Optimizing the Logistics Costs of the Organization's Services

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ABSTRACT

The closed-loop supply chain network (CLSC) includes all operations related to recyclable products. The CLSC consists of vendors, producers, warehouses, retail stores, clients, garbage dumps, and recycling facilities. Understandably, the manufacturer has a crucial function to play in this logistical ecosystem. After providing consulting services for several manufacturers in the CLSC, we have helped avoid issues like inadequate manufacturing capacity, high transportation costs, longer delivery times, and higher production prices. This study presents a mathematical planning model for creating a closed-loop supply chain system that includes several electronics manufacturers. The objective function of this optimization model minimizes the amount of costs as well as optimizes (maximizes) the amount of affordable and efficient transportation. General Algebraic Modeling Language software (GAMS) is used to solve this optimization model. Our simulated and real-world results demonstrate that the number of production decreases as demand decreases. Thus, given that the objective function of manufacturers is to minimize costs, whenever demand tends to zero, production does not occur. In such cases, shortage of products (the model's shortage variable) also approaches zero, and the value of the objective function (i.e. minimizing costs) will also approach zero. In this paradigm, rising demand generally does not increase the value of the objective function. Our model also demonstrates that increasing the production capacity does not worsen the value of the objective function. Building upon an assumed multi-product model, this study identifies a method to increase the efficiency of the proposed supply chain.

Keywords: Optimization, Minimization, Cost, Logistics.

ÖZ

Kapalı döngü tedarik zinciri ağı (CLSC), son zamanlarda yoğun olarak çalışılan en önemli konulardan biridir. Kapalı döngü tedarik zinciri, yeniden kullanılabilir ürünlerle ilgili tüm işlemleri içerir. Zincir tedarikçileri, üreticileri, dağıtım merkezlerini, müşterileri, toplama departmanlarını, çöp sahalarını ve rehabilitasyon merkezlerini içerir. Üretici bu zincirde çok önemli bir rol oynamaktadır. Bu çalışmada önerilen tedarik zincirinin verimliliğini artırmak için çok ürünlü bir model varsayılmıştır. Uygun üretim kapasitesi eksikliği ve yüksek nakliye maliyetleri gibi sorunları önlemek ve teslimat süresini artırmak ve üretim maliyetlerini artırmak için kapalı döngü tedarik zincirinde birkaç üretici kullanıyoruz. Bu araştırmada, birkaç üretici ile entegre bir kapalı döngü tedarik zinciri sistemi tasarlamak için bir matematiksel planlama modeli tanımlanmıştır. Amaç fonksiyonu, maliyet miktarını optimize etmenin yanı sıra nakliye miktarını optimize etmektir. Model GAMS yazılımı ile çözülmüştür. Ayrıca talep azaldıkça üretim sayısının azaldığını da gösteriyoruz. Amaç fonksiyonun maliyetleri en aza indirmek olduğu göz önüne alındığında, talep sıfır olma eğilimindeyse üretim gerçekleşmez. Bu durumda, eksiklik değişkeni de sıfır olma eğilimindedir. Ve amaç fonksiyonunun değeri sıfır olacaktır. Kıtlığın değişken maliyetleri azalırsa, üretim miktarı azalır veya en fazla sadece bir ürün üretir. Kıtlık maliyetleri küçükse, üretim sıfır olacaktır. Genel olarak, bu modelde artan talep, amaç fonksiyonunun değerini iyileştirmez. Ayrıca üretim kapasitesini artırmanın amaç fonksiyonunun değerini kötüleştirmediğini de gösterdik.

Anahtar Kelimeler: Optimizasyon, Minimizasyon, Maliyet, Lojistik.

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Chapter 1

GENERAL INVESTIGATION

1.1 Problem Statement

A closed loop supply chain is shown in Figure 1-1Parts are sent to plants by suppliers. Additionally, factories fill orders for products. The trucks from the factories themselves or by the transportation firms transport the manufactured goods to the distribution centers, where they are subsequently distributed to the clients. The selection of trucks is based on the optimal amount of cost, each of which has a lower cost, and the truck is used. Factory trucks and trucks from independent freight firms can be employed concurrently to speed up the delivery of products, meet consumer demand, avoid traffic jams, and avoid vehicle shortages. A number of after-consumption products by consumption the donors are returned and taken to collection centers. Some products have not yet reached the end of their shelf life and can be reused after re-cleaning and cleaning. Others are separated in the product separation section and turned into parts. Parts that are intact can be reused after cleaning and rebuilding. However, certain components are useless and ought to be buried or eliminated. These items, including chemical batteries, chips, and other parts made of chemicals, plastics, and other polluting materials, are bad for the environment and take a long time to recycle. In order to clean up technology, these parts are therefore taken to waste disposal and disposal facilities. Xerox and IKEA are among the companies that use the green supply chain. After the reconstruction and cleaning operations, the parts will be transferred to the rehabilitation centers to perform the rehabilitation operations, because the capacity of the rehabilitation section is limited. We will use several rehabilitation centers if necessary. The reconstructed pieces are brought to the factory warehouse following the reduction step so they can be employed as a new part. Since there aren't many recovery and collection facilities, suppliers are contacted as needed and given refurbished parts in exchange for new raw materials. For the original manufacturer, factors like quality and timely delivery are just as crucial as the part's price. The number of optimal components and products in each part of the network must be specified. For example, the return components themselves are a variable. These variables are tactical choices. The manufacturing rate and the cost price of the product are directly impacted by the availability of fresh raw materials and reconditioned parts in the CLSC network. Lack of parts needed to produce the product as well as lack of products in distribution centers will increase costs. Appropriate systems, especially in the electronics industry, can be implemented, for example, the customer delivers the product to the dealership after use, and the dealerships offer the new product to the customer with a reasonable discount percentage, in which the customer is encouraged to Use chain products. Other customer orientation policies can also be used in this chain. In the reverse part of the supply chain, quality standards in remanufactured items are far less than their new counterparts.

The military and the aircraft industry are examples of this model. Pishvaei (2015). Although the quality of products increases through remodeling, the useful life of these parts is far shorter than their new counterparts. Purchase costs include more than 50% of the costs of all factories. So, the purchase function is an impressive factor. In reverse logistics, new parts or raw materials are purchased by suppliers. In addition to purchase costs, delayed delivery can have a negative impact on production by increasing purchase costs, so shortages will be allowed in this system. We do not need to be content with just one manufacturer. In competitive markets, manufacturers should be used who produce high quality and reasonably priced products and also have the least shipping costs. In previous research, only one manufacturer was required, and several manufacturers were not used. The model that will be presented is the first model that uses several manufacturers in the closed chain supply chain. In this research, fixed producers are considered, and the model will determine how much each producer produces in order to optimize the conditions.

In a closed loop supply chain network, the criterion of product efficiency is much more important than an open loop. Because the product must have properties such as high durability, good quality to be able to be reused, in addition, a number of destroyed products are classified according to product performance criteria and affect the final price. The goal of the reverse supply chain is not only to reduce costs and increase profits, but also to reduce environmental pollution caused by polluting products, which is one of the important goals of this system, which is defined in various articles as green logistics. Among the environmental criteria that can be considered and mentioned in authoritative articles are recycling, technological cleaning, reduction of pollution and environmental costs, as well as the use of CO_2 equivalence.

This research presents a CLSC network that includes 1) collection, 2) recovery, 3) destruction centers where manufacturers use new and refurbished parts to produce a new product. So, manufacturers buy new parts from suppliers. The main purpose of this network is to determine the optimal amount of products and parts in each part of the network. figure 1. The network shows the reverse supply chain.

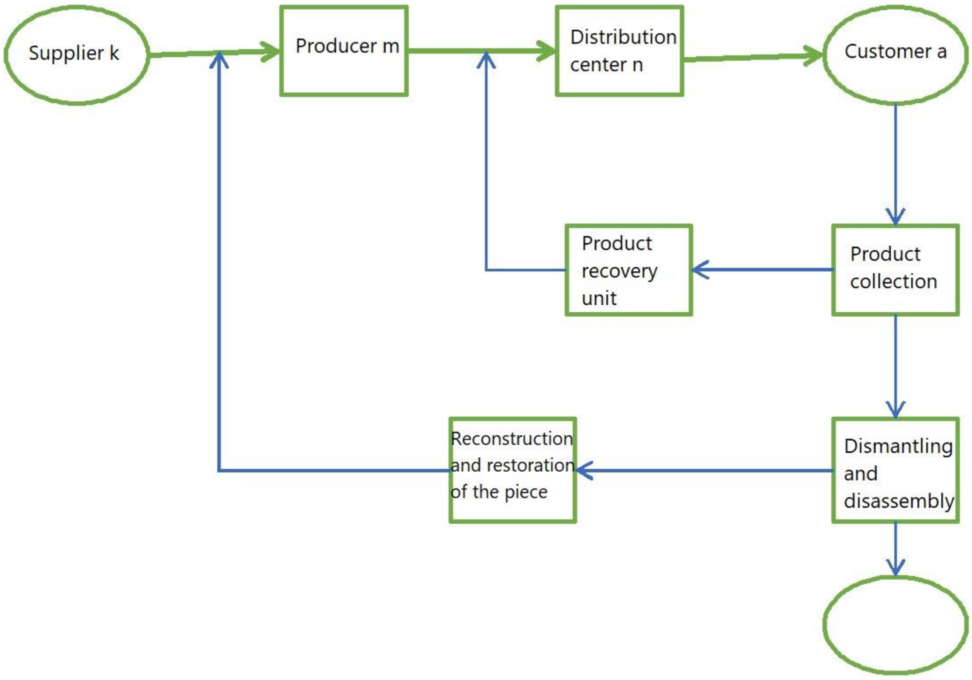

Figure 1.1: Reverse supply chain network with several manufacturers

1.2 Importance and Necessity of Research

Managing a logistics system efficiently has emerged as a critical issue in cutting costs for businesses, especially multinational corporations that operate in an environment of intense competition, as a result of the growth of the global economy and the spread of e-marketing among nations. The integrated design of direct and reverse logistics networks, which may avoid the obstacle generated by the separate design of direct and reverse logistics networks, is one of the ideal domains for integration in logistics networks.

1.3 Aspect of Novelty and Innovation of Research

In this research we use a different transport system which considers recycling points and multiple manufacturers.

1.4 Specific Objectives of the Research

Among the specific and main objectives of this research we are focusing on the following:

• Indicating the ideal number of goods and parts for each section of the network.

• Reducing the system's overall cost.

• maximizing the system's overall transport capacity.

• Disposal of waste, hazardous materials and other consumer wastes and industrial and manufacturing enterprises

1.5 Research Questions

In this study our research centers around the following questions:

- How to achieve the optimal amount of profit and cost with several manufacturers and several suppliers in the supply chain depending on the ring?
- Which manufacturer and which supplier should we use?
- How many pieces should we order? How much product to produce?
- How to reduce production costs by using reconstructed parts?
- What vehicles should we use to minimize shipping costs?

1.6 Research Hypotheses

In our research we consider the following hypotheses:

- An integrated supply chain network increases supply chain efficiency.
- Recycling points minimizes waste points.
- A hybrid meta-heuristic solution algorithm improves the problem-solving process.
- Environmental factors prevent the network from harming its surroundings.

1.7 Definition of Specialized Words and Terms

Logistics network:

> "Performing activities to ensure that the right product is delivered, in the right amount, at the right time and in the right conditions and in the right place for the right customer and at the right cost."

Reverse Logistics:

The term "logistics" refers to the actual movement of goods and materials from the stage of preparation for raw materials through the creation of the finished product, including jobs like transportation and warehousing. Reusing, recycling, or recycling products is one of the newest developments in logistics management. When a product reaches the end of its useful life, it is bought back from the user, and after being disassembled, the pieces that can be reused enter the life cycle as scrapped items.

Supply Chain:

Chain includes organizations and processes that create goods, information, and services and deliver them to consumers. Purchasing, cash flow, material handling, production planning and control, inventory and logistics control, distribution and delivery will also be included in this chain.

1.8 Chapter Summary

As we saw in this chapter, first the research problem was described and then we stated the goals, questions and innovation of the research and also we explained the keywords of the research which in the second chapter we will express the generalities of the research.

Chapter 2

A REVIEW OF THE RESEARCH'S LITERATURE AND BACKGROUND

2.1 Introduction

Supply chain management is one of the most commonly discussed topics in the business literature. It is a fundamental principle for organizations to build a sustainable competitive advantage to stay ahead of the market. The need for coherence and integration of different elements in supply chain management has been recognized by most companies as an important factor in staying competitive. The coordination and coherence of various supply chain management variables become increasingly important for establishing a competitive edge as more and more businesses become aware of the performance of their supply chains.

Today, distribution companies, raw materials, and transportation are designed to improve the efficiency and productivity of their systems due to the development of manufacturing industries, the existence of intense global competition between businesses, the shortening of the product life cycle, the time needed for marketing, and the various customer needs in various locations and distances from the place of production. In order for the products to be delivered to clients on time, distribution and transportation systems must be able to distribute the product at the lowest cost and in the shortest amount of time.

In production systems and workshop flows and in production lines and assembly of goods and products, the need for correct and economic planning with the lowest cost and production cycle time to maximize production and the ability to respond in a timely manner to customer needs in today's competitive markets.

In general, the need to reduce the production costs of companies in the production systems has led experts and planners of production systems in order to minimize material costs and increase production levels and Productivity Use the best planning, scheduling and sequence of operations possible.

This chapter aims to offer a general overview of the supply chain as well as articles on topics related to the integrated supply chain, including supply chain scheduling, facility location, routing, perishable items, and the use of cutting-edge and meta-heuristic algorithms.

2.2 The Concept of Supply Chain Management

One of the most important subjects examined by researchers over the past 20 years is the idea of "supply chain management." Undoubtedly, what has created and spread such an attitude is the effort for the survival of organizations, increasing competitiveness, closer communications, and advances in information technology. Organizations need to spend time and money on timely delivery, good quality and price reduction in order to stay in the manufacturing sector, and what works in this area is the use of supply chain management. With the advent of industry in the 21st century, drastic changes are taking place that are changing the industrial and economic landscape of the world.

Customers are requesting lesser quantities of customized goods as the market has truly gone worldwide. Most businesses focus on market demand and offer a greater variety of items as well as more new products more quickly. For all manufacturers, these shifts have brought about inescapable difficulties and fresh logistical problems. In the 1970s and 1980s, companies took complete control of their manufacturing operations. This is accomplished through the use of systems like production resource planning and human resource planning, as well as scientific production and material planning, workshop scheduling, and control. In the 1990s, companies tried to establish themselves globally. Companies used holistic quality management to control their processes and create continuous improvement, and timely production techniques and zero inventory were introduced so that factories could use them as a way to reduce costs while improving quality. Most of these companies believe that the next step they need to take to increase profits and market share is efficient supply chain management.

In a supply chain, raw materials are first made, then goods are produced in one or more factories, and finally delivered to wholesalers or customers. To reduce costs and improve service, supply chain efficiency strategies at different levels of the supply chain must be considered. Supply chains include manufacturers of raw materials, production centers, warehouses, distribution centers, and wholesalers, as well as raw materials, inventory, and finished products that flow between suppliers, factories, and customers. It is challenging for businesses to function independently from suppliers and other business partners in today's competitive environment. Companies are always looking to reduce costs and at the same time increase the quality of their goods and services.

Since the 1980s, interest in the idea of supply chain management has increased. This interest increased sharply when companies saw the benefits of doing business with other partners. The foundation of the supply chain management idea is the creation of a value network made up of many businesses. These entities are committed to providing resources and information to achieve the goal of managing suppliers as well as managing the flow of materials and components.

Supply chain is an integrated system of interrelated processes in order to: 1- Obtain the required materials and parts, 2- Convert raw materials into products, 3- Evaluate products, 4- Distribute products to customers and 5- Facilitate Information transfers between supply chain components, including suppliers, distributors, intermediaries, retailers, and customers. The main goal of this chain is to reduce costs, increase effectiveness and efficiency, and generally increase profits for all its stakeholders. The chain consists of two opposing currents: the direct movement of products from the supplier of raw materials to the customer and the movement of customers (photos) of information and materials from the customer to the suppliers.

This chain consists of two parts: internal logistics and external logistics. Internal logistics or material management refers to the activities of receiving materials, storing and controlling materials until the required product is prepared. External logistics or product distribution is the exit of products to reach the customer and provide the necessary services to him. An important point in the supply chain is the connection of components that are interconnected as links, information must be shared accurately and simultaneously to make the best decisions Christopher and Jacob (2005-2016)

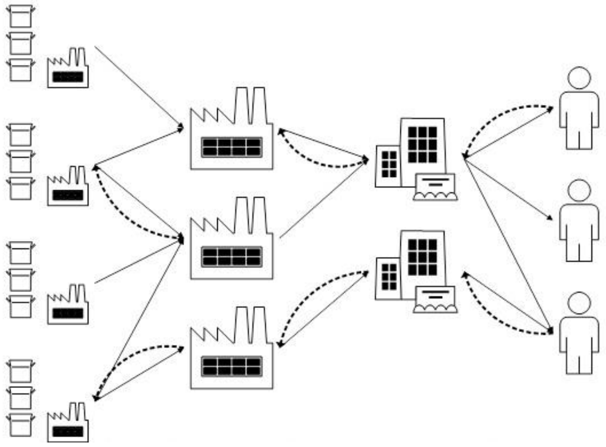

Figure 2.1: Display of supply chain configuration (Nakhaei, 2004)

2.3 Supply Chain History

The term "supply chain" was coined in the mid-1970s. The term was used to describe the transfer of electricity to the final consumer by Banbury (1975). Of course, it was not until 1980 that the term "supply chain management" was introduced as a concept. Oliver and Weber (1982) discussed the potential benefits of integrating internal business activities, including procurement, production, distribution, and sales, into a coherent framework. Steven (1989) defined supply chain management as the integration of the business activities of a business involved in the flow of materials and information from the input to the final output of the business. According to Hartland (1996), binary or multiple relationships between suppliers are becoming part of the supply chain process.

As a comprehensive definition, Thomas and Griffin (1996) defined supply chain management as follows:

> "Supply chain management is the monitoring of materials, information and financial flows, which moves in a process from supplier to producer and then wholesaler, retailer and consumer."

Other definitions of supply chain management include:

Gatorna (1998) defines supply chain management as expressed by Lambert(1998) as an integrated philosophy for managing the total flow of materials in a distribution channel from the primary supplier to the final customer.

Handfield and Nicholas (1999) defined supply chain management as follows:

> "Supply chain management to integrate all activities related to the flow and conversion of goods from the raw material stage (extraction) to the final state (for consumption) as well as related information flows, by improving supply chain relationships to achieve a viable position "It is called reliance and continuity."

From the perspective of Simchi. (2000), supply chain management is a set of measures that try to integrate service and product suppliers, manufacturers, warehouses, and vendors so that goods are shipped in optimal quantities to the right places and at the right time. Various activities are essential for the success of supply chain management, including:

- Integrated and coherent performance
- Information sharing
- Coordination and cooperation
- Having a common goal and focus on customer service
- Process integration
- Establish a long-term relationship

In another definition, the supply chain includes the manufacturer, suppliers, buyers and customers. In other words, all groups work in an expanded organization to market a product that the customer is willing to pay for. This multi-group company operates as a large organization and makes optimal use of shared resources (people, processes, technology, performance metrics) to achieve operational synergy, resulting in a high quality, low cost and ease product or service. Access Waters et al. (2003)

A system of facilities and operations that collaborate toward the supply, production, and distribution of items to clients makes up the supply chain. Supply chain management is a set of methods used to create efficient coordination and coordination of suppliers, manufacturers, storage centers and retailers to deliver the desired goods in the desired quantity and at the right time and place with The lowest possible cost (maximum possible revenue) and with the desired level of service to be provided to customers Zhou (2010)

2.4 Supply Chain Integration

One of the important goals of supply chain management is integration. Stadler and Kilger (2002) believe that a supply chain is integrated by combining the movement of goods with the flow of financial and operational information between the parties concerned. In the evolution of the manufacturing industry, some leading factories have come to the conclusion that selling them as expected would not be profitable if they relied solely on traditional supply chain management attitudes.

The answer to the question of how to achieve a successful supply chain is that information sharing and operational planning are the keys to success in supply chain integration:

- But what information should be shared?
- How should it be used?
- How does information affect supply chain design and operations?
- And finally, what kind of integration should be implemented?

Information systems and technical knowledge is one of the most important tools of efficient supply chain management. In fact, investment in supply chain management is made through the opportunities that result from the careful and complex analysis of chain information. The first issue with information in supply chain management is not how information is obtained but what information should be transferred, what information is important to the supply chain and which can be ignored without any problems, how information should be analyzed and how they are used, what is the effect of information technology in this field, what structure should exist within chain organizations and what structure should exist between supply chain organizations, and finally whether systems and information technology Can it be considered as the main tool to gain a competitive advantage in the market?

Efficient supply chain management is successful when it can fully meet the needs of the customer and create value for him, while ensuring the long-term profit of business partners. In fact, the goal is to create a win-win situation. A supply chain partnership is a relationship formed between two independent members of a supply chain through the sharing of information at different levels to achieve specific goals and benefits, including the reduction of overall costs and inventories.

Mentzer (20001) argue that the value chain is a network of steps that perform activities to create added value. While participating, this group tries to control uncertainty and threats at different levels of the chain. He calls this type of inter-organizational partnership channel cooperation or strategic outsourcing. He believes that survival in the global competitive market no longer depends on open strategy but on the ability of the company to cope with changing conditions and uncertainty on both sides (upstream and downstream partners) and this requires a review of inter-organizational management using It is an information technology tool.

2.5 Factors Leading Organizations to Supply Chain Management

2.5.1 Need for Improvement Activities

Over the past few decades, many organizations have adapted their operations to activities such as lean manufacturing and total quality management. As a result, they were able to improve quality. Improving quality increases production costs, and organizations try to reduce these costs through the use of supply chain management. Although there are still opportunities for improvement for many organizations and the main benefits have been realized, there are still many opportunities in supply, distribution and transportation in the supply chain that can be created by Simchi and Ba Lu (2004-2007).

2.5.2 Increasing the Level of Outsourcing

Organizations are increasing their outsource, they have put the purchase of goods and services on the agenda instead of producing and supplying them themselves. As outsourcing increases in organizations, organizations increase supply and procurement activities (warehousing, transportation, delivery, etc.). Although the cost and time spent on this activity and other activities may be unnecessary Simchi and with Lou (2004-2007)

2.5.3 Increasing the Cost of Transportation

Transportation costs are rising and need to be managed more carefully. Simchi and Ba Lou (2004-2007).

2.5.4 Increasing Globalization

The physical length of the supply chain has grown as a result of the spread of globalization. In a global supply chain, supply chain management challenges increase.

Long distances between customers and manufacturers lead to longer delays as well as increased opportunities for delivery irregularities. As much as there is a difference in money and currency, there is also a difference in language and culture. Simchi and Lu (2004-2007).

2.5.5 Need for Inventory Management

The effectiveness or ineffectiveness of the supply chain is significantly influenced by inventories. Therefore, inventory coordination across the supply chain is important. Lack of resources can severely disrupt the workflow over time and delay the production of the product, while excess inventory can also lead to unnecessary costs. There should be no shortage of inventory in some parts of the supply chain or there should be a surplus of inventory in some other parts of Simchi and Lou (2004-2007).

2.6 Supply Chain Types

Different types of supply chain include four types, which are:

partnership

In a partnership, there is a reciprocal relationship between the buyer and the seller.

Basic supply chain

The core supply chain consists of a company with a supplier and a customer. Which directly connects the upstream to the downstream by one or more streams (financial, material and information).

Extensive supply chain

Extensive supply chains include suppliers (first tier) and customers that link upstream to downstream by one or more streams (finance, materials, and information).

Final supply chain

The final supply chain includes all companies involved in the upstream flow of materials, information and finance from the primary supplier to the final customer.

2.7 Effective Factors in Implementing a Competitive Supply Chain

2.7.1 Buy

Purchasing and procurement include managing the procurement process, setting up contracts, and deciding where to buy. Procurement must meet the needs of the company's key suppliers and support the company's ability to produce goods and services. This task is difficult for any organization that is a retailer, service provider or manufacturer. The role of the internal and external supply chain depends on how well this task works Simchi and Lou (2004-2007).

2.7.2 Selecting a Supplier

Management should review market segments to select a supplier and review the performance of current suppliers. Outsourcing is a special example of a willingness to cooperate. The decision to outsource an activity sometimes goes back to decisions such as manufacturing or purchasing, and because it affects the amount of directly controlled activities in the internal supply chain, it implies supply chain management. The decision to build or buy is particularly important, because a company must first have a clear understanding of its core competencies (core competencies) and maintain them. The dimension is control and flexibility in outsourcing, where it relates directly to supply chain management. As a result, supply chain managers need to adjust and adjust high levels of control with flexibility in order to change. Long-term contracts should be used when the company is confident that suppliers are in line with the company's long-term strategic plans. Fauket (2007).

2.7.3 Distribution

While the purchasing process is related to the material input stream, the distribution is related to the material output stream. Distribution is the management of the flow of materials from the producer to the customer and from warehouses to retailers and involves the warehousing and transportation of goods. Distribution develops the company's market and creates temporal and spatial value for goods. Two examples of decisions faced by distribution managers are: warehousing of finished goods and the method of transportation Fawcett (2007).

There are different attitudes towards the location of warehouses of manufactured goods. The first approach is to locate inventory close to customers, distribution centers, or close to wholesalers or retailers. The above method can have two advantages: speed in delivery and reduction of transportation costs in a way that can stimulate sales. Companies that use a warehousing production strategy typically use this method. Fawcett (2007).

Finding the best way to locate inventory is especially important for international operations. Large companies around the world are trying to open distribution centers in strategic cities to support sales activities.

Placing inventory close to the customer reduces the slowness and time delay between receiving the order and delivering the goods, which is an important competitive advantage in local and international markets, as well as reducing shipping costs. If the competitive priority is to produce custom products, storing manufactured goods carries the risk of unwanted products.

The second method means keeping inventory in the factory or not keeping the manufactured goods. In some cases, the second method refers to inventory consolidation, and when demand is unpredictable in different areas and demand for goods fluctuates, an advantage is taken into account by Fawcett (2007).

2.8 Factors Affecting Supply Chain Management

2.8.1 Information Management

Today, the role, importance and position of information is very important for companies and organizations Processes become more effective and efficient as well as simpler to manage when information is transferred and circulated properly. The topic of activity coordination is a key one in the supply chain discussion. This also applies to the discussion around information management in the chain involving information systems management and information transfer. Coordinated and appropriate information management between partners will cause us to have increasing effects on speed, accuracy, quality and other aspects. Information management will be effective in various sectors, including: 1- Exchange and processing of data between partners (such as exchange and processing of technical information, orders, etc.), 2- Collection and processing of supply and demand information, etc. to predict market trends and Future conditions: 3. Establish and improve relationships between partners, transfer, move, process and access logistics information to integrate transport processes, order and fabricate order changes, production scheduling, logistics plans, and Chopra warehousing operations (2007).

2.8.2 Relationship Management

Relationship management has a tremendous impact on all areas of the supply chain as well as its level of performance. The most important factor for successful supply chain management is the relationship between the partners in the chain. In such a way that the partners have mutual trust in each other's capabilities and operations. Therefore, in the development of any integrated supply chain, the development of trust and confidence among partners and the design of reliability for them are critical and important elements for sustainable success. Chopra (2007).

2.9 Supply Chain Processes

A supply chain is a series of processes and flows that occur between different stages of the supply chain and are combined to meet a customer's need for a product. There are two different perspectives on implementing a process perspective in a supply chain. Processes are separated into a supply chain within a succession of cycles in the cyclical perspective. Each action is an interaction between successive stages of the chain. Compressive-tensile perspective: In the compressive-tensile perspective of processes, whether they respond to customer orders or anticipate them; They are divided into two dependent parts. The traction process begins with a customer order, while the compression process begins with a forecast of customer demand Buzart (2016) and Chuchen (2004).

2.9.1 Cyclical Perspective

In this view, the processes that take place along the supply chain are divided into four cycles, which are as follows:

- Customer order cycle
- Refill cycle
- Construction cycle
- Procurement cycle

Each of these cycles occurs between two stages in the chain. Of course, these four cycles cannot be clearly seen in all supply chains, but they can be seen in most chains.

2.9.2 Compression-tensile View

Tensile processes are performed when the customer demand starts, but compression processes are performed by anticipating the customer demand. However, in performing stretching processes, customer demand is known and specified, while in compressive processes, demand is unknown and must be anticipated.

Because they respond to client demand, stretching processes are sometimes referred to as reaction processes. Because compression processes are a response to forecast rather than actual demand, they are regarded as risky or uncertain processes. A supply chain's tensile and compressive limits are different from one another.

2.10 Supply Chain Challenges

The possibilities for supply chain management have undergone a fundamental transformation as a result of Internet connectivity and processing capacity, making supply chain management much more effective. Companies and organizations that make effective use of these capabilities will improve and expand their supply chain as follows:

- Through the Internet, the entire supply chain, from the supplier to the client, is connected to one another, sharing data on inventory levels, manufacturing capacity, order status, and customer demand.
- Companies across the supply chain use shared supply chain information to plan based on joint decisions.
- Decisions are made on a real-time basis using timely information about the status of supply chain issues.
- Revenue and profits are used as performance matrices for the supply chain. Failure to do so will result in difficult circumstances. For further explanation,

it should be noted that the challenges and solutions that exist in this regard are different for different industries, and here we refer to the challenges that some key industries face.

Organizations and companies that use advanced technology have been at the forefront of their supply chain flexibility and have operated effectively because of the short lifespan of their products, which requires flexibility and responsiveness. A close and accurate link between supply and demand, as well as exceptional customer responsiveness and effective communication across the supply chain, are required to preserve the product's profitability because a product's value rapidly drops throughout its limited lifespan. Fermi (2014).

The supply chain of businesses in this sector is made up of contract manufacturers and businesses that carry out logistics and support functions as third parties for those manufacturers. The high-tech industry uses outsourcing often. Therefore, in this supply chain, which is an intertwined network of different service providers, they should be given timely information about the supply and demand situation. In this case, it is vital for the organization to maintain responsibility for network control operations, while outsourcing most executive tasks to contractors outside the organization. With this strategy, the company can switch service providers as needed without interrupting the chain network. Williamson (2008).

In order to provide all service providers knowledge about the product and its components and to promptly update consumers about the status of their orders, it is crucial to establish a flow of information across the supply chain.

Orders can be received in real-time by organizations, and in that unit, as soon as orders are received via the Internet, information is provided to all participants in the supply chain network, and at the same time, efforts are made to satisfy the customer's actual need. In addition, service providers can use this opportunity to anticipate their future plans, so that they can plan their capacity properly.

Accurate information on inventory level and capacity allows customers to find out the actual delivery date. Online sales help successful and leading firms balance supply and demand through the use of dynamic pricing.

Prices are adjusted based on inventory level, production capacity and remaining product life, and customers will be able to compare prices in real time, order online and find out the exact delivery date of the product. For example, in the automotive industry, one of the major challenges is to produce the product required by the customer in a short time frame, thus preventing an increase in the level of inventory of products that are not requested by the customer.

Long latencies and large inventory levels are two common supply chain problems in this business, and tackling them calls for a flexible supply chain. The industry must switch from the push model to a traction one, where output is based on actual consumer demand. This model calls for a flexible and linked chain in which the proper links are formed among components of suppliers and service providers. A demand elasticity model enables dynamic pricing, and revenue can be raised by changing prices in response to actual demand and available capacity, for instance by producing cars in small quantities at higher prices when demand is higher and the price is lower.They turn a dynamic pricing model based on dynamic pricing supported by a responsive supply chain can reduce latency and eliminate the high level of inventory in the supply chain. The stock price of a firm can also directly be impacted by a successful supply chain.

Given the linear structure in the supply chain of most industries, the existing problems of this structure are Fermi (2014).

Accumulation of demand forecasting errors due to repetition of forecasting operations along the supply chain by members:

- Lack of knowledge about the capacity of suppliers
- Existence of long preparation times for ordering as an incentive to accumulate safeguards
- High ordering and shipping costs as an incentive to accumulate reliable reserves
- Lack of knowledge of false claims created by the application of discount policies
- Multiple decision points along the supply chain
- Lack of knowledge of the real pattern of strategic consumer market demand in relation to supply chain design

2.11 Supply Chain Network Design Issue

Supply chain network enables the creation of an effective and efficient platform for supply chain management. This network is a set of facilities that play a role in shaping the supply chain. The network includes a set of raw material suppliers, product factories, product distribution centers, and customers, with the goal of minimizing the total cost of building such a network to meet customer demand. There are two types of costs in the network, the first type includes the costs of establishing and constructing factories and distribution centers, and the second type includes the costs of purchasing, producing, distributing and transporting goods at each stage of the supply chain network. Bamoon and Sha (2006).

The following figure shows a three-tier supply chain network.

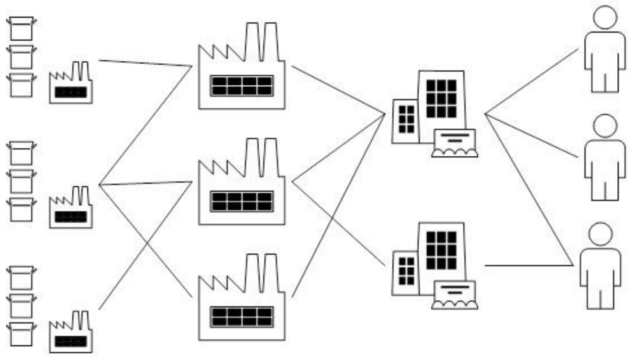

Figure 2.2: View of the three-level supply chain network (Nakhaei, 2004)

2.12 The Five Main Parts of Each Supply Chain

Each major and strategic category, such as supply chain management, has its components and components, which are described in detail in the following five main sections of each supply chain. Hugos (2011).

2.12.1 Production

What products does the market want? How many products should be produced and when? This activity includes the creation of core programs for plant capacity, workload balance, quality control and equipment maintenance.

2.12.2 Inventory

What inventories should be stored in the supply chain at each stage? How much inventory should be kept as raw materials, semi-finished and manufactured goods?

The main purpose of inventory control is to act as a shield against supply chain uncertainty. However, maintaining inventory can be costly.

2.12.3 Location

Where should facilities for production and storage of inventory be located? Which locations are most efficient for production and storage? Should existing facilities be used or newly built facilities used? One of the most important decisions is to determine the possible ways for the product to flow for delivery to the end customer.

2.12.4 Transportation

We start by the question of how should inventory be transferred from one supply chain location to another? Air and ground freight are usually faster and more reliable, but they are expensive. Sea or rail freight is less expensive but usually has a longer transportation time and more uncertainty. This uncertainty is offset by the carrying of more inventory by sea or rail. Finally, the question arises which method of transportation is better?

2.12.5 Information

Correct and timely information is maintained to make better decisions and better coordination. With the help of good information, people can make more efficient decisions about what to produce and how much, or to make more effective decisions about where inventory should be located and how best to transport inventory.

The interactions and interactions for these five main parts of the supply chain can be clearly seen in the figure below. In this picture, we can see the importance of information sharing in the supply chain, which is the boundary between the other four parts, so that their coordination and correct operation depends on the performance of this part, which is timely and at the best possible time and with excellent information quality. To share between other sections.

Finally, the sum of the interactions of these sectors determines the capabilities and efficiency of the supply chain of companies. The capacities and efficacy of the supply chain substantially influence what a company is able to do as well as how effectively it competes in the market. If a corporation plans to compete on price rather than quality, its supply chain must be cost-effectively optimized. If a service company's strategy in a competitive market and competition is based on customer service and customer convenience, that supply chain must be optimized for better accountability. The marketplaces in which a firm works and its supply chain both influence who it is and what it does.

Figure 2.3: The five main parts of each supply chain

2.13 Supply Chain Management Modeling

The supply chain system consists of various components from the supplier of raw materials to the final customer, each of which components of this integrated system have their own subsystems with different dimensions. In some chains the main focus is on the production system, and in others the distributors or suppliers are of strategic importance.

To achieve the required performance at the chain level, supply chain modeling identifies the various chain elements and how they relate to one another. In this regard, the type and level of modeling depends entirely on the conditions of the system.

Different businesses face different types of supply chain management issues and problems. From a conceptual point of view, all these problems can be solved in the same way. In this way, first the problem and problem are modeled, then the model is analyzed and a suitable solution is obtained. This method seems simple and efficient, but it is not. There are countless models, each with its own advantages and disadvantages.

Linear Programming Models

In linear programming, a problem is modeled using linear mathematical relations, and the relations and their effect on the actual performance of the model are examined. These models have no qualitative aspect and everything is small in them. The real power of linear programming is that if there is at least one suitable alternative method, an optimal solution will usually be found.

Capacity analysis or transportation issues are a good example of this. If the shipping cost of each product is the same, then the shipping cost variable is a linear equation. The same is true of the cost of producing products that have the same price. Omid (2006), Cao (2011) and Paxoi (2013) are some of the researches that can be mentioned in this field.

2.14 A Brief Review of the Literature

Review of Literature Related to Supply Chain

So far, numerous researches have been presented in the field of planning, production scheduling or supply chain network design. To this end, we have tried to report some of the latest research conducted in recent years.

Gnoni (2003) examined production planning in multi-location production systems. In their research, it is assumed that there is an external demand for some semi-finished parts, which is also a possible demand. These semi-finished items can be completed in various factories in the supply chain. Some raw materials and semi-finished materials may also be purchased from outside the supply chain to produce original products and semi-finished items. To solve the problem, they used a combination of complex integer mathematical programming models and simulations. Finally, they tried to take advantage of both models in dealing with this issue.

Rio et al. (2004) examined supply chain planning using two-stage planning. In their case, it is assumed that the supply chain consists of two stages of production and distribution. It is assumed that factories may share resources. In the distribution phase, each distributor has its own capacity to maintain inventory. The goal is to determine the level of production in factories and the level of inventory in distributors, so that the costs of production, shipping to distributors for manufacturing companies, and warehousing and shipping costs to distributors are minimized. They used two-tier planning to solve this problem.

Pishvaei et al. (2011) presented a robust optimization model to investigate the inherent uncertainty in the input data of the closed-loop supply chain design problem. They first developed a definite complex linear integer programming model for closed-loop supply chain network design. The robustness of the solutions produced by the robust optimization model and the solutions of the definite mixed-programming model of linear integer in various situations are then compared. Finally, the solid counterpart of the model is shown using the application of robust optimization theory.

Shankar et al. (2013) presented a multi-objective optimization problem for a four-tier single-product supply chain consisting of suppliers, manufacturing plants, distribution centers, and customer areas. The number and location of factories in the system, the flow of raw materials from suppliers to factories, the quantity of products sent from factories to distribution centers, and the flow of products from distribution centers to customer areas are some of the major decisions taken into account in this study. So that the goal is to minimize the cost of transportation and location of facilities and meet the maximum demand of customers. Finally, they used a hybrid multi-objective particle swarm optimization algorithm to solve the problem.

Wu and Zhang (2014) investigated how to build a supply chain network with an external source, a number of possible distribution hubs, and a number of retailers when there is uncertainty around the demand for a number of different items. They hypothesized that the demand of each retailer for all goods would be met by a distribution center. The goal is to minimize system costs such as location, transportation, and inventory. They presented a nonlinear integer programming model for the problem. In addition, they used a page-cutting approach based on mathematical inequality. Finally, the computational results show that the proposed algorithm is solvable for a medium size problem.

Fattahi et al. (2015) examined a new issue in the design and planning of multi-level and multi-product supply chain networks in a multi-period horizon so that customer regions have price-dependent demands. In this study, based on demand-price relationships, a general approach to achieve commodity price levels is presented and then a mixed linear integer programming model is developed. Finally, considering the problem of a refrigeration simulation algorithm using innovative developed liberalization-based methods for capacity planning and pricing is presented.

Among the important Persian studies studied in the field of supply chain, the following can be mentioned:

Sadeghi et al. (2009) in their research, after examining the various models of material flow in the supply chain, with an integrated approach to modeling material flow along the supply chain in the supply sectors, produced a distribution in Kachiran factory. In this study, after solving the model with genetic algorithm, they selected the best satisfactory answer that has the lowest cost. Then, for validation, the proposed model is compared with the actual amount of variables in the study period, which results in a reduction in cost in the proposed model.

Khodabandeh et al. (2013) investigated an issue of production and distribution integration with the aim of minimizing the total weight of the number of delayed jobs and transportation costs by considering supply chain routing. In this case, there are a number of customers and a production facility in which the works, after processing in the production system, are sent to customers in the form of routing and in batches. Shipping in batches usually reduces shipping costs; But it may increase the number of delayed jobs. The complexity of the NP-Hard case under consideration is strong. In this study, a mixed programming model and a genetic algorithm with an innovative intersection operator were proposed to solve the problem. At the end, the results of computational experiments with a complete design using the analysis of variance technique were presented. The results of computational experiments showed the efficiency of the metaheuristic algorithm.

Jamili and Ranjbar in (2014) Considering the increasing importance of supply chain management in order to achieve optimal system performance, in this paper, integrated production and distribution scheduling in a supply chain is studied. In this case, a manufacturer with a single machine environment is considered to produce orders for multiple customers. Orders prepared to be sent to the customer are categorized and the contents of each package are routed to determine the order of delivery to the customer. The purpose of this issue is to improve the level of customer service and reduce the company's transportation costs, in terms of suppliers, and its linear model is presented along with innovative solution methods.

Zgardi and Marandi (2016) in their research examined the integrated production and distribution scheduling in the three-stage supply chain, including the manufacturer, freight fleet and customers. Their approach was as follows:

A manufacturer is responsible for production based on customer demand and the vehicle delivers products manufactured by customers based on their demand, taking into account the routing of the vehicle. Vehicles are allowed to load and start distribution after the end of production of products requested by customers, and due to the limited capacity of the vehicle, time limits and no violation of it, customer service is provided. The model is formulated in the form of nonlinear programming of mixed integers with the aim of minimizing production delay costs and distance costs. According to NP-Hard, an improved particle swarm optimization algorithm has been used. In this algorithm, improvement operators are used to search the answer space extensively and prevent rapid convergence to the optimal local answer. In order to validate the proposed solution method, the proposed algorithm in small and large dimensions of the created problems was compared with the exact answer, which showed the superiority of the proposed algorithm and its efficiency. In the end, the case study was reviewed with real data, and the results compared to the real conditions indicate better performance of the proposed system than the production and distribution system of the case study, which improves and reduces costs.

2.15 History of Direct-reverse Supply Chain

In recent years, increasing attention to environmental issues and the growth of opportunities to save on costs and resources, or increase revenue through customer products, has encouraged researchers to look at reverse logistics. In the field of logistics network design, which includes various models of optimization and integration of facilities based on integer programming, a lot of work has been done around the world, which we will continue to review the proposed models.

The proposed direct-reverse logistics models can be examined from the following three perspectives:

- Modeling for reuse
- Modeling for recycling
- Modeling for reproduction

Reuse Modeling: Crohn et al. Developed a linear integer linear programming model for reusable products. The proposed model is a classical unlimited placement model designed for the case study of reusable transport boxes. Krone (1995).

Modeling for Recycling: A mixed integer linear programming model was put out by Barros et al. (1998) for constructing an inverse logistics network for a two-tier chain with the ability to recover rock. The proposed model uses an innovative approach to determine the number as well as the optimal capacity of warehouses.

Modeling for Reproduction: In order to reduce expenses in this study, Jayaraman et al. (1999) suggested a mixed integer linear programming model for reverse logistics network design. In this article, only the activities related to the revitalization of customers' products are dealt with, the purpose of which is to design a traction system based on customer demand.

Cricke et al. (1999) proposed a mixed linear programming model for a two-tier reverse logistics network for a copier manufacturer. In this model, the processing costs of customer products and inventory in the objective function are considered.

Jayaraman et al. (2003) proposed a linear integer linear programming model for reverse logistics network design. The proposed model, which is based on strategic levels, specifies which of the reproduction centers, according to customer products, construction to be.

Maine et al. (2005) presented a multi-commodity logistics network model using the Lagrangian relaxation approach.

Kim et al. (2006) provided a general framework for reproduction, so that the proposed mathematical model, with the aim of maximizing the profit from resource savings, could decide how many pieces to buy from the supplier, and How many pieces of products are used in each production center.

Oster et al. (2007) designed a semi-integrated network in which, only customer and resuscitation centers are located in reverse logistics but direct flow and Inverses are optimized simultaneously. In this paper, an exact solution method based on the decomposition method is presented.

Frouta Neto et al. (2008) provided a framework for designing and evaluating sustainable reverse logistics networks based on data envelopment analysis and multi-objective scheduling. Finally, in order to validate the proposed model, they implemented this model in the European paper and pulp industry. In the two-objective model presented in this paper, minimization of costs and environmental impacts are considered as two objectives in the design of logistics network.

Patti et al. (2008) proposed a model based on ideal mixed-integer programming to solve a problem and examine the relationships of objectives in a paper recycling distribution network. One of the goals of this model is to reduce reverse logistics costs (modeling for recycling).

As studies show, most past research has focused on only one of the main reverse logistics processes and operations. Therefore, since in all inverse logistics models, reproduction and reuse activities, repair and recycling are also major activities, it seems to provide a model that includes recycling for the use of recycled materials and products and reproduction for use. Re-production of parts is useful. so:

Lee et al. (2009) proposed a three-tier reverse logistics network using an integer programming model that aims to minimize reverse logistics costs.

2.16 Advantages and Problems of Using Reverse Supply Chain

In fact, the significant costs and potential benefits of RSCM have garnered much attention. For example, processing total costs and paying attention to customer products, for suppliers in the United States has had more than $ 100 billion a year in customer capital. Stock et al. (2002) Be. Hewlett-Packard's product customers were fixed as a low-level local problem until a detailed analysis showed that the total cost of the product's customers is equal to 2% of total output sales. Guide et al. (2003) 1960 It was created and implemented by manufacturers specializing in recycling or those who are responsible for manufacturing, remanufacturing and recycling of their products. Imperial Government et al. (2014). The most recent terms used for this emerging topic in the last few years include closed chain supply chain, reverse logistics, reverse supply chain, green supply chain and environmentally friendly. Most of this research is highly operational, including RSCM for a number of reasons. It has become increasingly important. More attention is paid to changes in industrial waste management laws. Many industries need to rearrange their products once and for all, especially if they contain hazardous substances. Due to the growing importance of the environment for most countries and consumers in this regard, laws can be stricter. Meanwhile, today, most customers are educated and can not tolerate defective products, et al. (2004).

In addition, wholesalers and retailers are under pressure to ensure that customers' risk is reduced. Given the fierce global competition, this means that most manufacturers must provide a warranty or guarantee for any sale, including damaged products, expiration dates, or their obsolete and sold products. Shorter product life cycle, frequent introduction of new products, leasing of products and updating of choices are some of the reasons for increasing the value of using the reverse supply chain. . It is estimated that 6% of all retail purchases in the United States are returned by customers. This means that the value of consumer goods is about $ 52 billion annually.

Some companies, such as Xerox and Kodak, have incorporated restructuring and recycling into their business models, and even investing in technology allows them to be more efficient. They have found that it will be very important to be able to Be able to retrieve and sort your products efficiently. Finally, new business models such as cataloging and mail ordering, and especially e-business, further illustrate the significant impact of the reverse supply chain. That means about 10,000 items per Roson Nomen (2004) The home page of the online shopping network is about 32 million packages per year, of which 6.4 million are customers, which makes it a real challenge to keep track of both forward and reverse product flows. Gear (2017) designed a closed supply chain problem in the direct and reverse logistics problem, which he used in his research as the exact solution method for his model. He designed the issue so that the manufacturer would sell his product to the customer and re-produce the product in the reverse chain.

In his case, Donald (2016) considered distribution centers and recycling centers. He used direct logistics for his direct flow and reverse logistics under the green supply chain for return flows.

Aksu et al. (2011) presented a nonlinear mixed integer mathematical model and looked at how it may be used in one of the Chinese businesses to solve the challenge of constructing a multi-objective supply chain network in a fuzzy environment. In their work, first the model is transformed into a nonlinear model of a multi-objective mixed integer and then three algorithms based on genetic algorithms are presented. The objectives studied by them in this issue are: maximizing customer satisfaction and minimizing costs. For the performance of the three proposed algorithms, they compared the results of these algorithms with the numerical results available in that factory.

Pishvaei and Torabi (2012) examined the design of closed-loop and closed-loop supply chain networks. Given the importance of this issue in production and commercial environments, they studied this issue in uncertain environments and studied possible planning methods in this environment. Their study showed that due to the uncertain conditions of risk in such networks, there is an urgent need for a decision-making system to overcome the risks arising from uncertain parameters. For the reasons mentioned, they proposed a possible two-objective mixed-integer mathematical model for the problem. Their proposed model includes decision making in reverse supply chain networks and strategic network decision making with tactical flow to avoid local optimization in both parts. To solve the problem under study, they used reaction fuzzy solution methods, which are a combination of solution methods obtained in previous research.

The challenge of creating a multi-stage reactive supply chain network was put up by Pishvaei and Rabbani (2013) under the two modes of free direct transit and forbidden direct solution. Due to the complexity of the complex integer programming model, they proposed a graph theory method based on robust optimization to study the problem structure. They contrasted the outcomes of their algorithm with the precise commercial outcomes in order to demonstrate the effectiveness of the suggested method.

Redesigning the multi-category and multi-product supply chain network was a topic of study for Mello et al. (2014). The facility must really be relocated to new locations while taking into account financial constraints, planning horizons, facility personnel, inventory levels in warehouses, and product circulation in the network. They suggested a solution based on a robust scenario-based approach, and since you represented this issue as uncertain, they suggested a solution based on a linear integer programming problem. Pishvaei and Razmi (2015) proposed a multi-objective fuzzy mathematical programming method for designing an environmental supply chain network under indeterminate input data. The model presented by them is able to minimize the multiple environmental impacts along with minimizing costs to create a balance between them. In order to penalize and limit different environmental implications for the supply chain network, they adopted a life cycle penalty-based method. To solve their problem, they also offered a passive fuzzy approach.

Taleizadeh et al. (2015) investigated the supply chain network problem, which includes several buyers, several sellers, several products and several constraints, and proposed a harmonic search algorithm to solve the problem. In this multi-product model, each buyer has a limited purchasing capacity and each seller has a limited warehouse capacity to store products. Customer demand for each product and lead time is random. Also in their model, the products will be packed in several predetermined packages and the service rate limit is considered for each buyer or customer. The purpose of this work is to determine the reordering points, inventory, number of means of transport and the capacity of each means of transport so that ultimately the overall cost in the supply chain network is minimized. They presented a nonlinear mathematical programming model of integer and solved this model using the harmonic search algorithm and compared the results of this algorithm with the genetic algorithm.

Ling and Wang (2015) examined the issue of supply chain network with uncertain supply and demand, which includes discount strategy, inventory and central supply. They proposed parallel multi-operator search and single-operator search methods to solve this problem.

Pak Sui and Chang (2015) studied the design of multi-stage, multi-period, multi-ideal supply chain network with a scenario-based approach with temporary warehouses that can be open in a few weeks or months or open seasonally. To solve this problem, they proposed a linear mathematical model of complex integers 0 and 1. This model involves selecting seasonal markets and allocating demand to the supply chain network with three goals or aspirations. The first goal is to minimize the total cost of transportation at all stages, the second goal is to minimize the cost of establishing seasonal markets, and the third goal is to minimize inventory maintenance costs.

Rezapour and Farahani Zanjirani (2015) investigated the problem of strategic design of centralized supply chain network with indeterminate demand and presented a balanced model with a competing chain.

Gamos et al. (2015) investigated a complete three-tier supply chain network model assuming indefinite demand and presented a complex integer linear mathematical model, using a combination of two methods, fuzzy and neural network, to solve this problem.

Pishvaei et al. (2015) proposed a robust optimization method to solve the closed loop supply chain network design problem with indeterminate parameters. In their work, they first proposed a linear mathematical model of complex integer and then a strong overview of the complex integer linear programming model by strongly developing optimization theory. Finally, to prove the efficiency of the proposed stable optimization method, the results of this algorithm were compared with the results of the exact mathematical model method.

Hamdach et al. (2016) investigated the problem of a multi-stage balanced supply chain network with limited capacity and revenue-generating strategy. This issue has three stages of factories, distribution centers and customers and determines the optimal multi-stage planning plan. They have used a new revenue-generating concept to model the behavior of salespeople and customers under uncertainty with a robust optimization approach in a supply chain network.

Nepal et al. (2016) addressed the issue of multi-objective product architecture alignment with the supply chain network. They used fuzzy logic to solve the study and modeled the optimization model as an ideal program with the two objectives of minimizing cost and maximizing compliance, and solved the proposed model with a genetic algorithm.

Pishvaei et al. (2016) examined the issue of supply chain network design in a group manager under uncertain circumstances. They first proposed a two-objective mathematical model with the aim of minimizing network costs and maximizing supply chain group responsibility, and then proposed a possible programming method to solve the model.

Rezapour et al. (2017) investigated the issue of monopoly supply chain network with variable prices. This model designs multi-tier chain operations with competitors, assuming that demand is uncertain and price-dependent, and that competitors are also interested in retaining new customers to generate revenue in the future. Also in this model, it is assumed that the structure of competitors is the same and price adjustment is possible.

Chen et al. (2017) examined the design of a multi-product, multi-stage, multi-level supply chain network. In the problem under consideration by them, the hypotheses are: several factories in fixed locations and several warehouses and distribution centers are also available in uncertain locations and areas related to customers, uncertain demand and model are examined in separate scenarios. For this problem, they proposed a mixed integer linear mathematical model with the objectives of minimizing overall cost, maximizing decision stability in different product scenarios, minimizing local turbulence, and shipping time. To solve this model, they designed and implemented a two-phase fuzzy decision method.

Jogiazis et al. (2017) studied the optimal design of supply chain networks under indeterminate unstable demand variables. Their work includes designing a mathematical model for designing a supply chain network with multi-purpose facilities with joint production resources, warehouses, distribution centers and customer areas, and operations with different times. For this problem, they have presented a linear mathematical model of complex integer programming and solved the model by the branch and standard limit algorithm.

Sintron et al. (2017) presented a linear mathematical model of multi-objective fuzzy mixed integer for the best supply chain network design. This model determines the optimal structure and configuration of factories, distribution centers and customers in the supply chain network. This model is designed to make tactical decisions to determine the optimal flow of goods from the factory to customers. Products can be obtained from 1) distribution centers 2) factories 3) independent distributors who supply goods from distribution centers. 4) Independent distributors who procure goods from factories. The proposed model for each customer or distributor determines the best method of procurement according to the criteria of profit, unemployment time, ability, efficiency and reputation of the distributor.

Liang and Cheng (2018) investigated the application of fuzzy logic in multi-product supply chain planning. For this problem, they proposed a multi-objective fuzzy linear model with the aim of minimizing cost and delivery time by considering inventory level constraints, transportation capacity, and available labor force.

Jalehchian et al. (2018) presented a study entitled Sustainable Routing Inventory Design of Closed-loop Supply Chain Network under Uncertainty. In this study, considering the economic, social and environmental effects, they presented a new closed-loop model of stable inventory routing under uncertainty. They solved an applied study using meta-heuristic algorithms.

Gao et al. (2018) conducted a study entitled Optimization of the car supply chain network model under macroeconomic fluctuations. They solved the designed supply chain network model by considering the problem of selecting suppliers and the problem of shipping and distributing products using the forbidden search algorithm. Yang et al. provided a multi-objective model for constructing supply chain networks based on biogeography under uncertainty (2018). They propose an unique two-step optimization method for the creation of multi-objective supply chain networks (MO-SCND) with unknown transportation costs and unknown customer demands. They used genetic algorithms to solve the model in large scale and Lingo software in small dimensions. Finally, a dairy company provided an example as a case study to evaluate the applicability of the model.

Martinez et al. (2018) presented a highly innovative MBSA multi-objective approach to green supply chain design and planning. They design the supply chain entities' capacity (factories, warehouses, and distribution hubs) for the supply and flow of commodities across the time horizon in their suggested algorithm. The suggested approach aims to increase earnings while minimizing environmental effect.

Big data optimization for managing a green supply chain has been demonstrated by Zhao et al. (2018). They provided three scenarios to enhance the management of the green supply chain. Three alternatives make up the first optimization scenario: the first option includes decreasing risk (and hence economic costs); the second option involves minimizing both risk and carbon; and the third option is attempting to concurrently minimize risk, carbon emissions, and economic costs.

Table 2.1: The research's gap

Research vacuum			References
Several Paths	*Several manufacturers*	*A manufacturer*	
		•	(2010)*Pishvaei & Torab*
	•	•	(2012)*Pishvaei & Razmi*
•		•	(2012*a*)*Pishvaaei*
	•	•	(2012,*b*)*Pishvaei*
		•	(2014) *Vahdani&Sharifi*
•		•	(2012)*Data*
		•	(2012) *Wang*
		•	(2013)*Fioth*
		•	(2013)*Vahdani*
	•	•	(2014)*Mohamadi*
•	•	•	(2014)*Doika*
•	•	•	(2014) *Yu*
•		•	(2014) *Beheshti far*
		•	(2014) *Paksoi*
		•	(2014)*Demiral*
•	•	•	(2015) *Muta*
	•	•	(2015)*Safar*
	•	•	(2016)*TAlaei pour*
•		•	(2018) *Tasa*
•	•	•	*This research*

But much research has been published on reverse logistics and the closed-loop supply chain, including Fleischmann (1997) who tested reverse logistics using research. Published articles are divided into three categories: distribution planning, inventory, production planning. Guide and Wasenhoe (2009) divided the closed-loop supply chain network into five phases:

- The Golden Age of Revival

- From resuscitation to reverse logistics assessment
- Reverse supply chain synchronization
- Close the loop
- Price and sales

In addition, they considered the end of product life and the end of product consumption and major returns as the most important types of returns. Mello, Nickel, and Dagama (2009) tested the application of equipment design models for industrial equipment and units in reverse supply chain management. In one of the categorized categories, they divided the subject literature from reverse logistics to closed-loop logistics. Pocharl and Moss (2009) focused on all aspects of reverse logistics, including networking and inventory analysis, product collection, pricing, resale, and revitalization. Research on logistics has increased dramatically since 2005. Reverse logistics network design is one of the main studies of reverse logistics. Most authors use equipment design models to formulate logistics networks. Jayaraman, Guide and Sirostava (1999) presented a different programming model with integers. This model can identify the locations of distribution and regeneration units, shipping, production, the optimal amount of reconstructed products and consumed parts. Fleischmann (2000) proposed a general model for the reverse supply chain network. This model was designed based on the forward equipment location model. Kim (2006) proposed a mathematical model in which he determined the number of parts and products in the reproduction process and the number of parts purchased from the supplier. Quinn (2007) proposed a mixed nonlinear programming model with integers in which a multi-period, two-stage, and multi-product model of inverse supply chain network design was discussed. They considered forward and reverse positions at the same time. Network analysis was given a framework by Sirvausta (2008). This model determined the deployment decision for different classes of different products along with the allocation of locations and capacity decisions for equipment. Petty and Kumar (2008) presented a different ideal planning model with integers in which the design of units and the flow and path of recyclable materials in multi-product, multi-level, multi-equipment modes were identified. Lee and Jen (2009) proposed a mathematical model for a public supply chain network that is solved by a genetic algorithm. This model was able to determine the optimal amount of dismantling and operational centers. Zhang (2011) presented a reverse supply chain network in which demand and returns were under conditions of uncertainty. Weber (1991) and Deborahlabro (2001) and Ham Frees (2003) and Lee Kang Whang (2009) have published numerous articles on the selection and evaluation of suppliers and their methods. Decisions with multiple criteria such as Delphi method, fuzzy AHP, etc. were used to find the best supplier. Use the manufacturer to achieve optimal conditions. Although supply chain techniques have been discussed, so far there has been no discussion of using the tactical dimension (order planning) as well as employing multiple manufacturers simultaneously in the closed-loop supply chain. The model that will be presented is the first closed-loop supply chain model, which is both in the tactical dimension (order planning) and in the strategic dimension (manufacturer selection). Uses several co-manufacturers in the closed loop supply chain. In this research, fixed producers are considered, and the model will determine how much each producer produces in order to optimize the conditions. In this model, shortages are allowed, and transportation planning is also considered.

Chapter 3

METHOD OF CODUCTING RESEARCH

3.1 Introduction

In order to optimize the multi-product reverse supply chain in the presence of various manufacturers and suppliers, a novel mathematical model is presented in this chapter. This model has limitations and assumptions. The mathematical model is designed to minimize the costs of transporting products through trucks belonging to the factory as well as trucks belonging to contractor freight companies, and also in order to Optimization of the number of manufactured and reference products in all parts of the supply chain is designed.

3.2 Research Method

This research is applied in terms of type of purpose and descriptive in terms of data collection. A survey because this information is obtained through company experts, considering that we are dealing with parameters in mathematical models, so the available information of parameters is obtained through experts.

3.3 Data Collection Tools

In the present study to collect data and information required from primary data (data collected through appropriate measurement tools such as questions from experts and library studies) and secondary data (including information available on relevant websites, documents and documents available in institutions The case study has been used in books, magazines, seminars, etc.) and quantitative data from the case study of an electronics manufacturing company have been used.

3.4 Information Analysis Method

A complete study of a managerial phenomenon requires a proper conceptual model. A framework or a conceptual model shows the theoretical relationships between the important variables under consideration. Therefore, the theoretical framework of the research is provided in order to better understand the stages of research and clarify the relationships between variables in the mathematical model. In this research, since a multi-objective mathematical model is used in the quantitative discussion, it will be solved through GAMS optimization software and ideal programming method.

GAMS intuitively is defined to be a modeling system is used for optimization problems and mathematical programming and consists of a language compiler with a range of associated solvers. The GAMS modeling language is useful for quickly translate and model a real world optimization problems into a computer code. Thereafter, a gams language compiler will translate that code to a format the solvers can solve and understand. The system is suitable for large-scale and complex modeling applications which allows the modeler to build large maintainable models that can be adapted to new situations.

3.5 An Overview of Modeling in Planning Issues

Linear programming is one of the most powerful techniques used in solving various problems taking into account the problem conditions. Linear programming is a mathematical model for choosing the best method from among the possible ways that is related to optimizing (minimizing or maximizing) the dependent variables and considering a number of linear constraints.

In this study, a new mathematical model for closed-loop supply chain optimization is developed, with the primary goals of figuring out the ideal number of goods and parts for each node in the network, reducing system costs, and maximizing transportation. In this study, a closed-loop supply chain model is created, with components such as suppliers, manufacturers, distribution centers, and consumers, as well as assembly and disassembly facilities, product and part recovery units, and parts disposal and disposal facilities. It is obtrusive and rounded. This model is solved through GAMS software and then the answers obtained from this software are examined. In this mathematical model, non-negative variables and integers are used.

3.6 The Purpose of Designing a Mathematical Model

The objectives of the proposed model are to determine the optimal amounts of commodities and components for each network node, to minimize system costs, and to maximize system transportation requirements (Truck capacity, resuscitation center capacity, product recovery unit capacity, and distribution center capacity. Other objectives pursued by this strategy include lowering manufacturing costs and selecting a suitable manufacturer with reduced production costs. Using the ideal quantity of the product and the optimal level of consumer demand, this model calculates which manufacturer the order should be sent to.

3.7 Closed Loop Supply Chain Network Design

According to Figure 1. A closed loop supply chain is shown. Factories get parts from suppliers, and then they make goods as needed. The factory trucks or outside transport firms transfer the manufactured items to distribution hubs, where they are subsequently distributed to clients. Each truck has a lower cost, which is taken into consideration when choosing which one to utilize. Factory trucks and trucks from independent freight firms can be utilized concurrently to move products more quickly, adapt to client requests, and avoid traffic jams and vehicle shortages. After being used, many goods are returned by customers and brought to collecting facilities. The product pieces are separated into useable and useless ones at the collecting facility. Some products have not yet reached the end of their shelf life and can be reused after re-cleaning and cleaning. These products are sent by the collection center to the product recovery unit. After rejuvenation, restoration, and repairs, these items are sent to distribution facilities.

Dismantled and disassembled items are also used. After being cleaned and repaired by the Repair and Rehabilitation Center, undamaged parts can be utilized again. However, certain components are useless and ought to be buried or eliminated. These items, including chemical batteries, chips, and other parts made of chemicals, plastics, and other polluting materials, are bad for the environment and take a long time to recycle. These pieces of technology are subsequently sent to waste disposal and disposal facilities for cleanup. We may employ several recovery facilities if necessary since the parts recovery unit's capacity is constrained. The rebuilt pieces are brought to the factory warehouse following the reduction step so they may be employed as a new part. Due to the lack of recovery and collection facilities, new raw materials are acquired from suppliers on demand and in possession of refurbished components.

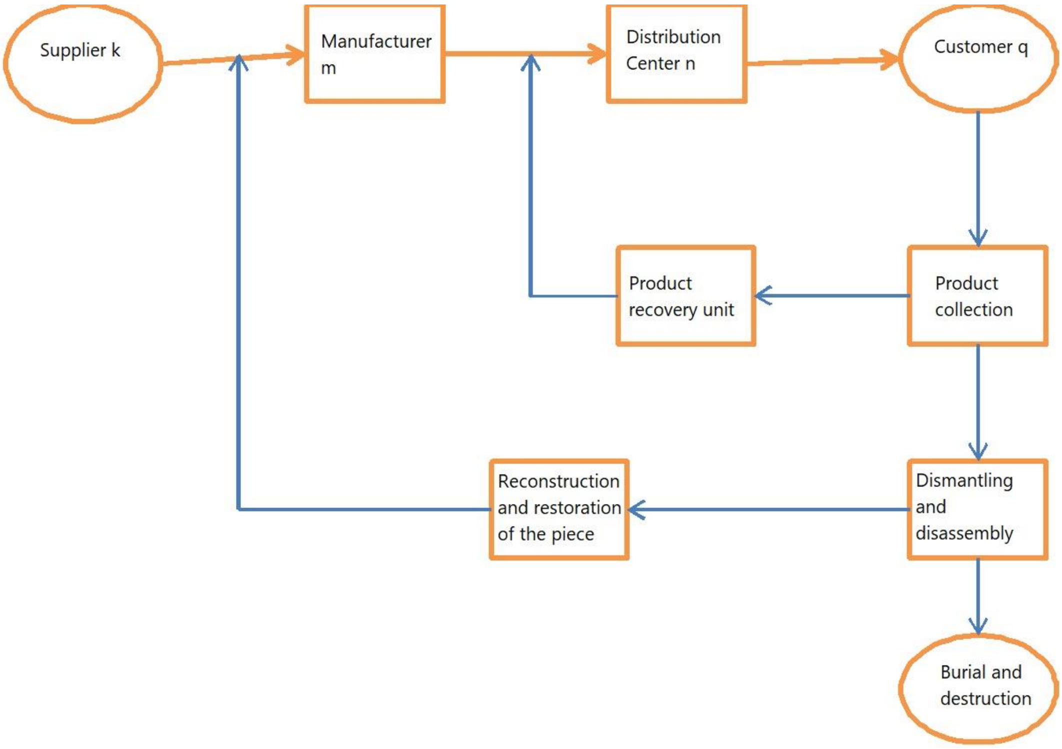

Figure 3.1: Reverse supply chain network with several manufacturers.

3.8 Mathematical Model Presented

To derive our mathematical model, we are using the optimization method in order to find the minimum value of the cost function C. This problem can be solved by defining key variables, finding the appropriate objective function, and then using techniques of calculus to find the maximum or the minimum value required, in our case Minimum Cost.

In general, an optimization problem will have the following mathematical format: Finding the optimized (largest/smallest) value of the objective function f(x) under a set of constraints. In what follows, we are defining all the variables as index and the constraints.

Model limitations (constraints) are as follows:

• The number of parts produced is equal to the total number of parts reconstructed and purchased by suppliers.

• The number of parts collected is equal to the sum of the number of usable parts and discarded parts.

• There must be a logical relationship between parts and products.

• Minimum purchases from suppliers and maximum capacity of manufacturers, recovery and collection centers should be available.

• Produced products meet the minimum demand.

• The maximum percentage of usable and disposable parts must be specified.

• Limit the number of reference sections.

The model assumptions are as follows:

• This is a single cycle model.

• Rehabilitated parts should be taken to factory warehouses after reconstruction.

• Deficiency is allowed.

• The factory's own trucks are employed in one of the two modes of the transportation system. 2. Make use of contract freight services. The price of shipping the merchandise is fixed in this instance.

3.9 Symbols and Collections

The symbols used in the mathematical model of this research are as follows:

i: Parts Index $(i \in \mathrm{I})$

j: Product Index $(j \in J)$

k: Supplier Index $(k \in K)$

m: Manufacturers Index $(m \in M)$

n: Distribution Center Index $(n \in N)$

l: Index of part recovery and recycling units $(l \in I)$

q: Customer Index $(q \in Q)$

α : Index of machines belonging to factories $(\alpha \in V)$

α' : Index of rental cars from contractor trucking companies $(\alpha' \in V')$

Subcategories:

J_i : A collection of products that have part i.

3.10 Model Parameters

Input parameters include the following:

S_{jm} : The selling price of each product j by the manufacturer m

C_{jm} : Cost of each product j by manufacturer m

D_{jq} :Demand for j product by customer q

d_j : Dismantling cost for product separation j

f_i : The cost of removing the i part

h_i : The cost of burying or destroying part i

o_{il} : The cost of reviving the 1st part in the 1st part of the rehabilitation center

r_{ik} : The cost of purchasing part i, which is provided by supplier k.

Co_j : Product collection cost j

O'_j : Product cost recovery

G_l : Maximum capacity of the resuscitation center

Cap1: Maximum capacity of the product recovery unit

Cap2: Maximum capacity of the disassembly and disassembly unit

B_k : Maximum supplier capacity k

υ_n : Maximum capacity of distribution center n

H_j : Maximum product return percentage j

O_i : Maximum percentage of usable piece i

A_m : Maximum factory capacity m

O''_j : Maximum percentage of usable return product j Revealed

q_{ij} : Number of pieces i required to produce a unit of product j

Trs_{ikm} : The cost of transporting the i part from the supplier k to the manufacturer m

Trr_{jq} : The cost of transporting the product j from the customer q to the product collection department

$Tr'_{jmn\alpha}$ The cost of transporting the j product from the factory m to the distribution center n by truck (owned by the factory m)

$Tr''_{jmn\alpha'}$: The cost of transporting the j product from the factory m to the distribution center n by truck (owned by contractor companies)

Trd_{jnq} : The cost of transporting the product j from the distribution center n to the customer q

$Tr\varpi_j$: The cost of transporting the product from the product collection to the product recovery unit.

Trf_{jn} : The cost of transporting the j product from the product recovery unit to the distribution center n

Tra_j : The cost of transporting the jm product from the product collection section to the disassembly and separation section

Trb_{il} The cost of transporting the i part from the dismantling and disassembly section to the reconstruction center and reviving the part

Trc_{ilm} : The cost of transporting the i part from the reconstruction center l and reviving the part to the manufacturer m

sco_j : Cost of product shortage j

$Cap3_{\alpha}$ **:** Maximum truck capacity

$Cap4_{\alpha'}$: Maximum truck capacity belongs to the contractor freight company

3.11 Decision Variables

P_{jmn} : Quantity of goods j that the producer has manufactured and sent to the distribution center n.

R_{jq} : Amount of merchandise j that the consumer has returned q.

Q_{ikm} : Quantity of items I that Supplier K is to send to Manufacturer M.

w_j : Number of renewable products j brought from the collection section to be regenerated.

T_{il} : The quantity of pieces I that the disassembly section separates and sends to the recovery facility (part) lm.

X_{ilm} : Number of parts i to be reconstructed by the recovery unit l and sent to the manufacturer m.

V_i' : Number of pieces i to be destroyed.

R_j' : The number of products j collected is sent to the disassembly section.

Y_{jn}' : Number of recovered products j that are sent to the warehouse of the distribution center n.

Y_{jnq} : Number of products j that are sent from the distribution center n to customer q.

S_{jq} : Number of product shortages j for customer q.

$X'_{jmn\alpha}$:Number of products j sent by truck α from manufacturer m to distributor n.

$X''_{jmn\alpha'}$:Number of products j sent by truck (belonging to contractor companies) from manufacturer m to distributor n.

3.12 Objective Function

$$\underbrace{Min_c = \sum_{m}\sum_{k}\sum_{i} r_{ik}\, Q_{ikm}}_{1} + \underbrace{\sum_{q}\sum_{j} Co_j\, R_{jq}}_{2} + \underbrace{\sum_{j} O'_j\, W_j}_{3} + \underbrace{\sum_{j} d_j\, R'_j}_{4}$$

Where,

(1) The total cost of the parts that must be provided by the suppliers and reach the manufacturers

(2) The total cost of collecting returned products from all customers

(3) The total cost of reviving recoverable products collected for recovery

(4) The total cost of collecting dismountable products and sending them to the disassembly department

$$+ \underbrace{\sum_{l}\sum_{i} f_i\, T_{il}}_{5} + \underbrace{\sum_{m}\sum_{k}\sum_{i} O_{ik}\, X_{ilm}}_{6} + \underbrace{\sum_{i} h_i\, V'_i}_{7} + \underbrace{\sum_{n}\sum_{m}\sum_{j} C_{jm}\, P_{jmn}}_{8} +$$

(5) The total cost of disassembling parts in the disassembly department and sending them to the part recovery center

(6) The total cost of reclamation of parts in reclamation units and sending them to manufacturers

(7) Cost of destruction of parts that must be destroyed

(8) The total cost of products produced by manufacturers and sending them to distribution centers

9 10

$$+\sum_{m}\sum_{k}\sum_{i} Q_{ikm}\, Trs_{ikm} + \sum_{\alpha}\sum_{n}\sum_{m}\sum_{j} X'_{jmn\alpha}\, Tr'_{jmn\alpha}$$

(9) The total cost of transporting parts produced by suppliers to manufacturers

(10) The total cost of transporting products by trucks from producers to distributors

11 12

$$+\sum_{\alpha}\sum_{n}\sum_{m}\sum_{j} X''_{jmn\alpha'}\, Tr''_{jmn\alpha'} + \sum_{q}\sum_{n}\sum_{j} Y_{jnq}\ Trd_{jnq}$$

(11) The total cost of transporting products by contract trucks from manufacturers to distributors

(12) The total cost of transporting products from distribution centers to customers

13 14 15 16

$$+\sum_{q}\sum_{j} R_{jq}\, Trr_{jq} + \sum_{j} W_{j}\, Tr\omega_{j} + \sum_{n}\sum_{j} Y'_{jn}\, Trf_{jn} + \sum_{j} R'_{j}\, Tra_{j} +$$

(13) The total cost of transporting returned products from customers to the product collection department

(14) The total cost of transportation of recyclable products in the collection area to the product recovery area

(15) The total cost of transporting the recovered products from the product recovery unit to the distribution centers

(16) The total cost of transporting products from the product collection section to the DE montage and separation section

17 18 19

$$+\sum_{l}\sum_{i} T_{il}\, Trb_{il} + \sum_{m}\sum_{l}\sum_{i} X_{ilm}\, Trc_{ilm} + \sum_{q}\sum_{j} S_{iq}\ sco_{j}$$

(17) The total cost of parts transportation from the disassembly and separation department to the parts restoration and restoration centers

(18) The total cost of parts transportation from parts restoration and restoration centers to manufacturers

(19) Total cost of product shortage for customers

3.13 Model Limitations

$$\sum_{n\in N}\sum_{j\in J_i} q_{ij}.P_{jmn} \le \sum_{l\in L} X_{ilm} + \sum_{k\in K} Q_{ikm} \qquad \forall i,m \qquad (3.1)$$

$$\sum_{m\in M} X_{ilm} = T_{il} \qquad \forall i,l \qquad (3.2)$$

$$W_j = O''_j \sum_{q\in Q} R_{jq} \qquad \forall j \qquad (3.3)$$

$$R'_j = (1-O''_j)\sum_{q\in Q} R_{jq} \qquad \forall j \qquad (3.4)$$

$$\sum_{q\in Q} Y_{jnq} = \sum_{m\in M} P_{jmn} + Y'_{jn} \qquad \forall j,n \qquad (3.5)$$

$$\sum_{n\in N} Y'_{jn} = W_j \qquad \forall j \qquad (3.6)$$

$$R_{jq} = \sum_{n\in N} H_j Y_{jnq} \qquad \forall j,q \qquad (3.7)$$

$$D_{jq} = \sum_{n\in N} Y_{jnq} + S_{jq} \qquad \forall j,q \qquad (3.8)$$

$$\sum_{l\in L} T_{il} = O_i \sum_{j\in J_i} q_{ij}.R'_j \qquad \forall i \qquad (3.9)$$

$$V_i' = \left(1-O_i\right)\sum_{j\in J_i} q_{ij}.R'_j \qquad \forall i \qquad (3.10)$$

$$\sum_{i\in I}\sum_{m\in M} Q_{ikm} \le B_k \qquad \forall k \qquad (3.11)$$

$$\sum_{\alpha\in\alpha_m} X'_{jmn\alpha} + \sum_{\alpha'} X''_{jmn\alpha'} = P_{jmn} \qquad \forall j,m,n \qquad (3.12)$$

$$\sum_{j\in J}\sum_{n\in N} P_{jmn} \le A_m \qquad \forall m \qquad (3.13)$$

$$\sum_{j\in J}\sum_{q\in Q} Y_{jnq} \le \upsilon_n \qquad \forall n \qquad (3.14)$$

$$\sum_{j\in J}\sum_{n\in N} Y'_{jn} \leq Cap1 \tag{3.15}$$

$$\sum_{i\in I}\sum_{l\in L} T_{il} \leq Cap2 \tag{3.16}$$

$$\sum_{i\in I}\sum_{m\in M} X_{ilm} \leq G_l \qquad \forall l \tag{3.17}$$

$$\sum_{j\in J}\sum_{m\in M}\sum_{n\in N} X'_{jmn\alpha} \leq Cap3_{\alpha} \qquad \forall \alpha \tag{3.18}$$

$$\sum_{j\in J}\sum_{m\in M}\sum_{n\in N} X''_{jmn\alpha'} \leq Cap4_{\alpha'} \qquad \forall \alpha' \tag{3.19}$$

$$P_{jmn}, R_{jq}, Q_{ikm}, W_j, T_{il}, X_{ilm}, V'_i, R'_j, Y'_{jn}, Y_{jnq}, S_{jq}, X'_{jmn\alpha}, X''_{jmn\alpha'} \geq 0 \tag{3.20}$$

The first constraint is that the total number of components rebuilt and purchased by suppliers must equal the total number of parts produced. According to constraint number two, the total number of separated parts must match the total number of parts recovered by the parts recovery facilities. The usable products are equal to the proportion of the reference products, according to constraint 3. It is equivalent to the rate of returned goods. The percentage of products gathered that are taken to the dismantling and separation reveal, as do the limits of 3 and 4 percent of products recovered by the product recovery unit. Limit 5 signifies that the quantity The products created and retrieved together make up the products that are shipped to customers. Limit 6 states that the quantity of items recovered and the quantity of products collected are equal. The seven product maximum is equivalent to the percentage of customers' purchases. The eight-person maximum ensures that the minimal demand will be met and the scarcity will be kept to a minimum. The number of useful and unusable parts in disassembly and disassembly are specified in Limits 9 and 10. and establishes the proportion of waste and useable components.

The maximum supply capacity k is defined by constraint 11. In accordance with constraint 12, the quantity of manufactured parts delivered to distribution centers must be equal to the quantity of goods transported by manufacturers and rental vehicles. The capacity restrictions for manufacturing and distribution facilities are depicted in constraints 13 and 14, respectively. The product recovery unit's and the disassembly section's respective capacity restrictions are also shown in Figure 16a. The capacity restrictions of the component recovery units are shown in Limit 17. The container capacities are also indicated by Limits 18 and 19.

3.14 Summary

This chapter describes the mathematical model and the limitations of the closed-loop supply chain problem. GAMS software will be used to solve the proposed model. In the next chapter, we will solve the mathematical model and review the results.

Chapter 4

DATA ANALYSIS

4.1 Introduction

Model solving is an important part of operational research. In many cases, it is the most complex aspect of the process, which is largely dependent on the development of algorithms and mathematical solution techniques. Usually, after creating a mathematical model, it is important to gather data for the modeling process and solve the model using the appropriate algorithm.

In the third chapter of this research, the proposed mathematical model for reverse supply chain optimization as well as its constraints, variables and parameters were discussed. In this chapter, we present a hypothetical example and solve it by Gomez software and then analyze the proposed mathematical model.

4.2 Problem Data

Due to the novelty of the reverse supply chain issue and also its non-implementation in Iranian industry, access to information is very difficult and not easily accessible. Therefore, we examine a hypothetical example with small simulated data using GAMS and evaluate the mathematical model.

This includes two products j1, j2, three parts a, b, c, three suppliers s1, s2, s3, three manufacturers m1, m2, m3, three distributors n1, n2, n3, two parts recovery centers l1, l2, A product recovery center, five customers 1,2,3,4,5, four vehicles owned by the factory, four vehicles owned by the contractor freight company and also includes collection, destruction and separation departments.

The following tables show the values of the parameters.

Table 4.1: What parts does each product consist of?

Product / piece	j1	j2
a	1	
b	1	1
c		1

This table is equivalent to a subset that is defined in code jadval2 (i, j).

Table 4.2: Cost of product j by factory m

Factory / Product	m1	m2	m3
j1	110	115	100
j2	115	97	107

This table is equivalent to the parameter defined in code as c (j, m).

Table 4.3: Customer demand q for product j

Customer / Product	1	2	3	4	5
j1	15000	12000	24000	15000	20000
j2	12000	15000	15000	13000	17000

This table is equivalent to the parameter defined in code as De (j, q).

Table 4.4: Cost of rehabilitation of part i by rehabilitation unit l

Unit / piece	l1	l2
a	2	2.1
b	3	2.9
c	4	4.1

This table is equivalent to the parameter defined in code as o (i, l).

Table 4.5: Part I's purchase price is provided by supplier K

Supplier / Piece	s1	s2	s3
a	10	11	9.5
b	12	12.5	13
c	15	14.3	15.2

This table is equivalent to the parameter defined in code as r (i, k).

Table 4.6: The quantity of parts I needed to make one unit of the product j

Product / piece	j1	j2
a	2	
b	1	1
c		2

This table is equivalent to the parameter defined in code as q (i, j).

Table 4.7: Cost of shipping a part from a supplier to a manufacturer, I

k/m/i	a	b	c
s1m1	0.1	0.11	0.14
s1m2	0.12	0.13	0.11
s1m3	0.11	0.12	0.1
s2m1	0.09	0.1	0.11
s2m2	0.11	0.12	0.1
s2m3	0.1	0.11	0.13

s3m1	0.12	0.13	0.11
s3m2	0.11	0.12	0.12
s3m3	0.09	0.1	0.1

This table is equivalent to the parameter that is defined as trs (k, m, i) in Gamz.

Table 4.8: Transporting item j from client q to collection department at a cost

j/q	1	2	3	4	5
j1	5	4		6	
j2	6		5	7	5

This table is equivalent to the parameter defined in code as trr (j, q).

Table 4.9: Cost of transporting product j from factory m to distribution center n by truck α

j/m/n/α	α1	α2	α3	α4
j1.m1.n1	2.5	3	2.5	3
j1.m1.n2	3	3	3	2.5
j1.m1.n3	3.5	4	3.5	3.5
j1.m2.n1	2	2	2	2
j1.m2.n2	3	2.5	2.5	2.4
j1.m2.n3	3.5	4	3.5	3.4
j1.m3.n1	4	3.4	3.5	3.5
j1.m3.n2	3.4	3	3	3.4
j1.m3.n3	4	4.5	3	3
j2.m1.n1	3.5	3	3	3.5
j2.m1.n2	2	2.5	2	2
j2.m1.n3	4	4	4	4
j2.m2.n1	2.5	3	3	3
j2.m2.n2	3.5	3	3	3.5
j2.m2.n3	5	4.5	5	4
j2.m3.n1	4	3.5	3.5	3
j2.m3.n2	3	3	3	2.9
j2.m3.n3	4	4	4	4

This table is equivalent to the parameter that is defined in code as tro (j, m, n, v).

Table 4.10: Transportation of product j from manufacturing m to distribution center n by truck α '

j/m/n/α'	α'1	α'2	α'3	α'4
j1.m1.n1	3.5	4	3.5	2
j1.m1.n2	4	4	4	3.5
j1.m1.n3	4.5	2	4.5	4
j1.m2.n1	3	3	3	3
j1.m2.n2	4	3	3.5	3.4
j1.m2.n3	4.5	5	4.5	4.4
j1.m3.n1	5	4	4.5	5.5
j1.m3.n2	5.4	4	3.5	5.4
j1.m3.n3	5	5.5	4	5
j2.m1.n1	4.5	4	4	5.5
j2.m1.n2	4	3.5	3.5	3
j2.m1.n3	5	5	5	5
j2.m2.n1	2	4	4	4
j2.m2.n2	4.5	5	4	4.5
j2.m2.n3	6	5	6	5
j2.m3.n1	5	4.5	4.5	5
j2.m3.n2	4	4	4	4.9
j2.m3.n3	5	5	5	5

This table is equivalent to the parameter that is defined as troo (j, m, n, vs) in code.

Table 4.11: The price of shipping the item j from the warehouse n to the consumer q

j/n/q	Customer 1	Customer 2	Customer 3	Customer 4	Customer 5
j1n1	5	6	6	3	5
j1n2	4	4	7	4	5
j1n3	5	5	6	4	6
j2n1	6	4	8	3	5
j2n2	5	5	7	3	4
j2n3	6	5	6	5	4

This table is equivalent to the parameter that is defined as trd (j, n, q) in code.

Table 4.12: Transporting a product from a product recovery unit to a distribution facility n will cost j

j/n	n1	n2	n3
j1	3	3	2.5
j2	3.4	4	3

This table is equivalent to the parameter defined in code as trf (j, n).

Table 4.13: The cost of transporting the i part from the dismantling and separation section to the part recovery center l

i/l	l1	l2
a	2	3
b	3	2
c	3	2

This table is equivalent to the parameter defined in code as trb (i, l).

Table 4.14: Cost of transporting the i part from the reconstruction center l and reviving the part to the manufacturer m

i/l/m/	m1	m2	m3
a.l1	2	2	3
a.l2	3	3	2
b.l1	2	3	2
b.l2	4	3	3
c.l1	2	3	2
c.l2	1	2	3

This table is equivalent to the parameter defined in codeas trc (i, l, m).

Table 4.15: Dismantling cost for product separation j

d_j	j1	j2
d(j)	0.1	0.12

Table 4.16: The cost of disassembling part i

f_i	a	b	c
f(i)	0.08	0.09	0.1

Table 4.17: The cost of burying or destroying part i

h_i	a	b	c
h(i)	0.2	0.18	0.24

Table 4.18: Product collection cost j

Co_j	j1	j2
co(j)	0.1	0.8

Table 4.19: Cost of product recovery

O'_j	j1	j2
oo(j)	10	11

Table 4.20: Maximum capacity of l resuscitation center

G_l	l1	l2
G(l)	20000	150000

Table 4.21: Capacity of resuscitation and dismantling unit

Cap1	200000	Maximum capacity of the product recovery unit
Cap2	300000	Maximum capacity of the separation and disassembly unit

Table 4.22: Maximum supplier capacity k

B_k	s1	s2	s3
B(k)	4500000	5000000	6000000

Table 4.23: Maximum capacity of distribution center n

υ_n	n1	n2
nu(n)	5000000	4000000

Table 4.24: Maximum percentage of product return j

H_j	j1	j2
HH(j)	30%	25%

Table 4.25: Maximum percentage of usable piece i

O_i	a	b	c
oe(i)	0.7	0.8	0.74

Table 4.26: Maximum factory capacity m

A_m	m1	m2	m3
A(m)	6200000	6000000	6000000

Table 4.27: Maximum percentage of usable revitalized reference product

O''_j	j1	j2
ooo(j)	40%	30%

Table 4.28: Product shortage cost j

	j1	j2
sco(j)	100000000	100000000

Table 4.29: Maximum truck capacity α

$Cap3_{\alpha}$	α 1	α 2	α 3	α4
cap3(v)	5000	5000	3000	3000

Table 4.30: Maximum capacity of α 'truck belongs to the contractor freight company

$Cap4_{\alpha'}$	α'1	α'2	α'3	α'4
cap4(vs)	5000	5000	5000	5000

Table 4.31: The cost of transporting the product j from the product collection section to the product recovery unit.

$Tr\omega_j$	j1	j2
trw(j)	2	3

Table 4.32: The cost of transporting the j product from the product collection section to the disassembly and separation section

Tra_j	j1	j2
tra(j)	1.5	2

4.3 Coding through GAMS Software

First, we enter the parameters presented in the above tables into the proposed mathematical model. By adding numerical values of parameters to the model, variables and writing constraints in the model, the proposed mathematical model is solved using GAMS software to determine the model variables and the value of the objective function, then analyzes the outputs. The coding of the mathematical model through GAMS is given in the appendix.

4.4 Solve Mathematical Model

The integrated mathematical model for the closed-loop supply chain in an environment with several manufacturers is solved by GAMS software. The complete solution of the model by GAMS algorithm using NEOS SOLVER site is presented in the appendix.

4.5 Numerical Results of Model Solving

The optimal value of each of the variables and the objective function obtained from solving the proposed mathematical model by GAMS, is obtained. The optimal values of all variables are shown in the following tables and graphs. Also, by analyzing the results, the optimal number of parts and products in each part of the chain is determined. In this section, the model determines from which manufacturer how many products are purchased and by what means. It also specifies the number of purchases from manufacturers. This model is designed to minimize supply chain costs and prevent bottlenecks as well as optimize transportation.

Using the results of this model, the optimal number of products sent from the manufacturer to distribution centers through a suitable vehicle and the number of returned products by customers can be determined. The model also determines the number of new parts purchased by which supplier and to which manufacturer. The proposed model determines how many products should be disassembled and disassembled and how many should be recycled. This model specifies how many pieces should be destroyed or to which part recovery center. The above model determines how many parts should be sent to which factory by which rehabilitation center. It also determines the amount of deficiency and finally determines which freight system to use by which vehicle.

4.6 Results of Software Solution

Numerical results obtained from the software through the values of variables are shown in the following tables:

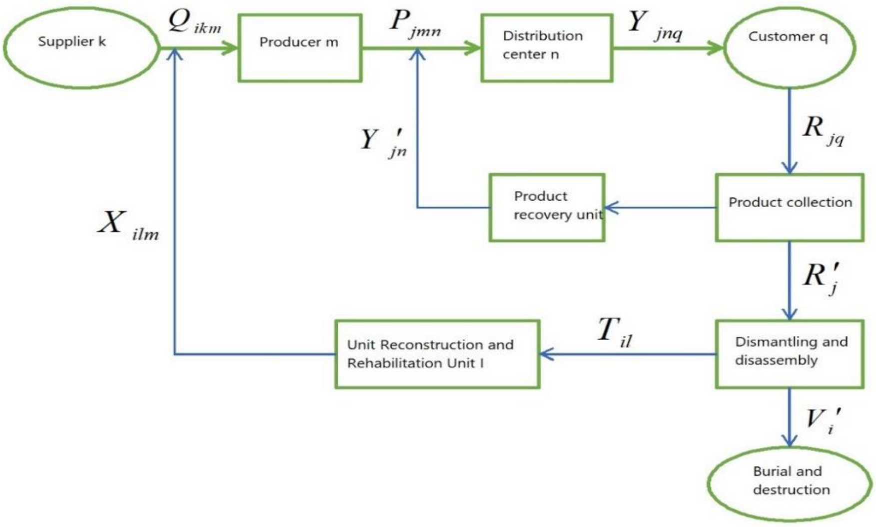

Figure 4.1: Numerical results obtained from the software through the values of variables

Note: In some of the tables mentioned, the main symbol is mentioned in one part and the symbol defined in GAMs is mentioned in the other part. For example, xx (j, m, n, v) is the same equivalent as specified in the tables with both symbols.

Table 4.33: The optimal number of parts i that must be supplied by the supplier k and sent to the manufacturer m.

Q_{ikm}	Qs*(i,k,m)
a.s3.m3	129690
b.s1.m2	44136
b.s1.m3	75680
c.s2.m2	114550

4.7 Data Analysis

By performing analysis on the model, according to the changes that occur in the model parameters, the model is examined and analyzed.

4.7.1 Demand Changes

As demand decreases, so does production. Given that the objective function is to minimize costs, if demand tends to zero, production does not occur. In this case, the shortage variable also tends to zero. And the value of the objective function will be zero. If the variable costs of the shortage are reduced, the amount of production is reduced or it produces only one product at most. If the costs of shortages are small, production will be zero.

As demand increases, the variable, which is the same as the number of production, increases. This increase occurs until production capacity is no longer complete. With a large increase in demand, the variable slc (j) or shortage becomes a value, which in the target function greatly adds the cost of shortage to the system. This is the worst case scenario as the system does not produce and has to pay. In general, increasing demand does not improve the value of the objective function. In the appendix of page 117, the solution of the model shows that in case the demand for j1 product changes from 15000 to 150,000, the factory production m3 will be equal to 194480 product. The value of the objective function increases to Z = 37369000.

4.7.2 Production Capacity Changes

If the production capacity of factories is reduced to the extent that it responds to demand, it has no effect on the response. But if production capacity increases to the point where it does not meet demand or can not supply at least one product, the shortage variable corresponding to that product will increase, which will increase the value of the objective function.

If the production capacity of the factories increases, if we have a shortage, it will reduce the value of the objective function. If we do not have a shortage, production will go to a factory that costs less. Increasing production capacity from the point that all customers are supplied and the best cost composition of factories onwards will not affect the objective function. In general, increasing the production capacity does not worsen the value of the objective function. In the appendix of page 126, the solution of the model shows that when the capacity of the m3 factory changes from 60,000 to 20,000 products, the value of the objective function increases by 502,000 and will be equal to z = 20959,000.

4.8 Summary

This chapter provides a numerical example. The model parameters were collected with the proposed sample data in tables. The data obtained from these tables are encoded in GAMS software, which is shown in the appendix. The model was solved through software and the optimal solution was determined. Then the results were analyzed. The next chapter will provide suggestions and general conclusions.

Chapter 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

An overview of the reverse logistics closed-loop supply chain (CLSC) models provides a platform for alleviating resource management issues. These problems are becoming more important for the following reasons:

- Environmental concerns focused on reducing industrial and commercial waste -- both hazardous materials and other consumer waste
- Economic value and impacts resulting from extending product life

Although considerable attention has been paid to environmental issues and impacts, little attention has been paid to the economic aspects of this equation. The concept of incorporating both economic and environmental considerations using integrated reverse logistics is partly influenced by new developments in the EU. The European Union has been very serious about environmental impact, leading to the design, development, and implementation of green laws to protect the environment. These green laws were originally focused solely on environmental considerations, but as a result of extensive research, it became increasingly clear that effective control of environmental pollution – especially by industrial, commercial, and consumer goods required logistics. The inverse of this approach considers manufacturers, intermediaries, distributors, retailers, and customers.

This study has attempted to investigate both economic and environmental issues as a symbiotic unit, which is the advantage of integrated optimization in the provided model. It has examined economic considerations from both a tactical (order planning) and a strategic perspective (using the right manufacturer) as well as accounting for transportation optimization. This research has also accounted for an environmental considerations approach which includes decisions such as considering landfills and destruction centers for the disposal of waste, hazardous materials, and other consumer wastes related to industrial and manufacturing enterprises.

In a closed loop supply chain network, the criterion of product efficiency is much more important than an open loop. Because the product must have properties such as high durability to be able to be reused, many destroyed products are classified according to product performance criteria and affect the final price.

In this study, the optimal number of products and parts in each part of the closed-loop supply chain was determined. Moreover, system costs were reduced as much as possible, and optimized transportation costs and efficiencies (such as finding the best route and vehicle) were examined.

5.2 Suggestions

- In this model, constant demand is considered. In reverse logistics, supply and demand adjustment is very difficult due to uncertainty. Therefore, it is possible to overcome this issue by using inventory control tools in the closed-loop supply chain. Inventory models in reverse logistics are definite, probabilistic, probable permanent review, and hybrid models of construction and reconstruction, which are more important than before.

- The proposed model is single-period. The time dimension can also be included in this system.
- Return of goods is a category that can be addressed in this research.
- Production planning and control in reverse logistics is one of the important issues that must be addressed. In the production planning department, in reverse logistics, in multi-manufacturer mode, more operations such as opening parts, reprocessing, rebuilding products have unique complexities.

Reverse supply chain routing with multiple manufacturers can also be a topic for further discussion. The distance can then be added to this research to find the best path.

5.3 Analysis of Research Hypotheses

Considering an integrated supply chain network increases supply chain efficiency:

- As it turned out, considering an integrated supply chain increased efficiency and reduced costs, so the research hypothesis is confirmed.
- Considering recycling points minimizes waste points.
- As it turned out, considering waste points reduced costs and recycling points reduced costs, so the second hypothesis is confirmed.
- Considering environmental factors prevents the network from harming its surroundings.
- Considering environmental factors, the chain did not harm the surrounding environment and had a green recovery.

5.4 Analysis of Research Questions

- How can we achieve the optimal amount of profit and cost with several manufacturers and several suppliers in the supply chain depending on the ring?

• In case the production capacity of factories increases, if we have a shortage, it will reduce the value of the objective function. If we do not have a shortage, production will go to a factory that costs less. Increasing production capacity from the point that all customers are supplied and the best cost composition of factories onwards will not affect the objective function. In general, increasing the production capacity does not worsen the value of the objective function. In the appendix of page 126, the solution of the model shows that when the capacity of the m3 factory changes from 60,000 to 20,000 products, the value of the objective function increases by 502,000 and will be equal to z = 20959,000.

Which manufacturer and which supplier should we use?

• How many pieces should we order? How much product to produce? How to reduce production costs by using reconstructed parts?

• As observed in the fourth chapter, the optimal amount of production by manufacturers and the optimal amount of supply by suppliers and the amount of order by the model were determined.

• What vehicles should we use to minimize shipping costs?

As seen in Chapter 4, the results determined the optimal allocation to the vehicles.

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