]

3.4 THE NEED FOR CLOSED LOOP SUPPLY CHAIN IN TODAY`S INDUSTRY

The importance of studying reverse supply chains (RSCs) has increased in recent years for several reasons:

a) The amount of product returns can be very high, with some industries experiencing returns at over 50% of sales. [13]

b) Sales opportunities in secondary and global markets have increased revenue generation from previously discarded products.

c) End-of-life take-back laws have proliferated over the past decade both in the European Union and in the United States, requiring businesses to effectively manage the entire life of the product .

d) Consumers have successfully pressured businesses to take responsibility for the disposal of their products that contain hazardous waste. [14]

e) Landfill capacity has become limited and expensive. Alternatives such as repackaging, remanufacturing and recycling have become more prevalent and viable.

Reverse logistics for recycling is growing, for two reasons: (1) to reclaim value through returned products that are further re-used for recycling and (2) the environmental concerns arising from a lack of future landfill availability for disposal options.

Through effective management of the RSC, managers can improve process efficiencies, customer service, supply chain design, product design, after-market product sales and after-sales service. Figure 3.2 gives the implementation challenges for closed loop supply chain;

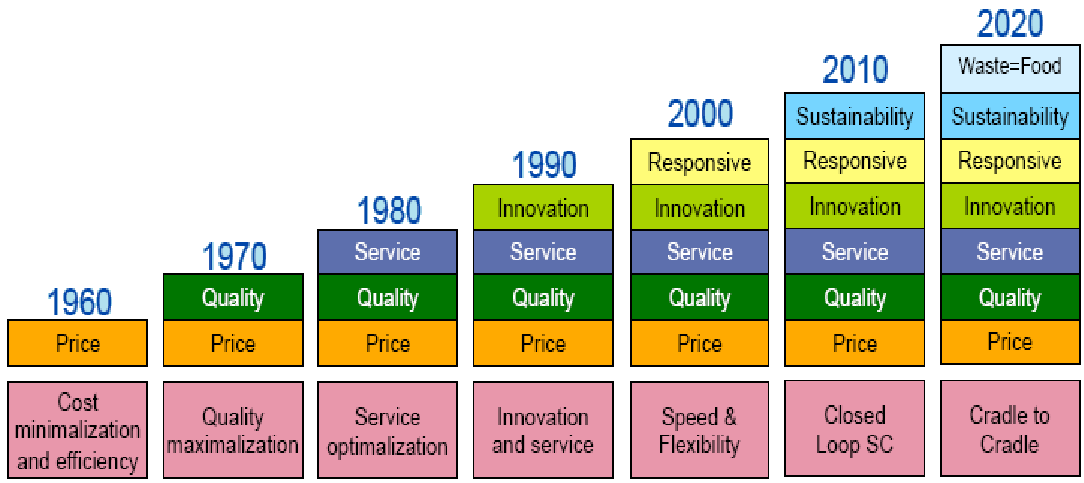

Figure 3.2: Implementation challenges for closed loop supply chain

Most research in RSCs has relied on case studies and optimization models. Opportunities exist to use survey-based research methods to explain current practices, predominant and critical issues, and managerial techniques used to manage the RSC. [7]

3.5 CLOSED LOOP SUPPLY CHAIN STRATEGIES

This section analyzes and evaluates the CLSC strategies according to the following decision-making focus: Reverse Logistics Network Structure, Relationships, Inventory Management, and Planning and Control. [11] Furthermore, we give an overview of deposition for processing and transmitting environmental sensitive material.

3.5.1 Return Management

Both products and packaging return for a variety of reasons, but returns can be broadly divided between those that are unplanned and those that are planned and desired. Unplanned returns are typically limited to products which customers have purchased. The list of reasons for return is lengthy and each requires different physical handling.

It is important that the reason for return is recorded and used to modify future business behavior.

The reasons for the returns of the used products can be;

a) The customer changed his/her mind
b) The product was defective
c) The customer perceived the product to be defective
d) The product was damaged in transit
e) A vendor error (such as wrong item or quantity sent)
f) Warranty returns

The effect on margin of not reselling the maximum amount of stock within the season can be substantial, yet it is often given little senior management attention. Credit disputes with suppliers can run to millions of dollars per year. Moreover, there could be a similar cost hidden in the shops. The cost to the business of price reductions and mark-downs is enormous and is often the factor that sets retailers apart at year end. Good stock management and information can help retailers to buy and sell better. [4] Retail buyers are motivated by the sale of goods and often factor into the bought price an allowance for returns, but this ignores the real costs and the unsold stock issues. Management of slow sellers can turn stock into cash. Retailers can have stockrooms jammed with unsold product, waiting months before it goes into sale. Money is tied up, damage and theft increases, it blocks the fire exits and when finally put on sale it does not make a coherent customer offer. Sale remainders are often dumped. Manufacturers can be deluged with batches of product returns due to retailers overstocking, end of promotion, end of accounting year, unseen build up in warehouses, water damaged packaging or product recalls. The retailers often deduct credit from the next invoice but it takes months to retrieve the item, if at all.

For retailers, returns are costly than they need to be in several ways. First, the returned inventory is idle while processing occurs and may take up to six weeks to be returned to the selling floor. [29] Second, because processing takes so long, the item may be obsolete or past season before it's available for resale, and consequently must be sold at a deep discount. Third, the customer relationship suffers if returns of an item purchased through one channel can't be handled efficiently through other channels. Also, consumers may return items through several channels, including mailing the item back to the DC or returning the item to a local store.

3.5.2 Recycle and Redistribution

Another dimension in the area of reverse logistics is recycling and redistribution that focuses on environmental awareness through effective value management. Reuse and Recycling, Reverse Logistics Opportunities, published by the Council of Logistics Management in 1993 talks briefly about the advent of recycling laws in different countries. The German Waste and Packaging Law were enacted in April 1991. Under this law, manufacturers, distributors, and retailers were responsible for recycling packaging waste. Many other European countries also established recycling programs. In fact, to resolve discrepancies in legislation between member countries, the European community proposed a “New Approach Standard" for reuse and recycling in July 1992. The standard was to replace the packaging rules in member countries at the time. The book also mentions mandatory recycling laws adopted by most states in the U.S.A. [47] These laws covered recycling goals for state governments, curbside collection requirements, commercial recycling requirements, and more general mandates for local governments to establish recycling programs.

The CLM (Career Limited Move) book (1993) in Reuse and Recycling, Reverse Logistics Opportunities, discusses the emerging issues and different options in non-hazardous waste reduction, and describes how these issues affect the supply chain. This book explains the concept of recycling, reusing, and source reduction--the three components of waste reduction. A short definition of each of these components would be appropriate at this point. Recycling is a four-stage process, involving:

a) Collecting recyclable materials from waste generators;

b) Processing recyclables materials, which are called secondary, as opposed to virgin, materials;

c) Using these secondary materials to manufacture new products; and

d) Returning the products to commerce.

Reusing is a process similar to recycling, except that instead of processing the products to create raw materials, the products are refurbished or repaired and used again in their original form. Source reduction involves reducing the amount and/or toxicity of material consumed or wastes generated (e.g., light-weighting packaging). Reuse may be considered as a type of source reduction. The CLM book (1993), on reuse and recycling, has, based on interviews with 17 companies and an extensive literature review, recognized that reuse and recycling programs often follow a three-phase pattern of development, namely: Reactive, Proactive, and Value-Seeking These phases represent increasing levels of corporate commitment to waste reduction and related environmental concerns. The reactive phase aims at compliance of existing laws, fulfilling individual environmental commitments, and achieving of cost savings. [45] The objectives of the proactive approach are to preempt new environmental laws by voluntarily starting programs, developing competitive advantage through more efficient compliance, and sell products that satisfy customers' environmental concerns. Finally, the value-seeking phase aims at integrating environmental activities into a business strategy, and operating the firm to reduce its impact on the environment.

3.5.3 Deposition and Environmental Concerns

Traditionally, reverse logistics has attracted little attention, as organizations focused on the forward moving supply chain including marketing, sales, procurement, manufacturing, and distribution. Waste reduction includes recycling, reuse, and source reduction of returned products or packaging wastes from end-users. Green Logistics has gained increased momentum in recent years among manufacturers and retailers following government mandates and social responsibilities to the society. The catalyst that sparked this interest in reverse logistics has been environmentalism. Reverse logistics practices have often been environmentally driven, particularly in European countries such as Germany, where environmental regulations are more stringent than in the U.S. However, many organizations are discovering that improving their reverse logistics processes can be a value-added proposition that may or may not have anything to do with environmental concerns. [38] The added value could be attributed to improved customer service leading to increased customer retention and sales. The added value could also be through reduced cost and/or reduced cycle time. So while environmentalism is and will continue to be a driver behind reverse logistics, it is by no means the only one.

The pathways that product can follow are:

a) Sell as new.
b) Return to supplier for credit. Financial penalties for faulty manufacture are common.
c) Sell at discount in shop or via an outlet.
d) Sell into secondary market.
e) Donate to charity.
f) Refurbish ,inspect, test, remanufacture, repackage
g) Recycle component materials
h) Scrap to a licensed agent.

Also, the lack of information on the product may prohibit higher levels of product recovery. Yet reuse and remanufacturing are generally economically more attractive than materials recycling. The economic efficiency of deposition programs is a major concern, particularly if a significant fraction of the products sold is returned through the deposition program. Guidance on sustainable product deposition design has to be provided. Especially higher product recovery levels require sound remarketing concepts. Reverse logistics in the context of deposition (collection, storage, and transportation of end-of-life products from the point of return to the point of product recovery and disposal) has not yet been well documented. [25 Concepts are required that allow the manufacturer to influence the customer's decision about when and where to return a product.

3.6 THE ISSUES FOR CLOSED LOOP SUPPLY CHAIN

In a remanufacturing environment, the used products serve as raw material for the remanufacturing process. There are several issues attached to this dependency on cores (used products). First of all, the core is usually seen as ‘trade-in’ for a remanufactured product. However, cores can differ largely in quality, depending on the way in which they have been used. A second obstacle in core management is the quantity and timing of returned products. Used products are being returned at any time, however, there are significant differences in the amount of products returned per variant. For some variants, the amount of cores can be quite low. Hence, the remanufacturing plant has to deal with not only one, but two major uncertainties: the supply of raw materials and the demand for remanufactured products. Forecasting has therefore been increasingly difficult. Unavailable parts are replaced with new parts, which results in the product being more expensive. A third challenge is the collection of end-of-life products, in other words, the reverse logistics of cores. Compared to the conventional supply chain, the remanufacturer is left with a logistics network of ‘many to one transportation’ or ‘many to one distribution points’ rather than a distribution of products from one location to a few destinations. [56]

Concluding, research in the area of reverse logistics and automotive remanufacturing will need to investigate solutions for the obstacles involved in the return-flow of cores, core as well as operations management. It furthermore has to address the problems of marketing recovered products, as for example increasing the consumer's awareness regarding remanufactured products. Manufacturers spend much of their time and energy coordinating their complex supply chains from raw material suppliers to producers, wholesalers, distributors, retailers and customer. With all the attention to the forward action of the supply chain, few manufacturers have considered how this supply chain can or should work in reverse to reclaim products at the end of their life-cycle and return them through the supply chain for decomposition, disposal or re-use of key components. Believing that once products are delivered the firm's responsibilities end is one of the deadly sins of logistics. [54] Taking a life-cycle approach to product distribution is vital, along with implementing educational programs for customers, suppliers, vendors and others in the supply chain. Strategic factors to consider in reverse logistics include costs, overall quality, customer service, environmental concerns and legislative concerns. On the operational side, factors to consider are cost–benefit analysis, transportation, warehousing, supply management, remanufacturing and recycling, and packaging.

According to Dowlatshahi (2000), insights about the factors form the state-of the-art knowledge on the keys to the successful design and use of reverse logistics systems. Other issues to consider in reverse logistics are the desires of the customers. For example, do customers feel a responsibility to recycle and return used products and do they demand recycled content in their new products? Often, incentive systems or no-cost return systems must be in place to make reverse logistics work without external governmental regulation. Because the quality of inputs for re-use is important in many situations, clean, safe return methods must be in place as well. All supply channel members must be committed to the process, and it needs to be financially attractive to participate in the process. Economies of scale must be sufficient to make environmental reverse logistics viable. [12]

The recycling of old materials requires collection, sorting and processing, and the profitability is influenced by the efficiency achieved through co-ordination and integration. The profits made at each stage are determined by the state of the competition and the nature of markets. The implementation of internal reverse logistics programs often involves significant allocations of capital and/or resources for the construction of reclamation and/or redistribution facilities and the purchasing of recycling equipment. Sustainable economic growth is achieved when firms choose the production technology process that will reduce the amount of pollution by-products and allow the final product to be used or reprocessed in further production operations. The usability and reprocessing characteristics of products requires initial planning and product design to allow future re-usability. A firm's incentive to design a more usable product will depend on whether such a change will require costly production technology. [2] Sustainable economic growth and reverse logistics merge when both emphasis the need for changing production technologies to reduce the by-products of a final good.

3.7 LITERATURE REVIEW OF CLOSED LOOP SUPPLY CHAIN

Several researchers have studied the design of reverse supply chain optimization on costs. Optimization occurs on supply chain costs, which are generally fixed, and variable costs for facilities and variable costs for intermediate transport.

Closed loop supply chains are similar to reverse supply chain models but the difference is closed loop supply chains optimize the forward and reverse network although the reverse supply chain optimize only the reverse network.
(Eoksu Sim, 2004) considered an extended model for closed loop supply chains which consists of transportation costs, operating costs and production/ storing costs. This research used heuristic methods to solve the problem.

For reverse logistic network design, (Mutha&Pokharel, 2008) can be a good example. In this article a mathematical model for the design of reverse logistics is proposed. It assumed that designing of network points and assigning capacities to them depend not only on the volume of returned products but also on the demand of remanufactured products.

(Jayaraman,2003) proposed a mathematical model for the reverse distribution. In this article according to the complexity of the model, a heuristic solution methodology is used. (S.Kara&Kaebernick, 2006) proposed a simulation model for the reverse logistic network for collecting the products at the end-of-life. (Jiuh- Biing, 2004) proposed a linear-multi objective programming model that both optimizes the forward and reverse logistics.

(Fuente&Ros, 2007) proposed integrated model for supply chain management (IMSCM). This management not only considers the traditional flow from raw materials to products along the supply chain towards the client, but also envisions reverse supply chain operations. (Lee&Dong, 2008) proposed a dynamic location and allocation models. An heuristic algorithm is used for the solution.

4. RESEARCH TECHNIQUES AND DESIGN OF CLOSED LOOP SUPPLY CHAIN NETWORK AND APPLICATION IN A HEATING INDUSTRY COMPANY

In today`s fiercely competitive global supply chains, the optimization of the disassembly and recovery processes in the most profitable and, as well, environmentally-friendly way is an issue of the importance for the manufacturing industry. Toward this direction, a linear multi objective model is proposed. The model`s data are taken from a Turkish heating industry company.

4.1 CONCEPTUAL DESIGN OF THE MODEL

The structures which contributed to the reverse supply chain and their relevant is illustrated in Figure 4.1.

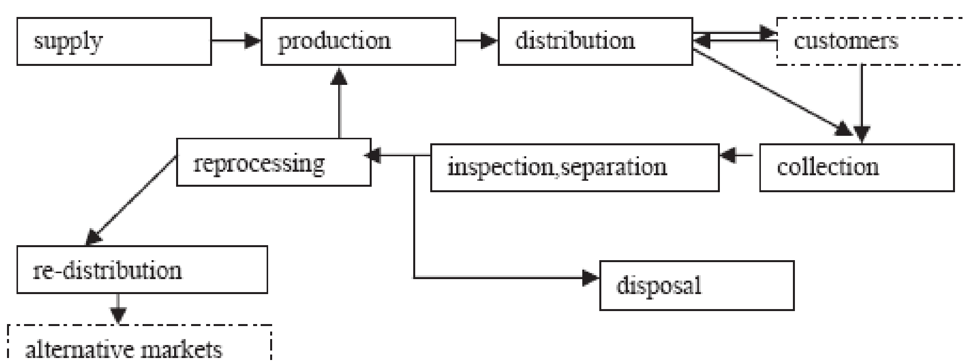

Figure 4.1: Structures contributed with reverse supply chain

As shown in Fig. 4.1, four intermediate facilities were considered. More precisely, we include the `reprocessing center`, where the inspection, disassembly and remanufacturing of products are carried out, `plants` where final products are manufactured, `retailer` used for delivering the products to various customers and the `refuse collector ` where the salvage products are sold. The plants produce the final products and deliver these products through the transportation channel to each retailer and then delivered to geographically dispersed customer zones via forward processing facilities. Returned products are taken back to customer zones by retailer and then delivered to the reverse facilities via return processing facilities for the purpose of recovery or safe disposal. In reprocessing center, the returned products would be recycled and decomposed into sub products. And recycled sub products would be delivered to the plants that want to use them.

4.2 REVENUE ASSOCIATED WITH CLOSED LOOP SUPPLY CHAINS

In a closed loop supply chain, two income sources are existing. They are revenues from products sales to the customers and income from salvage products sales to the secondary markets.

The total revenue from products sales is shown below; spp is unit selling price of product and xrc (r,c,t) is quantity of products delivering from retailers to the customers in t time zone.

$$\sum_r \sum_c \sum_t \mathrm{xrc}(r, c, t).\, \mathrm{spp} \tag{4.1}$$

The total income from salvage products sales to the market is shown below; di is income from disposal, xrf(r,t) is delivering products from retailers to the reprocessing center and disrate is disassembly rate for the used products.

$$\sum_r \sum_t (1 - \mathrm{disrate}).\, \mathrm{xrf}(r, t).\, \mathrm{di} \tag{4.2}$$

The total revenue is shown below;

$$\mathrm{Revenue} = \sum_r \sum_c \sum_t \mathrm{xrc}(r, c, t).\, \mathrm{spp} + \sum_r \sum_t (1 - \mathrm{disrate}).\mathrm{xrf}(r, t).\, \mathrm{di} \tag{4.3}$$

4.3 COSTS ASSOCIATED WITH CLOSED LOOP SUPPLY CHAIN

In designed closed loop supply chain model, there are five cost sources. They are purchasing, processing, transportation, holding and fixed costs. This costs sources have been explained in sub chapters.

4.3.1 Purchasing Costs

In designed closed loop supply chain, purchasing costs can be occurred in two ways:

a. Cost of raw materials from secondary raw materials markets.
b. Cash payments to customers for returning used products.

It is virtually impossible to reuse all the components of a returned product. In designed closed loop supply chain, if the plant can`t meet its component supply from reprocessing centre, it can purchase new components from secondary raw material markets. This purchasing costs are shown below; xsp(a,t) is new components from supplier and ns(a) is purchasing cost of new components.

$$\sum_t \mathrm{xsp}(a,t) * \mathrm{ns}(a) \tag{4.4}$$

The cash given to the customers for taking used products from them is shown below; xrf(r,t) is the quantity of used products coming from retailers to the reprocessing centre, spp is the unit selling price of product. The assumption for this equality the company is giving 10 percent of selling price for each of the products.

$$\sum_r \sum_t \mathrm{xrf}(r,t) * \mathrm{spp} * 0.1 \tag{4.5}$$

4.3.2 Processing Costs

In designed closed loop supply chain process costs may occur in two ways;

a. Cost of disassembly
b. Cost of production

Disassembly cost for returned product is the cost that incurred in disassembling the returned product in components a. xfp(a,t) is the quantity of component which is disassembled in reprocessing centre and udc is unit disassembly cost per component. This equality is shown below;

$$\sum_a \sum_t \mathrm{xfp}(a,t).\,\mathrm{udc} \tag{4.6}$$

Production cost is the cost involved an assembling the components at the plant to meet the market demand. xpr(r,t) is the quantity of product which is assembled in plant and upt is unit production cost in plant. This cost is given as;

$$\sum_r \sum_t \mathrm{xpr}(r,t).\,\mathrm{upt} \tag{4.7}$$

4.3.3 Transportation Costs

Transportation costs are the cost paid for transporting various products or components from one location to another.

The cost of transporting product from plant to various retailers is given below. dist1(p,r) is distance between plant and retailer, xpr(r,t) is the quantity of product from plant to retailers and utc is unit transport cost of product.

$$\sum_t \sum_p \sum_r \mathrm{xpr}(r,t).\,\mathrm{dist1}(p,r).\,\mathrm{utc} \tag{4.8}$$

The cost of transporting products from various retailers to the customer zones is shown below. dist2(r,c) is the distance between retailers and customer zones, xrc(r,c,t) is the quantity of products from retailers to the customer zones.

$$\sum_t \sum_r \sum_c \mathrm{dist2}(r, c).\, \mathrm{xrc}(r, c, t).\, \mathrm{utc} \tag{4.9}$$

The cost of transporting used products from customer zones to the various retailers is shown below. dist2(r,c) is the distance between retailers and customer zones, xcr(c,r) is the quantity of products from customer zones to the retailers.

$$\sum_t \sum_r \sum_c \mathrm{dist2}(r, c).\, \mathrm{xcr}(c, r, t).\, \mathrm{utc} \tag{4.10}$$

The cost of transporting used products from various retailers to the reprocessing centre is shown below. dist3(r,f) is the distance from various retailers to the reprocessing centre and xrf(r,t) is the quantity of used products from retailers to the reprocessing centre.

$$\sum_r \sum_f \sum_t \mathrm{dist3}(r, f).\, \mathrm{xrf}(r, t).\, \mathrm{utc} \tag{4.11}$$

The cost of transporting dissembled components from reprocessing centre to the plant is shown below. dist4 is the distance between reprocessing centre and plant, xfp(a,t) is the quantity of components from reprocessing centre to the plant.

$$\sum_a \sum_p \sum_t \mathrm{dist4}.\, \mathrm{xfp}(a, t).\, \mathrm{utc} \tag{4.12}$$

The total cost of transport cost is shown below;

$$\sum_{r}\sum_{p}\sum_{t} \mathrm{xpr(r,t).\,dist1.\,utc} + \sum_{t}\sum_{r}\sum_{c} \mathrm{xrc(r,c,t).\,dist2.\,utc} + \sum_{t}\sum_{c}\sum_{r} \mathrm{xcr(c,r,t).\,dist2.\,utc} + \sum_{t}\sum_{r}\sum_{f} \mathrm{xrf(r,t).\,dist3.\,utc} + \sum_{t}\sum_{f}\sum_{p} \mathrm{xfp(t).\,dist4.\,utc} \quad (4.13)$$

4.3.4 Fixed Costs

Since we assume that the reprocessing centre and the plant are rented, these facilities incur fixed charges. The total fixed cost for each facility is given as;

a. Fcf is the fixed cost for the reprocessing centre
b. Fcp is the fixed cost for the plant
c. Fcr(r) is the fixed cost for each of the retailers.

The total fixed cost is shown below;

$$\sum_{1}^{r} \mathrm{fcr} + \mathrm{fcp} + \mathrm{fcf} \quad (4.14)$$

4.3.5 Holding Costs

Holding costs at each facility could vary depending on the quantity of each product/component. In the designed reverse supply chain for two facilities (reprocessing centre and plant) inventory costs have occurred.

The inventory cost of product at reprocessing centre is shown below. uhcf is unit holding cost for product in reprocessing centre and sf(t) is storage level in reprocessing centre.

$$\sum_t \mathrm{uhcf}.\,\mathrm{sf(t)} \tag{4.15}$$

The inventory cost of product at plant is shown below. uhcp is unit holding cost for product in plant and sp(t) is storage level in plant.

$$\sum_t \mathrm{uhcp}.\,\mathrm{sp(t)} \tag{4.16}$$

The total holding cost is shown below;

$$\sum_t \mathrm{uhcf}.\,\mathrm{sf(t)} + \sum_t \mathrm{uhcp}.\,\mathrm{sp(t)} \tag{4.17}$$

4.4 MODELS SYMBOLS

Table 4.1: Symbols used in model formulation-parameters

Notation	Description
p	Set of plant in the network
r	Set of retailers in the network, r= 1,2,….,R
f	Set of reprocessing centre in the network
c	Set of customer zones in the network, c=1,2,……,C
t	Set of time in the network, t=1,2,….,T (season)
a	Set of components for each product in the network, a=1,2,….,A
dist1	Distance from plant to the retailers (km)
dist2	Distance from retailers to the customer zones (km)
dist3	Distance from retailers to the reprocessing centre (km)
dist4	Distance from reprocessing centre to the plant (km)
utc	Unit transport cost of product (TL)
udc	Unit disassembly cost of product in reprocessing centre (TL)
upt	Unit production cost of product in plant (TL)
uhcf	Unit holding cost of product in reprocessing centre (TL)
uhcp	Unit holding cost of product in plant (TL)
fcf	Fixed cost of reprocessing centre (TL)
fcp	Fixed cost of plant (TL)
fcr(r)	Fixed costs for retailer (TL)
spp	Unit selling price of product (TL)
di	Income from disposal (TL)
utca(a)	Unit transportation cost of component a (TL)
ns(a)	Purchasing cost of new component from suppliers(TL)
rmcp	Required production capacity per unit of product
tmcp	Total available production capacity in plant
trmf	Total available reverse processing capacity in reprocessing centre
rrpcf(a)	Required repair capacity per unit of component in reprocessing centre
BQ(a)	The bom quantity of one product
dmdrate(t)	Demand rate for product for each seasons

dmd(c)	Forecasted demand quantity of product for each customer zones
rrc(t)	Return rate of used product from customer zones for each season

Table 4.2: Symbols used in model formulation-decision variables

Notation	Description
xpr(r,t)	Quantity of product from plant to the retailers
xrc(r,c,t)	Quantity of product from retailers to the customer zones
xcr(c,r,t)	Quantity of used products from customer zones to the retailers
xrf(r,t)	Quantity of returned products from retailers to the reprocessing centre
xfq(t)	Quantity of disassembled product in reprocessing centre
xfp(a,t)	Quantity of component from reprocessing centre to the plant
xsp(a,t)	Quantity of new components from suppliers
pq(t)	Production quantity in plant
sp(t)	Storage level in plant
sf(t)	Storage level in reprocessing centre
hp(t)	Handling in plant
hf(t)	Handling in reprocessing centre
PZ	Indication as to whether reprocessing centre open at alternative 1
DZ	Indication as to whether reprocessing centre open at alternative 2
RZ	Indication as to whether reprocessing centre open at alternative 3
profit,revenue	
transport	
production	
loss	

4.5 CONSTRAINT EQUATIONS

a) The quantity of used products come from customer zones to retailers must be equal to the products sending from retailers to the reprocessing centre;

$$\mathrm{xrf}(r,t) = \sum_c \mathrm{xcr}(c,r,t) \qquad \forall r, \forall t \qquad (4.22)$$

b) The quantity of products which are disassembled in reprocessing centre must be equal to the quantity of products from retailers with a disrate;

$$\mathrm{xfq}(t) = \mathrm{disrate} * \sum_r \mathrm{xrf}(r,t) \qquad \forall t \qquad (4.23)$$

c) The quantity of disassembled components from reprocessing centre to plant must be equal to the disassembled used products bom quantity;

$$\mathrm{xfp}(a,t) = \mathrm{xfq}(t) * \mathrm{BQ}(a) \qquad \forall a, \forall t \qquad (4.24)$$

d) The quantity of new products components from plant to retailers must be equal to the components from suppliers and reprocessing centre;

$$\mathrm{xpr}(r,t) * \mathrm{BQ}(a) = \mathrm{xsp}(a,t) + \mathrm{xfp}(a,t) \qquad \forall a, \forall r, \forall t \qquad (4.25)$$

e) Handling components in plant must be equal to the storage level for components in plant and components from suppliers and reprocessing centre;

$$\mathrm{hp}(t) * \mathrm{BQ}(a) = \mathrm{sp}(t-1) * \mathrm{BQ}(a) + \mathrm{xfp}(a,t) + \mathrm{xsp}(a,t) \qquad \forall a, \forall t \qquad (4.26)$$

f) Storage level in plant must be equal to the difference between handling in plant and quantity of products from plant to retailers;

$$sp(t) = hp(t) - \sum_{r} xpr(r,t) \qquad \forall t \qquad (4.27)$$

g) Handling in reprocessing centre must be equal to the storage level in reprocessing centre and the quantity of products from retailers to reprocessing centre;

$$hf(t) = sf(t) + \sum_{r} xrf(r,t) \qquad \forall t \qquad (4.28)$$

h) Storage level in reprocessing centre must be equal to the difference between handling in reprocessing centre and quantity of products components from reprocessing centre to plant;

$$sf(t) = hf(t) - \frac{xfp(a,t)}{BQ(a)} \qquad \forall a, \forall t \qquad (4.29)$$

i) The quantity of products from the reprocessing centre to plant must be less than disassembled ;

$$xfp(a,t) \leq \frac{xfq(t)}{BQ(a)} * disrate \qquad \forall a, \forall t \qquad (4.30)$$

j) The quantity of disassembled components required repair capacity must be less than the total available reverse processing capacity in reprocessing centre;

$$\frac{xfq(t)}{BQ(a)} * rrpcf(a) \leq trmf \qquad \forall a, \forall \qquad (4.31)$$

4.6 OBJECTIVE FUNCTION

The objective function is to minimize the transportation costs, inventory costs, disposal costs and production costs. On the other hand maximize the revenue. The objective function is mentioned as below;

$$
\begin{aligned}
\text{Max} \sum_r \sum_c \sum_t \text{xrc}(r,c,t).\text{spp} + \sum_r \sum_t (1 - \text{disrate}).\text{xrf}(r,t).\text{di} \\
- \sum_r \sum_p \sum_t \text{xpr}(r,t).\text{dist1}.\text{utc} - \sum_t \sum_r \sum_c \text{xrc}(r,c,t).\text{dist2}.\text{utc} \\
- \sum_t \sum_c \sum_r \text{xcr}(c,r,t).\text{dist2}.\text{utc} - \sum_t \sum_r \sum_f \text{xrf}(r,t).\text{dist3}.\text{utc} \\
- \sum_a \sum_t \text{xfp}(a,t).\text{dist4}.\text{utca}(a) - \sum_a \sum_t \text{xfp}(a,t).\text{udc} \\
- \sum_r \sum_t \text{xpr}(r,t).\text{upt} - \sum_t \text{uhcf}.\text{sf}(t) - \sum_t \text{uhcp}(t).\text{sp}(t) \\
- \sum_r \text{fcr}(r) - \text{fcp} - \text{fcf} - \sum_r \sum_t \text{xrf}(r,t).\text{spp}.0{,}1 \\
- \sum_a \sum_t \text{xsp}(a,t).\text{ns}(a)
\end{aligned}
$$

4.7 MODEL ASSUMPTION

a) As suggested by Biehl et al. (2007), the model assumes retailers as collecting points as well.

b) The customer demand for final product is known.

c) The pay given to the customers for taking used products is 10% for selling price of this product.

d) Customers provide their used products to nearby retailers. The goods collected in each retailer are transported to the warehouse as soon as possible so that they do not incur any holding costs.

e) In reprocessing centre, where the modules are disassembled, cleaned, tested and sorted for reuse, remanufacture, spare and recycle.

f) The reprocessing centre, the plant and retailers are considered to have fixed costs.

g) When the plant can`t meet the component demand from reprocessing centre, new components may have purchased from suppliers.

h) Transport cost is calculated with respect to distance.

i) If the numbers of components are in excess of demand, then they are stored in reprocessing centre as product till further demand is received. (Mutha&Pokhorel, 2008)

j) The retailers are considered to be an initial collection point. This is a realistic assumption because the customer would be inclined to return the product to the closest origination site to get a refund or to purchase another product. [52]

k) We use a return rate for products from each of the customer zones.

l) For deciding the place for the reprocessing centre it assumed that there are three alternatives. (The alternatives are selected based on the distance to the plant and the rent for each of them.

5. RESULTS&CONCLUSION

In this part of the thesis model implementation, results of the model, conclusion, limitations and suggestions for further research will be given.

5.1 MODEL IMPLEMENTATION

A six echelon network consisting of three retailers, one reprocessing centre, one spare market, one new component supplier, one plant and nineteen customer zones has been considered for the model implementation. With the given assumptions model is implemented in nineteen times for finding the optimal solution. We used for finding the optimal solution an exhaustive search because in the model there is determination for selecting best place for reprocessing centre. For place selection there is three alternative.

For simple illustration of the model, a one type of returned product with two components is considered. The model is solved using GAMS® software.

The distances from plants to retailers and from retailers to customer zones are shown in table 5.1

Table 5.1: Data on distances

Plants to Retailers (p, r) (km)	Retailers to customer zones (r, c) (km)
(342, 111, 450)	(15, 233, 258, 320, 873, 244, 419, 191, 25, 243, 111, 700, 350, 350, 89, 700, 350, 350, 2000)

Also the distances for each alternative for reprocessing centre to the retailers and reprocessing centre to the plant. This data are taken from the website of highway in Turkey.

Table 5.2: The alternatives for reprocessing centre

Alternative 1 (Reprocessing centre in Ankara)	
Retailers to reprocessing centre (15, 453, 579)	Reprocessing centre to the plant 342
Alternative 2 (Reprocessing centre in Istanbul)	
Retailers to reprocessing centre (453, 28, 561)	Reprocessing centre to the plant 111
Alternative 3 (Reprocessing centre in Izmir)	
Retailers to reprocessing centre (579, 561, 11)	Reprocessing centre to the plant 450

The products have fixed cost for disassembly, assembly and transport per unit. And also transport cost for each of the components. This data are taken from purchasing department of the firm.

Table 5.3: Data on transport disassemble and assembly costs.

Transport cost per unit (TL)	Disassembly cost per unit (TL)	Assembly cost per unit (TL)	Transport cost of component per unit (TL)
0,5	50	70	(0.2 , 0.2)

Each of the plant, reprocessing centre and retailers has fixed costs. Fixed costs have involved expense (electricity bill, water bill…), salary of the workers. Also reprocessing centre and retailers have rents. They were shown in table 5.4;

Table 5.4: Data on fixed costs

Fixed cost of plant (TL/year)	Fixed cost of reprocessing centre for each of the alternatives (TL/ year)	Fixed cost of retailer (TL/ year)
2400000	(300000,350000,325000)	(50000, 60000, 50000)

Each of the products has holding costs for plant and the reprocessing centre. They are shown in table 5.5;

Table 5.5: Data on holding cost

Holding cost in plant per unit (TL)	Holding cost in reprocessing centre per unit (TL)
135	120

Demand for the products in each of the customer zones were taken from the purchasing department for the firm. This data are for the year 2008. They were shown in table 5.6;

Table 5.6: Demand rate of products, return rate of used products from customer zones and bom quantity of product

Demand at customer zones per year	Return rate of product in various time zones	Bom quantity of product per component
(1100, 800, 600, 900, 600, 400, 800, 700, 1500, 600, 800, 900, 1000, 800, 880, 1200, 700, 820, 900)	(0.25, 0.25, 0.25, 0.25)	(1, 1)

After we illustrated the model in Gams we find that alternative three (reprocessing centre in Izmir) is the best selection for the firm. The program output is shown below;

Quantity of the products send from plant to the retailers for each of the time period t is shown in table 5.7;

Table 5.7: Quantity of products from plant to the retailers

Plant	Retailer	t(Season)	Xpr
Izmit	Ankara	1	2950
	Ankara	2	1770
	Ankara	3	1180
	Ankara	4	1180
	Istanbul	1	2800
	Istanbul	2	1680
	Istanbul	3	1120
	Istanbul	4	1120
	Izmir	1	2250
	Izmir	2	1350
	Izmir	3	900
	Izmir	4	900

Quantity of products from retailers to the reprocessing centre for each of the time period t is shown in table 5.8;

Table 5.8: Quantity of products from retailers to the reprocessing centre

Retailer	Repro.Cen.	t	Xrf
Ankara	Izmir	1	1180
Ankara		2	442
Ankara		3	295
Ankara		4	295
Istanbul		1	1120
Istanbul		2	420
Istanbul		3	280
Istanbul		4	280
Izmir		1	900
Izmir		2	337
Izmir		3	225
Izmir		4	225

In table 5.9 the quantity of products from retailers to the each of the customer zones for each of the time period t is given;

Table 5.9: Quantity of products from retailers to the customer zones

Retailer	Cust.Zon.	t(Season)	Xrc	Retailer	Cust.Zon.	t(Season)	Xrc	Retailer	Cust.Zon.	t(Season)	Xrc
Ankara	ank	1	550	Istanbul	ist	1	750	Izmir	tek	1	440
Ankara	ank	2	330	Istanbul	ist	2	450	Izmir	tek	2	264
Ankara	ank	3	220	Istanbul	ist	3	300	Izmir	tek	3	176
Ankara	ank	4	220	Istanbul	ist	4	300	Izmir	tek	4	176
Ankara	esk	1	400	Istanbul	burs	1	300	Izmir	izm	1	600
Ankara	esk	2	240	Istanbul	burs	2	180	Izmir	izm	2	360
Ankara	esk	3	160	Istanbul	burs	3	120	Izmir	izm	3	240
Ankara	esk	4	160	Istanbul	burs	4	120	Izmir	izm	4	240
Ankara	kon	1	300	Istanbul	izt	1	400	Izmir	bal	1	350
Ankara	kon	2	180	Istanbul	izt	2	240	Izmir	bal	2	210
Ankara	kon	3	120	Istanbul	izt	3	160	Izmir	bal	3	140
Ankara	kon	4	120	Istanbul	izt	4	160	Izmir	bal	4	140
Ankara	kay	1	450	Istanbul	sak	1	450	Izmir	man	1	410
Ankara	kay	2	270	Istanbul	sak	2	270	Izmir	man	2	246
Ankara	kay	3	180	Istanbul	sak	3	180	Izmir	man	3	164
Ankara	kay	4	180	Istanbul	sak	4	180	Izmir	man	4	164
Ankara	erzrm	1	300	Istanbul	can	1	500	Izmir	den	1	450
Ankara	erzrm	2	180	Istanbul	can	2	300	Izmir	den	2	270
Ankara	erzrm	3	120	Istanbul	can	3	200	Izmir	den	3	180
Ankara	erzrm	4	120	Istanbul	can	4	200	Izmir	den	4	
Ankara	corm	1	200	Istanbul	bil	1	400				
Ankara	corm	2	120	Istanbul	bil	2	240				
Ankara	corm	3	80	Istanbul	bil	3	160				
Ankara	corm	4	80	Istanbul	bil	4	160				
Ankara	sam	1	400	Istanbul							
Ankara	sam	2	240	Istanbul							
Ankara	sam	3	160	Istanbul							
Ankara	sam	4	160	Istanbul							
Ankara	bol	1	350	Istanbul							
Ankara	bol	2	210	Istanbul							
Ankara	bol	3	160	Istanbul							
Ankara	bol	4	160	Istanbul							

In table 5.10 the quantity of products from customer zones to the retailers for each of the time period t is given;

Table 5.10: Quantity of products from customer zones to the retailers

Cus.Zon.	Retailer	t	Xcr	Cus.Zon.	Retailer	t	Xcr	Cus.Zon.	Retailer	t	Xcr
ank	Ankara	1	220	ist	Istanbul	1	300	tek	Izmir	1	176
ank	Ankara	2	82	ist	Istanbul	2	112	tek	Izmir	2	66
ank	Ankara	3	55	ist	Istanbul	3	75	tek	Izmir	3	44
ank	Ankara	4	55	ist	Istanbul	4	75	tek	Izmir	4	44
esk	Ankara	1	160	burs	Istanbul	1	120	izm	Izmir	1	240
esk	Ankara	2	60	burs	Istanbul	2	45	izm	Izmir	2	90
esk	Ankara	3	40	burs	Istanbul	3	30	izm	Izmir	3	60
esk	Ankara	4	40	burs	Istanbul	4	30	izm	Izmir	4	60
kon	Ankara	1	120	izt	Istanbul	1	160	bal	Izmir	1	140
kon	Ankara	2	45	izt	Istanbul	2	60	bal	Izmir	2	52
kon	Ankara	3	30	izt	Istanbul	3	40	bal	Izmir	3	35
kon	Ankara	4	30	izt	Istanbul	4	40	bal	Izmir	4	35
kay	Ankara	1	180	sak	Istanbul	1	180	man	Izmir	1	164
kay	Ankara	2	67	sak	Istanbul	2	67	man	Izmir	2	61
kay	Ankara	3	45	sak	Istanbul	3	45	man	Izmir	3	41
kay	Ankara	4	45	sak	Istanbul	4	45	man	Izmir	4	41
erzrm	Ankara	1	120	can	Istanbul	1	200	den	Izmir	1	180
erzrm	Ankara	2	45	can	Istanbul	2	75	den	Izmir	2	67
erzrm	Ankara	3	30	can	Istanbul	3	50	den	Izmir	3	45
erzrm	Ankara	4	30	can	Istanbul	4	50	den	Izmir	4	45
corm	Ankara	1	80	bil	Istanbul	1	160				
corm	Ankara	2	30	bil	Istanbul	2	60				
corm	Ankara	3	20	bil	Istanbul	3	40				
corm	Ankara	4	20	bil	Istanbul	4	40				
sam	Ankara	1	160								
sam	Ankara	2	60								
sam	Ankara	3	40								
sam	Ankara	4	40								
bol	Ankara	1	140								
bol	Ankara	2	52								
bol	Ankara	3	35								
bol	Ankara	4	35								

Table 5.11: Quantity of components from reprocessing centre to the plant

Repro.cen	Plant	t	Component	Xfp
Izmir	Izmit	1	a1	320
		2		240
		3		160
		4		80
		1	a2	320
		2		240
		3		160
		4		80

Table 5.12: Quantity of components from supplier to the plant

Supplier	Plant	t	Component	Xsp
Supplier	Izmit	1	a1	7680
		2		4560
		3		3040
		4		3120
		1	a2	7680
		2		4560
		3		3040
		4		3120

5.2 RESULTS

When we compare the profits of the firm from the program with reverse supply chain and from the last year profit of the firm without reverse supply chain;

Profit with reverse supply chain; 23.925.550
Profit without reverse supply chain [58]; 22.836.450

The program is calculated with return rate 0.25. That means that quarter of the used products came from the customers. This is a realistic assumption because in Turkey there isn`t a legislation about the used products. If the return rate of the products of the will be 1, the firm can have a closed loop supply chain.

Hence, to determine the differences between the scenarios that changing the return rate of products from customer zones, a more detailed investigation is necessary. Figure 5.1 thus pictures results for every profit for each of the scenarios.

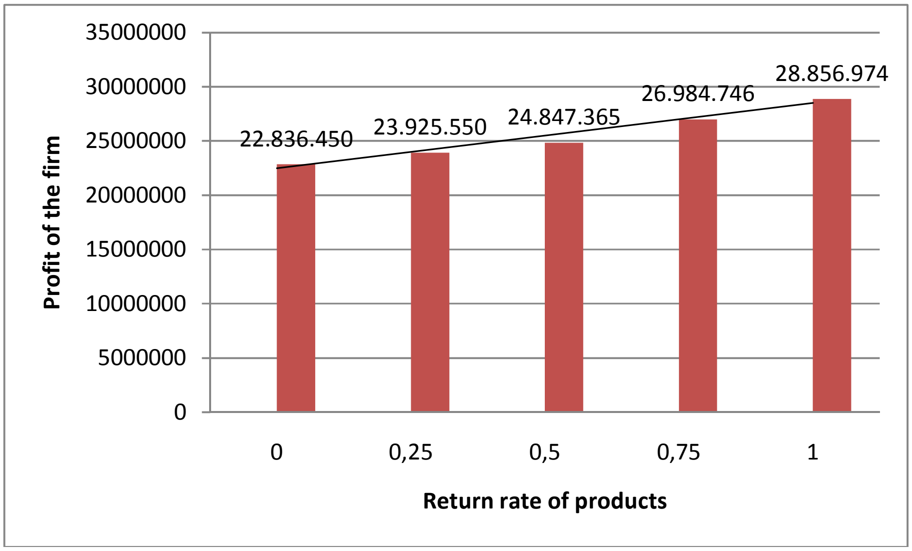

Figure 5.1: The changing of the profit of the firm for each of the scenarios.

These results indicate the differences between the return rates of the products from customers. As a consequence, the profit of the firm becomes bigger when the return rates of products from customers increasing.

5.3 CONCLUSION

Is it possible to have "zero-waste" in all cases? Is it possible to completely recycle, reuse, or compost all the materials from all the goods?

The answer should be yes. It is possible to produce zero waist...it's all around us in nature. Humans are the inventors and only producers of waste. In all sectors, while repair and resale makes up a large part of the activity, ultimately there are also many disposals, recycling and secure product destruction decisions to be made at the end of the reverse logistics chain

Globalization increases energy use and hence CO2 emissions, and causes many other inefficiencies as well. The manufacturing boom in China for example creates a volume imbalance in the global transport system. From European main ports, 41 percent of the containers return empty to Asia. Not only are the volumes of returned empty containers a problem, also the number of products and packaging returned, continue to grow. Reverse Logistics is becoming a strategic issue because returns costs are staggering, materials and energy become scarcer and customers demand green policies.

Now the environment is everybody's problem. So, politics joins in. Legislators increasingly hold Original Equipment Manufacturers (OEMs) responsible for greening their products and supply chains. This is often referred to as Extended Producer Responsibility or EPR for short. Its implementation is found worldwide, but mostly within the European Union. One of the most important industries is Electronics, both for professional and consumer markets.

Supply chain decisions involve number, capacities and locations for supply chain process facilities combined with allocation of goods flows in the system. Goods flows represent intermediate flows between facilities, inbound supply flows, outbound market deliveries, inbound return flows and outbound disposal/thermal disposal flows. Inbound and outbound flows relate to supply points (i.e., suppliers of raw materials), market locations and disposal/thermal disposal locations. The supply chain network structure has most impact on costs, whereas the product design has most impact on energy and waste. We applied an Integer Linear Programming model to support solving this optimization model. Results of numerical studies have indicated that using the proposed integrated logistics operational model, the chain-based aggregate net profits of a selected automotive firm can be improved by 5 percent relative to the existing operational performance of the supply chain. And from the model we can easily see that the return rates of the used products from customers is enormous impact for the closed loop supply chain. As a result of the assumption, there is no waste in the system, everything returned is reused. As with rate of return, the impact of recovery feasibility is enormous. As recovery feasibility goes down, again costs and energy use go up as a result of increased raw material supply and component manufacturing, and the other way around. Due to increased recycling, there is less waste and energy use in model for low recovery feasibility.

Reverse logistics can play a crucial role in logistics management. The latest technology, and the optimization technique, evolutionary algorithm could become a future promising combination for widespread applicability in reverse logistics.

Forward processes add to a large extent to the system`s cost and environmental impact. In other words: avoiding forward supply chain processes by closing the loops at the highest feasible level results in efficient and sustainable supply chains. We refer to this as the closed loop effect.

5.4 LIMITATIONS AND SUGGESTIONS FOR FURTHER RESEARCH

This study presents the framework of the environmental cost of reverse supply chain from a social viewpoint by taking into account the Activity-Based Costing as well as the results of past studies and determines the environmental cost by modeling and simulating the framework using system dynamics. The proposed cost analysis model is expected to be an excellent reference to policy makers. The calculated cost could validate to the companies the need for a reverse supply chain and be used as basic information for deciding on all kinds of subsidy payments. With this model, the whole cost structure of the supply chain can be studied, and the load arising from the restriction can be fairly distributed.

Also, the proposed model could be useful for the simulations needed for various scenario comparisons. For example, deciding on what course of action we are going to take to collect, reuse, reproduce, or recycle a product can be an important issue and the simulation could prove to be useful regarding this issue. The result of analyzing the methods of collecting or transporting products by scenarios could be a good reference in the decision-making process. However, for the proper use of the proposed model, a few more points must be added. For accurate cost distribution, we must determine what sorts of materials consume what sorts of resources, and study the costs. And also the model accepted that the pay given to the customers for returning old products is 10 percent of the selling price of the product. This is not a realistic assumption because of that the different alternatives for different quality products must be added to the model.

The research concludes that further research is required for developing planning and scheduling methods and tools to be implemented in a system environment.

In the future, it is possible to investigate the performance of the applied model on the large scale problems also including real-data.

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