GALATASARAY UNIVERSITY

GRADUATE SCHOOL OF SCIENCE AND ENGINEERING

DESIGN OF REVERSE LOGISTICS NETWORK FOR WASTE TIRE INCINERATION IN CEMENT FACTORIES

Merva DİNÇ

Oct 2018

DESIGN OF REVERSE LOGISTICS NETWORK FOR WASTE TIRE INCINERATION IN CEMENT FACTORIES

(ÇİMENTO FABRİKALARINDA ÖMRÜNÜ TAMAMLAMIŞ LASTİK YAKIMI İÇİN TERSİNE LOJİSTİK AĞ TASARIMI)

by

Merva DİNÇ , B . S .

Thesis

Submitted in Partial Fulfillment

of the Requirements

for the Degree of

MASTER OF SCIENCE

in

INDUSTRIAL ENGINEERING

in the

GRADUATE SCHOOL OF SCIENCE AND ENGINEERING

of

GALATASARAY UNIVERSITY

Oct 2018

This is to certify that the thesis entitled

DESIGN OF REVERSE LOGISTICS NETWORK FOR WASTE TIRE INCINERATION IN CEMENT FACTORIES

prepared by **Merva DİNÇ** in partial fulfillment of the requirements for the degree of **Master of Science in Industrial Engineering** at the **Galatasaray University** is approved by the

Examining Committee:

Assoc. Professor Müjde EROL GENEVOIS (Supervisor)
Department of Industrial Engineering
Galatasaray University -------------------------

Assist. Professor Zeynep ŞENER
Department of Industrial Engineering
Galatasaray University -------------------------

Assist. Professor Ethem ÇANAKOĞLU
Department of Industrial Engineering
Bahçeşehir University -------------------------

Date: -------------------------

ACKNOWLEDGEMENTS

I would first like to thank my thesis advisor Doç. Dr. Müjde Genevois who was abundantly helpful and offered invaluable assistance, she always supported me to conduct my research despite being away.

I would also like to thank Aydın Yalçınkaya who is Logistics Planning and Operations manager of LASDER. I contacted him many times in order to realize the application part of my thesis and he answered my questions with confidence and showed all kinds of support without hesitation.

I must express my very profound gratitude to my parents and to my husband for providing me with unfailing support and continuous encouragement throughout my years of study and through the process of researching and writing this thesis. This accomplishment would not have been possible without them.

Finally, I acknowledge the support of Industrial Engineering Department of İstanbul Galatasaray University during my master.

Oct 2018

Merva DİNÇ

TABLE OF CONTENTS

LIST OF SYMBOLS

CSCMP : Council of Supply Chain Management Professionals

GDP : Gross Domestic Product

EU : European Union

CRWI : Coalition for Responsible Waste Incineration

ERTMA : European Tyre and Rubber Manufacturers' Association

RMA : Rubber Manufacturers Association

WBCSD : World Business Council for Sustainable Development

ELT : End of Life Tire

USTMA : U.S. Tire Manufacturers Association

TDF : Tire-Derived Fuel

LASDER : Tire Industrialists' Association

TÇMB : Turkish Cement Manufacturers' Association

ICP : Initial Collection Point

CRC : Centralized Return Center

TSP : Travelling Salesman Problem

MTZ : Miller, Tucker and Zemlin

LIST OF FIGURES

LIST OF TABLES

ABSTRACT

In our current world, due to the growing human population, all resources should be used effectively, otherwise resources are not enough for sustainability of the life. That's why, recovery of used products is vital to find alternative resources and to minimize their negative effects to the environment. One of the recoverable wastes is end-of-life tires (ELTs). One of the recovery options for ELTs is incineration of them in cement plants which is one of the most proper options for recovery of ELTs. There are 49 integrated cement factories which have Environmental Permit and License Certificate in Turkey as the final processing plant. Besides benefits of recovering ELTs to environment, cost aspect of process is crucial. Because of the low economical value of ELTs, operations in such a supply chain which is constructed for ELT recovery are becoming more of an issue. In situations for returned or disposed products such as ELTs, reverse logistics is being practiced which has objective of proper disposal or capturing value of waste or returned product. In this study, logistic network design of waste tires sent from collection points to these factories to minimize the costs involved is planned. There are three echelons of supply chain as waste tires collection point, contractor firms and cement factories. Model for this network considers transshipment plan of waste tires between the echelons of supply chain and routes used to gather them. Model that deal with this system are expressed as mixed integer linear programming (MILP) problem. As a case study, model verified with data's for Ankara.

Keywords : Reverse logistics, Waste tire incineration, Cement factories, MILP

RÉSUMÉ

Dans notre monde actuel, en raison de la croissance de la population humaine, toutes les ressources devraient être utilisées efficacement, autrement les ressources ne sont pas suffisantes pour la durabilité de la vie. C'est pourquoi, la récupération des produits usagés est vitale pour trouver des ressources alternatives et minimiser leurs effets négatifs sur l'environnement. L'un des déchets récupérables est celui des pneus hors d'usage (ELT). L'une des options de récupération pour les ELT est leur incinération dans les cimenteries qui est l’une des options les plus appropriées pour la récupération des ELT. Il existe 49 usines de ciment intégrées qui ont un certificat de permis et de licence d’environnement en Turquie en tant qu’usine de traitement final. Outre les avantages de la récupération des ELT dans l'environnement, l'aspect coût du processus est crucial. En raison de la faible valeur économique des ELT, les opérations dans une telle chaîne d'approvisionnement conçue pour la récupération des ELT deviennent de plus en plus problématiques. Dans le cas de produits retournés ou éliminés tels que les ELT, on pratique la logistique inverse qui a pour objectif une élimination appropriée ou la saisie de la valeur des déchets ou du produit retourné. Dans cette étude, la conception du réseau logistique des pneumatiques de rebut envoyés des points de collecte à ces usines pour minimiser les coûts impliqués est prevue. Il existe trois échelons de la chaîne d'approvisionnement qui sont les points d'accumulation des pneus usés, les entreprises de sous-traitance et les cimenteries. Le modèle de ce réseau considère le plan de transbordement des pneus usés entre les échelons de la chaîne d'approvisionnement et les itinéraires utilisés pour les rassembler. Les modèles qui traitent de ce système sont exprimés sous forme de problème de programmation linéaire à nombres entiers mixtes (MILP). En tant qu’étude de cas, le modèle a été vérifié avec des données pour Ankara.

Mots-clés: Logistique inverse, Incinération de pneus usés, Cimenteries, MILP

ÖZET

Günümüz dünyasında, artan insan nüfusu nedeniyle, tüm kaynaklar etkili bir şekilde kullanılmalıdır, aksi takdirde kaynaklar yaşamın sürdürülebilirliği için yeterli değildir. Bu nedenle, kullanılmış ürünlerin geri kazanımı alternative kaynaklar bulmak ve çevreye olan olumsuz etkilerini en aza indirmek için hayati önem taşımaktadır. Geri kazanılabilir atıklardan biri ömrünü tamamlamış lastiklerdir (ÖTL). ÖTL'ler için en uygun geri kazanım seçeneklerinden biri çimento fabrikalarında yakılmasıdır. Türkiye'de son işleme tesisi olarak, çevre izni ve lisansına sahip olan 49 entegre çimento fabrikası bulunmaktadır. ÖTL'lerin geri kazanılmasının çevreye faydalarının yanı sıra, sürecin maliyet boyutu çok önemlidir. ÖTL'lerin düşük ekonomik değeri nedeniyle, ÖTL'lerin geri kazanımı için oluşturulmuş bir tedarik zincirindeki operasyonlar daha fazla önem arz ediyor. ÖTL'ler gibi iade edilmiş veya atılmış ürünlerde, atıkların veya iade edilmiş ürünlerin değerinin kazanılması ya da uygun şekilde berteraf edilmesi amacına yönelik tersine lojistik uygulanmaktadır. Bu çalışmada, toplama noktalarından bu fabrikalara gönderilen atık lastiklerin lojistik ağ tasarımı maliyetleri en aza indirecek şekilde planlanmıştır. Atık lastiklerin toplama noktası, yüklenici firmalar ve çimento fabrikaları olarak tedarik zincirinin üç aşaması bulunmaktadır. Bu ağ için model, atık lastiklerin tedarik zinciri aşamaları ve bunları toplamak için kullanılan yollar arasındaki nakliye planını değerlendirmektedir. Bu sistemle ilgilenen model, karma tamsayılı doğrusal programlama (MILP) problemi olarak ifade edilir. Bir örnek olay incelemesi olarak, model Ankara için verilerle doğrulandı.

Anahtar sözcükler : Tersine Lojistik, Atık lastik yakma, Çimento fabrikaları, MILP

1. INTRODUCTION

Consumption of natural resources increases proportional to the human population in the world and to the improvements in technology. After industrial revolution, depletion in natural resources became important as we started consuming more day by day. As an illustration for this situation, energy consumption can be given. If one checks for the report prepared by Keay (2007), from the table given below, it can be found that energy consumption per capita in tonnes of oil equivalent (toe) increased more than eight times from 1820 to 2003.

Table 1.1. Energy usage in tonnes of oil equivalent with relative population over years (Keay, 2007)

Year	Modern	Biomass	Total	Population	Toe/Capita
1820	13	208	221	1041	0.21
1870	134	254	388	1270	0.31
1913	735	358	1903	1791	0.61
1950	1625	505	2130	2524	0.84
1973	5369	674	6043	3913	1.54
2003	9759	1114	10723	6279	1.71

This trend in consumption is not likely to change. One of the most important result of it is increase in waste. This waste is referring to the any kind of waste not only the wastes generated from energy supply. Hoornweg and Bhada-Tata (2012) tried to arouse interest about the amount of solid waste generated by people over years and gave the figure below to show estimated amount of solid waste that will be produced in 2025.

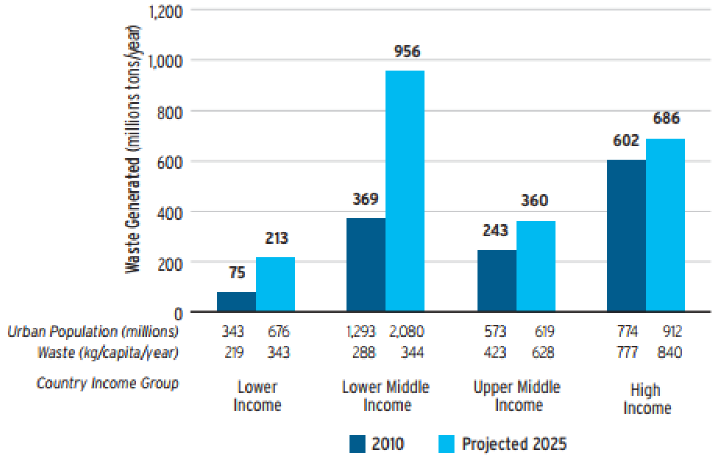

Figure 1.1. Waste generated per capita and per year according to income groups (Hoornweg and Bhada-Tata, 2012)

To create awareness about harm of wastes, lots of organizations and agencies are founded. Greenpeace, World Wildlife Fund and Natural Resources Defense Council can be given as examples for these kinds of foundations. From here one can say that, wastes of consumed products are important as products itself. Like these environment friendly foundations, states and producers are trying to reduce waste and effects of them. For example, in Turkey regulations about waste management is stated in “Atık Yönetimi Yönetmeliği” (2015). All the aspects of waste management are tried to be covered in that law in order to reduce effects of wastes.

There are many types of wastes ranging from organic wastes to industrial wastes and from non-hazardous to hazardous wastes. According to report published by European Commission (2006) which is about best available techniques for waste treatments, it is stated that there are 940 techniques to deal with these wastes and it is also given that some other techniques may be excluded. However, in general, in solid waste management, these techniques can be grouped under three sub-topics which are reducing, reusing and recycling (Rahman, 2014). Reduce is referring to reducing the amount of waste from beginning which is production by optimizing amount of used raw material. Reuse is meaning reutilizing the waste of used product for example using empty glass bottle again for storing any kind of liquid. Recycle is resolving materials from the waste and making it to usable for production.

Waste tires are one of the industrial wastes. In today's world, having an automobile is becoming a normal thing day by day. Also, improvements in industries are increasing the number of transportation vehicles. In its simplest form, it is not wrong to expect rise in number of tires that are being used and consequently increase in the amount of scrap tires. When one looks for the amount of scrap tires in world which is 19.3 million tons that is stated by Ostojic et al. (2017) importance of recycling them is emerging. There are number of usage areas of waste tires from civil engineering purposes, which are listed by Ostojic et al. (2017) and can be elaborated with examples like foundation for roads and railways and erosion barriers, to heat generation by burning them. In these areas, using them in cement factories is one of the most important ones. That is originating from the being alternative fuel property of waste tires. As cement factories mainly running with fossil fuels it is feasible to apply waste tires to them. Additionally, relatively lower cost of waste tires is making them attractive for cement producers.

As cost of waste tires is very low, a need for a network planning is arising. Additionally, source of these wastes are more separated, geographically, than other resources because not like other resources waste tires is not being mined from a mine and they are most likely to end up in city garbage or in tyre shops or traders. These two aspects make transportation of waste tires between the echelons of supply chain vital. Organ et al. (2013) demonstrated an example of supply chain for waste tires where supply chain is consisting of three levels which are namely municipal gathering points for waste tires, temporary depots between first and last levels and recycle facilities. Generally, supply chain for waste tires is consisting of three echelons levels. First level can be said as tyre changers or traders for waste tires where they are gathered at first. Second one is plant that is dedicated for processing waste tires into desired form or inventorying them until a demand occur. Third level is cement factories where waste tires are used.

One can see that supply chain for recycling waste tires have a backward flow. Namely, it is from users to plants. Like that happens in where an out of date product occurs or a defective product returns from a consumer. In short, this property arises the term reverse logistic. Network planning of supply chains that have reversed flow of money, product and information is dealt with reverse logistic.

At the first part of thesis reverse logistic will be investigated. Concept of reverse logistic and key points of it will be narrated with the approach of different authors. In the second part, tires will be studied. In the third part, current situation of waste tires in Turkey will be investigated. Later, literature review is located. In this part, past studies and articles will be explained in briefly. Moreover, related models which are giving insights for required network planning will be examined. In the fifth part of thesis, methodology that is going to be used for solving problems of network will be given within the details. Finally, in the last part, methodology will be tested with application on a case and outputs of it will be interpreted.

2. LOGISTICS AND REVERSE LOGISTICS

2.1. Logistics Concept

Logistics is related to all the issues including organizing moving and storage of materials and people. As issued in publication of Department of the Navy of United States in 1997, at the beginning, logistics was emerged for military purposes like other many issues to identify the activities related to positioning of house of military unities, ammunition depots, organization of all the needs and resource of troop and providing movement of any unity or military materiel in easy way in order to sustain fighting in war. This situation become more complex with the modern armies which are emerged in 17th and 18th century, and basis of logistics is founded. However, logistics were used in more business and service than military area year after year.

Concept of logistics in business environment is based on providing correct customers with true product, right timing and appropriate location. Logistics can be considered as developed network that connects to all the industries each other. As Rushton et al. (2010) are stated in his book, consideration of logistics by companies as an area that needs management is a perspective that is gaining popularity in recent years. Logistics can be considered as part of the overall supply chain management. Although terms of supply chain management and logistics are often used interchangeably, actually, logistics is the part of supply chain management. However, as logistic have different sub-functions, it should be seen as a distinct management operation.

Logistics concept should be well understood by industries in order to determine standards of it. According to Lambert and Armitage (1979), setting standards for logistics activities has been considered more difficult than for manufacturing because – depending on the production process – more activities may exist than in production, and output measures vary more than in production.

Another problem related to the concept of logistics is related to a broader perception of logistics as coordinating the internal operative processes. Although costs of these activities previously considered as joint costs of several departments or indirect cost of another area, it can now be recorded as direct costs of logistics department or responsibility area (Weber, 2002).

2.1.1. Definition of Logistics

While logistics services are perceived as a whole by some people, the concept of logistics gains a new definition in contemporary meaning. Various institutions and organizations are working on obtaining of contemporary definition of logistics. While companies were considering logistics as only transporting operations, but nowadays logistics services also include value-added service activities. The definition of logistics should be well understood by businesses; the goals of the companies can be achieved by being supported by the appropriate account, staff and information flow.

According to Council of Supply Chain Management Professionals (CSCMP), logistics is defined as: “The process of planning, implementing, and controlling procedures for the efficient and effective transportation and storage of goods including services, and related information from the point of origin to the point of consumption for the purpose of conforming to customer requirements. This definition includes inbound, outbound, internal, and external movements.” (CSCMP, 2013).

Gleissner and Femerling (2013) gave another definition for logistics, which is adopted from The European Committee for Standardization (2005), and stated logistic as “... the planning, execution and control of the movement and placement of people and/or goods and of the supporting activities related to such movement and placement, within an system organized to achieve specific objectives.”.

In most generally, logistics includes information related to planning and control of material flows in private and public sector. As mentioned before, its primary objective is to get correct material, true time and adequate place considering all the constraints and cost effectiveness. Logistics tries to find out where, how and when the raw material, work in process and finished goods should be obtained, transported and stored by minimizing related cost issues.

2.1.2. The Importance of Logistics

Peter Drucker likens logistics as dark continent and narrated importance of logistics like that: “Logistics is the most neglected and most promising business area.” (Drucker, 1962). Inarguable fact is that there are big differences between the world 100 years ago and the present world. Over the years, technology and economy have been developing together; the boundaries have been getting up. With the lifting of the borders, the world is globalizing and anyone who wants to purchase something that he or she can find it all over the place. That’s why every sector, every business area creates an incredible competition in order to obtain market share. When customer wants to buy a product in such an environment, customer is faced with very different options. Although customer can find almost the same product almost everywhere customer wants to buy, the product should be lowest price in high quality, at proper time, at required amount. That’s why, logistics is extremely important.

Logistics can be considered as one of the important issue for almost all the industries and businesses. According to Ghiani et al. (2004), it has been estimated that the total logistics cost incurred by USA organizations in 1997 was 862 billion Dollars, corresponding to approximately 11% of the USA Gross Domestic Product (GDP).

This cost is higher than the combined annual USA government expenditure in social security, health services and defense.

In addition to this, a research related to logistics costs in European countries is provided in report for analysis of the European Union logistics sector by European Commission in 2015. Related report is stating the Euro amounts of logistics cost and percentage of it to total GDP for the period between the years 2008 and 2012 and report is shown on Table 2.1.

Table 2.1. Logistics costs (as a percentage of GDP) in European Union (EU) countries (European Commission, 2015)

	2008	2009	2010	2011	2012
Logistics Costs in Billions	889.0	857.0	937.0	917.0	876.0
Share of GDP	7.1%	7.3%	7.6%	7.2%	6.8%

2.1.3. Logistics Management

With technological advances and globalization, today's businesses need a perfect distribution network to gain adequate share in local and international markets in a more competitive business environment. The excessive development of information technologies accelerated business processes as well as changed customer's behavior. Nowadays, the market is more demanding and including more impatient customers. Logistics and Logistics Management concepts are becoming more important in order to survive in such a difficult environment. Logistics is prevalent in all management and referral activities within the supply chain, from the supply of raw materials to the production environment to the final product to distribution channels and customers.

Logistics management is a part of management of all the supply chain. As Waters (2003) stated logistics management activities generally include the management of incoming and outgoing transportation management, warehouse management, management of order processing, constructing logistics network routing, inventory management, production control and planning and third-party logistics network.

As given in glossary published by Supply Chain Visions which is compiled by Vitasek (2006), CSCMP's definition for logistics management is given below:

"Logistics management is that part of supply chain management that plans, implements, and controls the efficient, effective forward and reverse flow and storage of goods, services, and related information between the point of origin and the point of consumption in order to meet customers' requirements. Logistics management activities typically include inbound and outbound transportation management, fleet management, warehousing, materials handling, order fulfillment, logistics network design, inventory management, supply/demand planning, and management of third party logistics services providers. To varying degrees, the logistics function also includes sourcing and procurement, production planning and scheduling, packaging and assembly, and customer service. It is involved in all levels of planning and execution—strategic, operational, and tactical. Logistics management is an integrating function which coordinates and optimizes all logistics activities, as well as integrates logistics activities with other functions, including marketing, sales, manufacturing, finance, and information technology."

Distribution and delivery processes in the international supply chain are becoming more complex. Customer-focused organizations are under extensive pressure to satisfy customer demands while minimizing cost and organizing operations. At the same time, they must be in accordance with the regulations of all the regions in which they run a business.

2.2. Reverse Logistics Concept

Most of the products that are distributed by logistic operations need to be gathered at some point. Situation of a faulty product or condition of waste that are generated after usage of product can be given as examples to occasions where material flow is reversed when comparing with logistic concept. Because of the differences like in given examples, there is a concept which is kind a derivative of logistic called as reverse logistics concept.

During the nineties, contemporary definition of Reverse Logistics is occurred by Council of Logistics Management like that (Stock, 1992):

"... the term often used to refer to the role of logistics in recycling, waste disposal, and management of hazardous materials; a broader perspective includes all relating to logistics activities carried out in source reduction, recycling, substitution, reuse of materials and disposal."

Another definition that is described by European Working Group on Reverse Logistics, REVLOG (1998) as follows:

"The process of planning, implementing and controlling backward flows of raw materials, in process inventory, packaging and finished goods, from a manufacturing, distribution or use point, to a point of recovery or point of proper disposal."

In the summary, reverse logistics is defined different from each other many times over years. Basically, the logic of reverse logistics is against to forward or traditional logistics; in other words; processes are progressed from customers to manufacturers.

Another approach to reverse logistics can be in means of revenue and cost. Rosier and Janzen (2008) have mentioned about it and said that as consumption levels have an increasing trend, product life cycles are becoming shorter and competition between companies are becoming more though, it is harder to experience revenue growth. So, new areas like reverse logistics have potential in revenue.

Reverse logistics is one of the key processes in the supply chain today. Due to economic and ecological reasons, institutional and social responsibilities, laws, sustainable development, protection of natural resources, less material and resource consumption, reverse logistics activities are becoming important day by day. As an example, to emphasize its importance, Moore (2005) stated that one percent of total United States gross domestic product is belong to reverse logistics costs and that percentage is expected to rise.

Systematic management of reverse logistics is becoming an ecological, economic and legal necessity. Retrieval of returned items, products that have expired or are removed from the market due to consumer purchases of new products is significant cost items and very strategic concept for the manufacturers.

The important issues should be considered how to make initial collection of products from customers, sorting and classification of collected product, how to transform collected waste to semi-finished products or raw materials or energy for another processes, determining location of transformation location and constructing network among components that customers, transformation centers and manufacturers etc. cost efficiently.

2.2.1. Difference Between Forward and Reverse Logistics

As mentioned before, the most important difference between them is the flow direction. While forward Logistics is progressed from manufacturers to customers, reverse logistics is progressed from customers to manufacturers. These flow directions are shown on Figure 2.1.

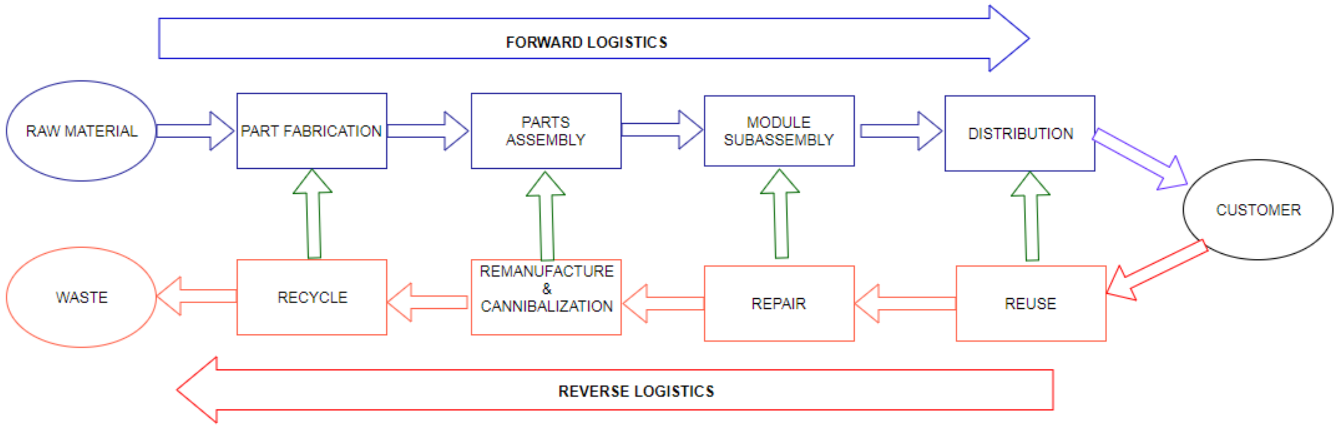

Figure 2.1. Match-up between forward logistics and reverse logistics

Reverse logistics should not be understood as the exact symmetric of the forward logistics. Flow direction is not the only difference between. Challenges are differentiation and faced difficulties are changing. For example, while in forward logistics agility of supply chain is crucially important, in reverse logistics being that much agile or having shorter reaction times in supply chain have lower levels of priority. Tibben-Lembke and Rogers (2002) illuminated the differences between them and, in short, following table taken from their article gives hints about discrepancies.

Table 2.2. Differences between forward logistics and reverse logistics (Tibben-Lembke & Rogers, 2002)

Forward	Backward
Forecasting relatively straightforward	Forecasting more difficult
One to many transportation	Many to one transportation
Product quality uniform	Product quality not uniform
Destination/routing clear	Destination/routing unclear
Standardized channel	Exception driven
Disposition options clear	Dispostion not clear
Pricing relatively uniform	Pricing dependent on many factors
Importance of speed recognized	Speed often not considered a priority
Forward distribution costs closely monitored	Reverse costs less directly visible
Inventory management consistent	Inventory management not consistent
Product lifecycle manageable	Product lifecycle issues more complex
Negotiation between parties straightforward	Negotiation complicated by additional considerations
Marketing methods well-known	Marketing complicated by several factors
Real-time İnformation readily available to track product	Visibility of process less transparent

As it can be seen, they are separated from each other in many aspects. First difference between them is that demand forecasting is more challenging in reverse logistics than forward logistics. Products are distributed from one point to many customers, where destinations are known, in forward logistics while products in reverse logistics are gathered from many points, which their locations are mostly uncertain, to one facility. Additionally, as Rogers and Tibben-Lembke (2002) stated that speed significance is also different between them as transported good in forward logistics have greater value than in reverse logistics. Also, characteristic of demand is another aspect which is affecting the speed significance because in forward logistics timing is important to keep customers satisfied but in reverse logistics customers is able to wait. When we examine the product quality for two logistics type, there is quality standardization in forward logistics and packaging of them is done carefully, but instability and low product quality are occurred in reverse logistics and as they are scrap packaging loses importance. Also, while distribution channels are used during the supply chain in forward logistics, return channels should be used, which are having exceptions, in reverse logistics. In addition, one of the most vital issues in forward logistics is inventory management that is that controlling ordering inventory, inventory storage and supervising the quantity of each product for sale. However, as Rogers and Tibben-Lembke (2002) stated that, traditional inventory models cannot be applied to reverse logistics because of the lack of information about demand and lack of predictability of arrival of product. Another difference is that cost is calculated in advance and during the process respectively in forward logistics and reverse logistics. Rogers and Tibben-Lembke (2002) remarked that even in forward logistics price of a product which have a standard quality can differ between vendors or retailers, so, in reverse logistics where quality of product is changing, price difference between products is higher than in forward logistics. Although marketing practices does not change much between sectors, it is complicated in reverse logistics. Last but not the least, while generally the customers are not known and certain during forward logistics processes, returners are known and certain during the forward logistics processes.

2.2.2. Reverse Logistics Process

According to Rosier and Janzen (2008) reverse logistics includes 5 main processes that are product acquisition, collecting, selection & sorting, dissembling, crushing or transformation and transporting items to manufacturers which are given below.

Product Acquisition: This step is meaning the retrieval of product from market. While doing this, management of product, which is including timing, quantity and quality of product, is needed to be done.

Collecting: This process is basically transportation process. This process includes operations that collecting scrap items or other kinds of items that need be recovered from customers, retailers etc. These points can be considered as a supply point of forward logistics.

Selection & Sorting: This process includes identifying each scrap items and separate from each other depending on product type and following process type.

Dissembling, Crushing or Transformation: This process is changed over the product types and transformation processes case by case. Basically, this process is identified like that the scrapped items are transformed into required resource, product or energy.

Transporting Items from Transformation Centers to Market: After an item is processed to a new output which can be a repaired, retreated or recycled product it is needed to be transported between demand points and transformation centers. At this point forward logistic operations are used.

2.3. Reverse Logistics Options

As stated before, there are different options where reverse logistics applied. They are explained by Thierry et al. in their book (1995). They divided product recovery options into five categories which are repair, refurbishing, remanufacturing, cannibalization and recycling. For more clarification, figure 2.2 shows flow of the product for different options in a supply chain.

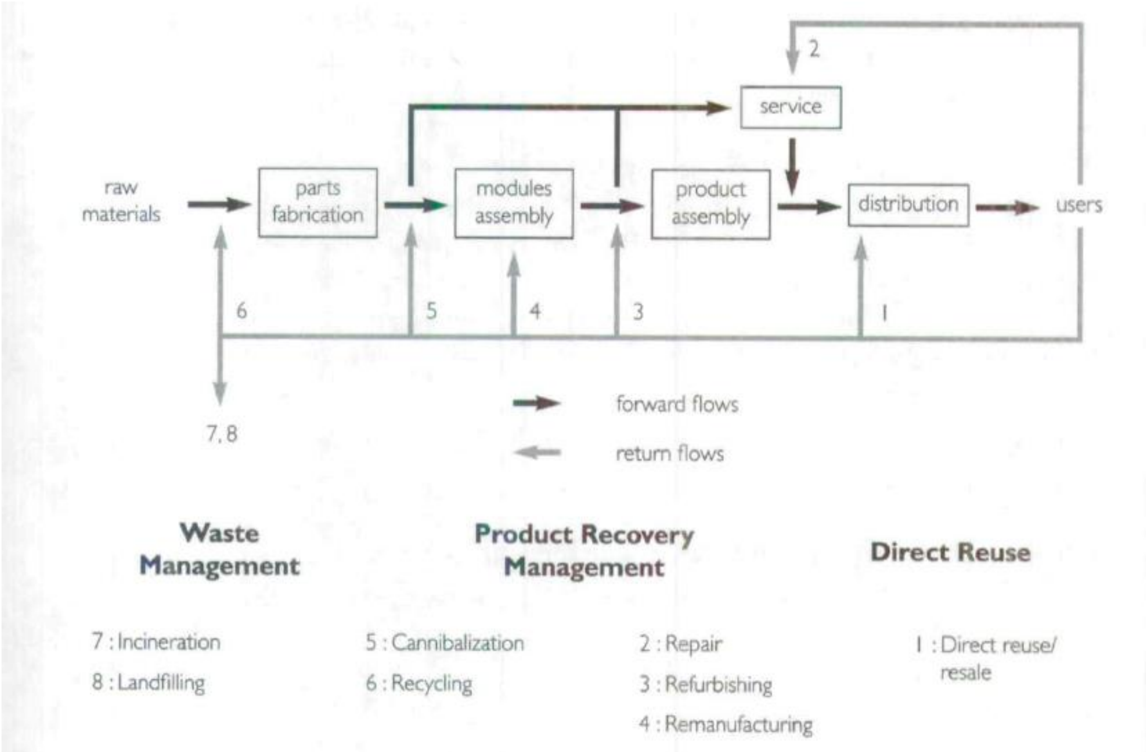

Figure 2.2. Flow of the product in a supply chain (Thierry et al., 1995)

In figure it can be seen that returned or collected products goes for different process which is according to their condition. As Thierry et al. (1995) stated that options in the figure are in an order according to necessary degree of disassembly. Also, from the figure it can be concluded that as options are closer to users, condition of returned or collected product gets better. For example, returned goods with little defects is proper for direct reuse but end of life products are most likely to end up in recycling process or in waste management section. In addition to product recovery options, as it can be seen there are waste management processes which are incineration and landfilling. However, these options are not primary options for returned products and they are only applied to products that can be named as waste.

2.3.1. Repair

Repair is applied on the products that are returned from customer to recover its state to a usable manner. As Thierry et al. (1995) stated that in repair option required product reassembly and disassembly is little and parts of product, except for broken parts, is not affected from the process. As repair does not require a major process it can be done at user’s location or at repair centers. According to Fernandez and Juunquera (2013), repair option is more appropriate for products which have greater value in fixed cost than cost imposed by failure. If product does not have a severe fault or defect it can be compensated. That is because, these returned products are already in a good condition and directly putting them in garbage regarded as being extravagates. If we consider a point of view of a company on that returned products, we put our time and money to produce that item, so it desires reconsideration. As challenges and competition between manufacturers are becoming more difficult, they started to recognize the value of this kind of actions. Finally, to manage the flow of returned goods, reverse logistics approach should be taken.

2.3.2. Refurbishing

As Thierry et al. (1995) stated that objective of refurbishing is to regenerate lost quality of a used product however standards for refurbished products are not strict like new products. However, that does not mean refurbished products are not usable and they are perfectly functional like new ones. As Vorasayan and Ryan (2006) expressed, these products are verified by producer to be as functional as new products. In the perspective of consumer, refurbished products are opportunity to get products which are perfectly functioning like new ones because of the lower prices than new ones. Like for consumers, refurbishment is an economic way for the producers when is becoming more and more critical with the increasing value that product possesses. As an example, Vaughn (2013) talked about opportunity of refurbishment in electronic devices industry.

As he stated, research indicates that between 11 and 20 percent of total sold products are returned by consumer and 68 percent of this amount is returned for failing to meet customer expectations. That means, the given amount of returned products is not broken or dysfunctional. He adds that, as its possible to regain lost value for returned products with refurbishing and repairing processes, it is possible to put them up for sale in the market again where producers generate revenue. Finally, refurbishing is consisting a reversed flow of product up to assembly lines in a supply chain, it is crucial to manage this system with a reverse logistics approach. Otherwise, this process can be infeasible for producers which end up in lost value of product.

2.3.3. Remanufacturing

Remanufacturing means that getting useful parts of the collected or returned product that can be used as an end product in market. Being a used product does not mean any part of it will not be useful in any process. As Thierry et al. (1995) clarified process of remanufacturing; in this process used products are disassembled into parts and modules which are inspected strictly. Usable parts or modules are fixed and tested for quality assurance and they are directed to production. Dysfunctional parts or modules are discarded and replaced with new ones. Additionally, he or she gave an example for it that is applied BMW and remanufactured parts are resold as exchange parts with same quality at a discounted price. Products have consisting of many parts are possible subjects of remanufacturing. For illustration, a crashed or dysfunctional electronic device, such as laptops, can have many parts that is well functioning. These parts like transistors, hard disk, rams and etcetera can be need of someone. Gilanlı et al. (2012) gave an exemplification for this situation where reverse logistics is robust. It is stated that market for reproduced car part is about 36 million Turkish liras and nearly all of the alternators and starters are reproduced. In short, any part of a waste may have value again in market or may be an opportunity for someone. When reverse logistics is applied successfully, results can be spectacularly beneficial.

2.3.4. Cannibalization

As Kumru (2009) stated its definition in his article, cannibalization is done for using parts that are removed from returned item in production of new products. Cannibalization is applied mostly on returned goods. As its literal meaning giving clue, it is taking the component of good that is labeled as disposed to use in the same kind of good. Also Thierry et al. (1995) elaborated this process in her or his book, in this process different from other recovery options, lesser parts of used product are in consideration because of the condition of product. These considered parts are used in production of new ones. As they gave an example for this process, Aurora, which is a company that cannibalizes used computers for circuits in it, has sales more than 40 million dollars in 1993. Although it seems a free of way getting the material for production, cost aspects in cannibalization should be considered. Without consideration, cannibalization operations which are mostly disassembling, can lead to inefficiencies in production. That is because we are putting an effort to disassemble which can be used in production and time spent on this action has an opportunity value. To sum up, cannibalization can be seen as a band-aid when necessary parts for production are scarce. While performing, the trade-off between time and value of that part should be conceived.

2.3.5. Recycle

Recycling is performed for obtaining the materials from the waste as raw materials for using in any suitable production of a good. Recycling is tried to be promoted in any industry because of its social and economic benefits. That is because; giving longer life to raw materials is meaning more sustainable structure of production. Valle et al. (2009) carried out a study about customer service determinants in recycling of household wastes which states that all of the levels, which are front-end and back-end of processes, explain consumer involvement while basic customer services is being the most critical predictor. Additionally, they expressed that, it is impossible to maintain a recycling system for household wastes without collaboration of consumer. Additionally, Factsheet published by Environment Protection Agency (2012) stated the importance of recycling with a striking fact. That is, in United States 87 million tons municipal solid waste is recycled which accounts for 168 million tons of carbon dioxide. Besides the beneficial effects of recycling, this market value has capability of attracting the investors in this sector. Moreover, as recycling process begins with consumer and generally having a continuous flow, reverse logistics systems is becoming a major part in recycling. That is because an incorrectly constructed network for recycling can eliminate the benefits of recycling. To conclude, not letting raw materials to lie in a garbage is surely contribute our society and doing the process within a well-structured reverse logistic network can be lucrative.

2.3.6. Landfilling and Incineration

Rather than other options where reverse logistics is applied, in these options products or parts of products are lost their value. As they are neither functional like new products nor shows same qualifications as new products, they are handled under waste management processes.

For beginning, landfilling is a method for waste management. Landfills are where trash or garbage of something goes for temporary storage. Objective of this process is taking away from these wastes from settlements and gathering them at one place. As it is stated in manual published for landfilling by Environmental Protection Agency (2000), that landfilling of wastes is posing risks to environment and human health. Reducing possible negative effects of wastes is expected from well-designed landfill sites. To summarize, because of the negative effects of wastes, landfilling method should be used carefully.

Secondly, in waste management section of reverse logistics options, incineration is present. According to glossary published by Coalition for Responsible Waste Incineration (CRWI) (2012), which is an organization that aims raising public consciousness in combustion of wastes, facilitating combustion research, collaborating with law makers to legislate in environmentally sound way in waste management and assist member companies of it to enhance their combustion process via sharing scientific knowledge, literal meaning of to incinerate is given below:

"… to cause to burn to ashes; to consume by fire; to become completely burned; to destroy a waste by combustion. cf. burning. "

Basic meaning of incineration is burning wastes. According to document published by European Commission in 2006, waste incineration is a method that used for a wide range of wastes. Waste incineration is generally a component of a complex system for waste management. Objective of this process is reducing the hazard and volume of waste while eliminating detrimental substances. However, emissions to air and water while applying this process is a critical issue that should be cared. Additionally, heat generated within burning process is proper to generate energy.

To conclude, in waste management section of reverse logistics options, mentioned processes are sub-parts of greater systems which are devoted to waste management. Additionally, as mentioned before, although these processes are helpful in waste management, they have possible drawbacks which should be in consideration.

3. TIRES

Tires are basically a part of land-based vehicles and used in cars, bicycles, buses and commercial or duty vehicles. Although they are used in different environments, their compositions constitute nearly same components. That components are mainly rubber, which are synthetic and natural, steel cord, bead and wire, carbon black and some chemicals (Rowhani & Rainey, 2016). At the end of their life wastes of them is creating an environmental issue that should be taken care of. In this chapter properties and types of tires are given, end-of-life tires are mentioned with their usage areas and one of the options for reutilization of waste tires, which is using them in cement factories, is elaborated.

3.1. Properties and Types of Tires

Tires are generally known as a part of vehicles like cars, trucks and buses that rotates in order to move that vehicle. As Ishikawa (2011) states, if one deeply investigates history of tires, he or she finds that past of tires goes to invention of wheel. However, pneumatic tires are not old that much, they are invented in 19^{th} century. Main objectives of tires in a vehicle is providing necessary grip for traction, supporting vehicle handling, carrying load of vehicle and absorbing shocks from road. Tires can be found in a very wide area such as cars, motorcycles, bicycles, trucks, buses and tractors. All of them have distinct shape and they are differentiated according to their usage purpose. In order to ensure these benefits for the driver, tires are designed according to their usage intention. Whitford et al. (2011) gave examples changing objectives of tires according to their usage areas which end up in different designs. For more clarification some of the examples they have given can be stated. First example is that passenger tires are designed for smooth ride, fuel economy and long product life but they are not designed for heavy loads. Second example can be tires that are used in agricultural drive. They are designed to enable grip while in dirt or loose soil. Nearly all of these tires are pneumatic which is meaning that tires are inflated by air and held under pressure. Air is sealed by pressure between the tire and the rim. While providing a comfortable driving and carrying the weight of the vehicle with the help of pressure air, tires are attentively engineered. A cross-section of a car tire is given in figure 3.1 for illustration.

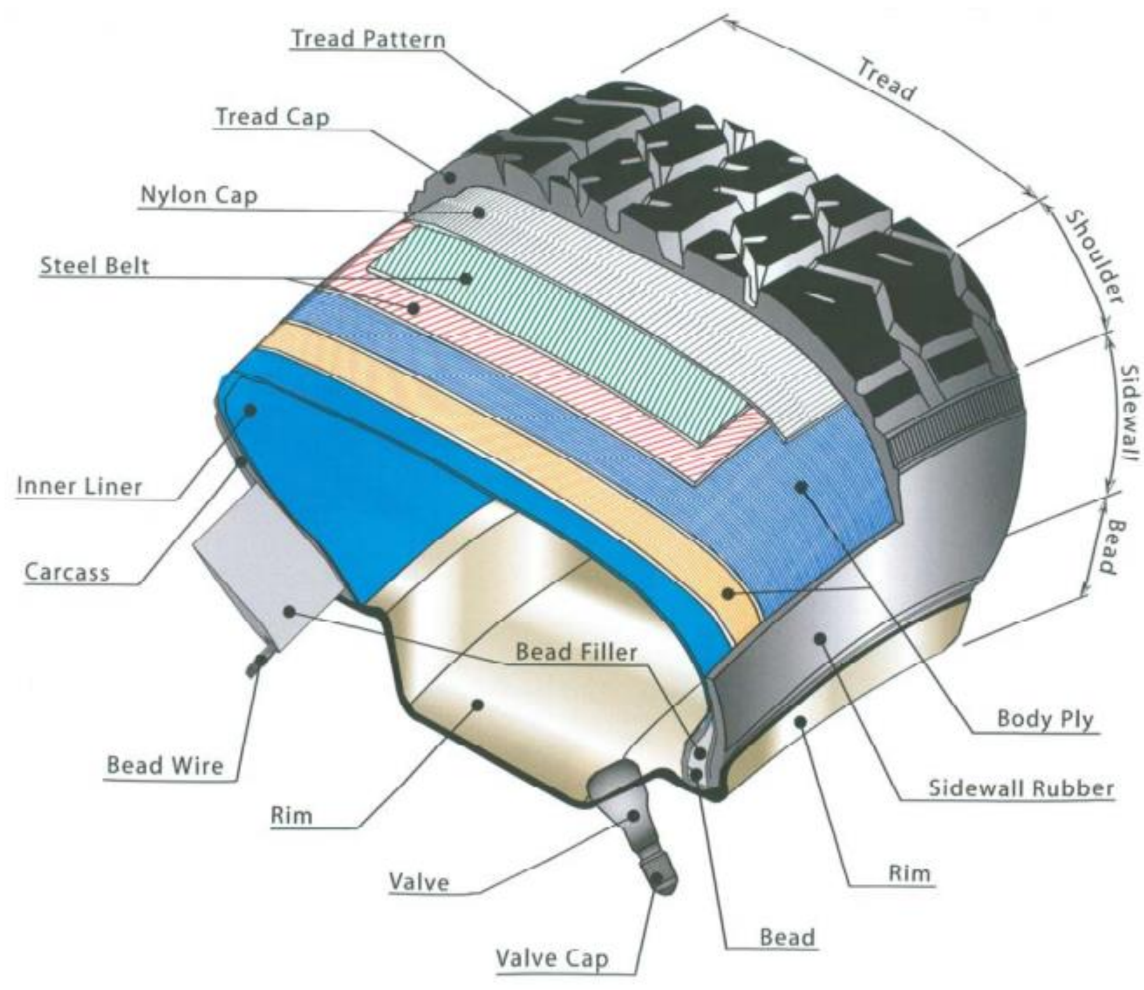

Figure 3.1. Cross-section of a tire (Evans & Evans, 2006)

In this figure, one can see the layers of tire. Tread cap, tread pattern, shoulder, sidewall, sidewall rubber and carcass parts are sub components of tread which is the outer part of the tires. These parts are mainly based on rubber. Valve and valve cap are other parts that are in the outer parts. They are used for controlling the air inside of the tire. Bead, bead filler and bead wire's function are to bond tire to rim. Nylon cap, steal belt, body ply and inner liner are the inner parts of the tire. These are used for reinforcement of the tire and gives tire structure strength. This representation is general representation for car tires and although the shape of tire is changing with vehicle, the other types of tires consisting these parts too. As the purpose of tires is ranging with usage area they can be divided into three categories which are, car tires, lorry tires and off-the-road tires. These are also divided into sub categories according to their diameter, targeted season and the type of vehicle. Within these categories, weight of a tire is another aspect that is changing. According to data on weighs of tires by Aliapur (2017), which is French company working in waste tire industry; weight of a tire is changing considerably between the tire types. Table that is constructed with given data by Aliapur is given below.

Table 3.1. Weights of tires by categories (Aliapur, 2017)

Type of Tire	Range of Weight of tire	Average Weight of a tire
Car tire	5 to 20 kg	7.89 kg
Lorry tire	20 to 80 kg	53.99 kg
Off-to-road tire	80 to 130 kg	92.12 kg

These values for tires do not correspond to a normal distribution because there is no statistical data about it and it is expected because of the commercial property of tires which is causing variety. Hence, using these values to estimate a tire's weigh may not be true. However, weight difference between the tire types is obvious.

As types of tires have a wide variety, design of these are changing by their main category. Changing the main objective of tires is resulting in different compositions. While for off-the-road tires strength of the tire is important, for a car tire handling may be more important than strength. Evans & Evans (2006) are stated differences in compositions of tires according their type. Ingredients of tires with percentages in weight by their vehicle type are given in table 3.2 below.

Table 3.2. Percentage composition of tires according to their type (Evans & Evans, 2006)

Ingredient	Car Tires	Lorry Tires	Off-the-road Tires
Rubber/Elastomers	47%	45%	47%
Carbon Black	21.5%	22%	22%
Metal	16.5%	25%	12%
Textile	5.5%	0%	10%
Zinc Oxide	1%	2%	2%
Sulphur	1%	1%	1%
Additives	7.5%	5%	6%
Carbon-based materials, total	74%	67%	76%

This table is showing the percentages after production not in used tires. Although this table is simplistic and general, these values do not change considerably in categories because tires are an industrialized and standardized product. This table gives an insight about carbon-based materials. If one checks for the carbon-based materials in total, large portion of tire is made up from carbon. Furthermore, rubber is main ingredient of the tires and along with the natural rubber, synthetic rubber is used also. Natural rubber gathered from the rubber tree and synthetic rubber produced from crude oil. The second highest percentage belongs to the carbon black, except for lorry tires. Carbon black is a powder that is created by burning the crude oil with limited oxygen. Metal can be regarded as one of the materials with high percentage in tires. Metal is referring to steel in tires which can be found as steel wires. Finally, more than 40 chemicals are used in the production of tires such as oils and silicas.

To conclude, tires are specialized mainly on the vehicle type that they are used in. As usage purposes of these vehicles are different from each other, design and composition of them are distinct from each other.

3.2. Waste Tires and Usage Areas

Although tires are tried to be built last longer, that does not mean expected life of them is infinite. Like every other industrial product, tires become dysfunctional or useless when they fill their expected life. At the end of life, waste generated by tires is itself. Main reasons behind waste tires can be named as a puncture due to a pointy object, road accidents that make tires dysfunctional and erosion due to usage. However, end-of-life tires are not directly sent to recycling because there are different options other than recycling. These options are demonstrated by Pennigton et al. (1996). Usage areas of waste tires are grouped by their particle size. These sizes are namely whole tire, crushed tire, shredded tire or ground rubber. As an example for them, whole tires can be used in erosion control, crushed tires can be used in shoe soles, shredded tire can be used as road construction material and ground rubber is utilizable in asphalt pavements as additive.

Firstly, as tires are pneumatic objects, they cannot function without air in them. A puncture on the tire can deflate that tire. Depending on the severity of that puncture, tire can be repaired to use it again for a limited time or cannot be repaired and becomes a waste tire. Secondly, road accidents are resulting in many undesired consequences.

Although, tires are not an important loss in an accident, this aspect is one of the causes of waste tires. Tires can be torn away or ruptured in an accident. Finally, the main resource of waste tires is erosion (Altin et al., 2013). Erosion is meaning that, the friction between the tire and asphalt, road, dirt or any surface is gradually denuding the tire. This erosion is occurring in so little particles that human eye cannot detect. However, this phenomenon can be observed by naked eye in the situations like emergency braking or sudden accelerations. In this situations tires, leave a black mark on the surface that they were on. Like in these situations, daily and normal usage of tires is causing the erosion on them. Altin et al. (2013) investigated this situation comprehensively in their article. They stated that a typical cars' tire is eroding between 30 and 90 mg per kilometer which is correlated with speed of the car. Additionally, they showed the correlation between the number of vehicles and waste tires. As expected, increasing number of vehicles means increasing number of tires being used. Also, as expected and using tires resulting in waste tires, it is a natural and inevitable correlation. In literature, life of a tire is calculated over kilometer in many articles. However, kilometer value for tire's life is changing in researches. It is mostly said to be between 50000 km and 60000 km for an average tire. According to annual report prepared by department of ecology state of Washington in 2012, waste tire generated from personal cars is one tire per year and average of waste tire for other vehicles like motorcycles, trucks or off-the-road vehicles is ranging from 0.25 to 0.4 tires per year. As motor vehicles are becoming a daily want for personal transportation and improvements in industries increasing the importance of transportation and usage of motor vehicles for transshipment. According to Ostojic et al. (2017) there are 19.3 million tonnes of waste tires in world and it is expected to rise. Also, European Tyre and Rubber Manufacturers' Association (ETRMA) (2015) is stating the amount of the used tires over 3.6 million tons in Europe in 2013. Moreover, in Turkey, the amount of waste tires is unignorably high. Altın et al. (2013) showed in their researches according to data from September 2009 that amount of waste tires from cars in Turkey is 41586.31 tons.

From these numbers, one can say that there is a great potential in recycling of waste tires.

There are different usage areas of waste tires. They are gathered under three main topics. These topics are usage of waste tires in civil engineering purposes, ground rubber applications and using end-of-life tires as fuel. According the article published in 2009 by Rubber Manufacturers Association (RMA), which is a group for trade and advocacy of rubber and tire manufacturers in United States, volume of market for scrap tires is 4105.8 thousand tons of tires while generated amount was 4595.7 thousand tons. Areas where waste tires are grouped under three main sections which are tire-derived fuel, ground rubber applications and civil engineering purposes. Share of these areas as percentages of total generated amount were 54, 17 and 12, respectively. The amount of used waste tires is remarkable which shows significance of market for waste tires.

Firstly, in civil engineering purposes waste tires mostly used as whole. That is because waste tires are substituted for other materials such as wood or stone. As Humphrey (2003) stated civil engineering applications of tire shreds in her publication, there is wide range of applications for waste tires in civil engineering. In short, these applications can be named as embanking for increasing stability in inclined surfaces, backfill for retaining wall, vibration damping, thermal insulation at under of roads and drainage at highways. In land filling, waste tires used to obtain a desired shape in an inclined surface such as in mountains. Main reason behind it is preventing from erosion in inclined grounds. Secondly, not all of the places in rural areas are suitable for asphalt roads in the aspect of economical infeasibility or physical infeasibility. In such cases, waste tires are buried under the ground to harden that ground and to make it suitable for vehicle transportation. Finally, waste tires are appropriate for barrier building at roadsides. Because of being durable, shock absorber and cheap, they are suitable for it.

Secondly, ground rubber can be obtained from waste tires by chipping them into smaller pieces. By chipping them it is possible to make use of them as groundcover and it is also possible to obtain rubber tiles by compressing or processing them. As Stutz et al. (2003) stated that there are different areas where ground rubber can be used. In chipped form, they are used in playgrounds, running tracks, astroturf and athletic fields. In these areas waste tires are used for softening the surface of the ground. In tile form, they are used in playground tiles and mats. In such cases, benefited property of waste tires is originating from rubber.

Finally, as mentioned before, carbon based materials in tires have a high percentage as weigh and carbon is the main element that is source of the heat in industries. As energy becoming a scarce resource and waste management gaining importance, wastes that can be used in energy production are being critical. Pipilikaki et al. (2005) stated that in general 88 percent of tires in mass is composition of carbon and oxygen which makes their burning process rapid and makes their calorific value high. Because of these properties of waste tires they are substitutes for fossil fuels, as an example one ton of tire derived fuel can substitute 1.25 tons of coal. There are three ways in using them as alternative fuel which are turning them into pyrolytic oil, burning as whole and burning them as chipped form.

As Wojtowicz and Serio (1996) explained pyrolysis process of waste tires in their article, it can be summarized as melting tires without burning them in high temperatures between 550 and 700 centigrade degrees and processing it with chemicals in order to obtain liquid and gas fuel. It is demonstrated that pyro-gas constitutes between 10-30 percent of input amount, pyro-oil is obtained as between 38-55 percent of input amount and char is attained as between 33-38 percent of input amount. After this process, steel and other noninflammable materials are extracted from the tires and the end product shows the properties of fuel. This end product is referred as tire derived fuel or pyrolysis oil. Williams (2013) stated common reactors used to burn this fuel which is rotary kiln, screw kiln, vacuum and fluidized-bed. So that means it is possible to use this fuel as alternative fuel in production sites that own these technologies. According to exchange rates, price of tire derived fuel per ton is $14.13 (Recycler’s World, 2017). So one can see that tire derived fuel is cheaper than fossil fuels.

Other ways do not consist of a chemical process, so tires are being burned directly. Even in chipped form, tires are only shredded which is meaning that composition of tires are not changed. As in that composition, carbon based materials have a high percentage it is possible directly burn them and use it in reactors that are suitable for it. According to Malekiha and Hajiahmadi (2015), when comparing thermal value of waste tires with natural gas and fuel oil, its thermal value is between them lower than fuel oil and higher than natural gas. This thermal value is calculated theoretically by making it equivalent to 0.86 liter of oil. Although theoretical calculation of thermal value of tires may deviate because of the different types of tires that will not remove its alternative fuel property. Also, Deolalkar (2016) has mentioned about calorific values of alternative fuels in his book. Table 3.3 given below shows the calorific values of different fuels and alternative fuels.

Table 3.3. Calorific values of fuels and some alternative fuels (Deolalkar, 2016)

Sr.No.	Fuel	Low Heat Value(kcal/kg)	High Heat Value(kcal/kg)
1	Coal	6600	6900
2	Petroleum Coke	7100	7800
3	**Waste-derived fuel**	**5400**	**6200**
4	**Waste tires**	**7500**	**7900**
5	Wood	4700	4900
6	Sawdust	4700	5100
7	Municipal solid waste	3200	3600
8	Oil	9600	10000
9	Waste oil	5000	5200
10	Plastics	9000	
11	Paper	2900	5300
12	Solvents	6000	

We can see that calorific value of waste tires are higher than coal which means that it is possible to use waste tires instead of coal. However, by only looking for calorific value for usability may be wrong because burning waste tires continuously may cause higher air pollution because of additional ingredients in tires rather than carbon.

To conclude, although waste tires are dysfunctional for cars, they can be used in other ways. It is possible to re-utilize them in civil engineering purposes and make use of them as alternative fuel in energy production. Additionally, it is possible to make use of by turning them into ground rubber. As they are scrap, their prices are relatively lower than substituted material.

4. END OF LIFE TIRES CONCEPT

Products made from natural and synthetic rubbers consisting of high molecular weight polymers which are difficult to destroy in the nature, after completion of their useful life, waste tires are formed. Having completed useful life, original or coated, which cannot be used again as a tire on the vehicle, is described as end of life tire. According to framework published by World Business Council for Sustainable Development (WBCSD) (2010), one billion waste tires which is nearly 17 million tons is generated across the world. Because of the negative effects of them which are risk of fire, hazard posed to human health because of dissolution in water or air and being proper for insect habitant, end of life tires should be handled in a way that is free of risk as much as possible (Sugözü,2009). Although the governments, the tire industry and manufacturers are making great effort to manage waste tires, need for more endeavor is existing. Practices that are applied across the world and Turkey is studied.

4.1. End of Life Tires Concept in World

As end-of-life tires are wastes which are mostly forgotten by people who discarded them after putting in a garbage or getting rid of, waste tires can be said as a concern of government or municipalities or the firms that are making profit out of them. As the publication of United Nations Environment Programme (2011), publication of North Dakota Department of Health (2011), guideline that is published by Environment Protection Authority of South Australia (2010) and publishing of the ministry of national education of Turkey (2011) suggests that waste tires pose hazard to environment and human health. Governments are concerned about waste tires because of environmental effects of it and possible health effects to people when stored improperly. Also, besides of these negative things of them, possible utilization areas of waste tires are attracting the governments. Additionally, as waste tires are valuable assets because of the materials in it, it is possible to gain profit from them when the recycling business done correctly and many recycling firms which are in this sector can be given as examples. In this position, where profit is possible for recycling firms and responsibility of governments or municipalities is existing, it is possible construct different modes for managing end-of-life tires.

European Tyre & Rubber Manufacturer's Association (ETRMA), which is an association that defends benefit of tyre and rubber manufacturing industries across Europe and other international levels and supports development and growth of this industry in favor of environment, health and safety protection, stated three different models that are being applied in Europe. First model is named as extended producer responsibility and it is including the producer of tire in the process of recycling fully or partially. This responsibility is consisting both of operational and financial responsibility of the product and volume of the recycled amount is forced to be equivalent amount of sold by companies by government. In this system producer should ensure the fact that end-of-life tires is discarded or disposed in a way that environmental effect of them is minimized. This process is handled in different methods by manufacturers (ETRMA, 2015). Managing of end-of-life tires can be handled in different ways in this system. This management can be done by a single company or multiple companies that are dealing with end-of-life tires, or individual producers. As reported this system is applied in 21 countries in Europe. Second model is referred as liberal system. In this system, free market conditions are valid for companies or firms that are dealing with end-of-life tires. However, they are supposed to report to authorities and act in compliance with the legislation. This system is applied by 4 countries in Europe. Last model for managing waste tires is tax system. In this system, management of end-of-life tires (ELT) is done by governments. Its financial responsibility is left to producer by a tax and a portion of this tax passed on to the consumer. In Denmark and Croatia tax system is applied. In short, it can be said that nearly all of the European countries have a system for management of waste tires.

Additionally to applied systems for waste management of tires, it is important to examine end-of-life tires utilization areas in these systems. That is because there are many options for waste tires as mentioned before. Products of these options are not same with each other. For example, while direct burning process of waste tires is mainly done for energy generation, crushing or grinding processes are done for landfilling purposes. Although objective of recycling process of them is same, percentages of wastes devoted to recycling methods can differ between countries. That situation can be dedicated to differences in needs and differences in sectors between countries. To illustrate this distinction between countries reports for some countries or regions is given. Firstly, ETRMA's report (2015) for European countries, where data of 31 countries is consisted, is stating that recovery of end-of-life tires is began in 1994 when there is no history for management plan for waste tires and today recovery of end-of-life tires is nearly 95 percentage of all produced amount on the average among reported countries. High portion of waste tires was devoted energy recovery back in 1994 with 68 percentage of total recovered amount, but in today devoted amounts for material recovery and energy recovery is roughly equal to each other. Secondly, U.S. Tire Manufacturers Association (USTMA) (2017), which is an association for traders and manufacturers of tires in the United States, have published a report for market of waste tires in United States for the year of 2015. In report of them, percentage of total managed amount of waste tires to generated amount of waste tires is nearly 100 percent on the average of since 2007. In some of the years this percentage is higher than 100 percent which is meaning that total utilized amount of waste tires is higher than generated amount. Also, statistics for usage areas in United States are included in report. It is summarized that percent of Tire-Derived Fuel to total tons generated is the highest percent in 2015 with 48.6 percent and the second highest one is ground rubber with 25.8 percent. Additionally, shares of sectors in tire-derived-fuel market are given with a pie-chart and related pie-chart is given below in figure 4.1. Volume of TDF market is stated as 1922000 tons of waste tires.

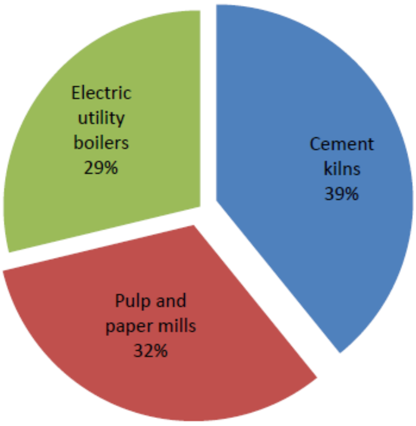

Figure 4.1. Shares of sectors in tire-derived-fuel market in U.S. in 2015 (USTMA, 2017)

In the tire-derived fuel market cement kilns have the highest share with 39 percent of total market for tire derived fuels in 2015. Hirvonen (2017) shared the statistics about waste tires utilization in Finland in his master thesis. Table for the statistics of waste tires in related years is given below in table 4.1.

Table 4.1. Waste tire amounts and utilization in Finland 2011-2016 (Hirvonen, 2017)

	2011	**2012**	**2013**	**2014**	**2015**	**2016**
Recieved	49137	48343	50111	49805	55453	53534
Coating[%]	0.7	1.5	1.4	1.9	1.5	0.9
Material Recovery[%]	93.0	71.4	75.4	68.2	62.3	51.6
Energy Recovery[%]	3.6	11.4	15.4	18.4	18.2	15.9
Other Recovery[%]	7.6	10.6	8.2	8.1	11.6	11.1
Export[%]	1.1	1.8	0.8	0.5	0.5	0.2
Total Recovery[%]	105.9	96.8	101.1	91.0	94.2	84.5

At the table received row is representing the received amount of waste tires. From the table, it can be seen that material recovery is with the highest percentages in all of the years given but its percentage is decreased dramatically over the years. Except for the year 2011 energy recovery have the second highest percentages over years. Also, it is stated that greater part of waste tires is used in the purposes of road operations and constructions. Report that is about status of tire industry and waste tires in Japan for the year of 2015 is published in 2017 by Japan Automobile Tyre Manufacturers Association, which is an association for tire and rubber manufacturers in Japan. In their report, statistics about waste tires and their usage areas is given. It is asserted that rate of total recycled amount of waste tires to generated amount is 91 percent and this rate is said to be decreased by one point. Also, it is stated in the report that in the period between the years 2012 and 2015 thermal recycling has the highest percentage with an average of 66 percent for the given period among the recycling types. When one checks for the share of thermal recycling techniques in the given percentage, it can be said that paper manufacturing has the highest share in the period with a substantial difference. Additionally, Uruburu et al. (2013) mentioned about end-of-life tire management system in Spain and shared statistics for the years between 2006 and 2010. According to them, granulated rubber and led steel recycling have the highest percentage between the kinds of recycling of waste tires with 54 percent on the average for given period. The second highest percentage is belonging to the energy recovery option with 32 percent. It is stated that, among the energy recovery options for waste tires cement manufacturing area have the highest percent, which is more than 95 percent, with a remarkable difference with other areas.

In these systems, as mentioned before, waste tires can be reutilized in different ways. There are different options for reusing them which are ranging from retreading to incineration. However, their effects on environment are unlike from each other. Rodriguez et al. (2017), researched the environmental effect of waste tires in three distinct usage alternatives for waste tires. They have used life cycle assessment methodology, which is a systematic analysis of environmental impact of a product throughout life cycle of it. These three usage alternatives are retreading, incineration and grinding for different purposes. In result of their analysis, it can be stated that, some of the grinding processes for different manufacturing options like tile and wire production and incineration is beneficial in environmental aspects. However, it cannot be said for retreading waste tires and grinding for production of asphalt. In conclusion, not all of the options for recycling of end-of-life tires are environmentally beneficial and in greater extents of recycling where different alternatives for usage of waste tires are present environmental aspects of it should be considered.

To sum up, with the different usage areas of waste tires which have different effects on environment and which are varying in operational costs, usage percentages for distinct purposes can vary between countries. Also, that is dependent on countries' needs and governments are using different methods when dealing with them and have specific legislations about them.

4.2. End of Life Tires Concept in Turkey

Like the examples of applications for waste tire managements across world, Turkey have legislation about end of life tires. In order to regulate the administrative and technical principles for the "End of Life Tires Control Regulation "was published in the Official Gazette dated 25 November 2006 and numbered 26357, was become valid on January 1, 2007. Also, this regulation determines tires of carcass type and also prohibits the import of end of life tires. End of Life Tires Control Regulation is given in Appendix A.

On 11.04.2007, tire manufacturers came together to establish Tire Industrialists' Association (LASDER) and took on the obligation to collect waste tires. In this context, a total of 19 facilities become entitled to receive recovery licenses from 2007 to 2012. At present, there are around 35-40 million tire production capacities in Turkey and all of the raw materials used in tire production are imported. The recovery / recycling of tires are very important in terms of economy and environment. ELTs operate in two basic areas: energy recovery and material recovery. As mentioned before, "Pyrolysis" is a chemical process which is an important method in the recovery of ELTs as material. By this method, "pyrolytic gases", "pyrolytic oils", "steel wire" and "industrial waste" are separated and high economic value is obtained. The oils are processed as fuel in the production of "electricity" without any change. The other output of the pyrolysis process is used as an alternative energy source to meet the energy demand of the plant or to be used as a gas because of its being flammable. The other product is “carbon black" can be used as raw material for many products based on rubber. In the case of a material recovery method applied to ELTs, the size of ELTs is reduced and parts, granules or powder are produced. These products; street furniture, street signs, traffic signs, carpets, barn flooring, security flooring for schools and playgrounds, sports and recreation area coatings can be used in these areas (LASDER, 2017). According to publishing by Ministry of Science, Industry and Technology of Turkey (2014), every year in Turkey about 200,000 tons of tire life has been ended. Many products can be obtained by recycling a tire. As a result of recovering 200,000 tons of end of life tire; about 146,000 tons of rubber granules and 38,000 tons of steel is being recovered. As a result of the pyrolysis process of 200.000 tons ELTs; approximately 80,000,000 liters of pyrolytic oil, 60,000 tons of carbon black and 30,000 tons of pyrolytic gas are recycled.

ELT is considered as an alternative fuel to obtain energy, especially in the cement plant used, in lower sulfur content and to obtain the same energy value. In Turkey, there are several recycling plants which can process ELTs by the Environmental Permit and Undergraduate Certificate from the Ministry of Environment and Urban Planning. They are shown on map given below in figure 4.2.

Figure 4.2. Licensed recycling plants and temporary storage areas (Ministry of Science, Industry and Technology, 2014)

In Turkey, the number of road motor vehicles in September according to the report (Turkish Statistical Institute, 2017) equals to 22,038,944. Road motor vehicles include automobile, minibus, bus, small truck, truck, motorcycle and special purpose vehicle, and tractor. The percentages of these road motor vehicle types are used are shown on figure 4.3.

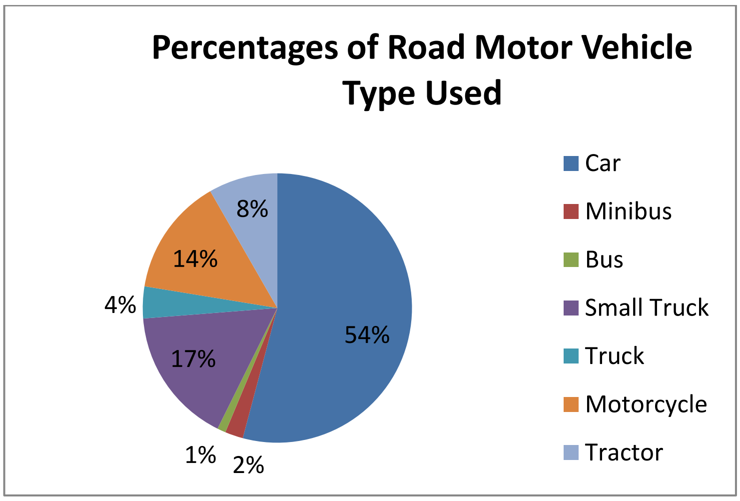

Figure 4.3. Percentages of vehicle type in Turkey (Turkish Statistical Institute, 2017)

Determining the type of vehicle is an important factor related to wheel size and mass. As mentioned before, obtaining energy using alternative fuel as ELTs is strictly related to this tire types in other words it's mass and size. In addition, the number of road motor vehicles by province is as important as vehicle type because obtaining ability of determining locations of supply points of our reverse logistics system. According to same data obtained from Turkish Statistical Institute in September 2017, 10 cities having most vehicles that are 55 percent of total vehicles shown on the Table 4.2.

Table 4.2. Number of motor vehicles by cities in Turkey (Turkish Statistical Institute, 2017)

City	The Number of Motor Vehicles
İstanbul	**4 013 551**
Ankara	**1 859 604**
İzmir	**1 330 258**
Antalya	**1 008 977**
Bursa	**830 078**
Konya	**700 551**
Adana	**630 046**
Mersin	**584 510**
Manisa	**567 795**
Gaziantep	**483 065**
Total	**12 008 435**

When determining locations of new potential recycling plants and temporary storage areas, the number of vehicles by province should have an important impact on that by minimizing transportation cost in recycling end of life tires logistics operations.

Another important issue tire recycling management is the cement factory that is considered as customer or demand point. According to Turkish Cement Manufacturers' Association (TÇMB) (2018) report, the total number of entegreted cement factories in Turkey is 49. With a production of approximately 100 million tons, Turkey is the 5th biggest producer of cement in the world. It is behind at China, India, USA and Japan. It is at first place in Europe in cement production. The more cement production, the more fuel energy needed in cement factories. Locations of cement factories in Turkey are shown on the Figure 4.4. All of the members of the association cement factory in Turkey is given in Appendix B.

Figure 4.4. Location of cement factories in Turkey (Turkish Cement Manufacturers' Association, 2018)

When have examined the two Turkey maps including cement factories and recycling plants, it is obvious that number of cement factories and recycling plants by city are correlated to each other. The most important factor of this correlation is seems like population of city which can be said to be proportional with waste amount for recycling plants and demand for cement for cement factories.

Another statistics made by the Ministry of Environment and Urban Planning in 2013 related to ELT amounts used as additional fuel in recycling facilities and cement factories between 2007 and 2012 is shown on below figure 4.5 with graph.

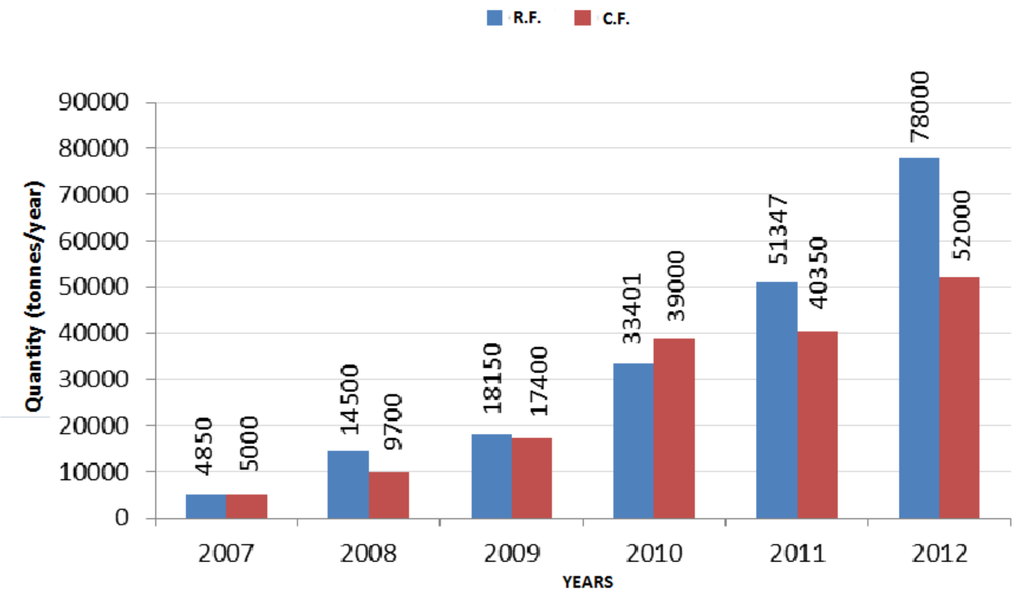

Figure 4.5. Graph of ELT quantities for recovery facilities and cement factories versus years (Ministry of Environment and Urban Planning, 2013)

If one examines the graph, he or she can see that ELT amounts used as additional fuel both in recycling facilities and cement factories have increased year by year. When considering environmental and economic benefits of ELTs used as a fuel, it is obvious that it is increased by years. One of the most crucial points in here is that usage in cement factories constitutes a great portion of total recovered amount of ELTs.

5. NETWORK DESIGN FOR ELT USAGE PROBLEM

To gain insights about related areas for designing a reverse logistic for waste tires necessary literature research is done. For beginning, because of the existence of flow of material between the nodes in supply chain, general models for transportation and models for supply chains is examined. Other crucial aspect of establishing a new facility is its location. To see how a decision about a facility's location is given, related works is researched. These works are including general models and solution methods for facility location problems. Additionally to these models and solution methods, there are new approaches to voluminous problems and vehicle routing problems. These approaches can be named as clustering algorithms. To consider solution methods with clustering algorithms in network problems, related works, which are about general clustering algorithms and their application areas, is searched. To clarify usage of end of life tires in cement factories, necessary research is done. Finally, past works about waste tire networks and waste tire supply chains is examined for getting info about considered aspects in waste tire recovery. Mentioned topics are given below.

5.1. Literature Review on Transportation and Supply Chain Problems

Firstly, to have insight about general transportation models and supply chain models, necessary researches conducted. Zanardelli et al. (2015), stated the differences between designs in network planning. A variety of network design problems in transportation, distribution, communication, and several other problem domains require trade-offs between variable operating costs and fixed design costs. Network design problems are considered by transportation types as called road, rail, air and marine. Researchers conclude such problem depends on specific country or region. For example, Yamada et al. (2009) apply his model on transportation in Phillippines and Tsao (2013) on supply chain in Taiwan. Their analysis and models are different from each other because they use different transportation mode depends on their country and different constraints of different regions. From here, it can be stated that network design models affected by different objectives and different planning horizons. There are three decision levels which can be called as strategic, tactical and operational planning. As planning horizon becomes wider, time representations in models become extended and frequency analysis become rare. Williams (2013), explained related models with the supply chain in his book. Related models are profit maximizing model with multiple plant, transportation models with single product and a derivative of travelling salesman problem model. First one is dealing with the capacity allocation when operating more than one facility, second model is dealing with the assignments of transportation vehicles and the last model is for routing of transportations vehicles for multiple periods. Goetschalckx (2011), illustrated related models with a supply chain network. They are single vehicle round trip routing models, vehicle routing models with time windows, some of the vehicle routing heuristics and multi echelon supply chain models. First two models are used for dealing with routing problems in a supply chain and last one is a generic model which finds optimal flow paths from sources to destinations with two different versions which are can be named as arc based and path based models. While these models applied to a wide variety in transportation and network models, voluminous problems may need other solution approaches because of computation time. One example of this kind of problems is multiple vehicle routing problem. In multiple vehicle routing problem there are a number of repositories, vehicles, and delivery locations and the problem is to optimize the routes of the vehicles. This is represented by an undirected graph with vertices representing locations and edges representing paths between locations. One important facet of this model is that each vertex is connected by an edge. Critical points of such problem can be summarized as edges in network are weighted which represents the distance between vertices, one vehicle must be assigned to each delivery and each vehicle has maximum carrying capacity and road capacity to travel.

The Clarke and Wright savings algorithm is one of the most known heuristic for VRP. It was developed by Clarke and Wright (1964) and it applies to problems for which the number of vehicles is not fixed (it is a decision variable), and it works equally well for both directed and undirected problems. When two routes can feasibly be merged into a single route, a distance saving is generated. The other heuristic for VRP is called Sweep Algorithm. The method heuristic by Wren and Holliday (1972). This algorithm is primarily used to find the shortest route. With knowledge of location of nodes, distance between each demand nodes and depot node, algorithm starts with a randomly selected node and calculates nearest nodes' distances to this point. Then, algorithm adds up points by their closeness until routes are formed or until capacity of vehicle is reached. To conclude, there are different ways to deal with a transportation problem in a supply chain. A solution can be obtained by a mathematical model or a heuristic. Choose of solution way is dependent on volume and complexity of problem.

5.2. Literature Review on Facility Location Problems

While planning a network, facility location problems is an important issue. It is crucial to give an optimal decision about facility's location because this decision is persistent. A Facility Location Problem (FLP) consists in defining the position of a set of points (facilities) within a given location space on the basis of the distribution of demand points (users) to be allocated to the facilities. Eiselt and Laporte (1995) illustrated main elements of Facility Location Problems as space where the facilities are to be located; service demand that are expressed by customers; interaction between customers and facilities; metrics to measure distances between customers and facilities; constraints to be satisfied. Many researchers showed interest in retail collection network design from different points of view but there is lack of a complete understanding and obtaining framework of the matter. The p-median problem on a network was investigated by Goldman (1971). Goldman provided simple algorithms for locating a single facility for both an acyclic network (a tree) and a network containing exactly one cycle. Another well-known, albeit trivial, algorithm for the 1-median on an acyclic network is known as the Chinese Algorithm. Dearing, Francis, and Lowe 1976 provide the interested reader with a thorough treatment of convexity on a network. Zhu et al. (2016) consider a new capacitated plant location problem with customer and supplier matching and they considered failure probability of a facility. Liu et al. (2010) introduce a location model that assigns online demands to the capacitated regional warehouses currently serving in store demands in a multi -channel supply chain. Problems with covering constraints were defined in the 70's. The objective in this case is to locate facilities such that demand areas (clients) are covered. A demand area is said to be covered by a facility (server) if it is within a critical, pre-defined distance (time) from this facility. The simplest of these models seeks to find the minimum number of facilities (and their locations) such that all demand areas are covered by at least one facility. Church & ReVelle (1974) defined a model in which the number of facilities to be located is fixed, but in this case coverage of all demand areas is not guaranteed. Galvão & Raggi (1989) have developed another algorithm for uncapacitated facility location problems. He has been working on uncapacitated facility location problem with non- Euclidean data set. The non-Euclidean data sets were randomly generated in the algorithm. They correspond to combinatorial optimization problems that are much harder to solve than the Euclidean problems. In this case the algorithm shows a clear advantage over the use of optimal procedures (e.g., the algorithm of Galvão & Raggi), when computing times are taken into consideration. It produced, on average, solutions of very good quality in very reduced computing times. In short, facility location problems are major issue in network planning. Different analytical approaches can be used to determine a facility's location.

5.3. Literature Review on Clustering Algorithm Applications in Network Problem

To have information about one of the current trends in industrial engineering which is using clustering algorithms, required study have been done. In the book written by Jain and Dubes (1988), types of clustering algorithms are explained and classification of them is given. There are 3 main topics where algorithms differ from each other. Being exclusive or non-exclusive, which is meaning that points of data is distinctively grouped into clusters or some of these points are not in any of the clusters, is top separation point of algorithms. Following separation is at being supervised or not. Clusters can be formed by the help of priory information provided or finding the differences between clusters can be done by algorithm. Final separation is being hierarchical or partitional. While in partitional algorithms only one classification is done to find clusters, in hierarchical algorithms clusters are obtained as a result of special sequence of partitional classifications. These separation of clustering algorithms can be rooted from the different objectives of clustering algorithms in varied areas. These algorithms are used in very wide areas ranging from big data analysis, pattern recognition to social sciences. It can be said that these algorithms can be applied to any area which involves a data about many different points and requires a classification between them. Geographical data sets are suitable for clustering algorithms. Thus, as models for vehicle routing can be hard to constitute and apply to problem, it may be useful to use clustering algorithms to get routes. Naalusamy et al. (2010), talked about using clustering algorithms in difficult and computationally voluminous environments. One of the areas that clustering used is NP-hard models. Vehicle routing problems is one of such models. They applied clustering algorithms to multiple vehicle routing problem and multiple travelling salesman problem and showed that the efficiency of it. It is based grouping closest points of nodes together except for source and destination. Jain (2010), mentioned about k-means clustering algorithm in his article. He gives general information about clustering algorithms and the purpose of them while stating the advantages of k-means algorithm. He continues with the explanation of k-means algorithm and extensions of it. Jain and Dubes (2010) explained in their books about clustering algorithms. They gave details about implementation ways of these clustering algorithms and basic information about how to prepare a proper data set for clustering algorithm such as normalizing the data.

5.4. Literature Review on Waste Tire Networks

Moreover, to see ways of dealing with waste tires, some of past works about waste tires or alike articles are examined. Most of them are focused on entire supply chain of waste tires and they have different methods. However, general problem is a cost minimization problem and some of them have profit maximization as a second objective. First of all, Han et al. (2009), in their studies, they developed a linear model that is minimizing the cost of building recycling facilities, cost of transportation and cost of processing the waste tires. They have aimed to obtain optimized flow assessments between the levels of reverse logistic supply chain. Dehghanian and Mansour (2009), in their article, proposed a multiple objective model for multiple optimization of recycling network of waste tires. Objectives of their model are maximizing the revenue generated from recycled waste tires and activities, minimizing the total cost incurred by activities while recycling the waste tires and maximizing the social benefit from it. Kannan et al. (2009), in their studies, they have developed multi echelon supply chain model and a closed loop multi echelon supply chain model for tire manufacturing industry and plastic products industry. Objective of closed loop multi echelon supply chain model is minimizing costs that are incurred by gathering the product that are being circulated, transportation cost between gathering centers and recycling facilities and necessary process for recycling. Sasikumar et al. (2010), constructed a mixed integer non-linear programming model that is maximizing the profit of multi echelon reverse logistic network which is for re-producing and resurfacing of waste tires. Subulan et al. (2015), formulized a mixed integer linear programming model and designed a closed loop supply chain network for gathering, stocking, recycling and disposing of waste tires in an efficient with the objective that is maximizing the profit and natural indicators. Amin et al. (2017), designed a closed loop supply chain network and constructed a mixed integer linear programming model for that network. Model is consisting of multiple products, multiple suppliers, multiple facilities, multiple retailers, multiple demand markets and multiple disposing depots and model has an objective that is maximizing the profit generated by this network. Finally, Pedram et al. (2016), developed mixed integer programming model with multiple products and with multiple objectives which are minimizing the pollution and waste caused by waste tires and maximizing the profit from the designated closed loop supply chain. By this model, information about number of facilities, location of them and material flow between facilities are obtained.

5.5. Using ELT as an Alternative Fuel for Cement Factories

One of the areas of utilization for energy generation from waste tires is using them in cement factories. Cement factories have a burning process in the production of cement where most of the time coal is used. Advantages of using waste tires in cement factories have been examined by many researchers and engineers. Kop et al. (2012) conducted a research for a selection between the ELT management methods in current conditions. They stated that incineration of waste tires in cement factories can be named as the most suitable method. Additionally, Deolalkar (2016) outlined advantages of using alternative fuels such as waste tires in cement plants. The most significant aspects can be said as running on lower cost for required burning process and making contribution to removal of waste tires from environment.

Nakajima and Matsuyuki (1981) have showed the burning process of waste tires in cement factories and they are directly burned in kiln by taking thermal load into consideration. It is known that quality of cement that is produced by using waste tires is not different from cement produced with conventional process. As stated before, calorific value range of waste tires is similar with the fossil fuels. So, waste tires are appropriate for cement factories. Blumenthal (2005) stated estimate of amount of waste tires that is used in cement industry in United States, for year 1996 which is between 75-100 million tires. Estimate for total generated scrap tires for same year is stated as 253 million. From here one can say that waste tires are one of the most used fuels by cement factories.

To sum up, because of the low-cost waste tires it is logical to use them in cement factories. One of the most important advantages of usage of waste tires in cement factories is that additional pollution from it to environment is insignificant. Nakajima and Matsuyki (1981) is stated that content of the tires presented no problem for the dust collector but as they burned completely may cause black smoke.

5.6. Network Design Examples for Waste Tire Utilization in Cement Factories

Because of the opportunity created by low cost of waste tires and by properness of waste tire utilization for cement factories, it is logical to put them to use in cement factories. However, because of the complexity of issue which is within the bounds of reverse logistic it requires a systematic approach. Otherwise, it is possible to end up with unforeseen consequences in the aspect of cost. There are past works which are about network design for environments where reverse logistics is applied and examples from them are given below.

Sasikumar et al. (2010) designed a reverse logistics network which has multi-echelons. Representation of network is given below in figure 5.1.

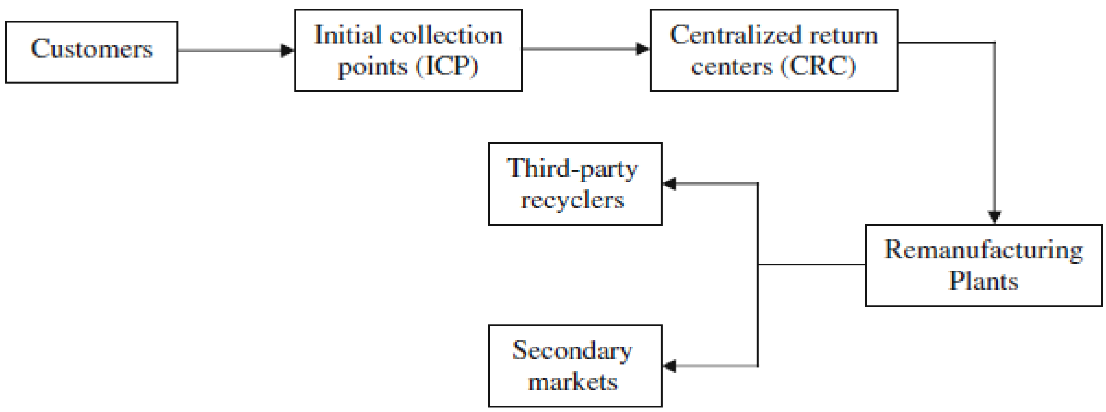

Figure 5.1. Representation of product recovery network (Sasikumar et al., 2010)

Their network is constructed for returned products which are recycled or remanufactured. The network is consisting many elements which are customers, initial collection points where returned goods from customers is gathering, centralized return centers which is the second step for returned goods after collection points, remanufacturing plants where goods are sent after centralized return centers and third-party sellers and secondary markets which are end points for the returned product in the network. If it is needed to be summarize considered points in their model they can be listed as given below.

- Rental or establishment costs for collection points and return centers
- Minimum number of establishments
- Costs related to inventorying and collection operations
- Physical distances between echelons of network
- Maximum capacities of collection points and return centers
- Fixed and variable costs that incurred from logistic operations in the network
- Variable cost of remanufacturing
- Revenue generated from final products
- Amount of remanufactured product

Formulated model for issued network have a variety of decision variables which are listed below.

- Allocation of customers to initial collection points
- Opening or establishment of collection points and centralized return centers
- Volume of the product that flows between echelons

With all of the given considered aspects and decision variables, they aimed to maximize profit generated in the network. Experimental result of mentioned model is showed usefulness of model and achieved validation of model.

Organ et al. (2013) have designed a reverse logistics network for end of life tires. Their network is consisting of three echelons which are shown in figure 5.2.

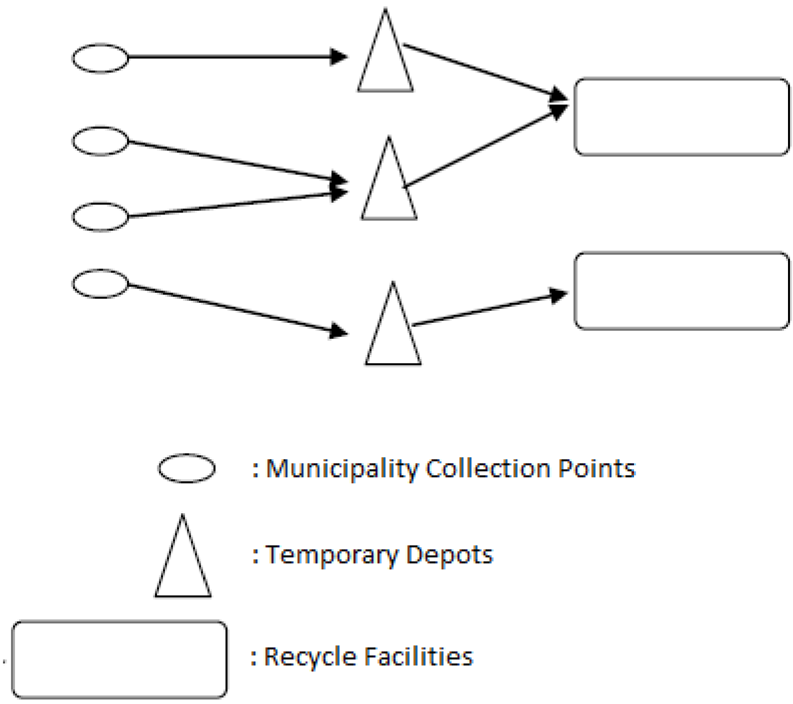

Figure 5.2. Network representation for end-of-life tire recovery (Organ et al, 2013)

In their network, they aimed to minimize cost associated with operations. Where they have defined costs according to given variables below:

- Transportation costs of material between points
- Inventorying costs at temporary depots
- Fixed costs of temporary depots
- Revenue generated from outputs of recycle facilities

In model this revenue aspect is given as negative to objective function because costs are given positive. To minimize total cost, they tried to decide location of municipality collection points among candidates, location of temporary depots among candidates and they tried to give decision about which of the recycle facilities will be used. They have tested their model for a province in Turkey which is Denizli. Also, they have applied this model for different scenarios where collection amount of end-of-life tires is changing. Conclusion they draw from study is that it is natural to incur cost instead of gaining profit. That is arising from that sale price outputs of such system is low and cost aspects are considerable.

To sum up, in a reverse logistics network, it is possible encounter with many different aspects which are related parties to mentioned network. That is because of the fact that systematic approach is taken, which is a holistic approach rather than a reductive approach. Moreover, result of the taken approach may be useful for some of the parties or entire parties in said network. That is dependent on considered points while constructing model for network.

6. CASE STUDY

Excessive amounts of waste tires are harmful to environment in some ways. Although they are waste, they are valuable assets because of potential uses of them. One of the usage areas of them is using them as energy source in cement factories. This process requires a system where reverse logistics is involved. In a reverse logistic supply chain, generally cost of transported good is relatively low comparing with other sectors. That makes network flow of that good between echelons of supply chain more important than the other cost aspects such as price of related good. However, there are some aspects in such a situation that should be taken care of.

In Turkey, LASDER, an organization that founded by tire producers which have operations in Turkey, is the biggest foundation that deals with the waste tires. Information that is gathered by talks with authorities of LASDER, it is stated that LASDER is gathering nearly 200000 tons of waste tires at Turkey. In order to manage this amount of waste tires a systematic approach should be taken. However, in current application for gathering of waste tires, LASDER is operating on daily decisions. For instance, whenever a demand for gathering waste tires is generated by tire traders or shops, LASDER transmits this demand to contractor firm which it sees to be proper for gathering job. In terms of the collection of waste tires, Turkey is divided into 8 regions and there are contractor firms that are authorized in each region. These regions are visualized on the map below.

Istanbul -Trakya
Marmara
Northern Central Anatolia
North
Aegean
South Central Anatolia
East Mediterranean
Southeastern Anatolia

Figure 6.1. Representation of Turkey in the region for the collection of waste tires

According to the information received from LASDER; approximately 30000 tons of waste tires was collected in North Central Anatolia region in 2017, and 20000 tonnes of these tires came from Ankara. Because of the great volume of the problem, study will be centered upon Ankara. For further clarification of system for waste tire recycling, firstly, tire brands are responsible from the gathering and recycling of tires they sell.

However, they are not fully responsible. They are responsible up to a degree which is %80 percent of they sell.

Under this condition, nearly all of the waste tires are held at responsible brands hand. These waste tires needed to move cement factories via contractor firms. To elaborate supply chain of waste tires a representation of system is given in figure 6.2 below.

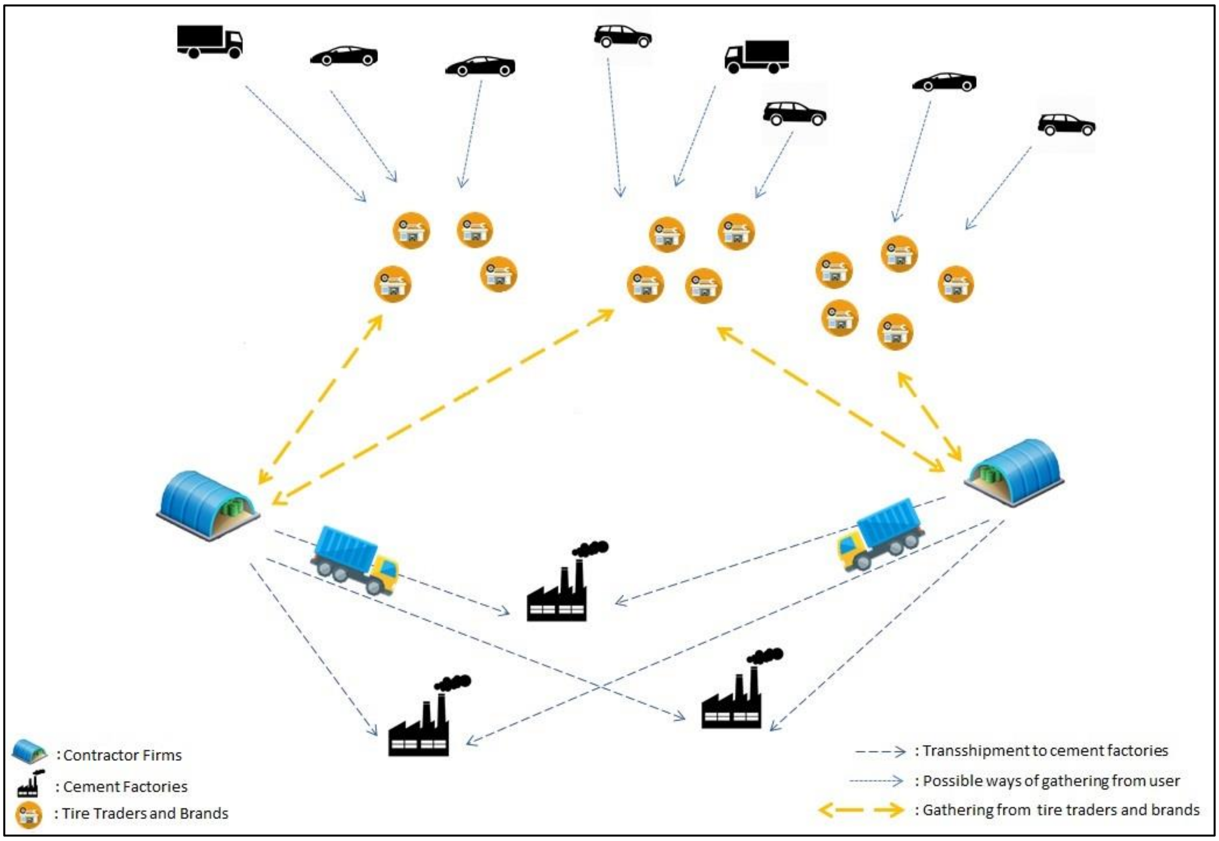

Figure 6.2. Representation of system of recycling of tires

In here, there are three echelons of supply chain. They can be named as, accumulation point of waste tires, contractor firms and cement factories. After customer done with their tires, waste of them are accumulated at tire shops. Blue facilities below tire shops are representing the contractor firms. Lastly, black facilities are representing the cement factories. Colored arrows are representing the flow of waste tires and shredded waste tires between echelons.

In current situation, in city Ankara amount of created waste tires is 1543425 tires in year of 2017. Although all of tires are not same with each other, an assumption states that 80 percent of generated amount is car tires and 20 percent of them is truck or bus tires. Additionally, average weight of car tires is 9 kg and average weight of truck tires is 45 kg. This amount of waste tires is accumulated at waste tire accumulation points which points needed to be visited at least weekly. These points are tire shops or brands where city Ankara have 107 different tire shops or traders. Nearly all of the waste tires generated by consumers is end up at these accumulation points. Although amount of waste tires accumulated at these points are different, accumulation rate of waste tires is assumed to be uniform over the year. Yearly accumulated amounts, that are required to be disposed properly, at points are given in table 6.1. These accumulation points are dispersed over the city. Coordinates, which are in units of latitude and longitude, of accumulation points are given in table 6.2. The normalized values of these coordinates are given in Appendix C with the dealer names.

Table 6.1. Yearly accumulated amounts in number of waste tires

Points	Amounts	Points	Amounts	Points	Amounts	Points	Amounts	Points	Amounts
1	13000	23	17550	45	16250	67	14300	89	11700
2	14300	24	15600	46	14950	68	15600	90	12350
3	14950	25	14300	47	11375	69	16900	91	11375
4	11700	26	16900	48	12350	70	16900	92	13325
5	16900	27	15600	49	13000	71	13325	93	13975
6	16575	28	15600	50	17550	72	10400	94	18850
7	16250	29	16250	51	13650	73	11700	95	15600
8	13000	30	13650	52	14300	74	12350	96	14950
9	14300	31	12350	53	13000	75	13650	97	14950
10	13650	32	14625	54	13325	76	16250	98	13000
11	16900	33	13650	55	12025	77	16900	99	17550
12	15600	34	16575	56	12350	78	11375	100	17875
13	16250	35	16900	57	15600	79	11375	101	14950
14	18200	36	17875	58	12350	80	12350	102	12350
15	13000	37	11700	59	12350	81	15600	103	15600
16	15600	38	13975	60	11700	82	15600	104	15600
17	14950	39	14300	61	10400	83	14300	105	12350
18	13650	40	15600	62	14300	84	14950	106	16250
19	13000	41	15925	63	13650	85	13650	107	15600
20	16250	42	12675	64	12350	86	14300		
21	18200	43	11700	65	13000	87	13000		
22	18850	44	16900	66	13650	88	11700		

Table 6.2. Coordinates of accumulation points

Points	Longitude	Latitude	Points	Longitude	Latitude	Points	Longitude	Latitude
1	32.806103	39.963756	37	32.887497	39.957559	73	32.851683	39.948312
2	32.845008	39.955424	38	32.841897	39.954592	74	32.721169	39.945612
3	32.852832	39.949560	39	32.839867	39.954290	75	32.824374	39.954631
4	32.750440	39.965209	40	32.843424	39.955875	76	32.854861	39.951155
5	32.822874	39.913446	41	32.839005	39.953867	77	32.751085	39.993681
6	32.736810	39.987700	42	32.774102	39.957748	78	32.765433	39.994561
7	32.713738	39.933828	43	32.763857	39.956303	79	32.880928	39.958104
8	32.714728	39.939533	44	32.771689	39.964392	80	32.815111	39.901342
9	32.714870	39.933880	45	32.755331	39.962301	81	32.752096	39.965098
10	32.853692	39.950533	46	32.717782	39.931400	82	32.776787	39.994484
11	32.853786	39.951575	47	32.744586	39.970759	83	32.764712	39.995159
12	32.844203	39.955271	48	32.843424	39.955875	84	32.777830	39.910121
13	32.841589	39.954221	49	32.646866	39.964643	85	32.838414	39.921961
14	32.901255	39.933762	50	32.766325	39.995242	86	32.816945	39.861473
15	32.763910	39.974681	51	32.677544	39.894695	87	32.809546	39.912790
16	32.763701	39.974818	52	32.713374	39.935039	88	32.696212	39.953928
17	32.750301	39.965089	53	32.641593	39.870257	89	32.735220	39.967449
18	32.749227	39.965824	54	32.584650	39.976372	90	32.755839	39.964144
19	32.771816	39.995396	55	32.752391	39.968675	91	32.761608	40.001864
20	32.749323	39.985154	56	32.766981	39.995473	92	32.711606	39.949508
21	32.719067	39.934423	57	32.713939	39.937930	93	32.657779	39.896185
22	32.713779	39.940196	58	32.712026	39.940754	94	32.821630	39.899741
23	32.579968	39.972440	59	32.757806	39.971291	95	32.850095	39.946945
24	32.847104	39.896443	60	32.763158	39.973910	96	32.639089	39.863177
25	32.859998	39.913364	61	32.841589	39.954221	97	32.693986	39.976893
26	32.881311	39.880853	62	32.841352	39.954223	98	32.695547	39.990429
27	32.828875	39.888323	63	32.822017	39.868057	99	32.697103	39.954395
28	32.854355	39.866525	64	32.849296	39.941480	100	32.580161	39.972045
29	32.823045	39.905514	65	32.766624	39.995335	101	32.566482	39.966336
30	32.815250	39.898044	66	32.711958	39.939799	102	32.889952	39.957475
31	32.809950	39.905896	67	32.859742	39.933363	103	32.844065	39.955520
32	32.819072	39.927486	68	32.753426	39.969583	104	32.802729	39.923044
33	32.847677	39.942237	69	32.840491	39.954374	105	32.805518	39.963886
34	32.817655	39.862115	70	32.840491	39.954374	106	32.845197	39.946097
35	32.852423	39.950013	71	32.761363	39.930189	107	32.759633	39.975174
36	32.841382	39.949039	72	32.648456	39.946823			

Second level of supply chain is consisting of waste tires processing facilities. Contractor firms are connection between the sources of waste tire and cement factories. They are gathering the waste tires in their hand and selling it to the factories. In here, these processing facilities are responsible from the gathering and transshipment process of waste tires. Their output is waste tires where they are not processed, and they are directed to factories. In Ankara, currently there are 3 other companies in this business. All of them is allowed to participate in recycling process. They are chosen facilities that are going to be in supply chain which is decided at the beginning of year. Additionally, coordinates of processing facilities are given in table 6.3.

Table 6.3. Coordinates of processing facilities

Contractor Firm	Longitude	Latitude
A	32.79245377	39.96375600
B	32.70876053	39.95542400
C	32.66691390	39.94955980

Third level of supply chain is cement factories. These are the final points for waste tires. As mentioned before, reason behind of usage of waste tires for cement factories is being less costly than other energy resources. So, this cost aspect for cement factories is creating a demand for waste tire based energy resources. However, cement factories are not completely free in demanding these products because of some regulations about this process which is applied by Turkish government. There is an indirect quota on using waste tires in factories. This quota which is limiting outputs of a factory such as NO_2 and SO_2, is coming from the regulations by ministry of environment and urbanization. This regulation is standing for preventing excess amounts of harmful outputs. Limitation of this is done over total energy consumption of cement factory and permitted amount of waste tire and its products is limited by a certain amount of energy that can be generated from them. Moreover, this quota is renewed yearly. As cement factories is demanding waste tires up to their quota, delivery of waste tires or its products can be assumed to be flexible in time over the year. In Ankara there are 3 different cement factories that are allowed to use waste tires. Coordinates of cement factories are given in table 6.4. Their quota for using waste tires are given in table 6.5 in units of tons.

Table 6.4. Coordinates of cement factories

Cement Factory	Longitude	Latitude
1	32.74725942	39.9637560
2	32.71712985	39.9554240
3	32.82258334	39.9495598

Table 6.5. Limits for usage of waste tires in cement factories in tons

Cement Factoreries	Limits
1	8200
2	5000
3	4200

To sum up, problem here can be stated as, amount of waste tires is likely to increase and to prevent society from huge stockpiles of waste tires and to use our natural sources efficiently they should be reused in a way. One of the ways of reusing them is substituting them for energy sources in cement factories. However, bringing waste tires to cement factories from the consumers of tires can lead to high costs if it is not done correctly. As in every reverse logistics, main cost aspect is the transportation cost which is 2 TL per kilometer for empty truck and additional 0.35 TL per ton. To manage flow between consumers and factories a systematic approach should be taken. As cost of waste tires low, their distribution is critical. To visualize distribution of accumulation points, candidate contractor firms and cement factories map for them is given below in figure 6.3.

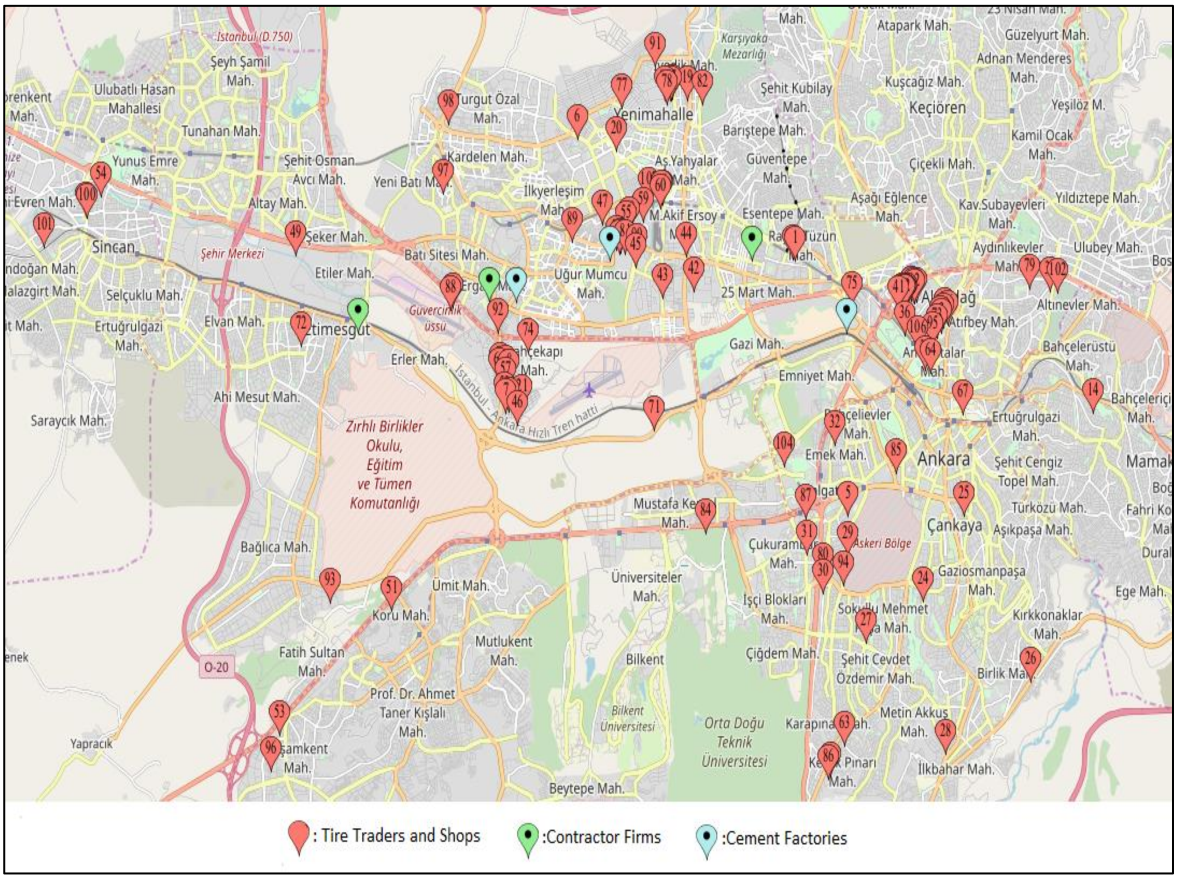

Figure 6.3. Map for accumulation points, contractor firms and cement factories

In this situation, quota of cement factories for usage of waste tires should be filled. This will be done by contractor firms. Contractor firms that will gather waste tires from accumulation points and tranship them to cement factories, is needed to be chosen among the candidates. To make this process cost efficient, gathering routes between contractor firms and accumulation points should be determined because waste tires at accumulation points should be gathered by contractor firms in order to prevent excessive amounts of waste tires. Under these conditions, overall cost for this process should be minimized.

7. SOLUTION METHOD

To begin with, although waste tires is the only material that flows through the given supply chain, they are being collected from many different points. As one can see from the map they are dispersed over Ankara but most of them are gathered at industrial zones. Optimal solution to problem can be obtained by applying multiple vehicle routing problem models however it is not possible to get solution in a reasonable time because of the volume of the problem. So, it is needed to simplify problem or break into parts to solve it properly. To handle problem, a step by step solution method is applied. Method is beginning with clustering algorithm which is used for reducing the size of roblem. After that, travelling salesman problem model applied to resulting clusters to get routes between accumulation points and contractor firms. Finally, a model is used to choose used routes by contractor firms and to determine to amount of waste tires that flows between contractor firms and cement factories. These models are programmed and implemented in GAMS (General Algebraic Modeling System) optimization package and solved using the CPLEX solver. To elaborate steps sequencing of them is given below.

Sequence of steps in method:

- Clustering accumulation points where number of clusters is 5k. Initial k is chosen to be 1.
- Obtaining distances for resulted clusters by using travelling salesman problem model.
- Solving network problem by using generated model for problem and recording their objective function values.

- Repeating steps until k=11.
- Choosing the number of clusters with best objective function value.
- Further searching to be sure about optimality which is repeating first three steps for the number of clusters with the best objective function value, n, between the interval n+4 and n-4.
- Choosing the optimal solution with best objective function value.

Clustering

Firstly, there is need for distinct and certain clusters because of the joint tenancy of accumulation points by contractor firms. To track amount gathered from accumulation points in an easy way clusters should be same for every other contractor firms.

According to Jain (2010), clustering methods can be investigated under two main topics which are hierarchic clustering methods and partitional clustering methods. Because of there is no hierarchic relation between points in problem partitional methods are chosen to be investigated. Further, as Jain stated (2010) there four different methods under partitional clustering. They are sum of squared error method, graphic theory, mixture solving method and iterative method. Moreover, Jain and Dubes (1988) pointed out that use of sum of squared error method yields more compact clusters also mentioned about advantage of k-means which is an algorithm that is widely used and the most effective one among these algorithms. As objective of applying clustering algorithms is obtain compact and isolated clusters, k-means algorithm chosen to be applied which is one of the sum of squared error method.

To clarify k-means algorithm, a flow chart is given in figure 7.1 below.

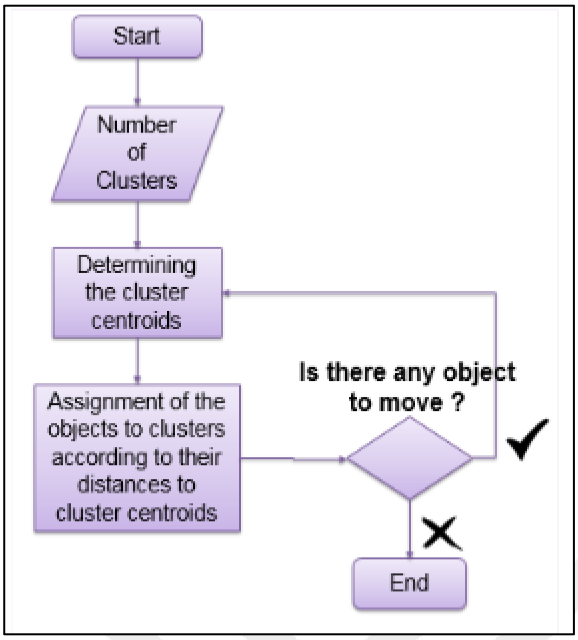

Figure 7.1. Demonstration of k-means algorithm

K-means algorithm starts with a determined number of clusters. Although there are number of methods that are used to obtain proper number of clusters, in problem these methods can lead to solutions which are not optimal. That is because of the evaluation of the clusters is dependent on the objective function value of network model. So, number of clusters is not determined at the beginning and searched through the solution method. Secondly, cluster centroids are determined by algorithm's itself randomly. It is impossible to determine exact centroids before applying the algorithm so it starts with randomly generated centroids. It continues with assignment of points to the clusters according to their closeness to the cluster centroids. In every iteration, algorithm updates clusters centroids because as points are added to clusters centroids are changing. This repetitive process continues until there is no possible assignment of points to the clusters.

Although k-means is a straight forward algorithm, because of the randomness in algorithm resulting clusters may differ applying again with different random parameters which are initial centroids. To prevent from this randomness replication method is used which is applying k-means algorithm again with different initial centroids.

To cluster accumulation points, their coordinates are used as features of them. K-means algorithm applied by using MATLAB and number of replicates is chosen to be 300. Resulting clusters is chosen among replications by their sum of squared error. As sum of squared error reduces, clusters becomes more proper. Matlab code example is attached in the Appendix D. As an example, clusters of first iteration is given below in figure 7.2 and in table 7.1.

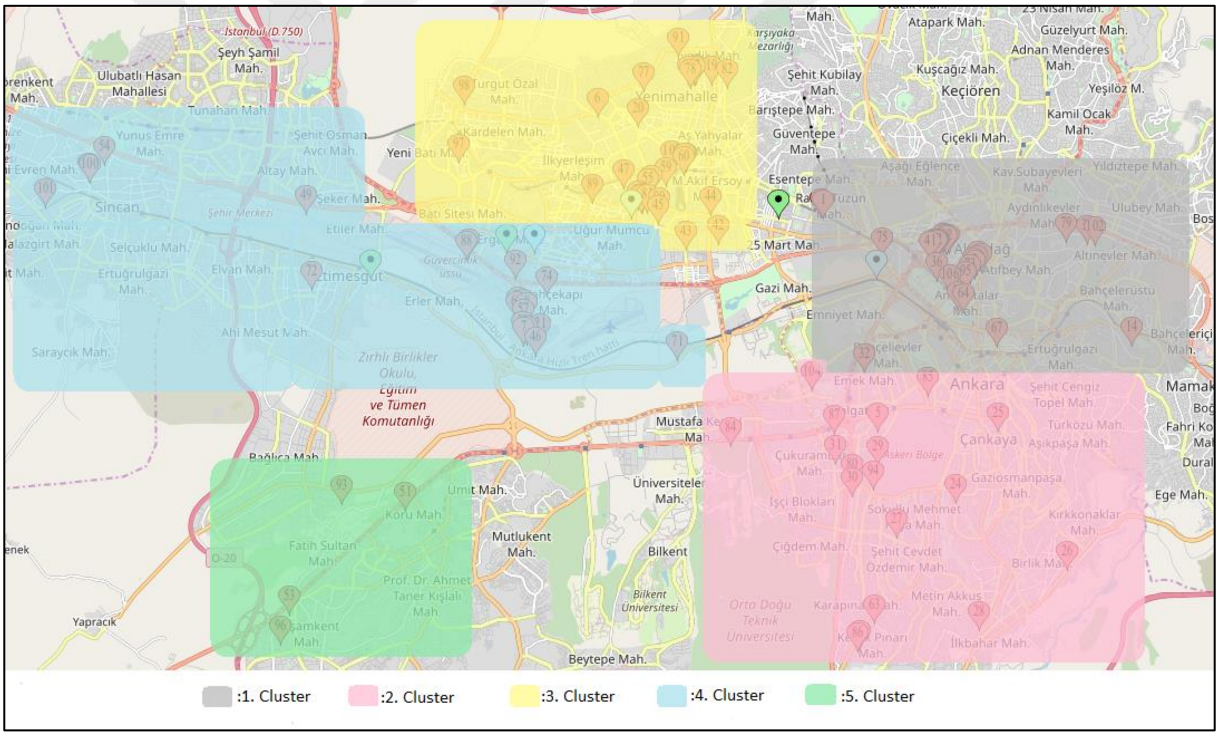

Figure 7.2. Representation of clusters on map

Table 7.1. Accumulation points and related cluster

Points	Cluster	Points	Cluster	Points	Cluster	Points	Cluster	Points	Cluster
1	1	5	2	4	3	7	4	51	5
2	1	24	2	6	3	8	4	53	5
3	1	25	2	15	3	9	4	93	5
10	1	26	2	16	3	21	4	96	5
11	1	27	2	17	3	22	4		
12	1	28	2	18	3	23	4		
13	1	29	2	19	3	46	4		
14	1	30	2	20	3	49	4		
32	1	31	2	42	3	52	4		
33	1	34	2	43	3	54	4		
35	1	63	2	44	3	57	4		
36	1	80	2	45	3	58	4		
37	1	84	2	47	3	66	4		
38	1	85	2	50	3	71	4		
39	1	86	2	55	3	72	4		
40	1	87	2	56	3	74	4		
41	1	94	2	59	3	88	4		
48	1	104	2	60	3	92	4		
61	1			65	3	99	4		
62	1			68	3	100	4		
64	1			77	3	101	4		
67	1			78	3				
69	1			81	3				
70	1			82	3				
73	1			83	3				
75	1			89	3				
76	1			90	3				
79	1			91	3				
95	1			97	3				
102	1			98	3				
103	1			107	3				
105	1								
106	1								

7.1. Obtaining Route Distances

After clusters are obtained, it is needed to be settle routes from contractor firms. Because of the amounts at accumulation points are less than a full truck load which is 12 tons and these amounts are needed to be collected every week, it is logical to aggregate points to increase truck load per travel. There are several methods to get routes but to reach optimality in routes TSP model is used.

There are several methods to solve travelling salesman problem. Laporte (1991) examined solution approaches for travelling salesman problem and stated that formulation done by Miller, Tucker and Zemlin (MTZ) is an exact model to solve the problem. MTZ model like other TSP models takes points as sets for model which are i and j and have one parameter which is cost associated with distance between points. In sets first unit is considered as source point where trucks begin their tour. Difference of MTZ model is having an additional decision variable. Decision variables and parameters that are used in model is given below with their definitions.

- X(i,j): Equals to 1 if a truck or person goes to j from i.
- U(i): Positive integer variable that states order of point i in tour.
- D(i,j): Distance or cost parameter of using arc between i and j.

MTZ model is given below beginning with objective and constraints.

$$Min\ z = \sum_i \sum_j d(i,j) * x\ (i,j)$$

$$\sum_j x(i,j) = 1 \qquad \forall i$$

$$\sum_i x(i,j) = 1 \qquad \forall j$$

$$U('1') = 1$$

$U(i) \geq 2 \qquad \forall i, i \neq 1$

$U(i) \leq n \qquad \forall i, i \neq 1$

$U(i) - U(j) + 1 \leq n * \big(1 - x(i,j)\big) \qquad \forall i, \forall j, i \neq 1, j \neq 1$

In here, objective is getting route for given points with the least cost. First two constraints are stating that every point should be visited exactly once. Following constraints are needed for subtour elimination third constraint is necessary for arranging beginning point of route. Last three constraints ensure that there is no subtour in optimal solution by ranking given points between 2 and n which is total number of units in sets i and j. Last constraint is needed for determine their exact sequence number in route.

In problem stated, to begin with its needed to find distances between points. Distances between accumulation points, contractor firms and cement factories are calculated by first getting Euclidian distances between them and scaling these distances to kilometers by proportion obtained from ratio between real distance of most distant points and their Euclidian distance in coordinates system. The most distant points are 28 and 54 according the Euclidian distance. Real distance between them is showed in figure 7.3 which is 30.0 km.

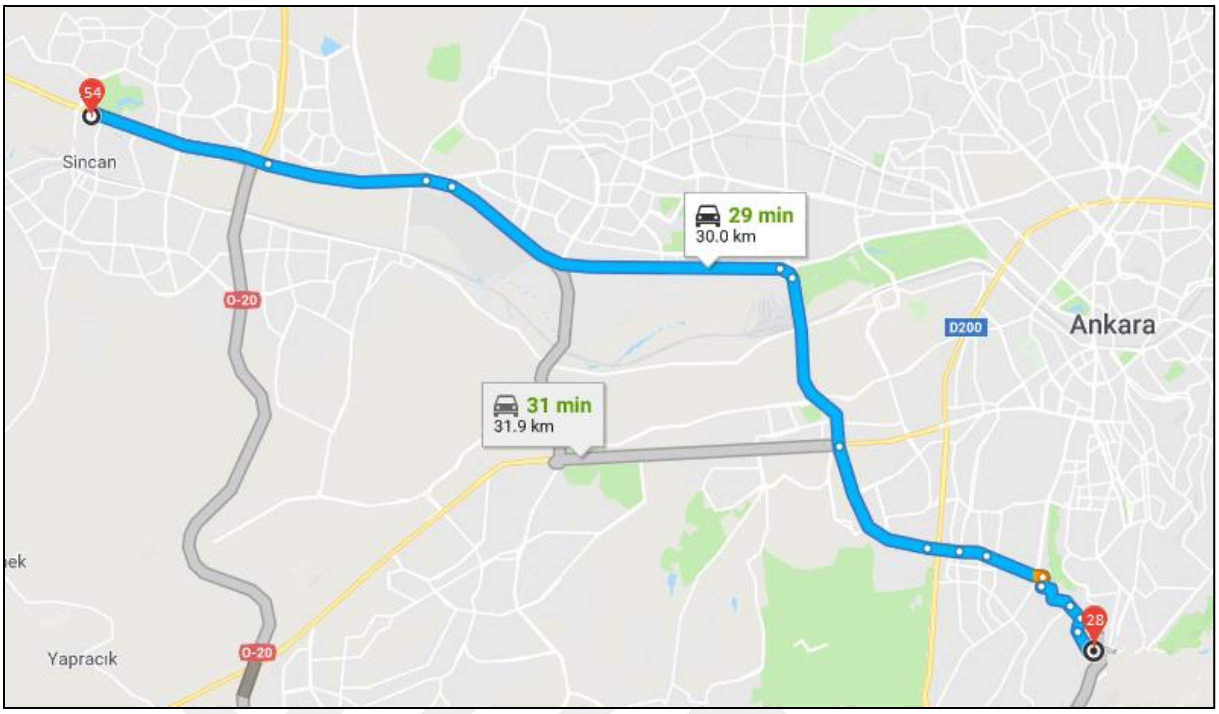

Figure 7.3. Real distance between the most distant points

Calculation of used scale is given below.

$$Scale = \frac{Euclidian\ Distance}{Real\ Distance} = \frac{0{,}291216}{30{,}0} = 103{,}016178$$

All accumulation points and contractor firms are entered as sets according to their clusters. All of the clusters routed by using MTZ model for every other contractor firms. That is because it is possible to get different routes for different contractor firms. Purpose of doing this is getting the distances of routes while collecting waste tires. These distances will be used in following steps as parameters. As an example, routes obtained for contractor firm ‘A’ by applying MTZ model for five clusters are given below in table 7.2 and resulted length of routes for each contractor firm is given in table 7.3. MTZ model code examples and their results in GAMS for one of five clusters are presented in Appendix E.

Table 7.2. Routes for clusters from contractor firm A and their lengths in kilometer

Cluster	Route	Length of Route
1	A-75-36-11-76-10-35-3-73-95-106-33-64-32-67-14-102-37-79-2-12-103-40-48-38-13-61-62-70-69-39-41-1-105-A	32.00
2	A-104-84-87-5-29-31-80-94-30-27-63-34-86-28-26-24-25-85-A	51.65
3	A-42-43-45-90-81-17-4-18-55-68-47-89-97-98-6-77-91-82-19-56-65-50-83-78-20-107-16-15-60-59-44-A	32.40
4	A-71-46-21-9-7-52-57-8-22-66-58-72-101-100-23-54-49-88-99-92-74-A	47.18
5	A-51-96-53-93-A	45.83

Table 7.3. Lengths of routes from contractor firms to clusters in kilometers

Contractor Firms/Clusters	1	2	3	4	5
A	32.00	51.65	32.40	47.18	45.83
B	56.36	50.31	61.13	55.40	18.52
C	48.01	57.65	39.61	38.17	32.39

7.2. Network Model

To begin with, network models in given literature have been examined and a proper model for problem have been constructed. To construct a model a few assumptions have been made. Firstly, parameters which are about capacity, amounts, weights and prices do not change over a year. Secondly, distribution of waste tires among accumulation points does not change over time and it accumulates evenly with time that is to say that accumulation per time is constant. About amounts, rate for type between car tires and truck or bus tires is constant over year and average weights for them do not change. This proportion is assumed to be same for every accumulation point. Tire amounts at accumulation points are converted to weight, in tons, from numbers. It is done by using proportion between car tires and truck or bus tires and their average weights of them. In short, a tire is assumed to be 16.2 kg which is weighted average for different tire types. Total amounts at accumulation points are given below in table 7.4.

Table 7.4. Waste tire amounts at accumulation points in tons

Points	Amounts	Points	Amounts	Points	Amounts	Points	Amounts	Points	Amounts
1	210.60	23	284.31	45	263.25	67	231.66	89	189.54
2	231.66	24	252.72	46	242.19	68	252.72	90	200.07
3	242.19	25	231.66	47	184.28	69	273.78	91	184.28
4	189.54	26	273.78	48	200.07	70	273.78	92	215.87
5	273.78	27	252.72	49	210.60	71	215.87	93	226.40
6	268.52	28	252.72	50	284.31	72	168.48	94	305.37
7	263.25	29	263.25	51	221.13	73	189.54	95	252.72
8	210.60	30	221.13	52	231.66	74	200.07	96	242.19
9	231.66	31	200.07	53	210.60	75	221.13	97	242.19
10	221.13	32	236.93	54	215.87	76	263.25	98	210.60
11	273.78	33	221.13	55	194.81	77	273.78	99	284.31
12	252.72	34	268.52	56	200.07	78	184.28	100	289.58
13	263.25	35	273.78	57	252.72	79	184.28	101	242.19
14	294.84	36	289.58	58	200.07	80	200.07	102	200.07
15	210.60	37	189.54	59	200.07	81	252.72	103	252.72
16	252.72	38	226.40	60	189.54	82	252.72	104	252.72
17	242.19	39	231.66	61	168.48	83	231.66	105	200.07
18	221.13	40	252.72	62	231.66	84	242.19	106	263.25
19	210.60	41	257.99	63	221.13	85	221.13	107	252.72
20	263.25	42	205.34	64	200.07	86	231.66		
21	294.84	43	189.54	65	210.60	87	210.60		
22	305.37	44	273.78	66	221.13	88	189.54		

Additionally, as these points are being clustered, total amount of a cluster have should be specified. It is simply done by summing up all amounts of elements of a cluster. As an example, total yearly amounts of clusters at first iteration is given below in table 7.5.

Table 7.5. Waste tire amount at clusters for first iteration in tons

Cluster	Total Amount
1	7776.41
2	4375.22
3	6981.39
4	4970.16
5	900.32

At second level of supply chain, contractor firms are assumed to be limitless in capacity. Truck numbers contractor firms have assumed to be enough for any plan. All of the trucks that are used in network assumed to be same. Additionally, gathering process of waste tires from routes for accumulation points is assumed to be done at exactly at full load of truck as waste tires accumulate at a constant rate. Excess amount that does not fulfill a truck assumed to be gathered by using same route in only one round. That is to say that there is no partitioning in routes in case of any route have less than full load of truck. Also it is assumed that there is no process about waste tires such as shredding or breaking.

At cement factories, they are assumed to be indifferent between waste tire types. Also, their demands are assumed to be nonrestricted by time. To clarify, cement factories accept waste tires whenever contractor firms send them. Also, distances between cement factories and contractor firms are calculated with same method that applied for routes. These distances scaled by same constant and resulting table for distances between them is given below in table 7.6.

Table 7.6. Distances between cement factories and contractor firms in kilometers

Cement Factories / Contractor Firms	A	B	C
1	5.49	21.06	9.85
2	13.20	4.99	9.32
3	15.81	9.15	17.47

According to problem given, model needs three different sets which are r for clusters, i for contractor firms and j for cement factories. Parameters that are used in model is listed below with their explanations.

- Rdist(i,r): Length of route for cluster r and contractor firm i.
- Fdist(i,j): Distance between contractor firm i and cement factory j.
- Dem(j): Demand of factory j.
- Ava(r): Available amount of waste tires at cluster r.
- Tvarcost: Variable cost for a ton of waste tire per kilometer which is 0.35 TL.
- Tdistcost: Fixed cost for travelling with truck which is 2 TL per kilometer.
- Truckcap: Capacity of a truck which is 12 tons.

To decide amounts of waste tires transferred between the echelons of supply chain different decision variables is used which are listed below.

- Cx(i,r): Amount of waste tires collected from cluster r by contractor firm i.
- Fx(i,j): Amount of waste tires sent to cement factory j from contractor firm i.
- NumofTravelRoute(i,r): Integer variable for number of travels to cluster r from contractor firm i.
- NumberofTravelFactory(i,j): Integer variable for number of travels to cement factory j from contractor firm i.

As problem requires the minimization of transshipment cost of waste tires within the supply chain, by help of given and obtained parameter and constituted decision variables, objective function for model can be written as given below.

$$Min\ z = \sum_i \sum_r Cx(i,r) * Tvarcost * Rdist(i,r)$$
$$+ \sum_i \sum_j Fx(i,j) * Tvarcost * Fdist(i,j)$$
$$+ \sum_i \sum_r NumofTravelRoute(i,r) * Tdistcost * Rdist(i,r)$$
$$+ \sum_i \sum_j NumofTravelFactory(i,j) * Tdistcost * Fdist(i,j)$$

In objective function, variable costs that arises from transferring amounts of waste tires between the echelons of supply chain is expressed distinctively in first two summations. It is the part of cost that dependent to amount of waste tires carried between points. Last two summation is the fixed part of the total cost. In these summations, usage number of routes or paths between cement factories and contractor firms are multiplied fixed parameter for cost and related distance which gives costs due to running truck between points.

As problem states there are some requirements and limitations in given supply chain and because of the existence of natural dependencies model requires some set of constraints which are listed below.

$$\sum_i Fx(i,j) \geq Dem(j) \qquad \forall j$$

Firstly, creation of flow in the reverse logistics system for waste tires originates from two main reasons. One of them is proper disposal of possibly dangerous and excessive amounts of waste tires and the other one is potential reuse of waste tires. This potential in waste tires creates demand in cement factories where they can be used as substitute energy source for fossil fuels. So, there should be a constraint which states total amount sent to every cement factory from any of the contractor firms should be greater or equal to demanded amount.

$$\sum_i Cx(i,r) \leq Ava(r) \qquad \forall r$$

As waste tires are not present at contractor firms by itself, they should be collected from the points where they arise. However, to reduce the size of the problem these points were aggregated to clusters, this collection occurs en masse for clusters. As there is a limit in collection from points, same condition holds for clusters. Total amount of waste tires that clusters have, is calculated while clustering them. So, limit for collection of waste tires should be indicated in model. This constraint states that total amount gathered from cluster r by contractor firms cannot exceed the total amount available at that cluster.

$$\sum_{j} Fx(i,j) \leq \sum_{r} Cx(i,r) \qquad \forall i$$

Although flow of the waste tires in supply chain is bounded by both start and end points, the balance of them at the midpoint of supply chain which is contractor firms should hold. To prevent sending waste tires to cement factories without gathering them, sent amount should be constrained by collected amount. This constraint indicates that in any of the contractor firms, sent amount cannot exceed the gathered amount.

$$Cx(i,r) \leq NumofTravelRoute(i,r) * Truckcap \qquad \forall i, \forall r$$

$$Fx(i,j) \leq NumofTravelFactory(i,j) * Truckcap \qquad \forall i, \forall j$$

Problem stated that there are two different cost aspects in transshipment process which are fixed cost part and variable cost. In order to track fixed part of that cost one should declare constraints that are related with the truck capacity. As it is assumed that trucks are sent to their gathering routes when toured cluster have exactly full load of truck or sent to cement factories at full, number of travel that done by trucks can be extracted by using capacity of truck. These constraints states that amount of collection from routes and amount of sent to cement factories from a contractor firm should be less or equal to total capacity in travels which is number of travels multiplied by capacity of trucks. Thus these set of constraints ensure tracking of number of travels.

$$\sum_{i}\sum_{r} Cx(i,r) \geq \sum_{r} Ava(r) * 0{,}8$$

In problem that is stated LASDER is responsible from a percent of waste tires which is 80 percent. That means gathered amount by contractor firms should be greater than 80 percent of the total waste tires. In this constraint total amount gathered from clusters by contractor firms imposed to be greater or equal to the 80 percent of total amount of waste tires in clusters, which provides desired condition.

$$\sum_{i} NumofTravelRoute(i,r) \geq 52 \qquad \forall r$$

Waste tires at accumulation points is being piled up and they are needed to be disposed properly. As excessive amounts of waste tires at accumulation points at accumulation points can lead to problems which is stated in problem, they are obligated to be collected weekly. Although gathering the necessary amount which is 80 percent of total waste or enough amount for demand from the nearest clusters seems logical, all the points should receive service as much as possible. When distribution of generation of waste tires over year is assumed to be uniform it is proper to track them in an aggregated manner rather than in individual time windows. Setting number of travels to a route from contractor firms greater or equal to 52 means that there should be a truck travelling to that cluster. So, this constraint should impose the weekly collection limit to model.

Finally, third step of the process is applying model to the problem. An illustration of outputs of model is given below in following tables for first iteration which is with 5 clusters. Optimal solution with 5 clusters gives the objective function value as 421630.70 TL. The code and outputs of the model which is minimization of the transshipment cost of waste tires is presented in the Appendix F.

Table 7.7. Amount of waste tires gathered from cluster r by contractor firm i in tons

Cx(i,r)	1	2	3	4	5
A	7776.00		6972.00		
B		622.80			900.00
C				3732.00	

Table 7.8. Number of travels to cluster r from contractor firm i

NumofTravelRoute(i,r)	1	2	3	4	5
A	648.00		581.00		
B		52.00			75.00
C				311.00	

Table 7.9. Amount of waste tires sent to cement factory j by contractor firm i in tons

Fx(i,j)	1	2	3
A	8200.00		3948.00
B		1270.80	252.00
C		3729.20	

Table 7.10. Number of travels to cement factory j by contractor firm i

NumofTravelFactory(i,j)	1	2	3
A	684.00		329.00
B		106.00	21.00
C		311.00	

7.3. Iterations

First objective function value was 421630.70 TL but to be sure from optimality, broad search for it should be done between the arrival where cluster numbers is ranging between 5 and 55. As an upper-bound for cluster numbers 55 is chosen because it is nearly half of the total numbers of points. Additionally, to find upper-bound in objective function, a single run of model with individual points, where points are entered as individual clusters to model, is carried out. As a conclusion graph given below in figure 7.4 is formed.

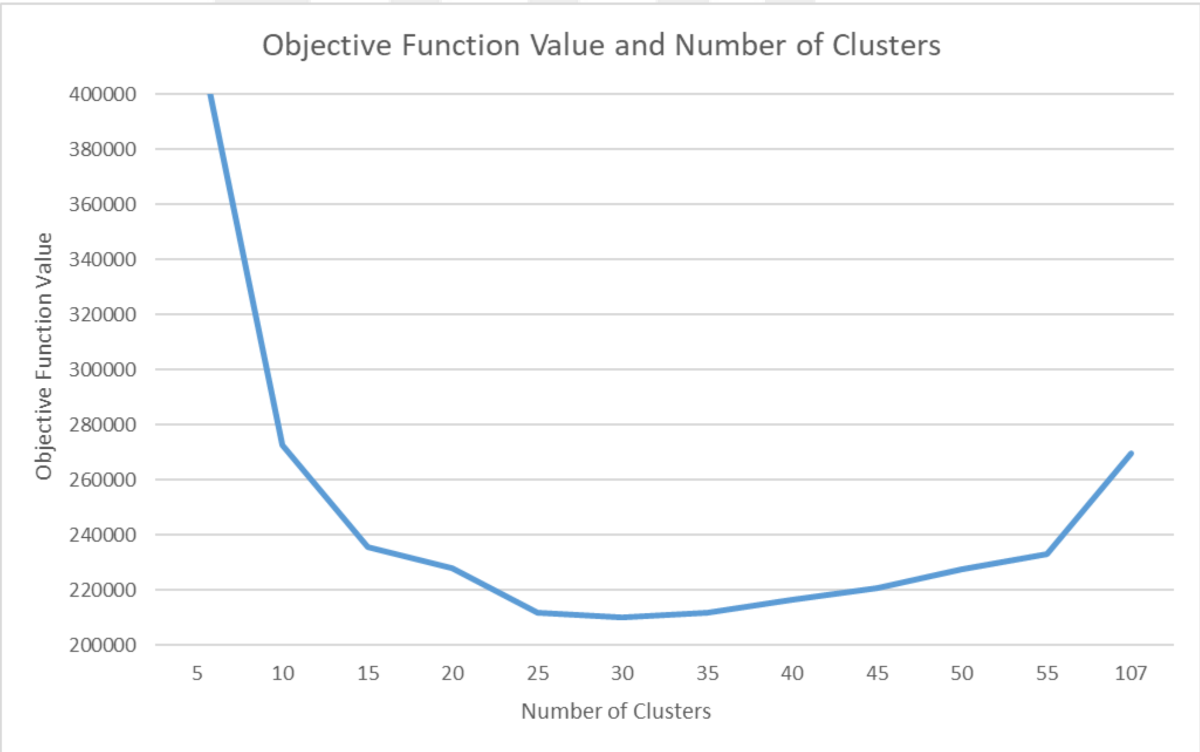

Figure 7.4. Objective function values at different number of clusters in TL

As it can be seen from the graph, increasing number of clusters dramatically reduces the objective function value at the low values of k. When one checks for the first two iterations which are with 5 and 10 clusters, objective function value is worse than the run with without clusters. Additionally, solutions with cluster numbers less than 10 is most likely to end up with having higher objective function value than the one without clusters. So, it is proper to say that it is better to not cluster points at low values for clusters. Secondly, graph is in u shape. This situation concludes that although high numbers for clusters is likely to have less objective function value than the one without clusters. So, it shows that it is possible to reduce transportation cost of collecting waste tires from accumulation points and sending them to cement factories via contractor firms with given solution approach. Finally, in the graph, line is nearly horizontal at the levels 25,30 and 35. As these three points have the lowest values in given interval optimal solution is most likely to be in this interval. For clarification, within these three cluster numbers 30 have the lowest objective function value with 209904.13 TL. Other two cluster numbers, 25 and 35, have nearly same objective function value which are 211955.80 TL and 211986.86 TL, respectively. To conclude, in first iterations which are made with multiplies of 5 from 5 to 55, best objective function value is obtained with number of clusters 30. So, that makes second interval for number of clusters between 25 and 35 which can be said to be proper for further search for optimal solution according graph for first iterations.

To be sure from solution obtained from first iterations is not a local optimal, it is needed to be search sides of chosen number of clusters. It is proper to indicate that, in any case of change in number of clusters that have the best objective function value, search for global optimal can be extended to an interval where the number of clusters with the best objective function value stands at middle of a such interval which can be 5 plus and minus of it. For clarification, assume that best objective function value found with 32 clusters so interval can be shifted to between 27 and 37 to be sure about global optimum. As the order of solution approaches suggests the interval as between 25 and 35, formed graph for that interval is given below in figure 7.5

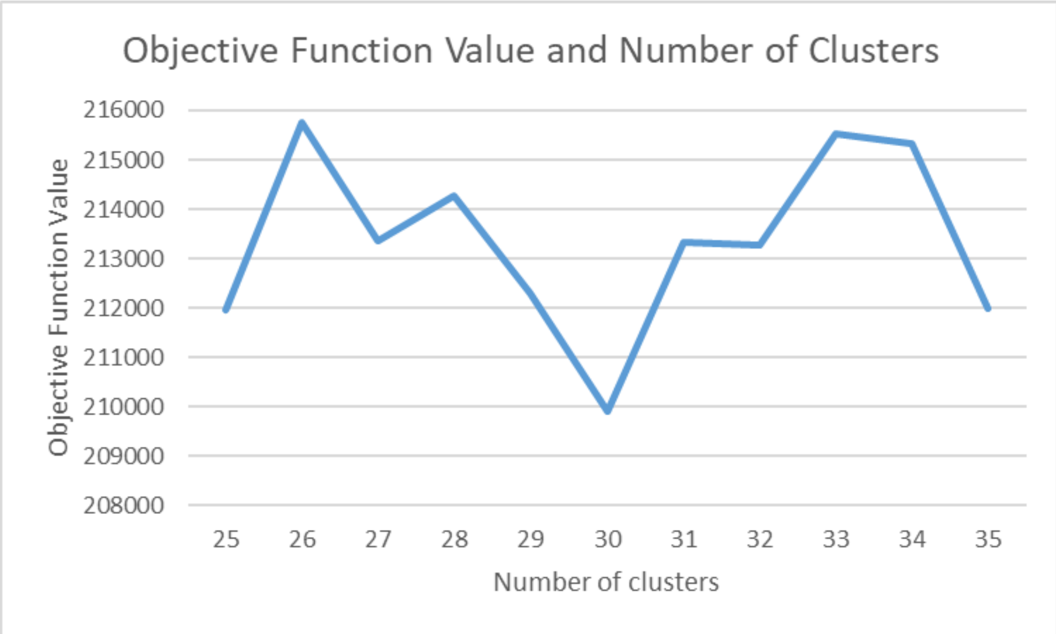

Figure 7.5. Objective function values for given number of clusters in TL

From graph, it can be seen that there are local optimum points. These points can be seen clearly in 27 and 32 which are have better objective function values at the intervals +1 and -1. Also this can be same for the 25 and 35. Although there is possibility for stuck in a local optimum by looking in figure 7.5, but, from the previous graph, finding lower values than these values apart from this interval is highly unlikely. As a result of this graph number of clusters that have the best objective function value is unchanged. So, the solution with 30 clusters can be regarded as global optimum solution.

Plan of the collection waste tires from accumulation points and transshipments of them to cement factories from contractor firms should be done according to result with 30 clusters. To illustrate clusters and routes, tables 7.11, 7.12 and 7.13 about them is given below and the result of the network model is given in tables 7.14, 7.15, 7.16 and 7.17. The model code and outputs of 30 the clusters with optimal results are presented in Appendix G.

Table 7.11. Routes for clusters from contractor firm A

Cluster	Route	Length of Routes
1	A-42-43-44-A	6
2	A-28-A	38.11
3	A-75-41-39-70-69-62-61-13-38-12-2-103-40-48-A	7.34
4	A-101-100-23-54-A	37.26
5	A-79-37-102-A	15.72
6	A-74-58-66-57-8-22-A	16.47
7	A-51-93-A	34.23
8	A-82-19-56-65-50-83-78-A	13.55
9	A-84-A	20.36
10	A-71-A	13.53
11	A-72-A	23.82
12	A-97-98-A	20.15
13	A-60-15-16-107-59	7.53
14	A-85-25-5-A	23.79
15	A-33-64-67-A	15.72
16	A-77-6-20-A	14.79
17	A-49-A	23.24
18	A-29-94-30-80-31-A	25.55
19	A-99-88-92-A	16.36
20	A-68-55-47-89-18-4-17-81-90-45-A	10.4
21	A-52-7-9-46-21-A	17.74
22	A-26-A	34.42
23	A-53-96-A	45.4
24	A-24-27-A	30.11
25	A-1-105-A	2.2
26	A-14-A	20.68
27	A-11-76-10-35-3-73-95-106-36-A	12.23
28	A-91-A	15.5
29	A-32-87-104-A	19.75
30	A-63-34-86-A	39.05

Table 7.12. Routes for clusters from contractor firm B

Cluster	Route	Length of Routes
1	B-43-44-42-B	35.42
2	B-28-B	23.49
3	B-41-39-69-70-62-13-61-38-12-2-103-48-40-75-B	36.59
4	B-101-100-23-54-B	44.73
5	B-79-37-102-B	42.87
6	B-66-58-74-22-8-57-B	27.12
7	B-51-93-B	11.68
8	B-78-83-50-65-56-19-82-B	47.52
9	B-84-B	17.17
10	B-71-B	22.44
11	B-72-B	28.79
12	B-97-98-B	43.8
13	B-60-15-16-107-59-B	39.13
14	B-25-85-5-B	30.09
15	B-33-64-67-B	35.12
16	B-20-77-6-B	45.81
17	B-49-B	35.33
18	B-31-29-80-94-30-B	22.72
19	B-92-99-88-B	30.63
20	B-45-90-81-17-4-18-55-68-47-89-B	38.08
21	B-9-7-52-21-46-B	23.15
22	B-26-B	27.61
23	B-53-96-B	12.85
24	B-24-27-B	23.75
25	B-1-105-B	37.06
26	B-14-B	37.88
27	B-106-95-73-3-35-10-76-11-36-B	37.4
28	B-91-B	48.82
29	B-104-32-87-B	26.92
30	B-86-34-63-B	19.5

Table 7.13. Routes for clusters from contractor firm C

Cluster	Route	Length of Routes
1	C-43-42-44-C	19.22
2	C-28-C	42.46
3	C-41-39-69-70-62-61-13-38-12-2-103-48-40-75-C	26.63
4	C-101-100-23-54-C	20.16
5	C-79-37-102-C	35.91
6	C-58-66-57-8-22-74-C	10.27
7	C-51-93-C	20.8
8	C-78-83-50-65-56-19-82-C	26.09
9	C-84-C	22.29
10	C-71-C	16.19
11	C-72-C	2.98
12	C-97-98-C	17.71
13	C-59-60-15-16-107-C	19.19
14	C-5-25-85-C	33.62
15	C-33-64-67-C	31.95
16	C-20-77-6-C	22.96
17	C-49-C	7.88
18	C-31-29-94-30-80-C	31.61
19	C-88-99-92-C	8.05
20	C-89-47-68-55-18-4-17-81-90-45-C	18.1
21	C-52-21-46-9-7-C	10.26
22	C-26-C	42.19
23	C-53-96-C	31.72
24	C-24-27-C	36.21
25	C-1-105-C	23.27
26	C-14-C	37.67
27	C-106-95-73-3-35-10-76-11-36-C	30.73
28	C-91-C	26.17
29	C-104-32-87-C	29.11
30	C-63-34-86-C	40.6

Table 7.14. Amount of waste tires collected from cluster r by contractor firm i in tons

Cx(i,r)	A	B	C
1	668.66		
2		252.72	
3	3,336.00		
4			616.45
5	573.89		
6			1,389.96
7		447.53	
8	624.00		
9		242.19	
10	215.87		
11			168.48
12			452.79
13	1,104.00		
14			
15	624.00		
16	624.00		
17			210.60
18		624.00	
19			689.72
20	2,184.00		
21			1,260.00
22		267.33	
23		452.79	
24		505.44	
25	410.67		
26			
27	1,248.00		
28	184.28		
29	1.462		
30		624.00	

Table 7.15. Number of travels to cluster r from contractor firm i

NumofTravelRoute(i,r)	A	B	C
1	56		
2		52	
3	278		
4			52
5	52		
6			116
7		52	
8	52		
9		52	
10	52		
11			52
12			52
13	92		
14	52		
15	52		
16	52		
17			52
18		52	
19			58
20	182		
21			105
22		52	
23		52	
24		52	
25	52		
26	52		
27	104		
28	52		
29	52		
30		52	

Table 7.16. Amount of waste tires sent to cement factory j by contractor firm i in tons

Fx(i,j)	1	2	3
A	8,200.00		996.00
B		212.00	3,204.00
C		4,788.00	

Table 7.17. Number of travels to cement factory j by contractor firm i

NumofTravelFactory(i,j)	1	2	3
A	684		83
B		18	267
C		399	

With this clusters and given solution has the objective function value 209904.13 TL. In model, binding constraint which drives waste tires accumulation points to contractor firms is the percentage limit on LASDER. As a result of this, total gathered amount of waste tires from accumulation points is 20000 tons. That shows it is possible to increase utilization of waste tires in other cement factories. Additionally, in the network model, fill rate of the trucks cannot be taken as a performance measure which is 86.91 percent at overall. That is because of the assumption which states distribution of waste tires at accumulation points over year is constant. However, this percentage can be considered as low but this percentage is dependent on the rate between fixed and variable parts of the transportation cost. If one checks for the number of travels to clusters from contractor firms, it can be seen that there are many 52s which is meaning that most of them are sent because of the obligation. Any relaxation in related obligation may result in a better situation for fill rate of trucks and also for objective function value. Also, it is proper to add that, network model does not consider capacity of the contractor firms. That causes the model to be free while assigning contractor firms to clusters and cement factories. So, model simply assigning the closest ones to contractor firms. However, introducing any limitation on contractor firms about waste tire amounts can lead to increase in cost. Moreover, when this solution is compared with the current situation, solution with 30 clusters objective function is less than the current situation which is the one without clusters more than 50000 TL. As this is the only cost of the transshipment of the waste tires to cement factories from accumulation points, it is also directly proportional to the CO_2 emission, so it is proper to say that this solution also beneficial for the environment. To sum up, although difference in objective function values at the flattest part of the graph obtained from the multiplies of 5 is small, difference between the optimal and the current situation is considerable.

8. CONCLUSION

As transportation is a part of life, waste tires can be regarded as a daily waste. However, waste tires are distinct from other daily wastes because of the reutilization opportunities of them. Also, it is proven that excessive amounts of waste tires can be harmful to environment. Thus, proper disposal of waste tires is important and there are several methods for it. They are ranged between refurbishment to ignition of them. Besides of reusing them as tires again, between the methods for waste tires, burning them in cement factories is one of the most proper methods. In Turkey, LASDER is responsible from the huge part of the waste tires. In their system, Ankara is chosen to be investigated.

In a reverse logistics system not only the disposal methods but also the network model can result in a remarkable difference. However, in a reverse logistics system accumulation points of wastes may be dispersed from each other. As the emergence of collection of them which originates from threats of them to environment and to people, a systematic approach should be taken. High numbers of accumulation points of wastes can lead in confusions in collection plan and high costs. Thus applying multiple vehicle planning or clustering and routing methods can be beneficial. Ankara is studied as a case study with real accumulation points. It is shown that it is critical to choose the correct of clusters because an incorrect decision about number of clusters can result in higher costs than the working without clusters. Additionally, as the given network model considers only transportation costs in reverse logistics system for waste tires it is directly proportional with the CO_2 emission of trucks. Therefore, it is possible to benefit from the network model solutions in the aspect of CO_2 emission and contribute to recycle process of waste tires.

Total 20000 tons of waste tires gathered from accumulation points. 17400 tons of them burned in cement factories as a fuel. There can be many different numbers of solutions for movement of waste tires between given echelons. However, it is shown that in given environment optimal plan is with the 30 clusters. Although there is no capacity constraints on contractor it is possible confront with partial amounts transported between contractor firms and cement factories. That shows the fact that not only the distances between them is important but also the route distances from contractor firms to clusters are important. Additionally, these waste tires are replaced with the fossil fuels that are used in cement factories so benefit of this process is not limited only with the proper disposal of waste tires. Another benefit gained from process is preservation of fossil fuels. Also, if one considers calorific value per kilogram of waste tires is higher than main energy source of cement factories, which is coal, it is proper to say that it is possible to reduce CO_2 emission of cement factories. To be precise about amounts, 17400 tons of waste tires, which have 7700 kcal per kg on average, that are utilized in cement factories is equivalent to nearly 19849 tons of coal, which have 6750 kcal per kg on average, in calorific value. Another aspect in this process is left amount of waste tires at accumulation points. However, waste tires are not only used in cement factories and they are also used in different sectors such as civil engineering purposes or used in recycling plants. As usage of waste tires in cement factories is studied, these aspects are not considered in model. Left amounts of waste tires may be reutilized in these sectors.

To sum up, even in moderate levels for reverse logistics system for waste tires, it is probable to end up with undesirable results. As the main purpose of the this process is proper disposal of waste tires, it should be done in a way that where process of it is with the minimum effort. In given case, it is proven that it is possible to reach an optimal level where the difference from not optimal ones is worthy of note in the aspects of cost and CO_2 emission.

9. REFERENCES

Aliapur. (2018). Weight and Contributions.

URL: *https://www.aliapur.fr/en/key-figures/weight-and-contributions*

Altin, M., Koca, A., Solmaz, H., Yılmaz, E. (2013). Türkiye'de Otomobillerden Kaynaklanan Lastik Atık Miktarının İncelenmesi. *Journal of Polytechnic,* 16(2), 51-56.

Amin, S. H., Zhang, G., Akhtar, P. (2017). Effects of uncertainty on a tire closed – loop supply chain network., *Journal of the Expert Systems With Applications, 73*, pp. 82–91.

Blumenthal, M. (2005). *The Use of Scrap Tires in Rotary Cement Kilns* (Scrap Tire Management Council). Washington.

Church, R. and ReVelle, C. (1974) Maximal Covering Location Problem. *Papers of the Regional Science Association, 32*, 101-118.

Clarke, G., Wright, J. W. (1964). Scheduling of Vehicles from a Central Depot to a Number of Delivery Points. *Operations Research, 12*(4), 568-581. URL: 10.1287/opre.12.4.568

Dearing, P. M., Francis, R. L., Lowe, T. J. (1976). Convex location problems on tree networks. *Operations Research*, *24*(4), 628-642.

Dehghanian, F., Mansour, S. (2009). Designing sustainable recovery network of end-of-life products using genetic algorithm., *Journal of the Resources, Conservation and Recycling, 53*, pp. 559 – 570.

Deolalkar, S. P. (2016). *Designing Green Cement Plants*.

Drucker, P. F. (1962). The Economy's Dark Continent. In *Fortune*, pp. 265-270.

Eiselt, H.A. & Laporte, G. (1995). Objectives in Location Problems. 10.1007/978-1-4612-5355-6_9. Environmental Protection Agency. (2000*). Landfill Manuals Landfill Site Design*, 1-3.

URL:*https://www.epa.ie/pubs/advice/licensee/EPA%20Landfill%20Operational%20Practices.pdf*

Environmental Protection Agency. (2012). *Municipal Solid Waste Generation, Recycling, and Disposal in the United States: Facts and Figures for 2012.*

URL: *https://www.epa.gov/sites/production/files/2015-09/documents/2012_msw_fs.pdf*

European Commission. (2006). Waste Incineration.

European Commission. (2006). Waste Treatments Industries.

European Commission. (2015). *Fact-finding studies in support of the development of an EU strategy for freight transport logistics Lot 1: Analysis of the EU logistics sector*.

European Tyre & Rubber Manufacturers' Association. (2015). *End-of-Life Tyre Report 2015.*

Evans, A., Evans, R. (2006). *The Composition of a Tyre: Typical Components*. The Waste & Resources Action Programme.

Galvao, R. D., Raggi, L. A. (1989). A method for solving to optimality uncapacitated location problems. *Annals of Operations Research, 18*(1), 225-244. URL: https://doi.org/10.1007/BF02097805

Ghiani, G., Laporte, G., Musmanno, R. (2004). *Introduction to logistics systems planning and control*. Chichester, West Sussex: J. Wiley.

Gilanlı, E., Altuğ, N., Oğuzhan, A. (2012). Reverse Logistics Activities in Turkey., *EGE ACADEMIC REVIEW, 12*, 391-399.

Gleissner, H., Femerling, J. C. (2013). The Principles of Logistics. In *Springer Texts in Business and Economics* (pp. 3-18). Switzerland: Springer International Publishing. URL: 10.1007/978-3-319-01769-3_2

Glossary of Terms What are the Terms of Art For Incineration? . (2012). In *Coalition for Responsible Waste Incineration*.

URL: *http://www.crwi.org/textfiles/gloss.pdf*

Goetschalckx, M. (2011). *Supply Chain Engineering*, Vol. 161, Springer. URL: 10.1007/978-1-4419-6512-7

Goldman, A. J. (1971). Optimal Center Location in Simple Networks. *Transportation Science*, *5*(2), 212-221.

URL: *http://www.jstor.org/stable/25767607*

Han, X., Ji, S., Wang, C., Song, Q. (2009). A study on used tire reverse logistics flow distribution based on minimum recycling cost. *5th International Conference on Natural Computation*, pp. 303 – 307. Tianjin, China.

Hirvonen, P. (2017). *The Potential of Waste Tire and Waste Plastics Pyrolysis in Southern Savonia Region*, Master's thesis, Lappeenranta University Of Technology.

Hoornweg, D., Bhada-Tata, P. (2012). Waste Generation. In *What a Waste*, pp. 8-13. Urban Development Series.

Humphrey, D. (2003). *Civil Engineering Applications Using Tire Derived Aggregate (TDA)*.

Ishikawa, Y. (2011). Systematic Review of Tyre Technology., *National Museum of Nature and Science*, *16*, 2-13.

Jain, A. K. (2010). Data clustering: 50 years beyond K-means., *Pattern Recognition Letters*,*31*, 651-666.

Jain, A. K., Dubes, R. C. (1988). *Algorithms for clustering data*. Englewood Cliffs, NJ: Prentice Hall.

Japan Automobile Tyre Manufacturers. (2017). *Tyre Industry of Japan*.

Kannan, G., Haq, A. N., Devika, M. (2009). Analysis of closed loop supply chain using genetic algorithm and particle swarm optimisation, *International Journal of Production Research*, *47*, pp. 1175 – 1200.

Keay, M. (2007). *Energy: The long view*. Oxford: Oxford Institute for Energy Studies.

Kop, Y., Genevois, M. E., Ulukan, H. Z. (2012). End-of-Life Tyres Recovery Method Selection by Using a Two Step Methodology, *J. of Mult.-Valued Logic & Soft Computing*, *22*, 481-500.

Kumru, M. (2009). Revenue Management for Returned Products in Reverse Logistics, *Research in Transport and Logistics*, 203-209.

Lambert, D. M., Armitage, H. M. (1979). Distribution costs: the challenge: the key to managing the physical distribution function is total cost analysis, rather than haphazard stabs at cutting specific costs, *Management Accounting* (pre-1986), 60 (11), 33-45.

Laporte, G. (1991). The Traveling Salesman Problem: An overview of exact and approximate algorithms., *European Journal of Operational Research 59,231-247*.

LASDER. (2017). ÖTL Geri Kazanım Yöntemleri.

URL: *http://www.lasder.org.tr/otl-2/belge-ve-mevzuat/*

Liu, K., Zhou, Y., Zhang, Z. (2010). Capacitated location model with online demand pooling in a multi-channel supply chain. *European Journal of Operational Research,207*(1).

Malekiha, M., Hajiahmadi, M. (2015). Waste Tire as an Alternative Fuel of Cement Production Process in Iran. In *Proceedings of 4th IASTEM International Conference*(pp. 78-81). Amsterdam, Netherlands.

Moore, R. (2005). Reverse Logistics – the least used differentiator [White paper]. Retrieved from UPS Supply Chain Solutions:

URL: *https://www.ups-scs.com/solutions/white_papers/wp_reverse_logistics.pdf*

Nakajima, Y., Matsuyuki, M. (1981). Utilization of Waste Tires as Fuel for Cement Production. *Conservation & Recycling, 4*, 145-151.

Nallusamy, R., Duraiswamy, K., Dhanalaksmi, R., Parthiban, P. (2010). Optimization of Non-Linear Multiple Traveling Salesman Problem Using K-Means Clustering, Shrink Wrap Algorithm and Meta-Heuristics. *International Journal of Nonlinear Science, 9*, 171-177.

North Dakota Department of Health, Division of Waste Management. (2011). *Guideline 21 - Scrap Tire Management*.

Organ, A., Ertuğrul, İ, Deniş, Ö F. (2013). TERSİNE LOJİSTİK AĞ MODELİNİN TAMSAYILI PROGRAMALAMAYLA TASARIMI: ÖMRÜNÜ TAMAMLAMIŞ LASTİK GERİ KAZANIM ÖRNEĞİ. *C.Ü. İktisadi Ve İdari Bilimler Dergisi, 14*(1), 439-460.

Ostojic, S. D., Simic, V., Miljus, M. (2017). USED TIRE MANAGEMENT: AN OVERVIEW, PART I. In *3rd Logistics International Conference*, pp. 210-215. Belgrade, Serbia.

Pedram, A., Yusoff, N. B., Udoncy, O. E., Mahat, A. B., Pedram, P., Babalola, A. (2016). Integrated forward and reverse supply chain: A tire case study., *Journal of the Waste Management, 60*, pp. 460 – 470.

Pennigton, D. G., Frazee, R. C., Chesbro, W., Gotch, J., Relis, P. (1996). Recycling, Reuse and Disposal of Waste Tires. In *EFFECTS OF WASTE TIRES, WASTE TIRE FACILITIES, AND WASTE TIRE PROJECTS ON THE ENVIRONMENT* , pp. 26-30.

Pipilikaki, P., Katsioti, M., Papageorgiou, D., Fragoulis, D., Chaniotakis, E. (2005). Use of tire derived fuel in clinker burning. *Cement & Concrete Composites, 27*, 843-847.

Rahman, F. A. (2014). Reduce, Reuse, Recycle: Alternatives for Waste Management. New Mexico State University.

Recycler's World. (2017). Retrieved December 1, 2017.

URL: *http://www.recycle.net/Rubber/shred/xv131000.html*

RevLog. (1998). The European Working group on Reverse Logistics (1998-). URL: 10.1007/978-3-540-24803-3_1

Rodríguez, O.O., Duque, W.O., Salazar, L.D. (2017). Environmental Impact of End-of-Life Tires: Life Cycle Assessment Comparison of Three Scenarios from a Case Study in Valle Del Cauca, Colombia. *Energies*, *10*(12), 2117. URL: 10.3390/en10122117

Rosier, M., Janzen, B. (2008). Reverse Logistics according to PwC. In *Reverse Logistics* (pp. 14-23). PricewaterhouseCoopers.

Rowhani, A., Rainey, T. J. (2016). Scrap Tyre Management Pathways and Their Use as a Fuel—A Review (T. E. Amidon, Ed.). *Energies*, 2-26. URL: 10.3390/en9110888

Rubber Manufacturer Association. (2009). *SCRAP TIRE MARKETS IN THE UNITED STATES 9th BIENNIAL REPORT*.

Rushton, A., Croucher, P., Baker, P. (2010). *The Handbook of Logistics & Distribution Management* (4th ed., pp. 3-15). KoganPage.

Sasikumar, P., Kannan, G., Haq, A. N. (2010). A multi – echelon reverse logistics network design for product recovery – a case of truck tire remanufacturing., *The International Journal of Advanced Manufacturing Technology*, *49*, pp. 1223 – 1234.

South Australia, Environment Protection Authority. (2010). *Waste Tyres*.

Stock, J.R., (1992). Reverse Logistics, In *Council of Logistics Management*, Oak Brook.

Stutz, J., Donahue, S., Mintzer, E., Cotter, A. (2003). (United States, Environmental Protection Agency).

Subulan, K., Taşan, A. S., Baykasoğlu, A. (2015). Designing environmentally conscious tire closed – loop supply chain network with multiple recovery options via interactive fuzzy goal programming., *Journal of the Applied Mathematical Modelling*, *39*, pp. 2661 – 2702.

Sugözü, İ., Mutlu, İ. (2009). Atık Taşıt Lastikleri ve Değerlendirme Yöntemleri. *Taşıt Teknolojileri Elektronik Dergisi*, *1*, 35-46.

Supply Chain and Logistics Terms and Glossary. (2005). In *Supply Chain Visions.*

URL: *http://www.diku.dk/hjemmesider/ansatte/pisinger/production/glossary03.pdf*

Supply Chain and Logistics Terms and Glossary. (2013). In *Council of Supply Chain Management Professionals.*

URL:*https://cscmp.org/CSCMP/Educate/SCM_Definitions_and_Glossary_of_Terms/CSCMP/Educate/SCM_Definitions_and_Glossary_of_Terms.aspx?hkey=60879588-f65f-4ab5-8c4b-6878815ef921*

Thierry, M., Salomon, M., Numen, J. V., Wassenhove, L. V. (1995). Strategic Issues in Product Recovery Management. *CALIFORNIA MANAGEMENT REVIEW*, *37*, 114-136.

Tibben-Lembke, R. S., Rogers, D. S. (2002). Differences between forward and reverse logistics in a retail environment. *Supply Chain Management: An International Journal,7,* 271-282. URL: 10.1108/13598540210447719

Tsao, Y. (2013). Designing a Fresh Food Supply Chain Network: An Application of Nonlinear Programming. *Journal of Applied Mathematics*. URL: http://dx.doi.org/10.1155/2013/506531

Turkey, Ministry of Environment and Urbanisation. (2013).

Turkey, Ministry of Environment and Urbanisation. (2012). *Çevresel Göstergeler 2012*

Turkey, Ministry of National Education, Aile ve Tüketici Hizmetleri. (2011). *Atık Lastikler*. Ankara.

Turkey, Ministry of Science, Industry and Technology. (2014). *Ulusal Geri Dönüşüm Strateji Belgesi ve Eylem Planı 2014-2017*.

Turkish Cement Manufacturers Association. (2018).

URL: *http://www.tcma.org.tr/index.php?page=icerikgoster&cntID=204*

URL: *http://www.tcma.org.tr/index.php?page=icerikgoster&cntID=99*

Turkish Statistical Institute. (2017). *Road Motor Vehicles*.

URL: *http://www.turkstat.gov.tr/PreHaberBultenleri.do?id=24604*

U.N.Cong., Basel Convention. (2011). *Revised technical guidelines for the environmentally sound management of used and waste pneumatic tyres* [Cong. Doc. from 10th Cong.]. Cartagena, Colombia.

United States, Departmant of the Navy, Headquarters United States Marine Cops. (1997). *Logistics*, pp. 37-44. Washington.

Urubru, A., Ponce-Cueto, E., Cobo-Benita, J. R., Ordieres-Mere, J. (2013). The new challenges of end-of-life tyres management systems: A Spanish case study. *Waste Management, 33*(3), 679-688. URL: https://doi.org/10.1016/j.wasman.2012.09.006.

U.S. Tire Manufacturers Association. (2017). *2015 U.S. Scrap Tire Management Summary*.

Valle, P. O., Menezes, J., Reis, E., Rebelo, E. (2009). Reverse logistics for recycling: The customer service determinants. *Int. Journal of Business Science and Applied Management, 4*(1), 2-17.

Vaughn, B. (2013, August 20). Consumer Electronics and Reverse Logistics: Play It Again.

URL: *http://www.inboundlogistics.com/cms/issue/2013-08/commentary/*

Vorasayan, J., Ryan, S. M. (2006). OPTIMAL PRICE AND QUANTITY OF REFURBISHED PRODUCTS. *Production and Operations Management, 15*, 1-39. URL: 0.1111/j.1937-5956.2006.tb00251.x.

Waters, D. The Context of Logistics. (2003). In *Logistics An Introduction to Supply Chain Management*, pp. 3-17. Palgrave Macmillan.

Whitford, F., Nowaskie, D., Buckmaster, D., Turner, S., Hawkins, S., Schaefer, K., Smith, K. L. (2013). *Tires For the Road and Field*.

Williams, H. P. (2013). Integer Programming. In *Model Building in Mathematical Programming* ,5th ed., pp. 155-164.

Williams, P.T., (2013). Pyrolysis of waste tyres: A review. *Waste Management*, 33, 1714-1728. URL: https://doi.org/10.1016/j.wasman.2013.05.003.

Wojtowicz, M. A., Serio, M. A. (1996). Pyrolysis of scrap tires: Can it be profitable? *Chemtech*, 48-54.

World Business Council for Sustainable Development. (2010). *End-of-Life Tires A Framework for Effective Management Systems*.

Wren, A., Holliday, A. (1972). Computer Scheduling of Vehicles from One or More Depots to a Number of Delivery Points. *Journal of the Operational Research Society,23*(3), 333-344. URL: https://doi.org/10.1057/jors.1972.53

Yamada, T., Russ, B. F., Castro, J., Taniguchi, E. (2009). Designing Multimodal Freight Transport Networks: A Heuristic Approach and Applications. *Transportation Science,43*, 129-143.

Zanardelli, A., Battini, D., Persona, A., Sgarbossa, F. (2015). Sustainable transportation network design: A literature review and a research agenda. *Industrial Systems Engineering*, 139-148.

Zhu, C., Tang, L., Lin, Z., Shi, J., Zhang, W. (2016). Reliable Facility Location Problem with Facility Protection. *Plos One, 11*(9). URL: https://doi.org/10.1371/journal.pone.0161532

URL: *https://www.pirelli.com/tyres/tr-tr/otomobil/yetkili-satici-bul/bayi-bulucu?city=Ankara%2C+T%C3%BCrkiye*

URL: *https://www.goodyear.eu/tr_tr/consumer/dealers/results.html?latlng=39.9333635,32.85974190000002*

URL: *https://bayiler.michelin.com.tr/michelinlastikleri/ankara/39.89659,32.8618/39.35699703644877,32.1584681451268,40.43618296355124,33.5651318548732?radius=60*

URL: *https://www.continental-lastikleri.com.tr/binek/dealer-locator-google-fullsize-filter?searchTerm=ankara*

URL: *https://www.bridgestone.com.tr/bayi-bulucu#ankara*

APPENDICES

Appendix A: End of Life Tires Control Regulation

Resmi Gazete Tarihi: 25.11.2006 Resmi Gazete Sayısı: 26357

ÖMRÜNÜ TAMAMLAMIŞ LASTİKLERİN KONTROLÜ YÖNETMELİĞİ

BİRİNCİ BÖLÜM
Amaç, Kapsam, Dayanak ve Tanımlar

Amaç

MADDE 1 – (1) Bu Yönetmeliğin amacı, ömrünü tamamlamış lastiklerin;

a) Çevreye zarar verecek şekilde doğrudan veya dolaylı olarak alıcı ortama verilmesinin önlenmesine,

b) Geri kazanım veya bertarafı için toplama ve taşıma sisteminin kurulması, yönetim planının oluşturulması ve ömrünü tamamlamış lastiklerin yönetiminde gerekli düzenlemelerin ve standartların sağlanmasına,

c) İthalatı, ihracatı ile transit geçişine ilişkin sınırlama ve yükümlülüklere, yönelik idari ve teknik esasları belirlemektir.

Kapsam

MADDE 2 – (1) Bu Yönetmelik, bisiklet ve dolgu lastikleri hariç, ömrünü tamamlamış diğer tüm lastiklerin atıklardan ayrı olarak toplanması, taşınması, geçici depolanması, geri kazanılması, bertarafı, ithalatı, ihracatı ile transit geçişine ilişkin yasal sınırlama ve yükümlülükleri, alınacak önlemleri, yapılacak denetimleri, tabi olunacak hukuki ve cezai sorumlulukları kapsar.

Dayanak

MADDE 3 – (1) Bu Yönetmelik;

a) **(Değişik:RG-10/11/2013-28817)** Bu Yönetmelik 9/8/1983 tarihli ve 2872 sayılı Çevre Kanununun 8, 11 ve 12 nci maddeleri ile 29/6/2011 tarihli ve 644 sayılı Çevre ve Şehircilik Bakanlığının Teşkilat ve Görevleri Hakkında Kanun Hükmünde Kararnamenin 8 inci maddesinin birinci fıkrasının (a) ve (i) bendine dayanılarak hazırlanmıştır,

b) 15/5/1994 tarihli ve 21935 sayılı Resmî Gazete'de yayımlanan Tehlikeli Atıkların Sınırlarötesi Taşınımının ve Bertarafının Kontrolüne İlişkin Bazel Sözleşmesine paralel olarak, hazırlanmıştır.

Tanımlar

MADDE 4 – (1) Bu Yönetmelikte geçen;

a) Araç muayene istasyonu: 11/7/2002 tarihli ve 24812 sayılı Resmî Gazete'de yayımlanan Araç Muayene İstasyonlarının Açılması, İşletilmesi ve Araç Muayenesi Hakkında Yönetmelikte belirtilen yerleri,

b) **(Değişik:RG-10/11/2013-28817)** Bakanlık: Çevre ve Şehircilik Bakanlığını,

c) Bazel Sözleşmesi: 15/5/1994 tarihli ve 21935 sayılı Resmî Gazete'de yayımlanan Tehlikeli Atıkların Sınırlarötesi Taşınımının ve Bertarafının Kontrolüne İlişkin Bazel Sözleşmesini,

ç) Bertaraf: Geri kazanıma uygun olmayan lastiklerin çevreyle uyumlu bir şekilde zararsız hale getirilmesini,

d) Geçici depolama: Bu Yönetmeliğin 15 inci maddesine göre yer seçimi yapılan ve bu Yönetmeliğin 16 ncı maddesinde belirtilen teknik özelliklere göre kurulan ve işletilen ÖTL toplama noktalarını,

e) Geri kazanım: Fiziksel ve/veya kimyasal işlemlerle ulusal veya uluslararası standartlar ve şartnamelere uygun ürün elde edilmesi, enerji kazanımı ve ilgili standartlara uygun mühendislik uygulamaları amaçlı kullanımları,

f) Kaplamacı: Kaplamalık lastik karkaslarını kaplayıp yeniden kullanılmasını sağlayan gerçek ve tüzel kişileri,

g) Karkas: Sırtındaki dişleri kısmen aşınmış ancak kaplanıp yenilendikten sonra tekrar kullanılabilecek durumdaki kullanılmış lastikleri,

ğ) Kanun: 2872 sayılı Çevre Kanununu,

h) Kota: Bu Yönetmeliğin 17 nci maddesinde belirtilen esaslar doğrultusunda üreticiler tarafından toplanması gereken tonaj bazında ÖTL miktarını,

ı) Lastik: Yolcu ve yük nakil araçları altında bazı bağlayıcı ve güçlendirici bileşenlerle, kauçuktan üretilen, kullanılan takviye malzemesine göre sınıflandırılan araç lastikleri olarak adlandırılan değişik tip ve ebattaki ürünleri,

i) **(Değişik:R.G-30/3/2010-27537)**[(1)] Çevre lisansı: 29/4/2009 tarihli ve 27214 sayılı Resmî Gazete'de yayımlanan Çevre Kanununca Alınması Gereken İzin ve Lisanslar Hakkında Yönetmelikte düzenlenen lisansı,

j) Lastik üreticisi: Lastiği imal eden, ürüne adını, ticari markasını veya ayırt edici işaretini koymak suretiyle kendini üretici olarak tanıtan gerçek veya tüzel kişiyi; üreticinin Türkiye dışında olması halinde, üretici tarafından yetkilendirilen temsilciyi ve/veya ithalatçı ile bağımsız ithalatçıları,

k) Orijinal ekipman: Araç üreticisi ve treyler üreticilerine verilen lastikleri,

l) Ömrünü tamamlamış lastik (ÖTL): Faydalı ömrünü tamamladığı belirlenerek araçtan sökülen orijinal veya kaplanmış, bir daha araç üzerinde lastik olarak kullanılamayacak durumda olan ve üretim esnasında ortaya çıkan ıskarta lastikleri,

m) Ömrünü tamamlamış lastik üreticisi: Lastiği araçlarında kullanarak ÖTL oluşumuna sebep veren gerçek ve tüzel kişiler ile ÖTL oluşumuna sebep verenin bilinmemesi durumunda ise ÖTL'leri zilyetliğinde veya mülkiyetinde bulunduran gerçek ve tüzel kişileri,

n) **(Değişik:RG-11/03/2015-29292)** Yetkili taşıyıcı: Bu Yönetmeliğin 14 üncü maddesinde belirtilen özelliklere sahip araçları olan üretici ile sözleşme yapmış gerçek ve tüzel kişileri, ifade eder.

Genel ilkeler

MADDE 5 – (1) ÖTL yönetimine ilişkin ilkeler şunlardır:

a) Geri kazanım ve bertaraf işlemlerinin, hava, su, toprak, bitki ve hayvanlar üzerinde tehlike yaratmadan, ses ve koku yoluyla çevreye herhangi bir olumsuz etkide bulunmadan ve doğal çevre ile koruma alanlarına zarar vermeden yapılması zorunludur.

b) ÖTL'lerin geri kazanımı esastır.

c) Lastik üreticileri lastik ömrünü uzatacak tedbirleri tasarım aşamasında alırlar.

ç) ÖTL'lerin ithalatı yasaktır.

d) Transit ve ihracat işlemlerinde Bazel Sözleşmesi esasları uygulanır.

e) ÖTL'lerin hangi sebeple olursa olsun vadi veya çukurlarda dolgu malzemesi olarak kullanılması, katı atık depolama tesislerine kabulü ve depolanması, ısınmada kullanılması, gösteri ve benzeri fiilleri kapsayacak şekilde her ne amaçla olursa olsun yakılması yasaktır. Aksine hallerde bu Yönetmeliğin 25 inci maddesi hükümleri uygulanır.

f) **(Değişik:RG-11/03/2015-29292)** Lastik tamirhaneleri, kaplamacılar, perakende satış noktaları, oto sanayi ve benzeri yerlerde ömrünü tamamlamış lastikler açık alanda biriktirilemez. Biriktirme yerlerinde yangına ve sivrisinek, fare gibi zararlıların üremesine karşı önlem alınır. ÖTL'ler yetkili taşıyıcılara teslim edilinceye kadar en fazla altmış gün bu yerlerde muhafaza edilebilir.

g) **(Değişik:RG-11/03/2015-29292)** ÖTL üreticisi, aracının lastiklerini değiştirdiğinde eski lastiklerini, lastik dağıtımını ve satışını yapan işletmelere veya yetkili taşıyıcılara teslim eder.

ğ) **(Değişik:RG-11/03/2015-29292)** ÖTL'ler yetkili taşıyıcılara bedelsiz olarak teslim edilir. Yetkisiz kuruluş ve kişilerin taşıma yapması yasaktır.

h) Yarış pistleri, çocuk oyun alanları, karting pistleri ve benzeri alanlarda çarpma bariyeri olarak kullanılan ÖTL'lerin bertarafı, bu yerleri işletenler tarafından sağlanır.

ı) ÖTL'lerin yarattığı çevresel kirlenme ve bozulmadan doğan zararlardan dolayı, lastik üreticileri, ÖTL üreticileri, taşıyıcılar, geçici depolama alanı işletmecileri, geri kazanım ve bertarafçılar kusur şartı aranmaksızın müteselsilen sorumludurlar.

i) Ömrünü tamamlamış taşıt söküm tesislerini işletenler, ortaya çıkan ÖTL'lerin bu Yönetmelik kapsamında geri kazanımını veya bertarafını sağlarlar veya sağlatırlar.

j) ÖTL'lerden kaynaklanan her türlü çevresel zararın giderilmesi için yapılan harcamalar, kirleten öder prensibine göre karşılanır. Ortaya çıkan ÖTL'lerin bertarafından sorumlu gerçek ve tüzel kişilerin çevresel zararı durdurmak, gidermek ve azaltmak için gerekli önlemleri almaması veya bu önlemlerin yetkili makamlarca doğrudan alınması nedeniyle kamu kurum ve kuruluşlarınca yapılan gerekli harcamalar 21/7/1953 tarihli ve 6183 sayılı Amme Alacaklarının Tahsil Usulü Hakkında Kanun hükümlerine göre ÖTL'lerin yönetiminden sorumlu olanlardan tahsil edilir. Ancak, kirletenlerin ödeme yükümlülüğünden kurtulabilmesi için, kirlenmenin önlenmesi ve sınırlanması konusunda her türlü tedbiri aldıklarını ispat etmeleri gerekir.

İKİNCİ BÖLÜM
Görev, Yetki ve Yükümlülükler

Bakanlığın görev ve yetkileri

MADDE 6 – (1) Bakanlık;

a) ÖTL'lerin çevreyle uyumlu bir şekilde yönetimini sağlamak için bu Yönetmelik kapsamında sorumlulukları belirtilen ilgili taraflar ile birlikte yönetim planlarını oluşturmakla,

b) Bu Yönetmeliğin uygulanmasına yönelik yeni sistem ve teknolojilerin uygulanmasında ulusal ve uluslararası işbirliği ve koordinasyonu sağlamakla,

c) **(Değişik:RG-10/11/2013-28817)** Çevre ve şehircilik il müdürlüklerinden gelen aylık raporları değerlendirmek, izin, tesis kapatma onayı gibi her türlü bildirimi almak ve gerekli denetimleri yapmakla,

ç) Geri kazanım tesislerine **(Değişik ibare:R.G-30/3/2010-27537)[(1)]** çevre lisansı vermekle,

d) Kota müracaatlarını değerlendirerek, belirlenen kota oranlarında üreticiler tarafından ÖTL'lerin taşınmasını, geri kazanımını ve bertarafını sağlatmakla,

e) Bu Yönetmeliğe aykırılık halinde gerekli cezanın uygulanmasını temin etmekle,

görevli ve yetkilidir.

(Değişik ibare:RG-10/11/2013-28817) Çevre ve şehircilik il müdürlüklerinin görev ve yetkileri

MADDE 7 – (1) **(Değişik ibare:RG-10/11/2013-28817)** çevre ve şehircilik il müdürlükleri;

a) Geçici depolama alanlarına bu Yönetmeliğin 21 inci maddesi gereğince izin vermek, izin verilen alanları Bakanlığa bildirmek ve bu alanları denetlemekle,

b) **(Değişik:RG-11/03/2015-29292)** Mücavir alan dışında, ÖTL üreticilerinin ÖTL'leri açık alanda biriktirmesini önlemekle, bunların yetkili taşıyıcılara teslim edilmesini sağlatmakla,

c) **(Değişik ibare:R.G-30/3/2010-27537)[(1)]** Çevre lisansı olmadan faaliyette bulunan geri kazanım tesislerini Bakanlığa bildirmekle, bu Yönetmeliğe aykırı faaliyette bulunan işletmelere gerekli cezai işlemi uygulamakla,

ç) Geçici depolama alanlarından alınacak aylık toplam stok bilgilerini Bakanlığa göndermekle,

d) Geri kazanım ve bertaraf tesislerinde bu Yönetmelik hükümleri gereğince denetim yapmakla,

e) (**Mülga:RG-11/03/2015-29292)**

görevli ve yetkilidir.

Belediyelerce alınacak tedbirler

MADDE 8 – (1) Belediyeler;

a) ÖTL'leri, belediye katı atık depolama tesislerine kabul etmemekle,

b) Geçici depolama alanları için uygun yer bulunamaması durumunda, geçici depolama alanları için yer göstermekle,

c) ÖTL'lerin toplanması ile ilgili olarak üreticilerin sorumluluğu ve programı dahilinde, gerektiğinde üretici ile işbirliği yaparak, ayrı toplama yapmakla, halkı bilgilendirmekle ve eğitim programları düzenlemekle,

ç) Mücavir alan içinde ÖTL üreticilerinin açık alanda ÖTL biriktirmesini önlemekle,

d) **(Değişik:RG-10/11/2013-28817)** Denetimlerde, ÖTL'lerin yasal olmayan yollarla taşındığının, izinsiz geçici depolandığının, çevre lisansı olmadan geri kazanıldığı ve bertaraf edildiğinin tespiti halinde, durumu tespit tutanağı ile çevre ve şehircilik il müdürlüğüne bildirmekle.

Lastik üreticisinin yükümlülükleri

MADDE 9 – (1) Lastik üreticileri;

a) Üretimde çevre kirlenmesini ve enerji tüketimini azaltıcı önlemler almakla,

b) Bu Yönetmeliğin 18 inci maddesine göre EK-2'de yer alan kota müracaat formunu doldurarak, her yıl mart ayı sonuna kadar Bakanlığa kota müracaatında bulunmakla,

c) Lastik kullanımı ve ÖTL'lerin düzenli toplanması konusunda tüketicinin bilgilendirilmesi için gerekli çalışmaları yapmakla, toplama faaliyetlerine kamuoyunun katılımının arttırılması için lastik tüketicilerinin yükümlülüklerini de içeren dokümanları ve uyarı işaretlerini lastik satış ve değiştirme noktalarında bulundurmakla,

ç) Geri kazanılması mümkün olmayan ÖTL'leri bu Yönetmeliğin 24 üncü maddesi doğrultusunda bertaraf ettirmekle,

yükümlüdür.

Kaplamacıların yükümlülükleri

MADDE 10 – (1) Kaplamacılar, lastiklerin can ve mal güvenliği açısından üretim ve kullanımında gerekli standardizasyonun sağlanması için ticari taşıtların ve römorkların havalı lastiklerinin kaplanmasında 1/2/2006 tarihli ve 26067 sayılı Resmî Gazete'de yayımlanan Motorlu Araçlar ve Römorkları İçin Kaplanmış Havalı (Pnömatik) Lastiklerin İmalatının Onayı ile İlgili Teknik Düzenlemeye (R-108) İlişkin Tebliğ (No: SGM-2006/7) de belirtilen kurallara ve buna ilişkin diğer teknik düzenlemelere uymakla yükümlüdürler.

(2) **(Değişik:RG-11/03/2015-29292)** Teknik açıdan kaplamaya uygun bulunmayan lastik karkasları, yetkili taşıyıcılar dışında hiçbir kişi veya kuruluşa, hiçbir amaçla verilemez. Kaplama faaliyeti esnasında ortaya çıkan atıklar türlerine uygun olarak bertaraf ettirilmesi kaplamacıların yükümlülüğündedir.

(3) Kaplamacılar, kaplanan ve/veya kaplanamayacak durumda olan lastik miktarlarıyla ilgili kayıtları tutar. Bu kayıtlar EK-3'te yer alan kaplamacı müracaat formu ile her yıl şubat ayı sonuna kadar Bakanlığa bildirilir. Bakanlık gerekli durumlarda beyanları yeminli mali müşavirlere kontrol ettirebilir. Bunun için yapılacak harcamalar, ilgili firma tarafından karşılanır. Tutulan kayıtlar gerektiğinde ibraz edilmek üzere üç yıl boyunca muhafaza edilir.

Geri kazanım tesislerini işletenlerin yükümlülükleri

MADDE 11 – (1) Geri kazanım tesislerini işletenler;

a) Bakanlıktan bu Yönetmeliğin 22 nci maddesi gereğince ÖTL geri kazanım **(Değişik ibare:R.G-30/3/2010-27537)[(1)]** çevre lisansı almakla,

b) **(Değişik:RG-11/03/2015-29292)** Yetkili taşıyıcılar ve ulusal atık taşıma formuyla getirilmeyen ÖTL'leri tesise kabul etmemekle,

c) Tesiste giriş bölümü, kabul ünitesi, depolama alanı bulundurmakla,

ç) Tesis içi depolama alanlarında bu Yönetmeliğin 16 ncı maddesinde belirtilen şartları sağlamakla,

d) Tesiste oda sıcaklığında kırım yapılıyor ise iç ortam gürültüsünün önlenmesi için 23/12/2003 tarihli ve 25325 sayılı Resmî Gazete'de yayımlanan Gürültü Yönetmeliği hükümleri gereğince gerekli önlemleri almakla, kırma işlemleri sırasında oluşacak tozdan çalışanların ve çevrenin olumsuz etkilenmesini önlemek için 4/12/1973 tarihli ve 7/7583 sayılı Bakanlar Kurulu Kararı ile kararlaştırılan İşçi Sağlığı ve İş Güvenliği Tüzüğü gereğince uygun nitelikte havalandırma ve filtre sistemleri kurmakla,

e) 26/12/2003 tarihli ve 25328 sayılı Resmî Gazete'de yayımlanan Kimyasal Maddelerle Çalışmalarda Sağlık ve Güvenlik Önlemleri Hakkında Yönetmelik hükümlerine uygun faaliyette bulunmakla,

f) Geri kazanım veya bertarafı sağlanan ÖTL miktarları için kayıt tutmakla, aylık faaliyet raporunu Bakanlığa göndermekle,

yükümlüdürler.

Yetkili taşıyıcı yükümlülükleri

MADDE 12 – (Başlığı ile birlikte değişik:RG-11/03/2015-29292) (1) Ömrünü tamamlamış lastikleri taşıyan gerçek ve tüzel kişiler;

a) Üretici adına lastik taşımak için üreticilerle sözleşme yapmakla,

b) Araçlarda bu Yönetmeliğin 14 üncü maddesinde belirtilen teknik özellikleri sağlamakla,

c) Taşıma işlemlerinde bu Yönetmeliğin 14 üncü maddesine göre ulusal atık taşıma formu kullanmakla,

yükümlüdür.

Geçici depo işletenlerin yükümlülükleri

MADDE 13 – (1) Geçici depolama alanı kuracak ve işletecek gerçek ve tüzel kişiler;

a) Bu Yönetmeliğin 15 inci ve 16 ncı maddelerine uygun olarak geçici depolama alanlarını kurmak ve işletmekle,

b) **(Değişik:RG-10/11/2013-28817)** Bu Yönetmeliğin 21 inci maddesine göre geçici depolama alanı için çevre ve şehircilik il müdürlüğünden izin almakla,

c) **(Değişik:RG-11/03/2015-29292)** ÖTL'lerin yetkili taşıyıcılar ile taşınmasını sağlamakla,

ç) **(Değişik:R.G-30/3/2010-27537)[(1)]** ÖTL'lerin, çevre lisansına sahip geri kazanım veya bertaraf tesislerine gönderilmesini sağlamakla,

d) **(Değişik:RG-10/11/2013-28817)** Toplanan, geri kazanıma ve bertarafa gönderilen ÖTL miktarları için kayıt tutmakla, bunları her ay çevre ve şehircilik il müdürlüğüne rapor etmekle,

yükümlüdürler.

ÜÇÜNCÜ BÖLÜM
Ömrünü Tamamlamış Lastiklerin Taşınması ile İlgili Hükümler

Ömrünü tamamlamış lastiklerin taşınması

MADDE 14 – (Değişik:RG-11/03/2015-29292)

(1) Ömrünü tamamlamış lastiklerin taşınması karayolu taşımacılığına uygun araçlarla yapılır. Taşıma araçlarının normal kasa ve ağ veya branda ile kapatılmış olması, kasanın her iki yüzünde dikey yüksekliği en az 20 cm olan "Ömrünü Tamamlamış Lastik Taşıma Aracı" ifadesinin yer aldığı sabit veya seyyar uyarı levhalarının bulundurulması zorunludur. Araçlarda 13/10/1983 tarihli ve 2918 sayılı Karayolları Trafik Kanunu gereğince yangın söndürme cihazları bulundurulması gerekmektedir. Ömrünü tamamlamış lastiklerin taşınmasında Ulusal Atık Taşıma Formu kullanılması zorunludur. UATF kullanılmasında 18/1/2013 tarihli ve 28532 sayılı Resmî Gazete'de yayımlanarak yürürlüğe giren Atıkların Karayolunda Taşınmasına İlişkin Tebliğ hükümleri uygulanır.

DÖRDÜNCÜ BÖLÜM
Ömrünü Tamamlamış Lastiklerin Geçici Depolama Alanları ile İlgili Hükümler

Geçici depolama alanlarının yer seçimi

MADDE 15 – (1) Geçici depolama alanları aşağıda belirtilen kriterlere göre seçilir:

a) Geçici depolama alanları, taşkın riskinin yüksek olduğu bölgelerde, heyelan, deprem, çığ ve erozyon bölgelerinde, yangın riski taşıyan alanlar ile tarım ve orman arazileri, meskun mahaller gibi yerlerde kurulamaz.

b) Lastik yığınları yüksek gerilim hatları altında bulunamaz.

Geçici depolama alanlarının teknik özellikleri ve işletme koşulları

MADDE 16 – (1) Geçici depolama alanlarında aşağıdaki teknik özellikler ve işletme koşulları sağlanır:

a) Bu alanların zemini, beton, sıkıştırılmış kil veya yangına meydan vermeyen buna benzer maddelerle kaplanarak sızdırmazlık koşulları sağlanır. Bu alanlarda yağmur suyu birikintilerinin oluşmasını önleyecek şekilde zemine şekil verilir ve depo çevresinde yağmur suyu drenaj kanalları bulundurulur.

b) Sahada yangına karşı gerekli tedbirler alınır. Depolanan lastiklerin toplam hacmi 2000 m3 ü geçecek ise dakikada 2500 litre suyu 6 saat boyunca sağlayabilecek bir su kaynağı hazırda bulundurulur.

c) Lastiklerin istiflenmesi ve depolanmasında 4/12/1973 tarihli ve 7/7583 sayılı Bakanlar Kurulu Kararı ile kararlaştırılan İşçi Sağlığı ve İş Güvenliği Tüzüğünün ilgili hükümleri doğrultusunda uygulama yapılır. Lastik yığınları ile depolama sahası sınırı arasında koruma hattı ve lastik yığınları arasında iç yangın yolları bırakılır.

ç) İlgili belediyenin itfaiye müdürlüğünden yangın tedbirlerinin yeterli olduğuna dair belgenin alınması zorunludur.

d) Sahanın etrafı en az 1,5 metre yüksekliğinde yapı malzemesi ile çevrilir.

e) Elektrik, aydınlatma direkleri tesisatı ve teçhizatı ile topraklama ilgili mevzuata göre yapılır. Yıldırım tehlikesine karşı TS 622'ye uygun bir paratoner sistemi kurulur.

f) İdari binalar, araç park alanı, yanıcı malzemeler dahil her türlü yangına açık maddeler, lastik yığınlarından en az 60 metre uzaklıkta olmalıdır.

g) Sahada çalışan bütün motorlu araçlarda yangın söndürme cihazı bulunmalıdır.

ğ) Tesise kabul edilen ve çıkışı yapılan ÖTL miktarlarının tespiti için kantar bulundurulması, kayıtların tutulması ve kayıt tutulmasından sorumlu en az bir teknik personelin tesiste bulundurulması gereklidir.

h) Lastik yığınlarının üzeri ve çevresi, sivrisinek, fare gibi zararlıların ürememesi için düzenli olarak ilaçlanır.

ı) Lastiklerin kapladığı alanın en aza indirilmesi ve taşıma kolaylığının sağlanması amacıyla bu alanlarda çevre kirliliği yaratmayacak şekilde lastik kırma ve parçalama üniteleri kurulabilir.

i) Lastik yığınlarının 300 metreden daha yakınında açık alanda ateş yakılmasına ve 60 metreden daha yakınında ise kaynak veya başka ısı üreten cihazların çalıştırılmasına izin verilmez.

BEŞİNCİ BÖLÜM
Kota Uygulaması ile İlgili Hükümler

Kota uygulaması ve sorumluluklar

MADDE 17 – (1) Bakanlık, ÖTL'lerin çevre ile uyumlu yönetiminin sağlanması amacıyla üretici sorumluluğu kapsamında kota uygulamasını zorunlu kılar.

(2) Bu kapsamda üreticiler, her yıl bir önceki yıl iç piyasaya sürülen lastik tonajını hesaba alarak bu Yönetmeliğin yürürlüğe girdiği ilk yıl %30, ikinci yıl %35, üçüncü yıl %40, dördüncü yıl %45 ve beşinci yıl %50 devamı yıllarda ise Bakanlığın ortalama lastik aşınma oranını dikkate alarak belirleyeceği oranlarda ÖTL'leri toplamak/toplatmak, toplanan miktarın geri kazanımını veya bertarafını sağlatmak ve bu işlemleri Bakanlığa belgelemekle yükümlüdürler. Bu amaçla, bu Yönetmeliğin 18 inci maddesine göre Bakanlığa başvuru yapılması zorunludur. Birinci yıl kota değerine ulaşılamaması durumunda, üreticilerin gerekçeleri Bakanlıkça makul bulunursa, ulaşılan reel toplama oranı bir defaya mahsus olmak üzere kota oranı olarak kabul edilebilir.

(3) Lastik üreticisi, ÖTL'lerini alıcı ortama olan etkilerini asgariye indirebilmek amacıyla, taşınması, geçici depolanması, geri kazanımı ve bertaraf edilmelerine dair yükümlülüklerini yerine getirmesi ve bunlara yönelik gerekli harcamaların karşılanması, eğitim faaliyetlerinin gerçekleştirilmesi için, Bakanlığın koordinasyonunda bir araya gelerek kâr amacı taşımayan tüzel kişiliğe haiz bir yapı oluşturabilirler. Bu yapıya karşı yükümlülüklerini yerine getiren ve harcamalara katılan kuruluşlar taşıma, geçici depolama, geri kazanım ve bertaraf yükümlülüklerini bu kuruluşa devredebilirler. Bu yapıya dahil olanlar kotanın tutturulmasından sorumludurlar.

Kota uygulaması izin başvurusu ve değerlendirilmesi

MADDE 18 – (1) Lastik üreticileri, EK-2'de yer alan Kota Uygulaması Müracaat Formunu doldurarak her yıl mart ayının son işgünü bitimine kadar kota uygulaması izni için Bakanlığa müracaat ederler. Bakanlık gerektiğinde ek bilgi ve belge isteyebilir. Bu Yönetmeliğin 10 uncu maddesine göre EK-3 kapsamında kaplamacı tarafından kaplanan lastik miktarına ilişkin bildirim, genel kota miktarından düşülür.

(2) Yukarıdaki bilgi ve belgelerin yeterli bulması durumunda ilgili lastik üreticisine kota uygulaması için izin verilir. İzin süresi bir yıldır. İzin başvuru süresi dışında başvurulması halinde de aynı kota oranı uygulanır. Bakanlık gerekli durumlarda izin başvurusu beyanlarını yeminli mali müşavirlere kontrol ettirebilir. Bunun için yapılacak harcamalar ilgili firmalar tarafından karşılanır.

(3) Kota uygulamasında orijinal ekipman olarak verilen, ihraç edilen lastikler ve üretim esnasında ortaya çıkan ıskarta lastikler kota uygulaması kapsamında değerlendirilemez.

ALTINCI BÖLÜM
Ömrünü Tamamlamış Lastiklerin Tespiti ile İlgili Hükümler

Trafik denetimleri

MADDE 19 – (1) Kullanılan lastiklerin kullanım ömrünü tamamlayıp tamamlamadığının tespiti, trafik zabıtası tarafından rutin veya şok denetimlerinde lastiklerin diş derinliğinin ölçülmesi ve hasar durumunun belirlenmesi ile yapılır. Buna ilişkin uygulama ve yaptırımlarda 13/10/1983 tarihli ve 2918 sayılı Karayolları Trafik Kanunu ve bağlı düzenlemeleri esas alınır.

Muayene istasyonları

MADDE 20 – (1) Araç muayene istasyonlarında lastik diş derinliği ve hasar durumu tespiti yapılır. Kullanılan lastiğin ömrünü tamamlamış lastik olduğunun tespiti halinde, can ve mal güvenliğinin sağlanması amacıyla bu lastiğin sürücü tarafından değiştirilmesi sağlanır.

YEDİNCİ BÖLÜM
(Değişik bölüm başlığı:R.G-30/3/2010-27537)[1]
Geçici Depolama İzni ve Çevre Lisansı Alınması ile İlgili Hükümler

Geçici depolama izni

MADDE 21 – (Değişik:RG-10/11/2013-28817)

(1) Geçici depolama tesisi işletecek gerçek veya tüzel kişiler, bu Yönetmeliğin 13, 15 ve 16 ncı maddelerinde belirtilen hükümlere uygun olarak çevre ve şehircilik il müdürlüğünden izin almak zorundadır. Bu Yönetmeliğin 5 inci maddesinin birinci fıkrasının (f) bendinde belirtilen lastik tamirhaneleri, kaplamacılar, perakende satış noktaları, oto sanayi ve benzeri işletmelerin ÖTL biriktirme yerleri için çevre ve şehircilik il müdürlüğünden izin alma zorunluluğu bulunmamaktadır.

Çevre lisansı alınması (Değişik başlık:R.G-30/3/2010-27537)(1)

MADDE 22 – (1) **(Değişik:RG-30/3/2010-27537)(1)** Mekanik kırmayla granül kauçuk, çelik ve tekstilin ayrıştırıldığı tesisler, proliz ve diğer yöntemlerle karbon siyahı ve aromatik yağlar elde eden tesisler, rejenere kauçuk tesisleri ile benzeri tesislerin çevre lisansı alması zorunludur. Çevre lisansı alınması işlemlerinde Çevre Kanununca Alınması Gereken İzin ve Lisanslar Hakkında Yönetmelik hükümleri uygulanır. Söz konusu Yönetmeliğin Ek-3 C sinde yer alan Teknik Uygunluk Raporunun içeriği, bu Yönetmelik kapsamında Bakanlıkça yapılacak çalışmalarla belirlenir.

(2) **(Değişik:RG-30/3/2010-27537)(1)** ÖTL'ler bütün, kesilmiş, dilimlenmiş veya sıkıştırılmış olarak, ses ve darbe absorbe etme özelliği nedeniyle otoyollarda çarpma bariyeri veya ses absorbisyon duvarı, limanlarda iskele takozu ve ayakkabı tabanı gibi işlemelerinde kullanılabilir. Bu gibi işlemler için geri kazanım konulu çevre lisansı alma şartı aranmaz.

(3) **(Değişik:RG-10/11/2013-28817)** Enerji geri kazanımı amaçlı uygulamalarda 6/10/2010 tarihli ve 27721 sayılı Resmî Gazete'de yayımlanan Atıkların Yakılmasına İlişkin Yönetmelik esasları uygulanır.

Geçici depolama izni iptali

MADDE 23 – (Başlığı ile birlikte değişik:R.G-30/3/2010-27537) (1)

(1) **(Değişik fıkra:RG-10/11/2013-28817)** Çevre ve şehircilik il müdürlüğünce yapılan denetimlerde depolama alanlarının izne uygun olarak çalıştırılmadığı, mevzuatta istenen şartların yerine getirilmediğinin tespit edilmesi halinde işletmeye, tespit edilen aksaklığın giderilmesi için, aksaklığın önemine ve kaynağına göre iki ay ile altı ay arasında süre verilir. Bu süre sonunda yapılan kontrollerde aksaklığın devam ettiği tespit edilirse, bu Yönetmeliğin 25 inci maddesi hükmü uygulanarak, işletmenin geçici depolama izni iptal edilir. Aksaklığı giderilen işletmenin yeniden geçici depolama izni alabilmesi için bu Yönetmeliğin 21 inci maddesine göre çevre ve şehircilik il müdürlüğüne müracaat etmesi zorunludur.

SEKİZİNCİ BÖLÜM
Çeşitli ve Son Hükümler

Bertaraf

MADDE 24 – (1) Tehlikeli madde ve atıklarla kontamine olmuş lastik ve lastik atıkları türlerine uygun olarak Bakanlıktan**(Değişik ibare:R.G-30/3/2010-27537)(1)** çevre lisansı veya çalışma onayı almış tesislerde bertaraf edilir.

Yönetmeliğe aykırılık

MADDE 25 – (1) Bu Yönetmeliğe aykırılık halinde 2872 sayılı Çevre Kanunu'nun 15 inci maddesi ile 20 nci maddesinin birinci fıkrasının (g), (r) ve (s) bentleri ve aynı Kanunun 23 üncü maddesi doğrultusunda idari ve cezai yaptırımlar uygulanır.

Dahilde işleme rejimi

MADDE 26 – (1) Kaplamalık lastik karkaslarının dahilde işleme rejimi kapsamında değerlendirilmesinde Dış Ticaret Müsteşarlığı düzenlemelerine uyulması zorunludur.

GEÇİCİ MADDE 1 – (Mülga:RG-10/11/2013-28817)

GEÇİCİ MADDE 2 – (Mülga:RG-10/11/2013-28817)

GEÇİCİ MADDE 3 – (Mülga:RG-10/11/2013-28817)

Yürürlük

MADDE 27 – (1) Bu Yönetmelik 1/1/2007 tarihinde yürürlüğe girer.

Yürütme

MADDE 28 – (Değişik:RG-10/11/2013-28817)

(1) Bu Yönetmelik hükümlerini Çevre ve Şehircilik Bakanı yürütür.

(1) Bu değişiklik 1/4/2010 tarihinde yürürlüğe girer.

	Yönetmeliğin Yayımlandığı Resmî Gazete'nin	
	Tarihi	**Sayısı**
	25/11/2006	26357
	Yönetmelikte Değişiklik Yapan Yönetmeliklerin Yayımlandığı Resmî Gazetelerin	
	Tarihi	**Sayısı**
1.	30/3/2010	27537
2.	10/11/2013	28817
3.	11/03/2015	29292

Appendix B: Turkey Cement Factories

Cities	Turkey Cement Factories
ADANA	Adana Çimento Sanayi T.A.Ş. (OYAK)
ADIYAMAN	Çimko Çimento ve Beton Sanayi Ticaret A.Ş. (Adıyaman Çimento Fabrikası)
AFYONKARAHİSAR	Afyon Çimento Sanayii T.A.Ş.
ANKARA	Baştaş Çimento Sanayi A.Ş.
ANKARA	Limak Çimento San. ve Tic. A.Ş. (Ergazi/ Ankara Şubesi)
ANKARA	Bolu Çimento Sanayi A.Ş. (Ankara Şubesi)
ANKARA	Çimsa Çimento Sanayi ve Ticaret A.Ş. (Ankara Öğütme Tesisi)
ANKARA	Limak Çimento San. ve Tic. A.Ş. Ankara Şubesi
ANKARA	Votorantim Çimento EAA S.L.U . (Merkez Ofis)
ANKARA	LİMÇİM Çimento Sanayi ve Ticaret A.Ş. (Merkez)
ANTALYA	Adoçim Çimento Beton San. ve Tic. A.Ş.
AYDIN	Batısöke Söke Çimento Sanayi T.A.Ş.
BAKIRÇAY	RECYDİA Atık Yönetimi Yenilenebilir Enerji Üretim Nak. Loj.Hiz. San. ve Tic. A.Ş
BALIKESİR	Limak Çimento San. ve Tic. A.Ş. Balıkesir Şubesi
BARTIN	SANKO Bartın Çimento San. ve Tic. A.Ş.
BİLECİK	Sançim Bilecik Çimento Madencilik Beton San. Tic. A.Ş.
BİTLİS / Tatvan	Limak Çimento San. ve Tic. A.Ş. (Bitlis Şubesi)
BOLU	Bolu Çimento Sanayi A.Ş.
BURDUR	AS Çimento San. ve Tic. A.Ş.
BURSA	Bursa Çimento Fabrikası A.Ş.
ÇANAKKALE / Ezine	Akçansa Çimento Sanayi ve Ticaret A.Ş.
ÇORUM	Votorantim Çimento Sanayi ve Ticaret A.Ş. (Çorum Fabrikası)
DENİZLİ	Denizli Çimento Sanayi T.A.Ş.

DİYARBAKIR / Ergani	Limak Çimento San. ve Tic. A.Ş. (Ergani Şubesi)
EDİRNE	Çimentaş İzmir Çimento Fabrikası Türk A.Ş.
ELAZIĞ	SEZA ÇİMENTO – SYCS İnşaat Çimento San.ve Tic. A.Ş.
ELAZIĞ	RECYDİA Atık Yönetimi Yenilenebilir Enerji Üretim Nak. Loj.Hiz. San. ve Tic. A.Ş Elazığ Çimento Şubesi
ERZİNCAN	Aşkale Çimento Sanayi T.A.Ş. (Erzincan Öğütme Tesisi)
ERZURUM	Aşkale Çimento Sanayi T.A.Ş.
ESKİŞEHİR	Çimsa Çimento Sanayi ve Ticaret A.Ş. (Eskişehir Çimento Fab.)
GAZİANTEP	Limak Çimento San. ve Tic. A.Ş. (Gaziantep Şubesi)
GÜMÜŞHANE	Aşkale Çimento Sanayi T.A.Ş. (Gümüşhane Fabrikası)
ISPARTA	Göltaş Göller Bölgesi Çimento San. ve Tic. A.Ş.
İSKENDERUN	Adana Çimento Sanayi T.A.Ş. (İskenderun Öğütme Tesisi)
İSTANBUL	Limak Batı Çimento San. ve Tic. A.Ş.
İSTANBUL / Altunizade	Akçansa Çimento Sanayi ve Ticaret A.Ş. (Merkez)
İSTANBUL / Altunizade	Çimsa Çimento Sanayi ve Ticaret A.Ş. (Merkez)
İSTANBUL / Büyükçekmece	Akçansa Çimento Sanayi ve Ticaret A.Ş.
İSTANBUL / Maslak	Adoçim Çimento Beton San. ve Tic. A.Ş. (Merkez)
İZMİR	Batıçim Batı Anadolu Çimento Sanayi A.Ş.
İZMİR	Çimentaş İzmir Çimento Fabrikası T.A.Ş.
K.MARAŞ	Kahramanmaraş Çimento Beton San.ve İşletmesi A.Ş.
KAHRAMANMARAŞ	Çimko Çimento ve Beton Sanayi Ticaret A.Ş. (Narlı Çimento Fabrikası)
KARS	Çimentaş - Kars Çimento San. ve Tic. A.Ş.
KAYSERİ	Çimsa Çimento Sanayi ve Ticaret A.Ş. (Kayseri Çimento Fab.)
KIRKLARELİ	Limak Çimento San. ve Tic. A.Ş. Trakya Şubesi
KOCAELİ	Nuh Çimento Sanayi A.Ş.
KOCAELİ / Gebze	Aslan Çimento A.Ş.
KONYA	Konya Çimento San. A.Ş.
MANİSA	Limak Ege Çimento San ve Tic.A.Ş.
MARDİN	Mardin Çimento Sanayii Ticaret A.Ş.
MARDİN / Derik	Limak Çimento San. ve Tic. A.Ş. (Mardin Şubesi)
MERSİN	Medcem Madencilik ve Yapı Malzemeleri A.Ş

MERSİN	Çimsa Çimento Sanayi ve Ticaret A.Ş. (Mersin Çimento Fab.)
MUŞ / Taşoluk Köyü Merkez	YURTÇİM/ Yurt Çimento San. Tic. ve A.Ş.
NEVŞEHİR	Votorantim Çimento Sanayi ve Ticaret A.Ş. (Nevşehir Öğütme Tesisi)
NİĞDE	Çimsa Çimento Sanayi ve Ticaret A.Ş. (Niğde Çimento Fab.)
ORDU	Ünye Çimento Sanayi ve Tic. A.Ş.
SAMSUN	Votorantim Çimento Sanayi ve Ticaret A.Ş. (Samsun Öğütme Tes.)
SAMSUN / Ladik	Akçansa Çimento Sanayi ve Ticaret A.Ş. (Ladik)
SİİRT	Limak Çimento San. ve Tic. A.Ş. (Kurtalan Şubesi)
SİVAS	Votorantim Çimento Sanayi ve Ticaret A.Ş. (Sivas Fabrikası)
ŞANLIURFA	Limak Çimento San. ve Tic. A.Ş. (Şanlıurfa Şubesi)
TEKİRDAĞ	Adoçim Çimento Beton San. ve Tic. A.Ş.
TOKAT / Artova	Adoçim Çimento Beton San. ve Tic. A.Ş.
TRABZON	Aşkale Çimento Sanayi T.A.Ş. (Trabzon Fabrikası)
VAN / Edremit	Aşkale Çimento Sanayi T.A.Ş. (Van Fabrikası)
YOZGAT	Votorantim Çimento Sanayi ve Ticaret A.Ş. (Yozgat Fabrikası)
ZONGULDAK / Ereğli	Bartın Çimento San. Tic. A.Ş. (SANKO Ereğli Şubesi)

Appendix C: Dealer Names and Their Coordinates for Ankara

DEALER NAME	**normx**	**normy**
METLAS OTOMOTİV	0,71577	0,72856
SEÇKİN OTO LASTİK	0,83198	0,66921
BÜLBÜL KARDEŞLER OTOMOTİV	0,85536	0,62744
YAŞAR OTO LASTİK	0,5495	0,73891
OSMAN ZERMAN LASTİK	0,76587	0,3702
CEYLAN OTO LASTİK	0,50879	0,89911
ŞENKAL OTO LASTİK	0,43987	0,51538
YUKE LASTİK	0,44282	0,55602
PERFORMA JANT	0,44325	0,51575
TUNAHANLILAR OTOMOTİV	0,85792	0,63437
ZEKİ ALTIN OTOMOTİV	0,85821	0,64179
ALTIN KARDEŞLER	0,82958	0,66812
ÇINAR LASTİK	0,82177	0,66064
MİR İNŞAAT	1	0,51491
ÖNDER OTO LASTİK	0,58974	0,80638
YÖNLAS	0,58911	0,80736
KURUÇAYIRLI LASTİK	0,54909	0,73805
MMY OTOMOTİV	0,54588	0,74329
KİRAZLAR OTOMOTİV	0,61335	0,95393
LİTSA TİCARET	0,54616	0,88097
FATİH KOLLEKTİF ŞTİ.	0,45579	0,51962
ERCAN OTO LASTİK	0,43999	0,56074
EROL İNŞAAT	0,04028	0,79041
ÇANKAYA LASTİK VE AKSESUAR	0,83825	0,24909
HASAN GÜLPINAR - GÖZDE OTO	0,87676	0,36962
KAPADOKYA OTO YIK.YAĞ.İNŞ	0,94042	0,13804
MEHMET KARADEDE ÇANKAYA LASTİK	0,78379	0,19125

ÜNİVERSAL YAYINCILIK	0,8599	0,03599
ESLAS OTOMOTİV İNŞAAT ...	0,76638	0,3137
ÖMER POYRAZ OTOMOTİV	0,7431	0,2605
TPL OTOMOTİV	0,72726	0,31642
HASAN GÜLPINAR GÖZDE O...	0,75451	0,47021
NACİ BAKIR OTO.MAMUL.G...	0,83996	0,57528
ŞENTÜRKLER LASTİK	0,75028	0,00457
DÖNMEZLER MOT ARAÇ YED...	0,85413	0,63067
ÇİNİCİ KARDEŞLER OTOM ...	0,82115	0,62373
MODA JANT LASTİK	0,9589	0,68442
ÇİFTÇİ TİCARET ŞUBE ME...	0,82269	0,66328
GÖKLAS OTO.SAN.TİC.LTD.ŞTİ.	0,81663	0,66113
MUSTAFA SAATÇİ OTOMOTİ...	0,82725	0,67242
EKİN TRAKTÖR	0,81405	0,65812
KOLPAŞ OTOMOTİV PAZ. VE TİC. A.Ş.	0,62018	0,68576
ALTINIŞIK LASTİKÇİLİK	0,58958	0,67547
GÜLER KARDEŞLER OTOMOT...	0,61297	0,73309
ENERJILAS ENERJI OTO LAS SERV.SAN.	0,56411	0,71819
BİLAL YÜKSEL OTOMOTİV	0,45195	0,49809
DERLAS OTOMOTİV	0,53201	0,77844
MUSTAFA SAATÇİ OSTİM ŞUBE	0,82725	0,67242
BAKIR OTOMOTİV MÜSLÜM BAKIR	0,24011	0,73487
ADEM GÜDEN - VEYSEL TİCARET	0,59695	0,95283
EGEMEN OTAN	0,33175	0,23664
KOÇAK LASTİK OTOMOTİV ŞUBE	0,43878	0,52401
KARSLIOĞLU MOBİL TUR N...	0,22436	0,06257
POLER OTOMOTİV SAN. TİC. LTD. ŞTİ.	0,05427	0,81842
SANİBEY OTOM. LASTİK SAN. TİC. LTD. STİ.	0,55533	0,7636
ISMET SİMSEK OTOM. LASTİK INS. TURZ. MAK.	0,59891	0,95448
KESKİN OTOM. TAS. INS. TİC. VE TUR. LTD. STİ.	0,44047	0,5446
CAGLAR OTO LASTİK JANT VE OTOM. SAN. TİC. LTD. STİ.	0,43475	0,56472
ADALİ LASTİK OTO SAN. TİC. VE TİC. LTD. STİ.	0,5715	0,78223

EKOL GİDA ENDUSTRİSİ VE AKARYAKİT TECH. SAN. TİC. LTD. STİ.	0,58749	0,80088
CİNAR LASTİK	0,82177	0,66064
B&S LASTİK	0,82106	0,66065
HK OTO LASTİK	0,76331	0,0469
NACİ BAKİR OTO. MAM. GİD. MAD. TİC. SAN. A.S.	0,84479	0,56989
ABDULLAH ÖZDOĞAN TİC.OT.TUR.TEK İNŞ.NAK.MAK.SAN.İTH.İHR.TİC.LTD.ŞTİ	0,59784	0,95349
ANKARA MODEL MAĞAZA	0,43455	0,55791
ANKARA PARK OTOMOTİV TURİZM GIDA SANAYİ VE TİC.LTD.ŞTİ.	0,876	0,51207
AYDIN LASTİK SAT.SER.HİZ.LTD.ŞTİ.	0,55842	0,77006
BAKIRLAR OTOMOTİV SANAYİ VE TİC. LTD.ŞTİ.	0,81849	0,66173
BAKIRLAR OTOMOTİV SANAYİ VE TİC. LTD.ŞTİ.	0,81849	0,66173
BİLGİNLER TURİZM İNŞAAT VE TİCARET A.Ş	0,58213	0,48946
CENGİZLER OTO LAS.P.İNŞ.TUR.N.T. EMLAK.İTH VE İHR.SAN.TİC.LTD.ŞTİ.	0,24486	0,60794
DURKUTLAR OTOM LAS SAN VE TİC LTD ŞTİ	0,85192	0,61855
DURKUTLAR OTOM LAS SAN VE TİC. LTD ŞTİ	0,46207	0,59932
DURKUTLAR OTOM LAS SAN VE TİC. LTD ŞTİ	0,77035	0,66356
ERTAN LASTİK HURDA.TUR.İNŞ.OTO.SAN. VE TİC.LTD.ŞTİ.	0,86142	0,6388
FATİH YILMAZ İNŞAAT OTOMOTİV SAN. VE TİC.LTD.ŞTİ.	0,55143	0,94171
FATİH YILMAZ-YILMAZ OTO LASTİK JANT	0,59429	0,94798
GÜRLAS OTO LAS.SAN VE TİC LTD.ŞTİ.	0,93928	0,6883
KAR CAR OTO TURİZM ANONİM ŞİRKETİ	0,74268	0,28399
KARDEŞLER ULAŞIM JANT MOT.ARAÇ. VE SERV.HİZM.TİC.LTD.ŞTİ.	0,55445	0,73812
KİRAZLAR OTOMOTİV İNŞAAT PETROL SAN.VE TİC.LTD.ŞTİ.	0,6282	0,94743
MENEKŞE LASTİK OTOM.İNŞ.TUZ.NAK. PETROL SAN.VE TİC.LTD.ŞTİ.	0,59213	0,95224
MFA OTOMOTİV GID.SAN. VE TİC. LTD.ŞTİ.	0,63132	0,34652

NUH GÜNGÖR OTO.İNŞ.İÇ VE DIŞ TİC.LTD.ŞTİ.	0,81229	0,43085
ORTADOĞU LASTİK LTD. ŞTİ.	0,74816	0
ÖZCANLAR LASTİK SAN.VE TİC LTD.ŞTİ.	0,72606	0,36553
ÖZCANLAR LASTİK SAN.VE TİC LTD.ŞTİ.	0,38752	0,65855
ÖZCANLAR LASTİK SAN.VE TİC LTD.ŞTİ.	0,50404	0,75486
ÖZCANLAR LASTİK SAN.VE TİC LTD.ŞTİ.	0,56563	0,73132
ÖZDEMİR KARDEŞLER ROT BALANS VE LASTİK SATIŞI ADEM ÖZDEMİR	0,58286	1
ÖZDEMİR KARDEŞLER ROT BALANS VE LASTİK SATIŞI ADEM ÖZDEMİR	0,4335	0,62707
ÖZER GRUP OTOMOTİV LASTİKLERİ SAN.TİC.LTD.ŞTİ.	0,27271	0,24725
ÖZKAL OTO LASTİK YEDEK PARÇA İNŞ.NAK.VE GIDA SAN TİC LTD ŞTİ	0,76215	0,27258
PROLAS OTOM.NAK.HIRDAVAT SAN. VE TİCARET LTD.ŞTİ.	0,84718	0,60881
PROLAS OTOM.NAK.HIRDAVAT SAN. VE TİCARET LTD.ŞTİ.	0,21688	0,01214
PROLAS OTOM.NAK.HIRDAVAT SAN. VE TİCARET LTD.ŞTİ.	0,38087	0,82213
PROLAS OTOM.NAK.HIRDAVAT SAN. VE TİCARET LTD.ŞTİ.	0,38553	0,91855
SAMET AYDOĞDU OTOMOTİV İNŞ.TAAH. TEKS.MAK.GI.PET.S.VE T.L.Ş	0,39018	0,66188
SAYILDI OTO LASTİK SANAYİ TİCARET LİMİTED ŞİRKETİ	0,04086	0,7876
ŞENTÜRK TİC.OTOM.MADENİ YAĞ.AKR. İNŞ.GIDA SAN.LTD.ŞTİ.	0	0,74694
ŞERBETÇİ OTOM.SAN.VE TİC.LTD.ŞTİ.	0,96624	0,68382
TEKİN OTOMOTİV LASTİK SAN. TİC. LTD.ŞTİ.	0,82917	0,66989
TURAN LASTİK OTOM.DANIŞMANLIK İNŞ. GIDA SAN.VE TİC.LTD.ŞTİ.	0,70569	0,43857
UCA OTOM LASTİK İNŞ.ELEKT.SAN.TİC. LTD.ŞTİ..	0,71402	0,72948
YAMAN OTO LASTİK TİC.LTD.ŞTİ.	0,83255	0,60277
Z LASTİK MAKİNE İNŞAAT İTHALAT İHR. SAN.VE TİC.LTD.ŞTİ.	0,57696	0,80989

Appendix D: Matlab Code

```
clear

clc

data=xlsread('Dataat','Sayfa1','B3:D109');

k=50;

[A,C,SSE, ~]=kmeans(data,k,'Replicates',300,'emptyaction','drop');

raw_data=xlsread('Dataat','Sayfa2','B3:D109');
```

Appendix E: MTZ Model Five Cluster Code Examples And Their Results

```
Sets

i cities

/A,B,C,1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23,24,25,26,27,28,29,3
0,31,32,33,34,35,36,37,38,39,40,41,42,43,44,45,46,47,48,49,50,51,52,53,54,55,56,57,5
8,59,60,61,62,63,64,65,66,67,68,69,70,71,72,73,74,75,76,77,78,79,80,81,82,83,84,85,8
6,87,88,89,90,91,92,93,94,95,96,97,98,99,100,101,102,103,104,105,106,107 /

S1(i) /A,51,53,93,96/

;

alias(i,j);

table d(i,j) distance matrix

$include "C:\Users\DİNÇ\Desktop\Ankara uygulama\Rotalama\totalmatrix.txt";

   ;

binary variable

x(i,j) ;

positive variable

u(i) ;

variable

z ;

equations

objective objective function

assign1(j) assignment1
```

```
assign2(i) assignement2

subtour1

subtour2(i)

subtour3(i)

subtour4(i,j) ;

objective.. z =e= sum((i,j), d(i,j)*x(i,j))                ;

assign1(S1(j)).. sum(i$(S1(i)),x(i,j)) =e= 1   ;

assign2(S1(i)).. sum(j$(S1(j)),x(i,j)) =e= 1   ;

subtour1..  u('A') =e= 1 ;

subtour2(i)$(ord(i)>3).. u(i) =g= 2 ;

subtour3(i)$(ord(i)>3).. u(i) =l= 5  ;

subtour4(i,j)$(ord(i)>3 and ord(j)>3).. u(i)-u(j)+1 =l=5*(1-x(i,j)) ;

Model MTZfivecluster  /all/

mods /all/;

mods.optFile=1;

Option

reslim = 600

optcr=0.00

optca=0.00

Solve MTZfivecluster using MIP minimizing z ;

display x.l, z.l ;
```

General Algebraic Modeling System

Execution

----   161 VARIABLE x.L

	A	51	53	93	96
A		1.000			
51					1.000
53				1.000	
93	1.000				
96			1.000		

----   161 VARIABLE z.L   =   343.110

EXECUTION TIME   =   0.047 SECONDS   5 Mb WEX239-239 Nov 9, 2012

```
Sets

i cities

/A,B,C,1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23,24,25,26,27,28,29,3
0,31,32,33,34,35,36,37,38,39,40,41,42,43,44,45,46,47,48,49,50,51,52,53,54,55,56,57,5
8,59,60,61,62,63,64,65,66,67,68,69,70,71,72,73,74,75,76,77,78,79,80,81,82,83,84,85,8
6,87,88,89,90,91,92,93,94,95,96,97,98,99,100,101,102,103,104,105,106,107 /

S1(i) /B,51,53,93,96/

;

alias(i,j);

table d(i,j) distance matrix

$include "C:\Users\DİNÇ\Desktop\Ankara uygulama\Rotalama\totalmatrix.txt";

   ;

binary variable

x(i,j) ;

positive variable

u(i) ;

variable

z ;

equations

objective objective function

assign1(j) assignment1

assign2(i) assignement2

subtour1
```

```
subtour2(i)

subtour3(i)

subtour4(i,j) ;


objective.. z =e= sum((i,j), d(i,j)*x(i,j))              ;

assign1(S1(j)).. sum(i$(S1(i)),x(i,j)) =e= 1   ;

assign2(S1(i)).. sum(j$(S1(j)),x(i,j)) =e= 1   ;

subtour1..  u('B') =e= 1 ;

subtour2(i)$(ord(i)>3).. u(i) =g= 2 ;

subtour3(i)$(ord(i)>3).. u(i) =l= 5  ;

subtour4(i,j)$(ord(i)>3 and ord(j)>3).. u(i)-u(j)+1 =l=5*(1-x(i,j)) ;

Model MTZfivecluster  /all/

mods /all/;

mods.optFile=1;

Option

reslim = 600

optcr=0.00

optca=0.00

Solve MTZfivecluster using MIP minimizing z ;

display x.l, z.l ;
```

G e n e r a l   A l g e b r a i c   M o d e l i n g   S y s t e m

E x e c u t i o n

----   161 VARIABLE x.L

	B	51	53	93	96
B		1.000			
51				1.000	
53					1.000
93			1.000		
96	1.000				

----   161 VARIABLE z.L   =   138.640

EXECUTION TIME   =   0.047 SECONDS   5 Mb WEX239-239 Nov 9, 2012

```
Sets

i cities

/A,B,C,1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23,24,25,26,27,28,29,3
0,31,32,33,34,35,36,37,38,39,40,41,42,43,44,45,46,47,48,49,50,51,52,53,54,55,56,57,5
8,59,60,61,62,63,64,65,66,67,68,69,70,71,72,73,74,75,76,77,78,79,80,81,82,83,84,85,8
6,87,88,89,90,91,92,93,94,95,96,97,98,99,100,101,102,103,104,105,106,107 /

S1(i) /C,51,53,93,96/

;

alias(i,j);

table d(i,j) distance matrix

$include "C:\Users\DİNÇ\Desktop\Ankara uygulama\Rotalama\totalmatrix.txt";

   ;

binary variable

x(i,j) ;

positive variable

u(i) ;

variable

z ;

equations

objective objective function

assign1(j) assignment1

assign2(i) assignement2

subtour1
```

```
subtour2(i)

subtour3(i)

subtour4(i,j) ;

objective.. z =e= sum((i,j), d(i,j)*x(i,j))               ;

assign1(S1(j)).. sum(i$(S1(i)),x(i,j)) =e= 1   ;

assign2(S1(i)).. sum(j$(S1(j)),x(i,j)) =e= 1   ;

subtour1..  u('C') =e= 1 ;

subtour2(i)$(ord(i)>3).. u(i) =g= 2 ;

subtour3(i)$(ord(i)>3).. u(i) =l= 5  ;

subtour4(i,j)$(ord(i)>3 and ord(j)>3).. u(i)-u(j)+1 =l=5*(1-x(i,j)) ;

Model MTZfivecluster  /all/

mods /all/;

mods.optFile=1;

Option

reslim = 600

optcr=0.00

optca=0.00

Solve MTZfivecluster using MIP minimizing z ;

display x.l, z.l ;
```

G e n e r a l   A l g e b r a i c   M o d e l i n g   S y s t e m

E x e c u t i o n

----   161 VARIABLE x.L

	C	51	53	93	96
C		1.000			
51					1.000
53				1.000	
93	1.000				
96			1.000		

----   161 VARIABLE z.L   =   242.530

EXECUTION TIME   =   0.047 SECONDS   5 Mb WEX239-239 Nov 9, 2012

Appendix F: Model Code And Outputs With 5 Clusters

```
Sets
i contractor firms /A,B,C/
j cement factories /1,2,3/
r routes for accumulation points /1*5/ ;
table Rdist(i,r)
$include "C:\Users\DİNÇ\Desktop\Ankara uygulama\5 kümeli k-means\5li için\5KMEANSTABLO.txt";
   ;
table Fdist(j,i)
$include "C:\Users\DİNÇ\Desktop\Ankara uygulama\5 kümeli k-means\5li için\FDIST.txt";
   ;
Parameter Dem(j)
/
$include "C:\Users\DİNÇ\Desktop\Ankara uygulama\5 kümeli k-means\5li için\DEMAND.txt";
/
Parameter Ava(r)
/
$include "C:\Users\DİNÇ\Desktop\Ankara uygulama\5 kümeli k-means\5li için\AVAR.txt";
```

```
/
Parameter Tvarcost /0.35/
Parameter Tdistcost / 2 /
Parameter Truckcap /12/ ;
Positive variables
Cx(i,r)
Fx(i,j) ;
Integer Variables
NumofTravelRoute(i,r)
NumofTravelFactory(i,j)
 ;
NumofTravelRoute.up(i,r) = 1000 ;
NumofTravelFactory.up(i,j) = 1000 ;
Variable
z ;
Equations
Objective
DemandCons(j)
RouteCons(r)
BalanceCons(i)
Count1(i,r)
Count2(i,j)
```

```
Percentage

Weekly(r)

;

Objective.. z =e= sum((i,r), Cx(i,r)*Tvarcost*Rdist(i,r)) + sum((i,j), Fx(i,j)*Tvarcost*Fdist(j,i)) + sum((i,r), NumofTravelRoute(i,r)*Tdistcost*Rdist(i,r)) + sum((i,j), NumofTravelFactory(i,j)*Tdistcost*Fdist(j,i)) ;

DemandCons(j).. sum(i,Fx(i,j)) =g= Dem(j) ;

RouteCons(r).. sum(i,Cx(i,r)) =l= Ava(r) ;

BalanceCons(i).. sum(j, Fx(i,j)) =l= sum(r, Cx(i,r)) ;

Count1(i,r).. Cx(i,r) =l= NumofTravelRoute(i,r)*Truckcap ;

Count2(i,j).. Fx(i,j) =l= NumofTravelFactory(i,j)*Truckcap ;

Percentage.. sum((i,r), Cx(i,r)) =g= sum(r,Ava(r))*0.8 ;

Weekly(r).. sum(i,NumofTravelRoute(i,r)) =g= 52 ;

Model fivecluster  /all/

mods /all/;

mods.optFile=1;

Option

optcr=0.00

optca=0.00

Solve fivecluster using mip minimizing z ;

display  Cx.l, Fx.l, NumofTravelRoute.l, NumofTravelFactory.l, z.l ;
```

G e n e r a l   A l g e b r a i c   M o d e l i n g   S y s t e m

E x e c u t i o n

----   104 VARIABLE Cx.L

	1	2	3	4	5
A	7776.000		6972.000		
B		622.800			900.000
C				3732.000	

----   104 VARIABLE Fx.L

	1	2	3
A	8200.000		3948.000
B		1270.800	252.000
C		3729.200	

----   104 VARIABLE NumofTravelRoute.L

	1	2	3	4	5
A	648.000		581.000		
B		52.000			75.000
C				311.000	

----   104 VARIABLE NumofTravelFactory.L

	1	2	3
A	684.000		329.000
B		106.000	21.000
C		311.000	

----   104 VARIABLE z.L   =   421630.70

EXECUTION TIME   =   0.000 SECONDS   3 Mb WEX239-239 Nov 9, 201

Appendix G: Optimal Model Code And Outputs With 30 Clusters

```
Sets

i contractor firms /A,B,C/

j cement factories /1,2,3/

r routes for accumulation points /1*30/ ;

table Rdist(i,r)

$include "C:\Users\DİNÇ\Desktop\Ankara uygulama\30 kümeli k-means\30lu için\30KMEANSTABLO.txt";

   ;

table Fdist(j,i)

$include "C:\Users\DİNÇ\Desktop\Ankara uygulama\30 kümeli k-means\30lu için\FDIST.txt";

   ;

Parameter Dem(j)

/

$include "C:\Users\DİNÇ\Desktop\Ankara uygulama\30 kümeli k-means\30lu için\DEMAND.txt";

/

Parameter Ava(r)

/

$include "C:\Users\DİNÇ\Desktop\Ankara uygulama\30 kümeli k-means\30lu için\AVAR.txt";
```

```
/
Parameter Tvarcost /0.35/
Parameter Tdistcost / 2 /
Parameter Truckcap /12/ ;
Positive variables
Cx(i,r)
Fx(i,j) ;
Integer Variables
NumofTravelRoute(i,r)
NumofTravelFactory(i,j)
 ;
NumofTravelRoute.up(i,r) = 1000 ;
NumofTravelFactory.up(i,j) = 1000 ;
Variable
z ;
Equations
Objective
DemandCons(j)
RouteCons(r)
BalanceCons(i)
Count1(i,r)
Count2(i,j)
```

```
Percentage

Weekly(r)

;

Objective.. z =e= sum((i,r), Cx(i,r)*Tvarcost*Rdist(i,r)) + sum((i,j), Fx(i,j)*Tvarcost*Fdist(j,i)) + sum((i,r), NumofTravelRoute(i,r)*Tdistcost*Rdist(i,r)) + sum((i,j), NumofTravelFactory(i,j)*Tdistcost*Fdist(j,i)) ;

DemandCons(j).. sum(i,Fx(i,j)) =g= Dem(j) ;

RouteCons(r).. sum(i,Cx(i,r)) =l= Ava(r) ;

BalanceCons(i).. sum(j, Fx(i,j)) =l= sum(r, Cx(i,r)) ;

Count1(i,r).. Cx(i,r) =l= NumofTravelRoute(i,r)*Truckcap ;

Count2(i,j).. Fx(i,j) =l= NumofTravelFactory(i,j)*Truckcap ;

Percentage.. sum((i,r), Cx(i,r)) =g= sum(r,Ava(r))*0.8 ;

Weekly(r).. sum(i,NumofTravelRoute(i,r)) =g= 52 ;

Model thirtycluster  /all/

mods /all/;

mods.optFile=1;

Option

optcr=0.00

optca=0.00

Solve thirtycluster using mip minimizing z ;

display  Cx.l, Fx.l, NumofTravelRoute.l, NumofTravelFactory.l, z.l ;
```

G e n e r a l   A l g e b r a i c   M o d e l i n g   S y s t e m

E x e c u t i o n

----   127 VARIABLE Cx.L

	1	2	3	4	5	6
A	668.660		3336.000			573.890
B		252.720				
C				616.450		1389.960

+	7	8	9	10	11	12
A		624.000		215.870		
B	447.530		242.190			
C					168.480	452.790

+	13	15	16	17	18	19
A	1104.000	624.000		624.000		
B				624.000		
C				210.600		689.720

+	20	21	22	23	24	25
A	2184.000					410.670
B			267.330	452.790	505.440	
C		1260.000				

+	27	28	29	30
A	1248.000	184.280	1.462	
B				624.000

---- 127 VARIABLE Fx.L

	1	2	3
A	8200.000		996.000
B		212.000	3204.000
C		4788.000	

---- 127 VARIABLE NumofTravelRoute.L

	1	2	3	4	5	6
A	56.000		278.000			52.000
B		52.000				
C				52.000		116.000

+	7	8	9	10	11	12
A		52.000		52.000		
B	52.000		52.000			
C					52.000	52.000

+	13	14	15	16	17	18
A	92.000	52.000	52.000		52.000	
B					52.000	
C				52.000		

+	19	20	21	22	23	24
A		182.000				
B				52.000	52.000	52.000

C	58.000		105.000			

+	25	26	27	28	29	30
A	52.000	52.000	104.000	52.000	52.000	
B						52.000

----   127 VARIABLE NumofTravelFactory.L

	1	2	3
A	684.000		83.000
B		18.000	267.000
C		399.000	

----   127 VARIABLE z.L   =   209904.128

EXECUTION TIME   =   0.000 SECONDS   3 Mb WEX239-239 Nov 9, 2012

BIOGRAPHICAL SKETCH

Merva DİNÇ who was born in Elazığ, Turkey on January, 1989. She is graduated from Elazığ Anatolian High school in 2007. She received her B.S. degree in Industrial Engineering from Galatasaray University, Istanbul, in July 2012. She joined the M.S. program in Industrial Engineering at Galatasaray University while working in automotive industry.

She has married and settled in Tokat after having 3 years work experience in İstanbul.

She is currently studying for her master's degree in production management and marketing at Gaziosmanpaşa University in Tokat.