OPTIMAL LOCATION OF WASTE LANDFILL SITE FOR İZMİR

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This is to certify that we have read this thesis and that in our opinion it is fully adequate, in scope and quality, as a thesis for the degree of Master of Science/Doctor of Philosophy.

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ABSTRACT

OPTIMAL LOCATION OF WASTE LANDFILL SITE FOR İZMİR

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The amount of waste generated is rapidly increasing with the increasing population. Moreover, urban life trends boost consumption, thus amount of waste increases. As an important consequence, waste management became an important issue for people and environmental health. This study aims to identify an optimal location for a landfill site in İzmir. The facility under consideration will be the second landfill site, and the decision needs to consider the existence of the decided location of first landfill site. First the criteria that used in the literature for solid waste landfill site selection are determined and evaluated the criteria used in. Then additional criteria are proposed and evaluation methods of the criteria are examined. After that, a view of solid waste management over an extended supply chain structure is demonstrated and the extended supply chain is examined in terms of additional flows and responsibilities.

Geographical Information System (GIS) based approach is used to process the criteria and identify candidate facility locations. Besides, Mathematical Modelling is used for examining the logistics related criteria. Then Analytical Hierarchy Process (AHP) and analytical methods used to decide on the most suitable location for the landfill site. Further analysis that considers the projected changes in the values of the relevant parameters over the life time of the facility is also carried out in order to assess the robustness of the location decision. Finally, the optimal location for landfill site was pointed out with total scores of the all analysis.

Keywords: Landfill Site, Facility Location, Geographical Information System (GIS), Supply Chain, Solid Waste Management

ÖZET

İZMİR İÇİN OPTİMUM ATIK DEPOLAMA TESİSİ YERSEÇİMİ

Yıldıran, Ladin

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Tez Yöneticisi: Yrd. Doç. Dr. Muhittin H. Demir

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Üretilen atık miktarı hızla artan nüfus ile birlikte artmaktadır. Ayrıca, kentsel yaşam tarzları değiştikçe atık miktarı ve tüketim alışkanlıkları artmaktadır. Bu artışın önemli bir sonucu olarak, atık yönetimi insan ve çevre sağlığı için önemli bir sorun haline gelmiştir. Bu çalışma İzmir'de bir katı atık düzenli depolama alanı için en uygun yeri tespit etmeyi amaçlamaktadır. Araştırmaya konu olan tesis İzmir için ikinci depolama alanı olacaktır. Çünkü kararı verilmiş olan tesisin varlığını dikkate almamız gerekmektedir. Öncelikle katı atık sahasının yer seçimi için literatürde kullanılan kriterleri tespit ettik ve değerlendirdik. Daha sonra ek kriterler belirlendi ve kriterler için değerlendirme metotlarını incelendi. Devamında tedarik zinciri yapısı üzerinde katı atık yönetimini ekleyerek genişletilmiş bir görünüm ortaya konmuş ve genişletilmiş tedarik zinciri, akış ve sorumluluklar açısından incelenmiştir.

Biz kriterleri süreci ve aday tesis yerlerinin belirlenmesi için Coğrafi Bilgi Sistemi (CBS), lojistik maliyetleri belirlemek için Genel Cebirsel Modelleme Sistemi (GAMS) kullandık. Daha sonra katı atık sahası için uygun olan alternatiflere Analitik Hiyerarşi Süreci (AHP) ve analitik yöntemleri kullandık. Tesisin ömrü nü göz önünde bulundurarak bu süre içerisinde parametrelerin değerleri değişse dahi tesisin en uygun yeri hala sağlıyor olması için verileri tahminleyerek analizleri tekrar gerçekleştirdik. Son olarak tüm analizlerin nihai skorlarını kullanarak en iyi alternatifi gösterdik.

Anahtar Kelimeler: Katı Atık Depolama Alanı, Tesis Yer Seçimi, Coğrafi Bilgi Sistemleri (CBS), Tedarik Zinciri, Katı Atık Yönetimi

…….To My Dearest Mother

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CHAPTER 1

INTRODUCTION

1.1 Purpose of the Study

In the era characterized by globalization, amount of waste is growing rapidly depending on the increase of population, development of industry thus increase of needs and consumption. Parallel to the increase in volume, the processes associated with waste become more complicated, making waste management more critical a ever. For instance when people have higher life standards, their consumption of paper, plastic and other organic waste amounts increase. This is becoming one of the main issues of living the urban areas (Mi, Liu and Zhou, 2010). An important aspect of waste management is of course related with human health. The increase in waste volume has an adverse effect on human health. Clearly, all these developments make waste management a necessity. When we look back in history we see that, over 2500 years ago, government officials in the Greek city-state of Athens, opened a municipal landfill site and decreed that waste had to be transported at least one mile beyond the city gates. Many years later, in 1408, King Henry IV's removal order instructed that refuses had to be removed or a forfeit had to be paid. In 1588, Elizabeth I granted special privileges for the collection of rags for papermaking. The Public Health Act in 1848 initiated the process of waste regulation in Britain (http://www.wasteonline.org.uk/resources/InformationSheets/HistoryofWaste.htm last accessed 18/09/2010).

In Turkey, waste management was first mentioned in Municipality Law N: 1580 in 14.04.1930. This was followed by a sense of related laws that aimed at regulating and developing waste management issues. Currently the most recent laws Regulation for Solid Waste Control (no: 20814 and 14.03.1991 date) is valid. However, it is remarkable that there is still no complete national and local strategy document about waste management.

There are various processes involved in waste management. The structures of these processes are shaped mainly by method of waste disposal. The earliest and the most primitive method involves the use of open dump sites. Within the terminology of waste management, open dump sites are defined as unplanned 'landfill' sites that incorporate few if any of the characteristics of a controlled landfill. Typically, there is no access control, no cover, thus no management; whereas there are many waste pickers in such a method. Other main methods involve the utilization of disposal sites and landfill sites. Disposal is the final handling of solid waste, following collection, processing, or incineration. Disposal sites are often used for the placement of wastes. The term disposal site usually means that the waste is placed in a dump or a landfill in a controlled way. Landfill sites are more developed versions of disposal sites, with better technology and less harm to the environment. In a landfill site, solid waste is placed in a controlled fashion with the intention of permanently keeping it. We would like to remark however that, the literature does not contain an agreement on the distinction between a disposal site and landfill site. The terms disposal site, landfill site, sanitary landfill site, municipal landfill site are used interchangeably in the literature. The Waste Management Glossary published by Global Development

Research Center also uses the term landfill site for both controlled dumps and sanitary landfills.

The main practices are; reduce waste then reuse and recycle incineration, composting and disposal. Disposal to landfill is still most preferred way of waste management, because it is the cheapest, simplest and most-effective method. The outstanding aspect of this method is environmental advantages. Storage of waste in a disposal facility serves to minimize the effects of waste on the environment. Modern waste management practices involves disposal of waste in specially sited and engineered areas known as sanitary landfills (Taylor and Allen, 2006).

Despite the cost, implementation, and environmental advantages, landfill sites are not very common in Turkey. Main reasons for this are the high costs of investments and lack of awareness on issue. Whereas waste management is very important for the national economy and also for the environment, there are only 16 landfill sites in Turkey as of 2007 (Turkish Court of Accounts, 2007).

Considering the various aspects that point out the significance of landfill sites this study tries to solve location problem of disposal sites. Along with the traditional criteria employed for similar problems we additionally use a class of logistics criteria. Clearly, a precise definition of the surrounding constraints and the objective function is critical for any location analysis. The literature on facility location involves a number of various criteria like distance to demand point, distance to supplier, land price and etc. We use a selected subset of these criteria; but also include the class of logistics criteria, utilize Geographical Information System (GIS) software tool and mathematical modeling with socio-demographic projections.

In doing so, we present a methodological framework that integrates several tools in order to decide on the optimal location of a waste landfill site. This thesis also provides a supply chain perspective for waste management. This aspect is traditionally ignored. However, for instance, it also emphasizes that there is a close multi-directional relationship between all facilities, population centers, transportation stations, other disposal sites, and other members of the supply chain.

1.2 Literature Review

Location decisions are important decisions. They are usually one-time, or cover a long planning horizon, strategic decisions. There is usually a high amount of cost associated; therefore the accuracy of such decision is critical. Similarly, choosing the locations of disposal sites passes the same significance. Researchers and practitioners have used various criteria for location analysis. The literature review that we carried out is based on the primary keywords “facility location”, “strategic planning”, “integrated logistics system” and “systematic optimization”. We also include a discussion of research on diversity types of facility kinds including “k-center, k-median, undesirable facility, fuzzy sets, networks” keywords. We finally research about several articles on “sanitary landfilling”, “solid waste management”, “waste management", "landfill siting", "hazardous wastes", "nonnoxious facility", "obnoxious facility" keywords and "multiple decision criteria decision making", "analytical hierarchy process", "fuzzy multiple decision", "multi-criteria analysis", "integer linear programming model" and "GIS".

A location problem deals with the choice of set of points for establishing certain facilities taking into account different criteria and verifying a given set of constraints, they optimally fulfill the needs of the user (Perez, Vega and Verdegay, 2004).

Many researchers point out the importance study by Hakimi (1964). This study considers the more general problems of locating one or more facilities on a network so as to minimize the total distance between customers and their closest facility or to minimize the distance.

Static and deterministic formulations are used to solve location problems. The most basic facility location problem formulations can be characterized as both static and deterministic. These problems take constant, known quantities as inputs and derive a single solution to be implemented at one point in time. The solution will be chosen according to one of many possible criteria or objectives, as selected by the decision maker. The social and environmental adverse effects place landfill site location into the class of undesirable facility where the decision makers would prefer facilities to be as close to demand points as possible. We would like to remark, however that it is worthwhile considering the cost of service that depend on locating a disposal site.

Therefore, the problem under consideration in this thesis is not a purely undesirable location problem. A number of researchers, particularly those working with applied problems and those interested in locating obnoxious facilities, have examined multi-objective extensions of basic facility location models (Owen and Daskin, 1998).

There are many variants of location problems. For instance, the study by Konforty and Tamir (1997) first discussed the k-median problem. The problem aims at locating k facilities to minimize the total transportation costs. In the restricted k-median model, they use the sum of the weighted rectilinear distances from the n customers to k facilities. In the next model, the authors consider the k-center problem. Objective is to minimize the maximum of the weighted rectilinear distances between the customers and the serving facility (Konforty and Tamir, 1997). They present a solution methodology for both problems with minimum distance constraints for 1-median and costs arising from undesirable characteristic facilities are included implicitly in the form of constraints forcing the location of the facility to be outside a specified forbidden region around each demand point.

Investments, which involve long term strategic decisions, are difficult decisions. With regard to Owen and Daskin (1998), facility location decisions play a critical role in strategic planning for a wide range of private and public firms. High costs associated with property acquisition and facility construction make facility location or relocation projects long-term investments. Similarly, deciding the location of a landfill site is a strategic decision. Moreover, landfill site location is a component of an integrated process: waste management. This integrated process involves alternatives such as composting, incineration, recycling and land filling, with disposal land filling still being the most preferred ways.

Researchers point out disposal to landfill sites has become more difficult to implement because of its increasing cost. Australian Department of Health and Community Services (ADHCS) (1995) recommended that the landfill must be designed for at least 10 years of operation, whereas Siddiqui et al. (1996) suggested 20 years of operation. The practice in Turkey is based on generally 20 years of operation like Harmandalı Disposal Site in İzmir, Middle Edirne Landfill Site Project, Kuşatak Landfill Site in Aydın.

Landfill site location differs from traditional facility location in several aspects: There is social opposition to landfill siting and there are more restrictive environmental regulations regarding the siting and operation of landfills. Therefore, even though land filling used a lot, it still possesses complicated and uncertain issues (Leao, Bishop and Evans, 2001).

Nowadays, there is an increasing interest from researchers to location of undesirable or obnoxious facilities, such as nuclear reactors, garbage depots and chemical plants. Such facilities may cause lower quality of life or even pose a severe danger to people living nearby (Konforty and Tamir, 1997).

Although waste disposal site location can be classified into this type of facility location, there are some critical differences. For instance, the risk of environmental impact associated with a waste disposal site is much lower than that of a nuclear plant. The service relationships between social and demographic conditions in the neighborhood of the facility and problem objectives also differ from other facilities. The above discussion also shows that we need to consider a number of conflicting objectives when looking at landfill site location problem, therefore we should employ a multi criteria analysis.

Landfill siting is integrated decisions and involves many stakeholders. Researchers that deal with the landfill site location problem point out to the complexity of the problem that include laws, municipalities, governmental incentives, public awareness, technical criteria, environmental criteria, social problems.

Selection of a landfill site generally requires both qualitative and quantitative methods and heuristics. In order to select the best landfill location, it is often necessary to compromise among possibly conflicting tangible and intangible factors (Lin and Kao, 1998; Cheng, Chan and Huang, 2003)

Different multi-objective programming models have been proposed to solve the problem. Multi-objective programming models used to solve the problem is that they are usually based on mathematical models. These models fail to fully incorporate qualitative and often subjective considerations such as the risk of groundwater pollution as well as other environmental and socio-economic factors which are important in landfill selection (Cheng, Chan and Huang, 2003). Systemic approaches are needed to understand the environmental implications of industrial systems, of which supply chains are a key component and also system approaches are system analysis approach that is concerned with creating models or representations of real-world systems and studying their dynamics (Hall, 2000; Yuana et al. 2010).

Several considerations are more critical for landfill site location than for traditional problems. The building and constructing a new facility is a high costly and time-sensitive project (Cheng, Chan and Huang, 2003). Before the facility building, optimal location must be defined and large amount of funds must be allocated. Owen and Daskin (1998) also point out that, while the objectives driving a facility location decision depend on the firm or government agency, the high costs associated with this process make almost any location project a long-term investment. Thus, facilities which are located or planned today are expected to remain in operation for an extended point of time. Environmental changes during the facility's lifetime can drastically alter the appeal of a particular site as well turning today's optimal location into tomorrow's investment blunder (Owen and Daskin, 1998).

To accord all these changes, researchers try to develop new methods J.J. Saameño Rodríguez at al. (2006) explained this as follow In general, the objective is to locate the facility as far away as possible from an identified set of population centers; the *maxisum* criterion attempts to maximize the sum of the distances from the undesirable (obnoxious) facility to the population centers and the optimal facility location will always be on the boundary of the feasible region. It is more appropriate when an aggregate measure of quality is desired and each population center has a measurable contribution in the objective function. The *maximin* criterion attempts to maximize the minimum level of quality among the population centers and it aims at providing that the facility location will not be too close to any population center (Rodrígueza et al., 2006).

J. Fernandez at al. (2000) review several models purposed in the location analysis literature to attack this problem. The most popular models are maximin models, whose objective is to maximize the minimum distance between existing cities and the facility. In particular, maximization of the weighted Euclidean distance is the most used (Taylor and Allen, 2006; Fernandez et. al., 2000). Taylor and Allen (2000) also purpose a new model for main problem of undesirable location which tries to overcome undesirable location problems and that can be applied to many real world problems. Their model deals with the location, in a given geographical region, of a facility considered undesirable by the inhabitants of that region, but which is not noxious for the health of the people (nor for the environment), in the sense that its effects do not endanger peoples' lives, at least directly or in a sudden way, unlike other facilities such as nuclear plants or chemical plants which can do so if an accident occurs. The objective is to minimize the global repulsion of the inhabitants of the region to the location of the facility while taking into account environmental concerns which make some areas unsuitable for the location of the facility, as for instance nature reserves or water reservoirs.

Ni-Bin Chang (2008) explained that landfill selection in an urban area is a critical issue in the urban planning process because of its enormous impact on the economy, ecology, and the environmental health of the region. Landfill site selection can generally be divided into two main steps: the identification of potential sites through preliminary screening, and the evaluation of their suitability based on environmental impact assessment. The ‘‘not in my backyard’’ (NIMBY) and ‘‘not in anyone’s backyard’’ (NIABY) phenomena is becoming popular nowadays creating a tremendous pressure on the decision makers involved in the selection of a landfill site. Other issues related to the availability of land, public acceptance, increasing amounts of waste generation complicate the process of selection of a suitable site for landfill. There are some different applications for solve these problems (Changa, Parvathinathan and Breeden, 2008).

The use of problem-specific special methods for such problems with unique characteristics is becoming more widely applied. One such methodology is the use of Geographical Information System (GIS) for waste site location problems.

The use of GIS systems is rapidly increasing with technological improvements. GIS is an '*information system*', that is a set of processes, executed on raw data, to produce information which will be useful in decision-making (Kingston Center for GIS, 2005). Chen and Gelderman (2004) defined GIS as an intuitive method to organize information based on spatial positions. In GIS, various information is linked to a geographic map, so when a user queries a specific location, all information associated with it will be displayed and processed.

Church (2002) is the first to establish the connection between location science and GIS. Guiqin et al. (2009) use the GIS in their researches about the location and capacity of hazardous waste disposal area.

Yeşilnacar and Çetin (2005) made analysis the location of waste facility using GIS. In their research, they add geological, topographical, build up areas, transportation, usage of area, earthquake hazard related criteria into GIS application

Şener at al. (2010) use GIS with 16 base maps (each of them for one or more related criterion) and a Multi Criteria Decision Making (MCDM) for deciding on the location of a disposal area in Konya.

One common methodology for solving MCDM is the Analytical Hierarchy Process (AHP). AHP was introduced by Saaty (1980), and accepted as one of the useful methodology which plays an important role in selecting among alternatives (Fanti et al., 1998; Labib et al., 1998; Chan et al., 2000). AHP is an analytical tool that enables people to explicitly rank tangible and intangible criteria against each other for the purpose of selecting priorities. The process involves structuring a problem from a primary objective to secondary levels of criteria and alternatives. Once the hierarchy has been established, a pair-wise comparison matrix of each element within each level is constructed (Saaty, 1980).

AHP also allows group decision-making, where group members can use their experience, values and knowledge to break down a problem into a hierarchy and solve it by the AHP steps. Participants can weigh each element against each other within each level, each level is related to the levels above and below it, and the entire scheme is tied together mathematically (Chang, Parvathinathan and Breeden, 2008).

Fuzzy set principle is used to integrate AHP to determine the best alternative (Chen, 1996; Hauser and Tadikamalla, 1996; Levary and Ke, 1998). Fuzzy set theory was developed and extensively applied in previous decade (Zadeh, 1965). It was designed to supplement the interpretation of linguistic or measured uncertainties for real-world uncertain phenomena.

Fuzzy set approaches are suitable to use when the modeling of human knowledge is necessary and when human evaluations are needed. Fuzzy set theory is recognized as an important problem modeling and solution technique. Fuzzy set theory has been studied extensively over the past 40 years. Most of the early interest in fuzzy set theory pertained to representing uncertainty in human cognitive processes. Fuzzy set theory is now applied to problems in engineering, business, medical and related health sciences, and the natural sciences (Kahraman, 2008).

Perez et. al. (2004) multi criteria decision making and Sarptas (2006) combine fuzzy multi criteria decision making with GIS.

1.3 Landfill Site Location Criteria

We now review the main criteria used for landfill site location in the literature.

Land Use: This criterion suggests that the type and intended use of land is important in landfill facility location decisions. With rapid developments and urbanization land is a limited resource with increasing value (Zhang, Huang and He, 2011). Therefore when deciding a landfill site in urban areas, this criterion comes out as a binding constraint. For instance, it is more preferable to build a landfill site in an industrial area than building it in an agricultural area or commercial area (Charikar et al., 2001).

This criterion can be evaluated according to the city development plans. If available and compatible, the land use map showing the land utilized by the human and the natural cover in the research area can be fed into GIS software.

Proximity to Ground Waters and Surface Waters-Rivers-Lakes-Wetlands: This criterion is used to consider a safe distance to ground and surface waters. According to Turkish Water Pollution Control Regulations landfill sites should not be placed near surface water (lake, pond, river and stream). Specifically, there should be 500 m buffer zones around all surface waters (Gemitzi et. al., 2007). Also according to Solid Waste Control Regulation there should be 1 meter at least between the bottom of the disposal site and ground water.

Proximity to Wildlife Parks, Protected Area, Historical Area, and Tourism Centers: Due to social and economic consideration, waste disposal sites should not be very close to parks, historical and touristic areas, environmental protected areas and social public area. These types of sites are protected by legal restrictions from the build a landfill site. For this, the local or central governments put such restrictions in effect. In this way generally governments or legal authorities protect these areas (Chang, Parvathinathan and Breeden, 2008; Croom, Romano and Giannakis, 2000).

Proximity to Airports: It is desirable to have waste landfill sites far away from airports. Researchers have also used this criterion. For instance, the 3 km buffer zone is used for selecting suitable area for landfill site in the China (Li and Kao, 1998). One other method is to utilize a multiclass scoring. In such a case, the area class closer to airport gets the lower score. The 0-3 km. class gets a score of 0, and the class 12 km. or higher gets the highest score (Chang, Parvathinathan and Breeden, 2008; Guiqin, et. al., 2009; Moeinaddinia et. al., 2010).

Soil Types: Since soil is a scarce and valuable resource, we wish to guarantee that waste landfill sites do not destroy this resource. There is also a legal framework that defines the restrictions related with soil types and waste sites. Soils have a direct effect on the types of vegetation and ultimately the animal species that will survive in an area (Changa, Parvathinathan and Breeden, 2008).

Agricultural, Forest Land: This criterion is actually a more specific version of land use criterion. Usually, more detailed maps that show agricultural and forest lands are used. It is accepted to be more preferable to build industrial area than building it in an agricultural area or commercial area (Cheng, Chan and Huang, 2003).

Wind-Flood: When selecting area for landfill the physical characteristic of land is very important for human health and society. Wind direction, wind gust and flood are the main issue involved in these physical specifications. Thus, potential areas are examined also with respect to these physical characteristics (Moeinaddinia et al., 2010; Zamorano et al., 2008).

Population: Probably the foremost social consideration related with undesirable facility location is based on proximity to population centers. In disposal sites it is important that being further from population centers (Sheu, Chou and Hu, 2005). Residents are directly affected by nearly waste sites due to smell, noise, explosion risk of gasses like methane, visual pollution etc. Therefore, there is usually a social reaction against waste landfill sites. The legal restrictions purpose a minimum distance of 250 meters. We note, however that closeness of waste landfill sites to population centers will probably increase service level (faster roundtrips) and decrease associated costs (positively affects social welfare). Hence, we believe that this trade off needs to be explicitly involved in the decision process being for between population centers and landfill sites. Housing developments are now increasingly encircling the existing dumps and the environmental degradation associated with these dumps is directly affecting the population. (Qingzhang, Tan and Gersberg, 2010).

Socio-economic, demographic situations: Literature review shows us researchers gives more importance to environmental criteria than economical criteria (Şener et. al. 2010). The socio-economic structure in a certain area directly affects the amount and type of waste production people in higher socio economic areas are more eager to accept nearby waste location sites. Demography also affects the amount of waste areas in high-population increase regions will be more likely to be allocated for resident location than for waste landfill facility.

Existing Road Network: This criterion also has several dimensions. Some studies try to move landfill sites away from major roads in order to avoid traffic jams. The general practice is to use 250 m. or 100 m. buffer zone around the existing roads. There are also different applications in literature like 1 km. buffer zone (Allen et. al., 2003). AHP models incorporate this aspect in the accessibility criterion by giving scores based on accessibility classes. (Şener et. al., 2010; Guiqin, et. al., 2009; Kanat, 2010; Lin and Kao 1998).

Slope: As with any facility location, slope is an important criterion for landfill site location. Land slope and height are basic parameters for the construction of a landfill site because very steep slopes lead to higher excavation costs (Şener et. al, 2010;

Hugos and Thomas, 2006). Moreover, higher slopes pose higher environmental risks of erosion, smell problem etc.

So areas with high altitude or high slope are not suitable landfill sites. In terms of slope, the best candidate locations for waste disposal are considered to be areas with medium altitude surrounded by hills and with no more than 20% slope.

Distance to Clustered High Waste Potential Areas: When considering economic feasibility of a candidate landfill site, the proximity to waste production sources is an important factor; landfill sites close to the waste production centers will decrease transportation costs (Guiqina et. al., 2009).

Distance from Developing Areas: M. Zamarona et. al. (2008) were analyze distance from waste production center in terms of human and society health. If disposal sites are close to the residential areas then it may pose several risks (Guiqina et. al., 2009). Guiqina et. al. (2009) considered the distance from waste production centers and use buffer tool in GIS software because to account for pollution control on the landfill sites (Zamorano et. al., 2008). Moinaddini et. al. (2010) argue that landfill areas must also have a bound on maximum distance for economical justification. In their study, they use 40 km buffer to transport waste for landfilling.

Next we discuss the development of the methodology utilized in this to determine the location of the waste landfill site.

CHAPTER 2
METHODOLOGY

The methodology is composed of two main phases. The first phase is setting the framework concerning the selection process. This involves the implementation of the framework. Specifically, this is the implementation using actual data and actual criteria.

2.1 Waste Landfill Site Location Selecting Process

We perceive facility location decisions as an important subject of logistics discipline. The effects of urbanism, in case increase in population, changes in life standards in İzmir and logistics considerations align the problem under consideration in the intersection of environmental studies and logistics.

This study therefore requires a multi-perspective viewpoint. We consider the existence of one landfill site and decide on the second landfill site location with the joint consideration of environmental and supply chain aspect.

The research mainly involves the following research questions:

- Which components do the waste management include?
- Which elements are related with the location analysis?

- How related the location of landfill sites and another facility location problems?
- What are the main relations between the supply chain and the waste management?
- When considering the whole supply chain of the city, what are the differences between the traditional supply chain and the extended supply chain with waste management?
- Which methodology should be used for selecting optimum location of landfill sites both waste management view and supply chain view?

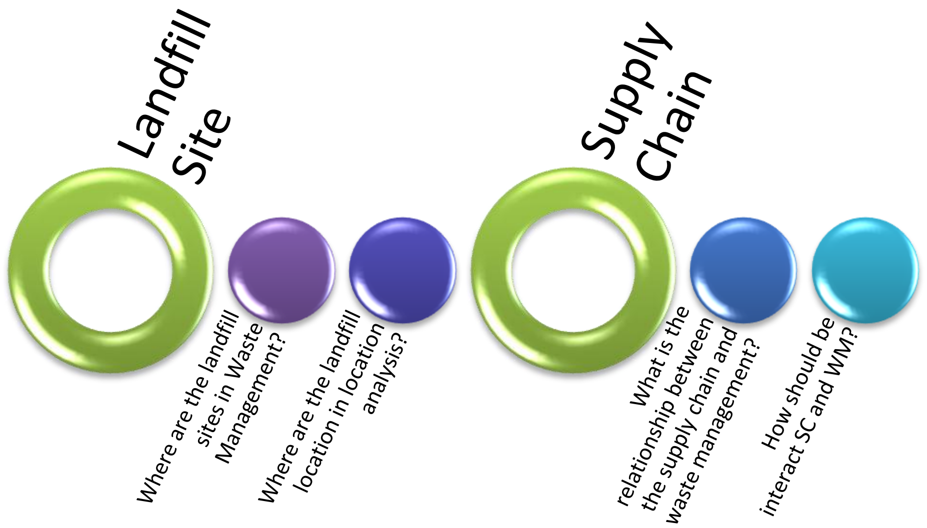


Figure 1: Research Questions on Two Main Scopes of Study.

Analysis of the literature establishes the similarity between the problem under consideration, and undesirable facility location. Through the guidance of the literature review, we identify a long list of criteria implied by laws or environmental considerations. It is remarkable to note that almost every researcher uses a unique set of criteria with different classifications. An analysis of methodologies applied also show variations. This is rather valid for non-traditional criteria. For instance, when we look at the group of criteria that we propose as “logistics criteria”, distance from population centers criterion was examined by few researchers, under different headings.

It was important to know which researchers use which constraints, how they used and what results occurred at the end of these studies. Also it was important to determine the criteria that used because of the laws or environmental requirement. Each researcher used different criteria exact standard criteria and used different classifications to group them so we continued our search which methods applied to analysis these criteria. Especially logistics point of view criteria have differences in this study. For example in Table 1 the “distance from population centers” criterion was examined by few researchers, we looked at similar different criteria and classified them in a logistics criteria if they any logistics effect.

Generally, location of undesirable facilities is restricted by laws, so that they are as far enough from population centers.

In this study also we take this consideration into account, in order to protect environmental and public health. On the other hand, we take the logistics point of view. This view perceives population centers as demand points that actually receive service from waste landfill facility. To this end, distance from population centers is important for long term transportation costs and also for satisfying long term needs of citizens.

One other criterion that needs to include in the analysis is the potential for development of an area. Such areas with high development potential are significant in terms of future logistics costs. This is true since these areas are expected to have high population increase rates as well as leveraged economical status, implying higher waste volumes. With a similar mind of thought, we propose that locating the facility close to areas with higher development potential will promises potential for higher service levels and lower logistics cost in the future.

In order to be able to process the last two criteria, we need to access data that evaluate candidate locations with respect to the criteria. For the former, we estimate and use population projections of İzmir's regions over the lifetime of the facility. For the latter, we convert and use the Master Plan of İzmir Metropolitan Municipality that includes projections for developing areas.

Following the discussion on criteria by the help of the literature, we devise a methodology to process the criteria in order to aid in deciding the landfill site location. An important number of criteria (distance to surface water, distance to protected areas, distance to agricultural areas, etc.) are suitable for analysis using GIS software, provided that we can access compatible data. The data is needed in the form of GIS maps. Through the phase of data collection and data processing we obtained data and maps from different institutions. As there is standard format and institutions use several different formats, we need to standardize all GIS maps ourselves.

The remaining criteria are not suitable for analysis using GIS software (educational and cultural structure of regions, price of land and logistics costs) or we had some trouble to find a data of some necessary criteria. This why we decided to use another models for determine criteria. For example the economical structure of area affects the amount of waste (Zerbock and Candidate, 2004).

This means that we need either to use GIS software as the tool for the research and this regard those criteria that GIS cannot handle or use some other methodology to analysis such criteria clearly, it is not wise to leave important criteria out of consideration. Therefore, we need to specify have to incorporate each such criterion into the analysis and, we also need to device a methodology to use GIS and non-GIS criteria within the same decision making framework.

The methodology with develop mainly relies on the AHP. In order to evaluate candidate locations with respect to criteria, we use a combination of GIS (digital maps), expert judgment, mathematical program (with GAMS software) field measurements. Then, prioritization of the multiple objectives was performed by the expert rating based the model of AHP.

The details pertaining to the methodology is further discussed in the following chapters. Figure 2 provides a flow chart representation the methodology.

There are not any digital maps about the economical structure. This and similar criteria were prioritized from decision makers that consist of experts. After this prioritized we used AHP as one of the MCDA. Also we used General Algebraic Modeling System (GAMS) for examine the logistics costs. Logistics costs are really important because of facility location decision is strategic decision. All results are collected and processed.

All analysis and their orders in this research go as follows:

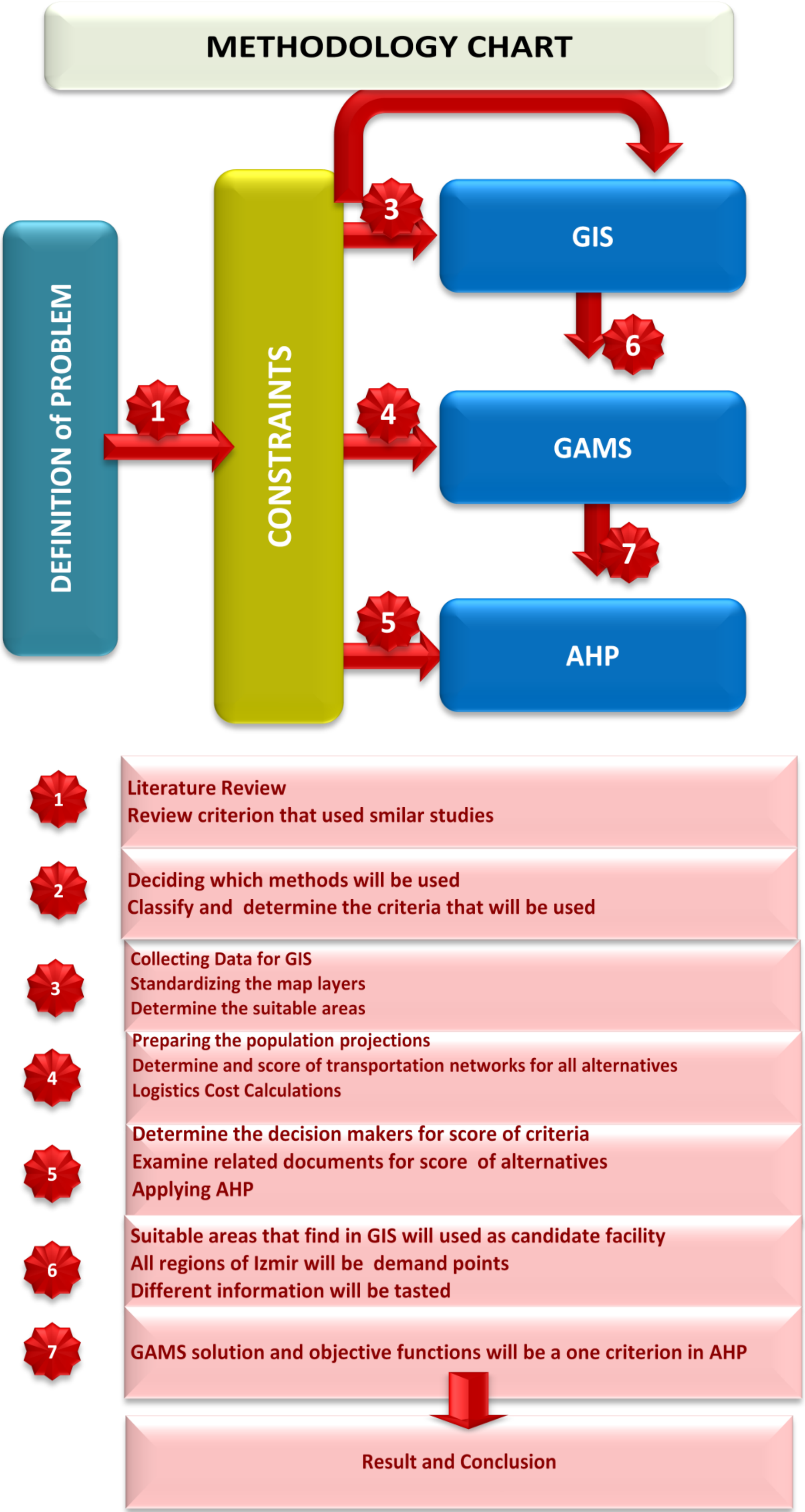


Figure 2: Methodology Chart

Next, we present a detailed discussion of criteria and state how we process each criterion.

2.2 Processing the Criteria

An analysis of the literature shows that there is a common set of criteria used for deciding on the location of waste landfill sites. A subset of the criteria is impaired by legal restrictions. The remaining criteria show a higher spectrum of a view points that may change with respect to the view point of the researcher. We plays a higher important on examples based on implementations in Turkey since the surrounding structure (laws, geography, social factors, etc.) are similar. (Turan et. al., 2009; Tuzkaya et. al., 2008; Öztemur, 2007; Sarptaş, 2006 and Doyuran et. al., 2008).

Table 1 presents a long list of criteria which are used in the literature. The table further demonstrates our classification of the criteria. We analyze the criteria in for main categories: Environmental, Demgraphical, Economics and Logistics criteria. The environmental, demographical and economic criteria are rather traditional (Sarptaş, 2006; Moeinaddini et. al. 2010, and Yeşilnacar and Çetin, 2005). We propose that the logistics criteria should be explicitly handled and are important for decision making. The table also shows how each criteria is processed and the preferred direction. For instance the demographic criteria applied with AHP analysis at the end of the research but the environmental criteria are used in GIS software. If there is a quantities evaluation associated with a criterion, we also stayed that, for instance there is a digital evaluation map for slope criterion and we showed this in Figure 19 at Chapter 6. Some of the criteria are viewed as 0/1 type. That is, an area is either totally feasible or totally infeasible with such criteria; there is no intermediate evaluation. For instance the seismic risk, some sub criteria that in land use map like forest, meadow. We extracted such these areas and don't use for landfill siting.

	CRITERIA	(Taylor and Allen)	(Şener et. al.)	(Guiqina et. al.)	(Misgav, Perla and Avnimelech)	(Zamorano et. al.)	(Chaeng, Chan and Huang)	(Chang, Parvathinathan and Breeden)	(Moeinaddini et. al.)	(Yesilnacar , Çetin)	(Lin, Kao)	(Sumat, Natesan , Sarkar)	(Sarptaş)	PROCESS	VALUE
ENVIRONMENTAL	Land Use		√	√	√		√	√	√	√		√	√	Avoid of high quality agriculturel areas, forest and meadow areas	
	Wildlife Parks, Protected Area		√	√			√	√	√		√	√	√	The higher the better	Min 500 m. distance
	Airports			√				√	√					The higher the better	Min 3000 m. distance
	Soil Types							√		√	√		√	Not suitable areas with loamy sand	
	Ground Water Wells	√		√		√	√	√	√		√	√	√	The higher the better	Min 30 m. distance
	Surface Water		√	√		√		√	√		√	√	√	The higher the better	Min 300 m. Distance
	Agricultural Land		√	√	√		√			√			√	Classification	V<=X<=VIII
	Forest Land			√									√	Preferably not	
	Seismic Risk					√				√				Classification	Not suitable if risk is high
	Wind					√			√					Classification	Not suitable if risk is high
	Permeability								√				√	The higher the better	min 10^-7
	Flood								√					Not suitable if risk is high	
	Climate									√				Not suitable if tempreture is so hig or low	
	Erosion									√				Not suitable if risk is high	
	Rain								√					Not suitable if there is a flood in last 10 years	
DEMOGRAPHY	Population					√			√		√		√	With future projections	Minimum 1000m. Distance with AHP
	Demography		√		√			√						The higher the better	Evaluate with AHP
ECONOMICS	Price of Land			√			√							The cheaper the better	Evaluate with AHP
	Developing Possibility													Preferable more developing posibility	Examined according to master plans; with AHP
	Land Ownership										√			Public owner more preferable then private owner	
LOGISTICS	Existing Road Network		√	√				√	√	√	√	√	√	Classification	500m<X<3000m
	Slope		√	√	√	√		√	√		√		√	Classification	Max % 20-%40 slope is acceptable
	Distance from existing facilities													The farther the better	Out of the exist service area
	Distance to Clustered High Waste Potential Area			√										The closer the better	Min 500-max 3000

Table 1: Criteria and Literature Review

In what follows, we detail how we process each criterion:

Land Use: This criterion is processed using GIS software and landuse maps. A landuse map identifies any point in a geographical region as industrial areas, agricultural areas, forest areas, olive area, meadow area, brush area, pasture area, airports. We assume that landfill site cannot be located on residential, industrial, 1st, 2nd, 3rd and 4th degree of agricultural and olive areas, meadows and airports but on pasture, brush areas landfill site can be located.

Proximity to Ground Waters and Surface Waters: Rivers-Lakes-Dams-Wetlands:

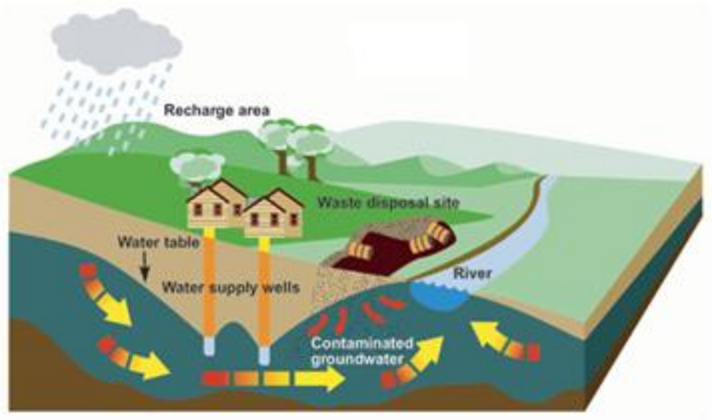


Figure 3: Environmental Effects of Disposal Sites

By regulations, the landfill site should be located considering a minimum of set distance to groundwater and surface waters. We obtained river, lakes, dams, and wetlands GIS map of İzmir for this. The application in GIS software is through the buffer tool. For surface water rivers, lakes, wetland we use 300 meters buffer. For dams we use 2000 metres buffer.

Proximitty to Wildlife Parks, Protected Area, Tourism Centers: The landfill site should be as far away from wildlife parks, protected area, historical area, tourism centers as possible.

Proximity to Airports: We use land use map in GIS and buffer tools to process this criterion. Waste landfill sites attract birds and there is a rising dust from landfill sites. These may pose risks for pilots: Therefore we try to locate waste landfill site at a safe distance from airports. This criterion is also suitable for processing GIS software. We use the locations of airport with a 5000 meters buffer and exclude such locations from consideration of locating waste landfill site.

Distance to Agricultural: Land can be classified into eight types. Four of these are accepted as suitable for agriculture. Y legal restrictions, we cannot choose agricultural type of land area for landfill site location. In order to process this criterion, we use the land use map. GIS has a built-in “reclass” tool. We utilize that tool to eliminate the four agricultural land type areas. We will use GIS reclassification tool for eliminate unsuitable areas.

Unsuitable Forest Lands: Any area that is determined as forest land is unsuitable for waste landfill site location. We use GIS land use maps and we use reclassification to remove such areas from the suitability map.

Unsuitable Fault Lines and Disaster Areas: The areas that have a high earthquake risk or any other disaster risks are not preferred as a facility location for waste landfill site. We use the Protection Area Map obtained from GIS Department of İzmir Metropolitan Municipality and use "reclass" tool to remove such areas from the suitability map.

Population: Population is important from multiple dimensions. First, population is important not only for landfill sites, but any facility location problem. As mentioned before we take population into consideration based on different conflicting objectives. With the consideration of transportation costs, it is more preferable to locate facilities closer to demand points. In the context of a landfill site we don't want to a landfill site location to be too close to residential areas. For the latter objective, we used population centers in GIS software and apply a 1000 meters buffer for residential areas.

We handled the transportation cost objective within a two-stage methodology. We first apply the GIS type criteria to result in a number of suitable regions for the landfill site. Thereafter we take these suitable regions and evaluate their transportation costs. In doing so, we use a mathematical programming formulation and the General Algebraic Mathematical Model (GAMS) software. The mathematical program allows us to provide further insights to the landfill site location decision. First, it provides the optimal (best possible) value of the population weighted transportation costs. We can evaluate each suitable candidate location by its induced transportation costs and with respect to deviation from optimal cost. We are also able through the mathematical program to answer what if questions regarding changes in the data (such as population, development plans, etc.). The results obtained the mathematical program are then fed into the AHP, to evaluate the candidate locations based on other criteria along with the logistics costs criteria.

Socio-economic, demographic situations: In the thesis, we place emphasis on a given areas' demographical and socio-economical conditions. To begin with, the amount of type of waste generation changes with respect to income levels (socio-economic conditions). Higher income areas are more likely to generate more waste. Researchers also support this idea. For instance, solid waste generation is estimated in low income areas as 0.4 to 0.6 kg/person day, in fully industrialized areas as 0.7 to 1.8 kg/person day (Zerbock and Candidate, 2003; Zamorano et. al., 2009).

This shows us that there is a considerable correlation between socio economic indicators of the population and waste management. To this end, is not enough to consider only the population. Household population, socio economic status of the members and the development of the region must be considered.

However, such factors are more intangible and it is not easy to process these criteria using GIS and other models. We analyze this criterion by feeding the collected data in the AHP process.

Existing Road Network: The road infrastructure also poses a multiple-objective criterion. That is we argued that we need to identify both lower bound and an upper bound on distance of landfill sites to existing road network. The commonly accepted minimum distance to main road is 300 meters. This is in order to prevent undesirable effects like smell. We follow this 300 meters rule and use GIS buffer tool. We also apply 100 meters buffer for secondary roads.

We also use an upper bound since the landfill sites are long term facilities it is necessary find an optimum distance the phrase "distance to road network" is a very important term for logistics discipline which takes place in lots of articles. Transportation and collection cost are important considerations for logistics. For that reason, we think that will be proper to analyze the distance to road network criteria - which we used to see in many economic criteria- under the title of "logistics".

It must be easy to access to the existing roads. The transfer stations must have the qualifications to shipping with semi-trailers. The GIS map of the existing roads, which will be provided from The Ministry of Environment and Forest, is processed to find the shortest routes between the candidate facility location and road networks. We incorporate this criterion within the AHP analysis.

Slope: Higher slopes make it more difficult to construct and operate the landfill sites. This is reflected by higher construction and transportation costs. Moreover, there are risks associated with high slope areas.

Because high slope has the possibility to trigger the environmental risks, slope is an important criterion that environmental engineers dwell upon. For instance, if the area takes heavy rain, storing waste in such an area, is a factor that poses risks to its neighborhood because of erosion and flood possibility. If the facility locates on a slope area, bad smell reaches easily to the residential areas because of the wind and it will be a more permanent and serious problem. We process this criterion using the map in GIS software. We identify two levels of slope. Beyond which we assume it is not acceptable to build a landfill facility. We utilize each slope threshold in a separate scenario. Majority of the research that explicitly analyses slope as a criterion include among logistics criteria. We argue that slope will act rather as a logistics criterion since it is related with everyday transportation costs and significant construction costs that are actually logistics costs.

Distance to Clustered High Waste Potential Areas: The previously mentioned criteria cover many aspect of landfill site with respect to population. That is we account for the considerations of keeping landfill site away from people to minimize adverse effect and keeping total logistics costs as small as possible. We now consider a criterion that aims at involving locations that produce massive amount of waste into the decision making framework, such locations are mainly industrial zones.

In processing this criterion, we wish to evaluate each candidate location based on its distance to waste production centers. This is a complicated task since such locations are high in number and geographically disparaged. To handle this situation we identify to alternative methodologies:

1) Identifying a threshold capacity: this approach calls for determining the set waste production centers that have capacity (thus waste producing potential) beyond a threshold value and this regarding others. However method has the major disadvantage of leaving a significant total capacity out of consideration. For instance, there are 526 firms in İzmir Ataturk Organized Industrial Zone (IAOIZ). Applied average capacity as threshold value leaves more a 50% capacities out of the analysis.

2) Clustering: This approach aims at combining smaller and neighboring waste production centers into demand points that is into a cluster. The location of the cluster can be taken as the "center" of locations o f its components. This is advantages since it helps consider almost all waste production areas.

The difficulty in processing this criterion is the problem associated with accessing the data. We also incorporate this criterion in the AHP model, with the consideration of candidate alternate locations.

Distance from Developing Areas: To reflect to future aspects of the problem, we need to look at project that may affect our parameters, constraints even objectives. For instance, building a facility in closer location to developing areas, promises lower transportation costs in the future. Especially when we recall the facility lifetime 20 years, we need to incorporate data regarding development plans or population size with a 10 year projections.

One reason that we place higher emphasis on logistics considerations, trying to minimize logistics costs relies on the recent development in landfill sites. The risks posed by landfill areas to population centers change with respect to waste content. However modern technologies in the past few years have reduced such risks. This is also reflected by changing (more related) legislations.

Since the risks such as leakage from waste to drinking water, the spreading of the wastes with the wind or floods and bad smell because of the heat or the other environmental factors are always perceived as possibilities, the distance of landfills to the waste production areas or population centers has always been a research subject.

However, when consider increasing logistics costs due to rising waste production quantities per person and population growth, the collecting of these wastes, and transportation from one area to another is becoming a more complex and high cost process.

One wise alternative to cut down risks and associated costs is to utilize an integrated serious of processes involving the composition at source, recycling facilities, transfer stations and finally disposal areas. As stated by (Mbuligwe, 2002) minimizing waste amounts by focusing on management practices at the source can save landfilll sites space, reduce illegal dumping, and therefore, cut down on pollution potential from solid waste.

In the traditional case where decomposition at source not implemented waste collected, wastes collected are sent to the transfer station with small volume vehicles and then directed to the storage areas with large volume vehicles. And this process repeats 1-2 times a week for every neighborhood.

The associated transfer cost is very high and need explicit consideration. Some components of this cost are stated below:

- Investment costs for trucks,
- Investment costs for container for every neighborhood,
- Labor costs minimum two worker teams for every truck,
- Employing the (high skilled drives that will use these different vehicles) labor costs.
- Transportation costs to the transfer stations,
- Costs of buying equipment to be used in the transfer stations, landfill site and other facilities,
- Transportation costs to the intermediate facility (if exist) or landfill.

Although these costs are supposed to reduce with the decomposing at source, it still has a high portion in total.

CHAPTER 3

EXPANSION OF THE TRADITIONAL SUPPLY CHAIN PERSPECTIVE WITH WASTE MANAGEMENT

In this chapter, we aim at aligning waste management within the supply chain perspective, one reason for this is to further emphasize the significance of the logistics (supply chain related) point of view concerning waste management. We particularly, pinpoint the interrelation between waste management and associated supply chains we identify the oft-reglected volume of waste within practically any supply chain both in terms of the reverse flow and the forward flow.

3.1 Supply Chain and Environmental Supply Chain

We also propose a counter view to the case; to this ends we try to define the components and processes of the supply chain whose main actor is waste. We believe that this view point should be investigated as an important topic of research to follow. Researchers first started to give more attention to "supply chain management" starting early 1980s (Croom, Romano and Giannakis, 2000). Logistics management is viewed as an important component of supply chain management.

Logistics is essentially a planning orientation and framework that seeks to create a single plan for the flow of product and information through a business (Christopher, 2005*)*. Supply chain management is certainly a broader concept as compared to logistics (Christopher, 2005). Another definition for supply chain management from Martin Christopher is "The management of upstream and downstream relationship with suppliers and customers to deliver superior customer value at less cost to the supply chain as a whole" (Christopher, 2005*)*.

For a company, developing supply chain capabilities support roles the company plays. Improving the company's role within the supply chain as well as the supply chain's performance typically relies on efficiently managing the supply chain drivers. The 5 drivers of supply chain can be listed as follows: (Levi and Kaminsky, 2003)

- Production: Production is the main process of all other management issues because without production many other processes do not exist. Logistics is very important for production. There is a significant flow through supplier to producer and to the customer. This flow is a part of logistics discipline.
- Inventory: Efficient management of inventory provides benefits in terms of costs and operations. The concept of inventory management is closely related with the management of risks of a company.

- Location: Location decisions are strategic decisions. They are also important for supply chain responsiveness. For instance if the company operates in many locations, the location of each facility is desired to be physically close to the customer. On the other hand efficiency can be achieved by operating from only a few locations and centralizing activities in common locations.

• Transportation: Transportation is moving a variety of loads from raw materials to finished goods between different facilities in a supply chain. Different modes of transportation and the locations of the facilities in a supply chain should be managed and routes along with the design of networks should be designed for higher value added and efficiency of the chain.

• Information: In our era, the importance of information is far realized by every company. Information is a critical resource because it can directly add value to the process involved (Hugos and Thomas, 2006). Forecasting and planning are also related to information that share between the chain members.

3.2 An Extended View of the Traditional Supply Chain

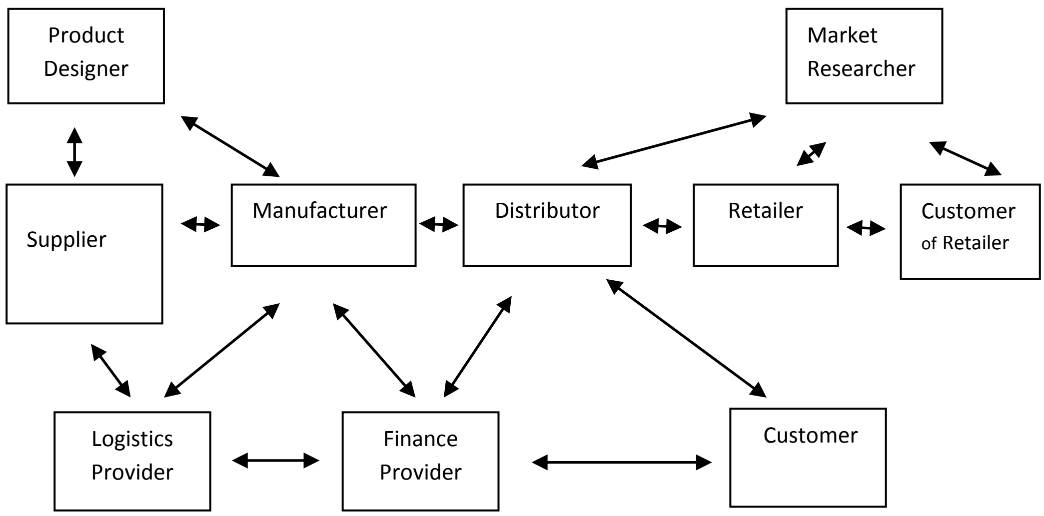


Figure 4: Traditional Supply Chain - Extended View

Source: Hugos and Thomas, 2006

Many definitions of the supply chain involve the main players such as raw material producer, supplier, manufacturer, distributor, retailer, and finally the customer. The main focus within the supply chain is on the flow of materials from suppliers to the customer.

An extended view may be provided with the inclusion of the companies that take part in the first layer environment of this main supply chain (Hugos and Thomas, 2006). That is, product designer that interacts, for instance, with suppliers and/or the manufacturer, logistics provider that may provide service to the retailer and the manufacturer, market researcher, finance provider, and the business customers. In general, the new layer of players may provide services or materials to every member of the main supply chain that is there is not necessarily a dedicated relationship.

Figure 4 provides schematic representation of this extended view of the supply chain.

This approach extends the traditional supply chain with only additional chain members. Addition of new members into the picture clearly results in a more sophisticated supply chain perspective. However, the main flow under consideration, the direction of this flow, relationships and distribution of responsibilities among supply chain members remain almost unchanged.

3.3 Extended Supply Chain Perspective with Waste Management (ESCWM)

In what follows, we propose an extended supply chain perspective with waste that looks at the whole supply chain as a living organism. All members of the traditional supply chain have a waste output. We believe that the flow of waste within the supply chain is important; therefore it should be included in the definition and analysis of supply chains. Moreover, the inclusion of the flow of waste and the related components into the supply chain will most probably result in a redefinition of the responsibilities and relationships within the supply chain.

Consider the collection of supply chains in a city. These are high in number, and if we think of the waste amounts of these supply chains collectively, there will be a serious volume. This basic thinking shows us that there is a significant volume of flow to be considered. This flow is occasionally comparable to the flow of material (the traditional forward flow) within the supply chain. Therefore, a more explicit consideration of waste management is necessary for supply chains.

Consider a typical supply chain if the waste following consumption within this supply chain is immediately decomposed at the source, then waste management would be rather easy. However, the practice in many countries, especially in developing countries shows us that the percentage of waste decomposed at the source is still low (See Table 2). For instance, in the area of our research, İzmir, decomposition at the source is not common. Then, it turns out that there is a complex supply chain structure involving flows from/to transfer stations, waste disposal sites, compost facilities, incineration facilities in addition to flows within the traditional supply chain. This flow is typically left out of consideration when designing or managing supply chain. This flow related with waste also makes the underlying network more complex and the supply chain more difficult to manage efficiently and effectively.

Country	Incieration %	Composting %	Recycling %	Landfilling %
Ireland*	0	0	3	97
UK*	6	0	6	88
Portugal*	0	15	0	85
Australia*	2,5	0	15,5	82
Canada*	8	2	10	80
Italy*	16	7	3	74
USA*	16	2	15	67
Spain*	6	0	6	65
New Zealand**	30	6	0	64
Belgium**	27	9	2	62
Germany*	36	2	16	46
France*	42	10	3	45
Netherland*	35	4	16	45

Table 2: Waste Management Methods (%)
Source: * (Leao et. al.,2001); **(Mi, Liu, Zhou.2006)

Table 2 demonstrates the usage percentages of waste management methods with respect to different developing and developed countries. The methods are namely incineration, composting, recycling and landfilling.

3.3.1 Flows within the Extended Supply Chain with Waste

When we consider the waste-related flow within the supply chain, the direction of the main flow will be from each member of the traditional supply chain to waste management facilities. This flow will be routed through waste process plant (if it exists) in order to classify and separate recyclable or reusable materials. These are directed to the appropriate facility for reuse as materials, for compost, or for energy. The remaining waste is sent to the landfill site. We wish to remark that the addition of process plants along with the process involved (e.g. decomposition, compost, or incineration) followed by further routing to landfill sites makes the supply chain more complicated as compared to direct sending of waste to landfill sites. It also requires additional investments for process plants and associated operational costs.

On the other hand, this practice does not only come with extra costs. It promises serious environmental and economic benefits. These benefits will be discussed in the further sections in more detail.

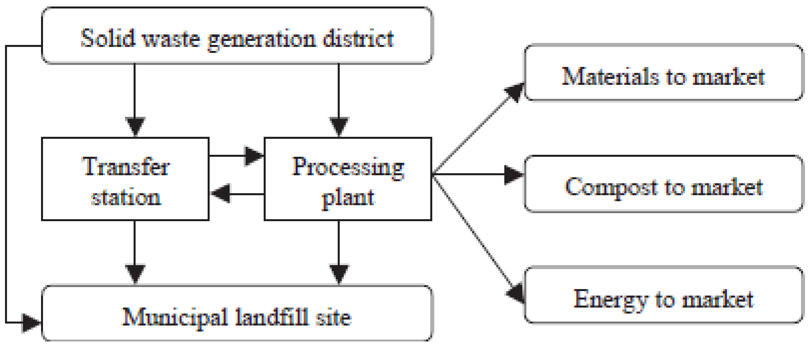


Figure 5: Structural model of solid-waste management

Source: (Cheng, Chan and Huang, 2003).

Figure 5 presents our flowchart showing the flows concerning the waste-related components of the supply chain as mentioned. We can see from the figure that there is a flow from both transfer stations and processing plants through landfill sites.

A more detailed view that involves multiple supply chains, the interrelationship between the supply chains, and the combined flows concerning waste can be seen in Figure 6. Considering the case with our research area, İzmir, there is no compost or energy facility. So the main flow of waste is from waste producer to transfer stations or direct to disposal site.

3.3.2 Responsibilities within the Extended Supply Chain with Waste

Typical analysis of supply chains focus on managing the flow within the supply chain. There is another main issue that should be examined in relation with management of flows: Sharing of responsibilities within the supply chain. When we consider the supply chain with the inclusion of waste and related flows, we see that we have on hand a network of interrelated supply chains. Within this supply chain, every player carrier its traditional responsibilities (as defined by business contracts); but they also have a responsibility to the environment concerning waste management. There is also another layer of responsibilities concerning issues such as the installation and operation of waste-related facilities, flow from and to these facilities and legislations on waste management. This point of view demonstrates a rather more complex structure; therefore the responsibility management within the network of supply chains should be more systematical. Although there are laws and regulations associated with the flow of waste, management of responsibilities is not only possible with laws and administration. Authorities must react and try to reduce waste generation and disposal by implementing recycling programs and new facilities (Zamorano et al., 2008). The system can only function effectively through a supply chain management perspective involving economic analysis as well as strict adherence to environmental sustainability principles. This overall viewpoint adds new components (players, flows, responsibilities) to the supply chains, which need to be well-managed.

Figure 6 illustrates the flows on a network of supply chains, based on the extension with waste management. All chain members are related with each other, they are also related with other members of the external supply chain. We can observe that important flows are formed by retail flows and the flow of waste.

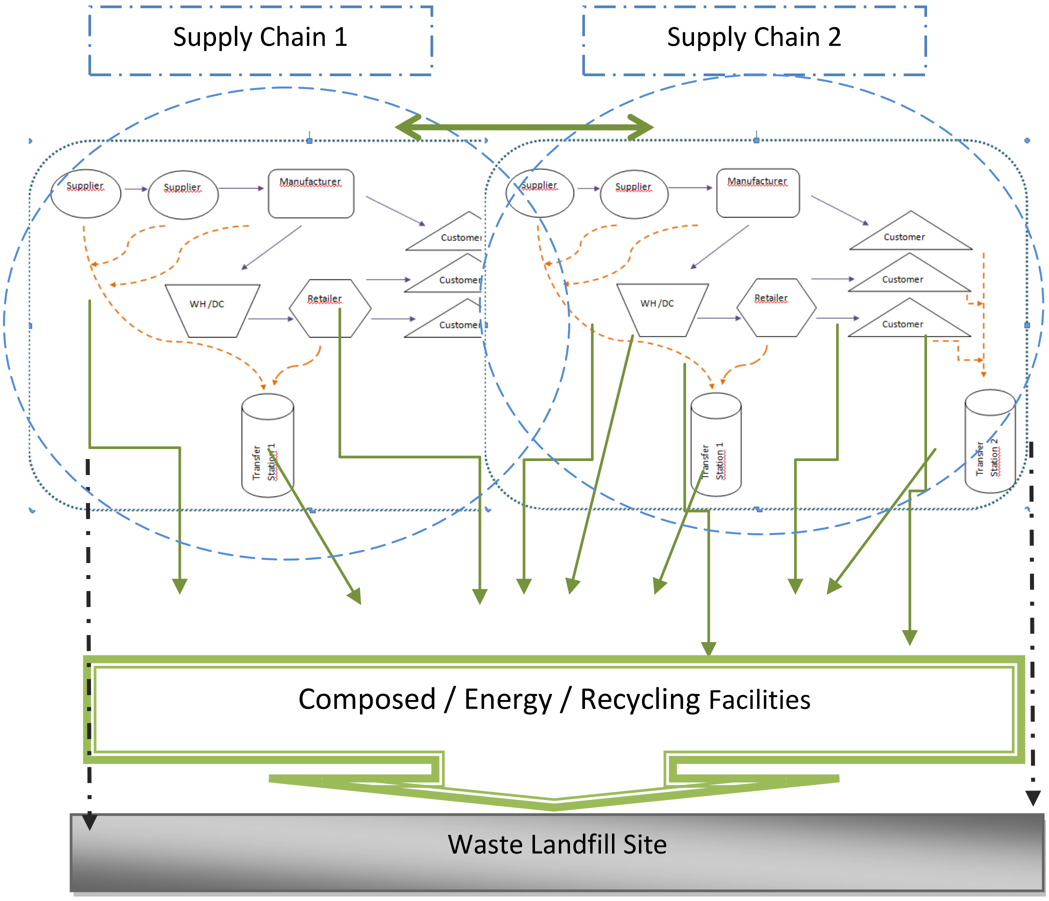


Figure 6. The whole view to extended supply chain with waste

The actors within the Extended Supply Chain with Waste Management (ESCWM), their roles and responsibilities with respect to the traditional and the extended supply chains, along with the agents that they employ for managing these processes can be listed as follows:

- Suppliers- flow of main material + waste producer : suppliers are responsible from traditional flow of goods or service, also they are waste producer for ESCWM overall view)
- Manufacturer- flow of main material + waste producer
- Customer- end member of main material + waste producer
- Central Government-manages flow of waste (with laws)
- Local Government- manages flow of waste (Traditionally local authorities makes investigations for waste management and also collecting equipment investigations. They use authorization granted by laws and acts. The waste management and the whole supply chain view in city should connected and combined together then manage and operate this system will be more effective and efficient.)
- Environmental Institutions- manages flow of waste (with activities and campaigns)
- Public-manages flow of waste (with sensitivity and consciousness)

3.3.3 A Comparison of the Members of Traditional Supply Chain with the Extended Supply Chain with Waste

From one point of view, all supply chains have similar members. But for any chain the members' role can be different.

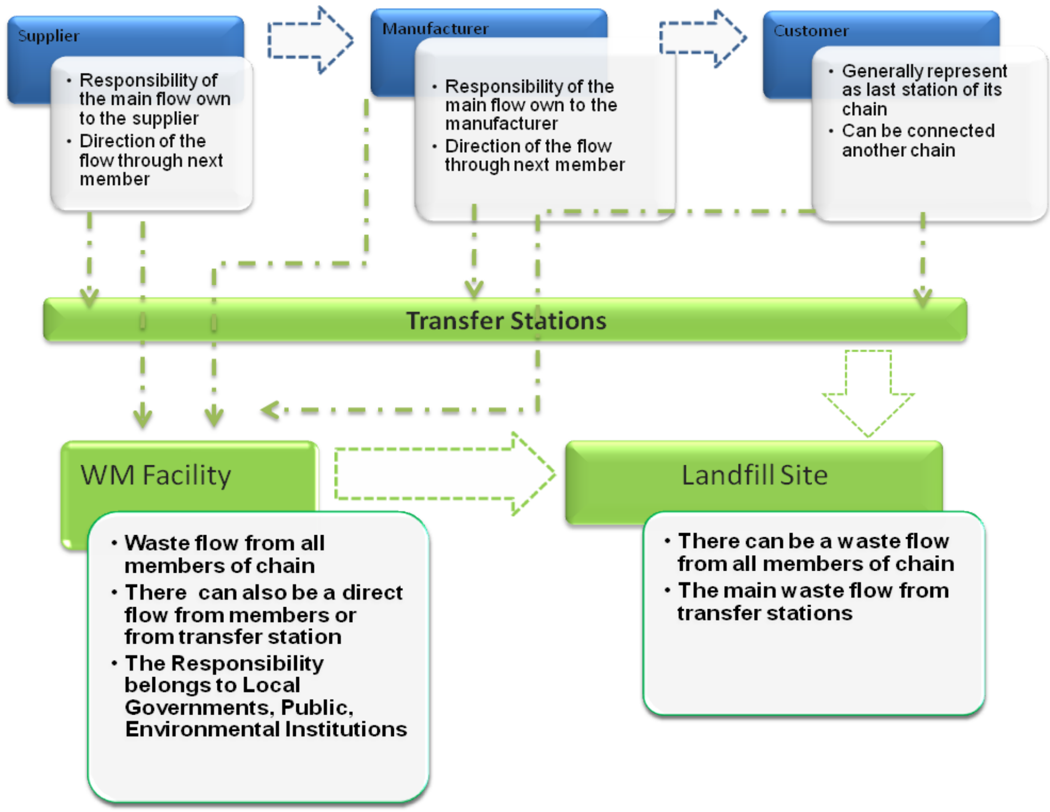


Figure 7: Relations between Traditional SC and ESCWM

Figure 7 demonstrates our perception of relationships within members of ESCWM (that also involves traditional SC). Next, we elaborate on these relationships.

Similarity/Differences of Producer: Producer is the next member of chain and it is the next link after the supplier. Regardless of whether the chain is a product or a service supply chain, there is typically at least one producer. Similarly producers also exist within the ESCWM. The primary difference in the ESCWM perspective is that they produce both product/services and wastes.

Similarity of Supplier: Supplier's role is nearly same in both traditional supply chain and ESCWM.

Warehouses, in the traditional SC can be viewed as analogous to the landfill facilities in the extended supply chain.

3.4 Waste Management and the Value Added Within the Supply Chain

The main idea behind the integral supply chain view as compared to an isolated view of each member is that this approach adds value to the supply chain and makes the supply chain more efficient than the individual efforts of its members.

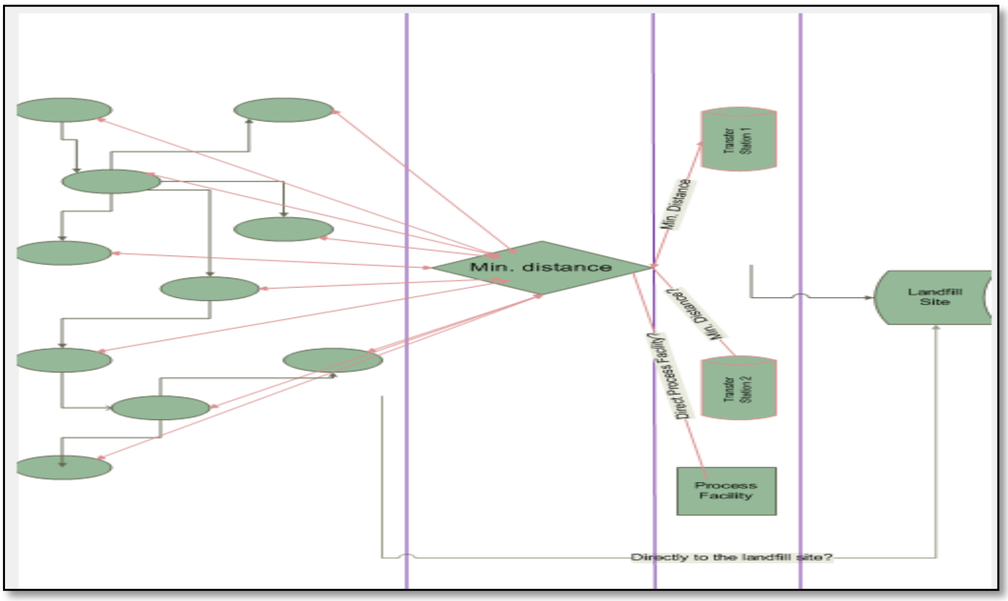
There are many examples regarding this phenomenon in such areas as joint procurement, information sharing, overall lead time management. We now detail one process within the extended supply chain with waste, that is decomposition at the source, and demonstrate how it adds value to the overall supply chain.

Decomposing at the source is an important and effective component of waste management. Through this method, the amount of waste that will be transported to downstream process facilities can be reduced. Part of the waste identified through decomposition as recyclable or reusable is directed to recycle facilities and the remaining rather worthless waste is sent to landfill sites. The overall supply chain then enjoys the economic benefits from the processes of recycle or reuse. These include the value of materials recycled/reused that would otherwise be treated as worthless, possible incentives by governments, increased corporate images as well as savings by municipalities through better management of waste storage space. There is also the environmental gain, which can be cast into value added in several different ways.

As a further contribution, the method also helps to reduce the complexity of the supply chain: When each company does the decomposition of its waste, in house; this means that the process is performed in smaller volumes, by people who have information and specific experience on the particular waste. This will enhance a more efficient process because it is much easier for employees of a company to decide on which part of their waste can be recycled/reused than the workers of the process plant serving the whole city. This will in turn induce a smaller capacity requirement for the municipal process plant.

On the other hand, there are additional considerations brought about by decomposition at the source. To begin with, each company has to allocate resources in order to design, plan and implement this process. This may induce installing additional facilities, a higher variety of flows, a higher number of roundtrips within the supply chain; thus resulting in a more complex network.

Figure 8 demonstrates the waste management network in a city:



Legend:

:Waste Production Centers

:Waste Process Facility

:Transfer Stations

:Landfill Site

Figure 8: Waste Management Network in a City

However, these additional considerations do not outweigh the value added by the process itself. When one adds the more intangible benefits such as environmental considerations and sustainability, the gains become more significant.

Moreover, the inclusion of the decomposition process within the supply chain results in a better allocation of the costs in the supply chain. Without decomposition at the source, the costs associated with waste management are primarily bared by governments, that is, the public. However, with decomposition at the source, each company will eventually develop its own model of gaining value from recycle and reuse and incurs the associated costs.

CHAPTER 4

CURRENT WASTE MANAGEMENT SYSTEM in İZMİR

4.1 Waste Management

Waste management is the collection, transport, processing, recycling or disposal, and monitoring of waste materials (Demirbaş, 2010). Like all management issues, waste management also involves some ways to control and manage all components of the supply chain like transportation, transportation centers, decomposing facilities, composting facilities, etc.

Table 3 demonstrates the main components of the waste management system and its subparts.

Main Components	Subparts
Production of materials	Waste Source Source separation Internal collection Production rates Waste types
Treatment or reprocessing	Physical reprocessing (Shredding, sorting, compacting) Thermal reprocessing (incineration, gastification) Biological reprocessing (anaerobic digestion, aerobic composting)
Final Disposition	Recycling Land filling

Table 3: Components of Waste Management

Source : Demirbas, Energy Conversion and Management (2010)

The scope of thesis considers İzmir as the research area. In the research area, there is one disposal site in Harmandalı. The waste management system in İzmir also includes 7 transfer stations. The consortium institution İZGEP (Waste Collection and Recycle Industry and Trade Corporation), also takes part within the system. İZGEP was founded in 2007. After the establishment of İZGEP, packaging wastes of İzmir are collected separately for some regions.

There are 21 regions in administrative boundaries of İzmir Metropolitan Municipality. As of 2010 the administrative boundaries contain around 292.000 households from which waste is collected separately.

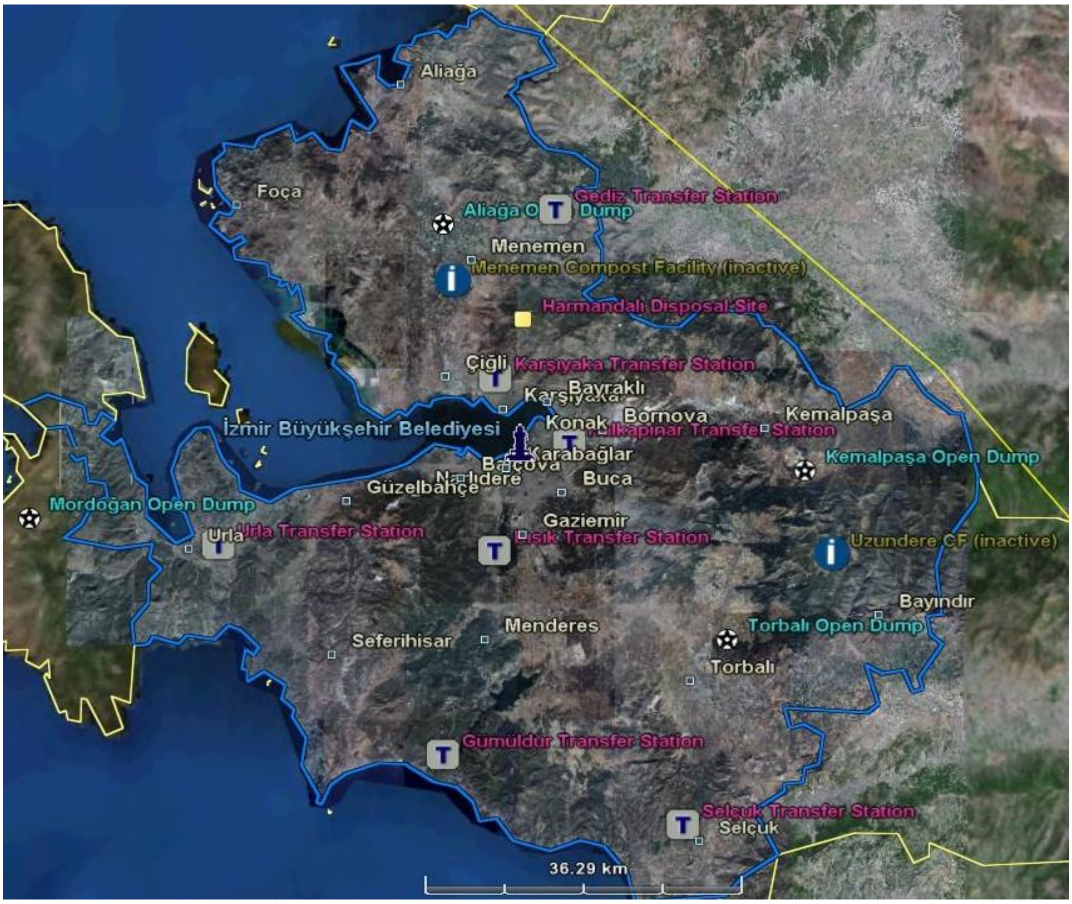


Figure 9:All facilities related with waste in İzmir

Figure 9 demonstrations the components of the waste management system in İzmir. The facilities denoted with letter "T" and are the 7 transfer stations. Disposal sites, are denoted by stars and inactive facilities are denoted by letter "i". The square denotes the existing disposal sites in İzmir.

The disposal site is located in Harmandalı with capacity of 900.000 m^2. There are plans for a new landfill site in Torbalı. Transfer stations are located in Gediz, Karşıyaka, Halkapınar, Kısık, Urla, Gümüldür and Selçuk. They serve as intermediate storage. Inactive facilities are in Menemen and Uzundere and both of them were composting facilities.

4.2 Landfill Sites

Waste management systems may involve all or some of the components started from waste generation, composting, recycling, and incineration to energy and Landfilling Figure 10 displays a flow chart of such a system. The disposal of hazardous wastes is the final and vital step of an effective hazardous waste management plan (Visvanathan, 1996).

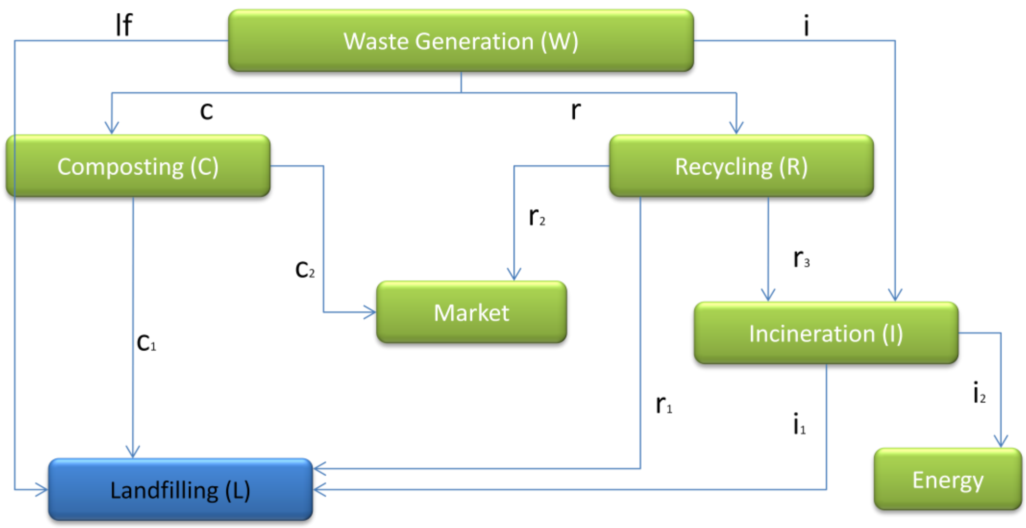


Figure10: Amount of Landfilled Waste

Source: Sarptaş,2006

Based on the flow chart in Figure 10, one can go for identifying the amount of the waste that goes to landfill. To do this, we first define:

c: the amount of waste diverted to composting
r: the amount of waste diverted to recycling
i: the amount of waste diverted to incineration
lf: the amount of waste diverted to landfilling
c_1: the amount of residuals diverted from composting to landfilling
r_1: amount of residuals from recycling to landfilling
i_1: amount of residuals from incineration to landfilling
r_3: amount of residuals from recycling to incineration

The ratio for landfilled waste amount (r_L) then becomes:

r_L: $lf+c_1.c+r_1.r+i_1.i+i_1.r.r_3$

This result shows that, even if the waste amount sent directly to landfill site may not be too high, other components of the waste management system result in waste volumes sent indirectly to landfill site. The total amount directed to the landfill site will then be the sum of direct and indirect volume. This observation reveals that the total waste amount that is sent to landfills may be very high. This makes landfills probably the main component of waste management systems. The role of landfill sites is further emphasized in cities that do not have processing facilities (such as composting and incineration). The city under consideration within the scope of this thesis, İzmir, demonstrates an example for this.

Clearly, the decisions regarding the management of landfill sites constitute a major component of waste management. If managers of a city fail to plays sufficient importance on landfill management, then the city is highly likely to face significant costs in the near future. These costs can be classified in three main categories: logistics, social, and environmental costs.

Logistics costs include investment, transportation, operating and equipment costs. The cost components are mainly implied by the location, capacity, and technology of the landfill site.

One relevant example of such costs can be observed in İzmir. Given the location of the landfill site in Harmandalı, the transportation cost for sending waste from southern locations of the city to the landfill site is very high. For locations like Urla, this cost becomes unacceptable. As a result, the local municipality in Urla decides to use a secondary open dump site close to Urla instead of sending waste to Harmandalı.

In such a situation, the waste management system is not executed as planned, with further potential for additional undesirable effects. This may further need to social costs that result from dissatisfaction of residents caused by inadequate waste management.

In the case that waste collection process is inefficiently planned, residents will most likely be unhappy about the timing, frequency, pollution to the streets, smell and noise of waste collection. Following these direct consequences of social costs, we can further argue that the residents may lose confidence and trust against the municipalities that they perceive as the major responsible authority when waste management is concerned.

Environmental costs include costs of immediate and future adverse effects of landfill sites to the environment as well as costs of efforts and resources spent for the resolution of these effects. These effects vary from water pollution to noise pollution or risk of methane gas explosion.

The Harmandalı facility in İzmir is located at a high area. This brings together continuous smell pollution to residents located in the surrounding settlements. Moreover, the facility completed more than half of its economic life when the government realized that there was a severe effect on the land. The built capacity of the facility can no more handle additional waste, the residents living around face with piles of waste falling outside the borders of the facility.

The amounts and diversity of waste are important drivers of a waste management system.

The main determining factor affecting the waste amounts and waste diversity is the diversion is the area. In this context, area can be classified as industrial, settlement, public, etc. Majority of the waste within the scope of this research is generated by settlements. The determinants of waste in settlements include: Size of the household, economical structure of the area, cultural tendency of people in the area, and consumption patterns of people in that area.

The above discussion reveals that the waste management process is multi dimensional issue.

Within the setting, we summarize the parameters and defining constraints of the research as follows: It is confirmed by municipality officials that Harmandalı landfill site has completed its economic life due to its geographical position and its insufficient capacity.

We also note that the decision on constructing a new landfill site in Torbalı is finalized. Concerning the thesis research then we have a landfill facility that covers a certain part of the city. That is the new landfill site in Torbalı will serve part of İzmir; we are yet to decide on the location of another landfill site to serve the rest of İzmir. We wish to remark that the region of service of the Torbalı facility actually depends on the location of the new facility.

The new facility location should be able to serve for an economic life time of around 20 year; therefore it needs to be able to answer changing needs of the city. For this, we incorporate Master Plans prepared by the Municipality in our research.

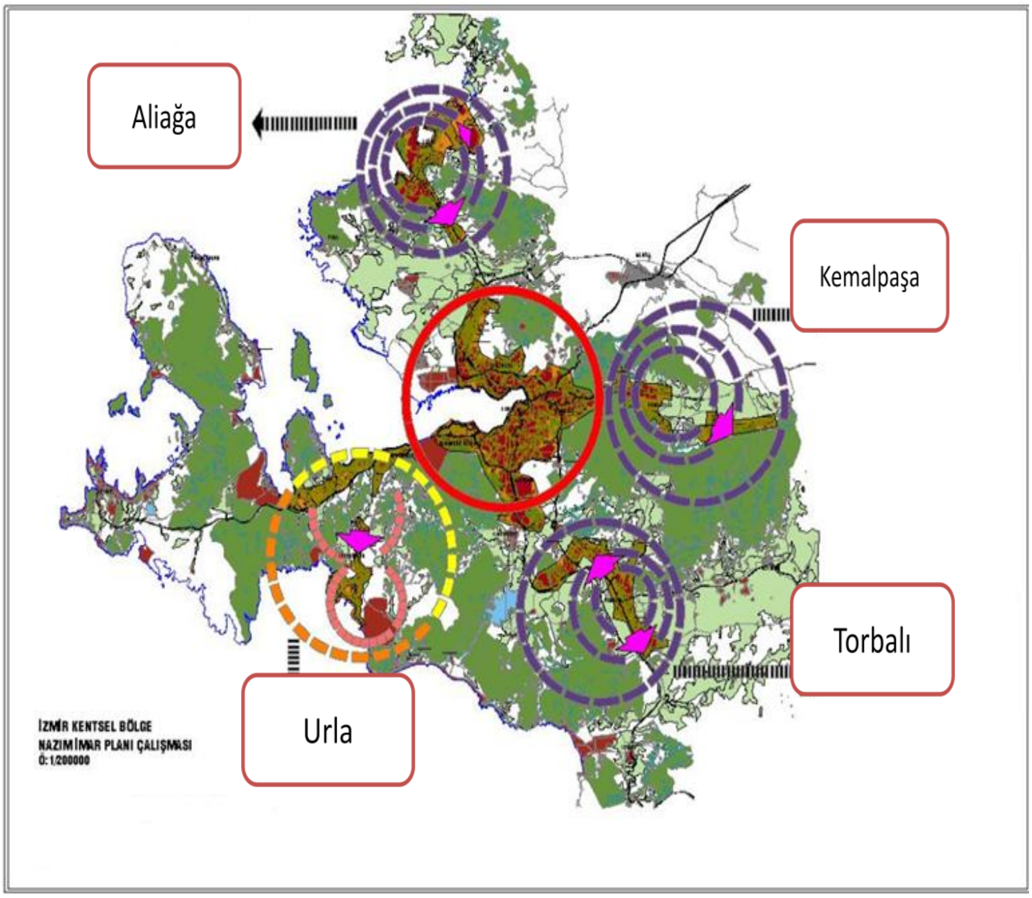


Figure 11:Master Plan of İzmir

Source: İzmir Metropolitan Municipalty

See, for instance, Figure 11 that is taken from the Master Plan of İzmir. In the figure, the areas that have high developing potential are shown by purple circles. When such areas are included in the Master Plan, the municipality gives construction and developing permissions for the area. Regions the noted by red circles are are regions with no expansion and developing possibility. The municipality does not allow new constructions in these areas. Such areas should be left out of consideration for landfill site location.

4.3 Transfer Stations

Until recent years the concept of waste systems was not perceived within the context an integrated management philosophy. With a simple system setup waste was collected from households and then transported to the open dump sites. With increased number of open dump sites, their adverse effects on environment and public health also increased. It is significant to note that restricting an existing facility to decrease its adverse effects is very difficult, if not impossible. It is then more desirable to design and open a new facility with little harm to the environmental. Because of these facts abandoning open dump sites and establishing a small number of facilities with sufficient capacity to collect the whole city’s waste became a common activity that may also be seen as environmental activity. However, on the other hand, collecting waste from population centers and transferring them directly to high-capacity facilities terms out to be costly since it involves a good deal of less than truckload rountrips. With urbanization, the system also started facing some transportation problems. For instance, lack of large roads for large waste vehicles, crowded traffic, legal time limits for big vehicles, noise and smell pollution become more and more disturbing. One solution is the utilazition of intermediate facilities named “transfer stations”. Transfer stations serves collecting regional waste with smaller vehicles, and reduce transportation costs.

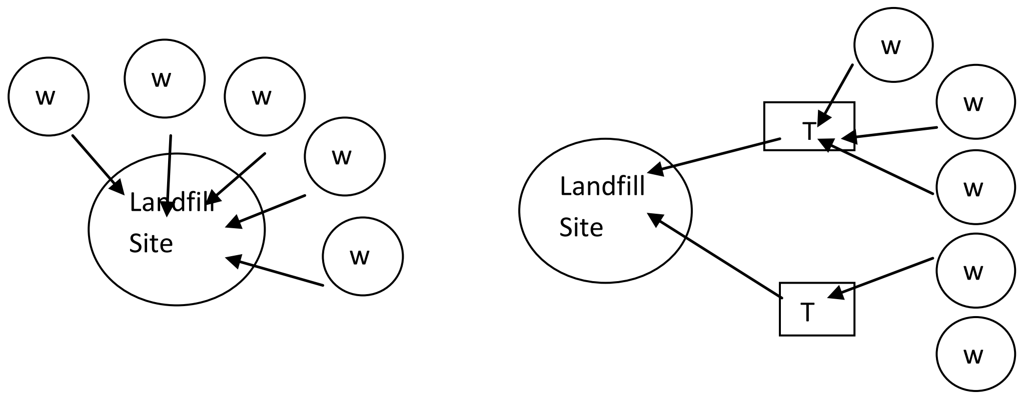


Figure 12. Transfer Stations

Transfer stations allow the use of smaller trucks that make full truckload possible. Besides, smaller vehicles make a positive effect on traffic problems. Transfer stations have equipment for compassing waste thus decreasing the volume. This allows a smaller number of trips from transfer stations to landfill sites and provides a more efficient use of landfill site capacity.

Until 2006 there were 26 open dump sites in the research area and the locations of these Menemen, Kemalpaşa and Aliağa, Urla, Gümüldür, Özdere, Bayındır, Subaşı, Karakuyu, Pancar, Ayrancılar,Yazıbaşı, Canlı, Çırpı, Yukarı Kızılca, Ören, Bağyurdu, Emiralem, Gerenköy, Seferihisar, Helvacı, Ulucak and Ürkmez, Kemalpaşa, Torbalı, Aliağa, Selçuk. Following The Metropolitan Municipality Law 5216 in (2004) on metropolitan municipality's responsibilities and works with effective and efficient managements most of these sites were closed by municipality. There remained only 4 open. These are later closed after new transfer stations.

Figure 13. Transfer Stations Service Areas

Figure 13 demonstrates the transfer stations and their areas of service. Wastes from areas are collected and consolidates in the associated transfer stations. After compressing they are sent to the landfill sites. This operation makes the waste management network more effective and use of landfill site's capacity more efficient.

The above discussion reviews that transfer stations are important for environmental protection prolong landfill site's life time and decreases transportation costs.

4.4 Waste Amounts

Waste amounts are the most important parameters of the waste management system. The amount of waste generated in a given area depends on the population, socio-economic scale, urbanization and consumption patterns.

İzmir Metropolitan Municipality estimates the amount of wastes to be processed in Urla transfer station as around 100 tons per day for the winter season, and as around 200 tons per day for the summer season (İzmir City Heath Profile, İzmir Metropolitan Municipality, 2009). In case Urla transfer station was not opened this waste amount would possibly be collected in an open dump site. Urla transfer station collects waste from Gümüldür, Özedere, Ürkmez, Doğanbeyli and Seferihisar regions. These 6 regions have a total population of around 90.000 during winter season and around 200.000 during summer season. The relationship of population with amount of waste demonstrates strong correlation. Therefore many researches take the one of population as the main determinant of amount of waste.

In this research we also consider population explicitly. We compute the population for the next 10 years, considering the lifetime of the landfill site. Since landfill sites are generally built considering an economic lifetime of 25 years, we also calculate population projections for the next 25 years.

The size and capacity of the landfill sites are also important decision variables. Similar studies and evidence from municipality authorities reveal that we need to look for a minimum of 10 hectare area for İzmir (Sarptaş, 2006). The current landfill site in Harmandalı has an area of 900.000 m^2 (90 hectare).

CHAPTER 5

IMPLEMENTATION with GIS-RELATED CRITERIA

5.1 Data Preparation

“Since the 1970s the field of Geographical Information Systems (GIS) has evolved into a mature research and application area involving a number of academic fields including Geography, Civil Engineering, Computer Science, Land Use Planning, and Environmental Science. GIS can support a wide range of spatial queries that can be used to support location studies.” (Church, 2002).

Figure 14: Boundaries of Research Area

There is a growing interest from companies as well as public institutions on GIS and GIS implementations. GIS is defined by Kingston Center for GIS (2005) as an '*information system*', that is a set of processes, executed on raw data, to produce information which will be useful in decision-making. This information system is typically processed with a software interface. Ohio EPA Learn GIS (2003), defines GIS as a computer program and a kind of information system that deals specifically with geographic or spatial data/information. A more operational definition is provided by Chen & Gelderman (2004) as: GIS is an intuitive method to organize information based on spatial positions; and information is linked to a geographic map, so when a user queries a specific location. The software producer, ESRI developed a repository of documents related with GIS. They refer to GIS as a computer technology that uses a geographic information system as an analytic framework for managing and integrating data; solving a problem; or understanding a past, present, or future situation. There are three main views provide by a typical GIS software:

The database view: A GIS is a unique kind of database of the world—a geographic database (*geodatabase*), or in other terms, it is based on a structured database that describes locations in geographic terms.

The map view: A GIS is a set of intelligent maps and other views that show features and feature relationships on the earth's surface. Maps of the underlying geographic information can be constructed and used as 'windows into the database' to support queries, analysis, and editing of the information.

The model view: A GIS is a set of information transformation tools that derive new geographic datasets from existing datasets. These *geoprocessing* functions take information from existing datasets, apply analytic functions, and write results into new derived datasets. In other words, by combining data and applying some analytic rules, a model that helps to answer the question posed can be created (ESRI, 2001).

GIS is recently utilized by various disciplines and also it has particularly found a very large implementation ground in the following five major fields:

- Cartography and mapping.
- Environmental and urban information analysis.
- Environmental and urban model development.
- Environmental and urban information management.
- Planning support and decision-making.

In all five fields GIS uses two types of mapping formats, which are static maps and dynamic maps. (Yiğitcanlar, Gudes, 2008)

As with many researchers and practitioners, we believe that GIS and related software will play a significant role in future location model development and application. In this research we utilize GIS software to process a set of suitable and relevant criteria. The power of GIS allows us to comprehensively handle the constraints pertaining to the landfill site location.

In order to use GIS software, we need a number of related GIS maps. Namely, "Surface Water", "Land Use Map", "Protected Areas Map", "Topography Map" and "Transportation Network" are used. Appendix 1 demonstrates a table of institutions that provided the maps needed for this thesis research, along with the particular map provided by each institution. Since there is no single standard to GIS software, we need to do a conversion to be able to utilize all maps within the same software, ArcGIS. The projection used in this research is UTM35N.

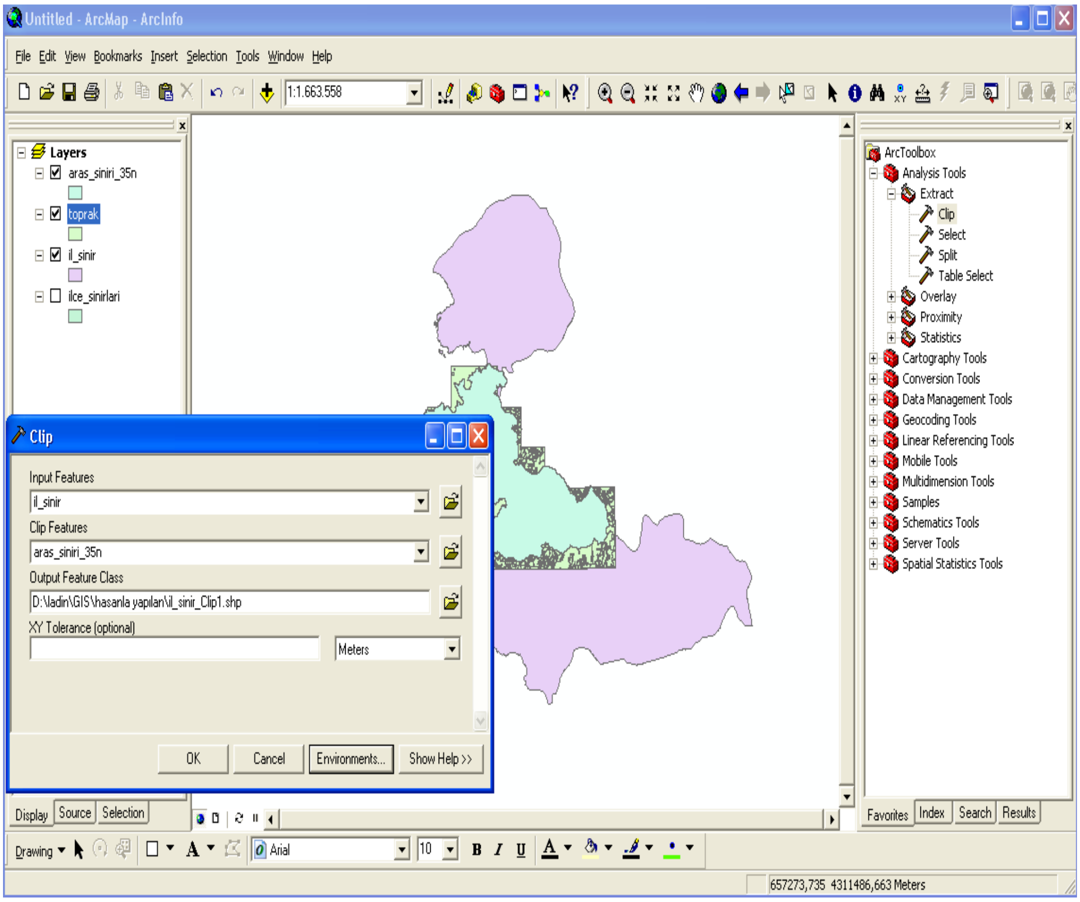


Figure 15: Clip Tool of GIS

Then going through a process called "clip" is need. This step is basically for fitting the resulting maps using the reference points in the research area. Figure 15 involves a snapshot of the clip process. Finally, applying each criterion with respect to predefined constraints is started.

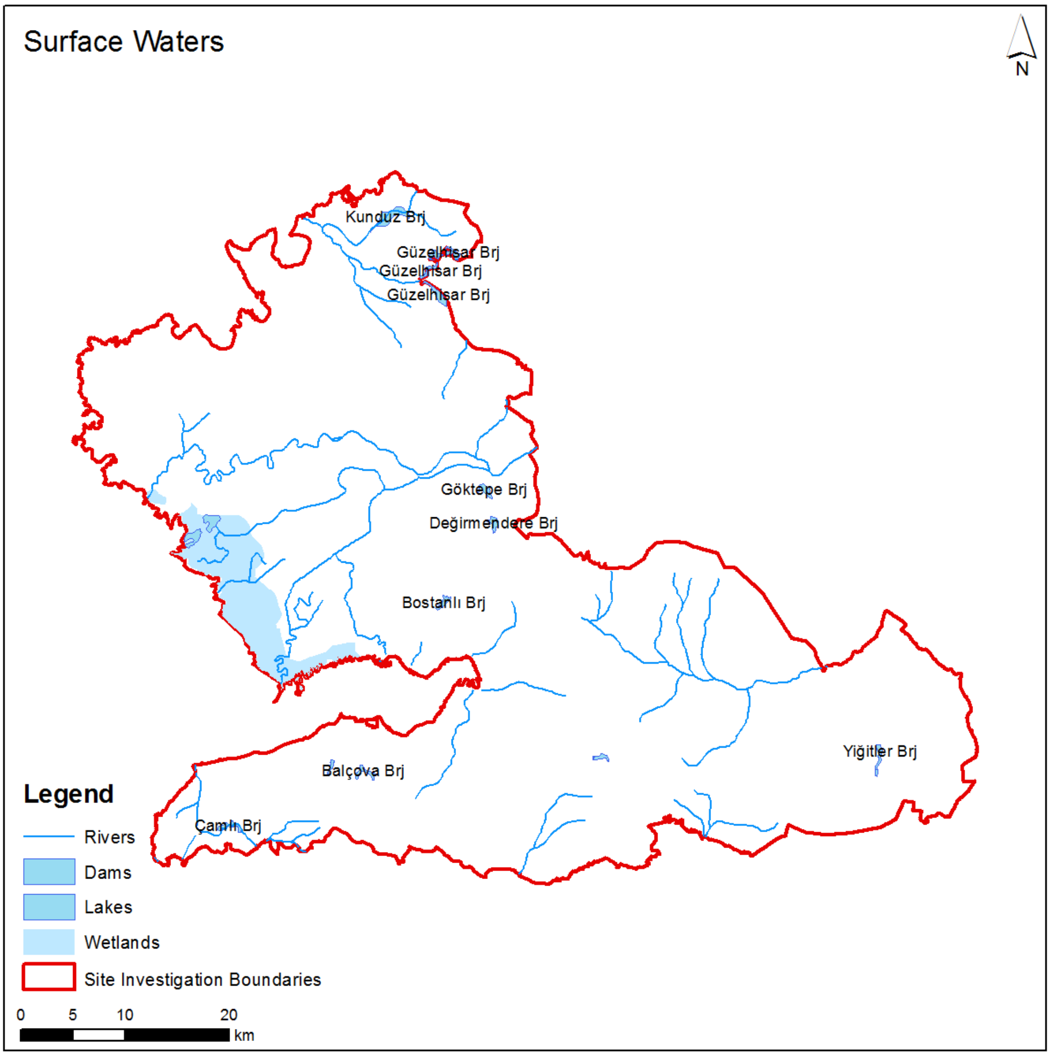


Figure 16: Surface Water

Next, we present a brief description of the aforementioned process.

Surface Water Map: Figure 16 depicts the GIS map of surface waters, clipped to the research area İzmir. Rivers, wet lands, dams and lakes are classified as surface water. However, further distinguish each of these classes since they have different associated constraints.

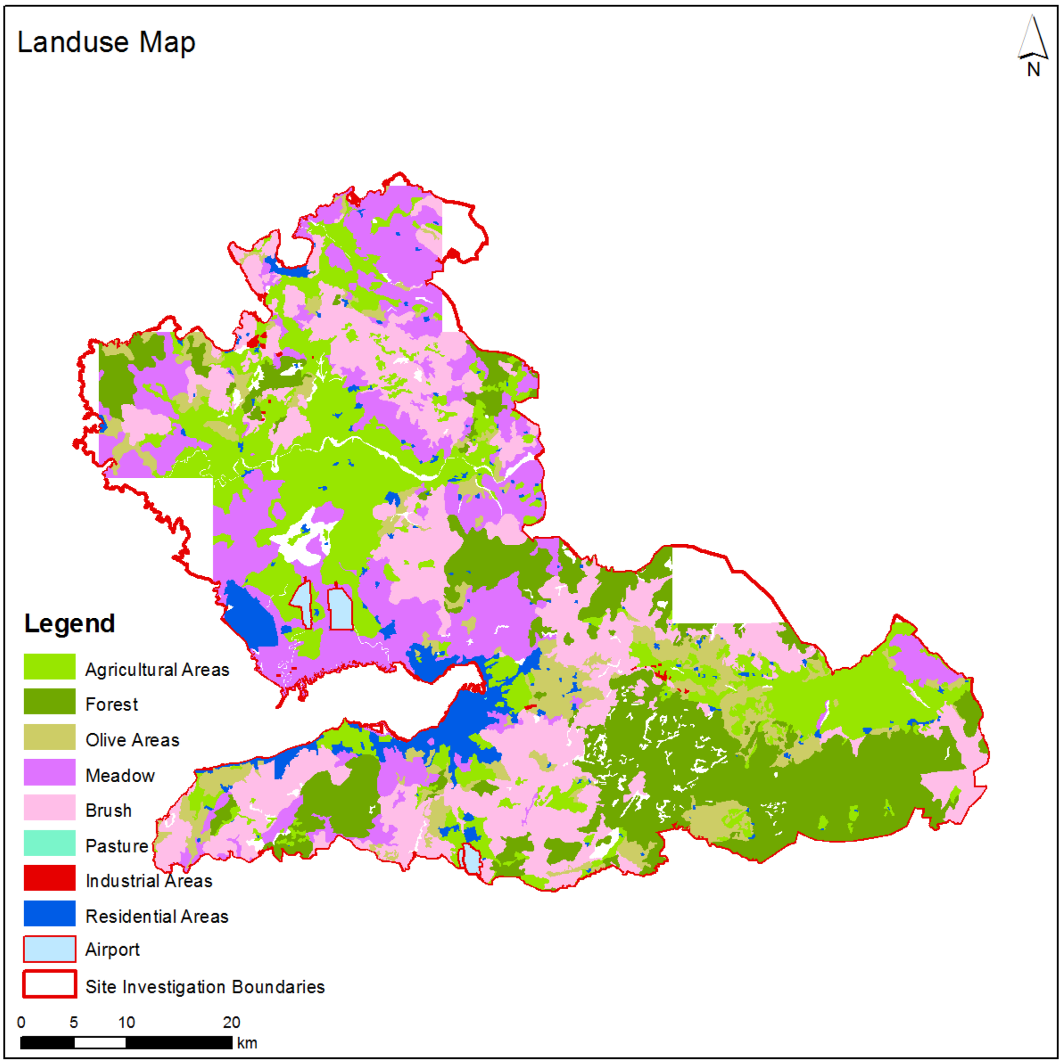


Figure 17: Land Use Map

Land Use Map: Figure 17 demonstrates the land use map. We collect regarding data from various sources: Agricultural Areas, Forest, Olive Areas, Meadow, Brush, Pasture, Industrial Areas and Residential Areas GIS maps are provided from Directorate of Agricultural Production and Development (TUGEM), whereas map of airports is provided from Geography Information Systems Department of İzmir Metropolitan Municipality (CBS Department of IBB). These are projected and integrated for use as the land use map.

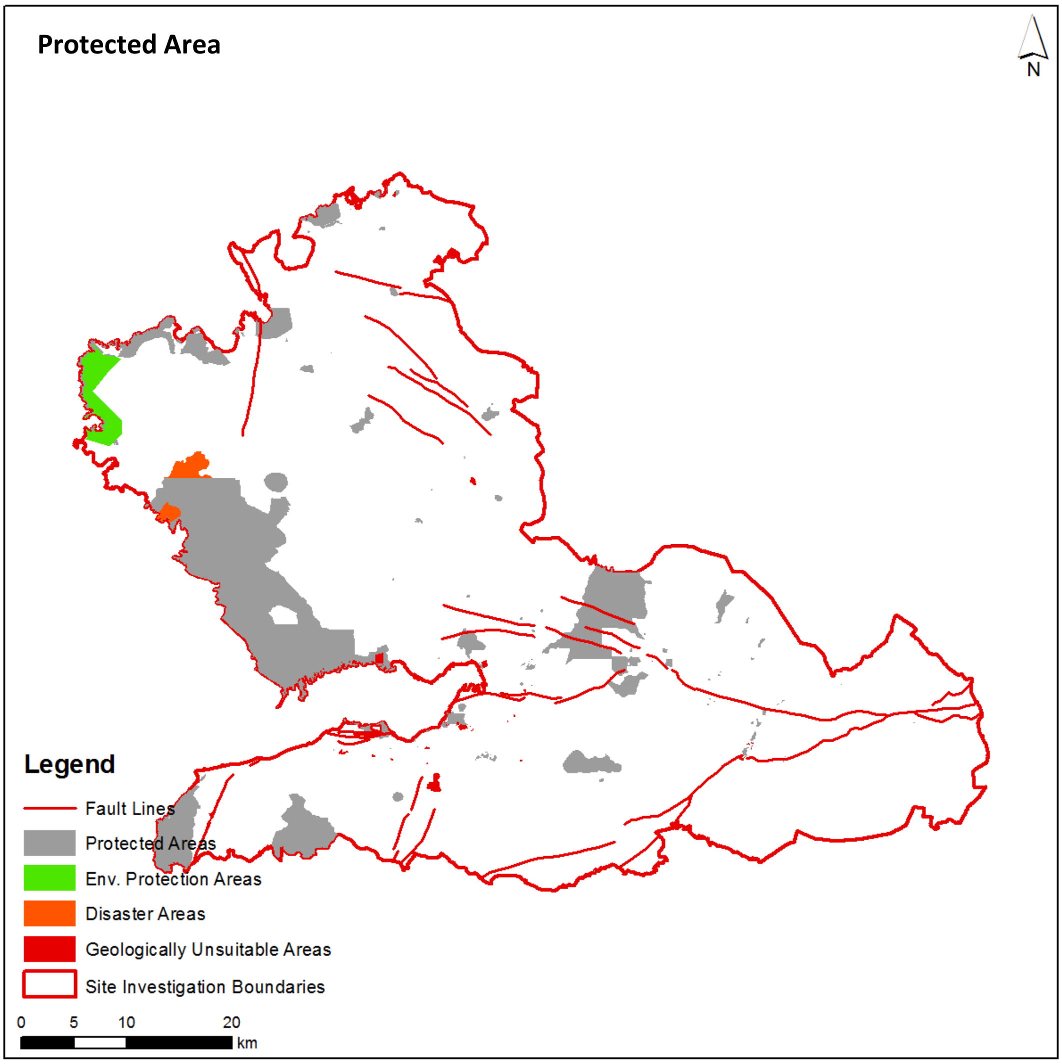


Figure 18: Protected Area Map

Protected areas: Protected areas are classified as restricted area for reasons such as being an archaeological or touristic area. Also fault lines and disaster areas are classified as protected areas. Restricted area map and environmental protected area map are obtained from TUGEM. Fault line map, disaster areas map and geologically unsuitable areas map are taken from CBS Department of IBB. As discussed earlier, such areas are excluded from consideration for locating landfill facility. Protected Area Map is provided in Figure 18.

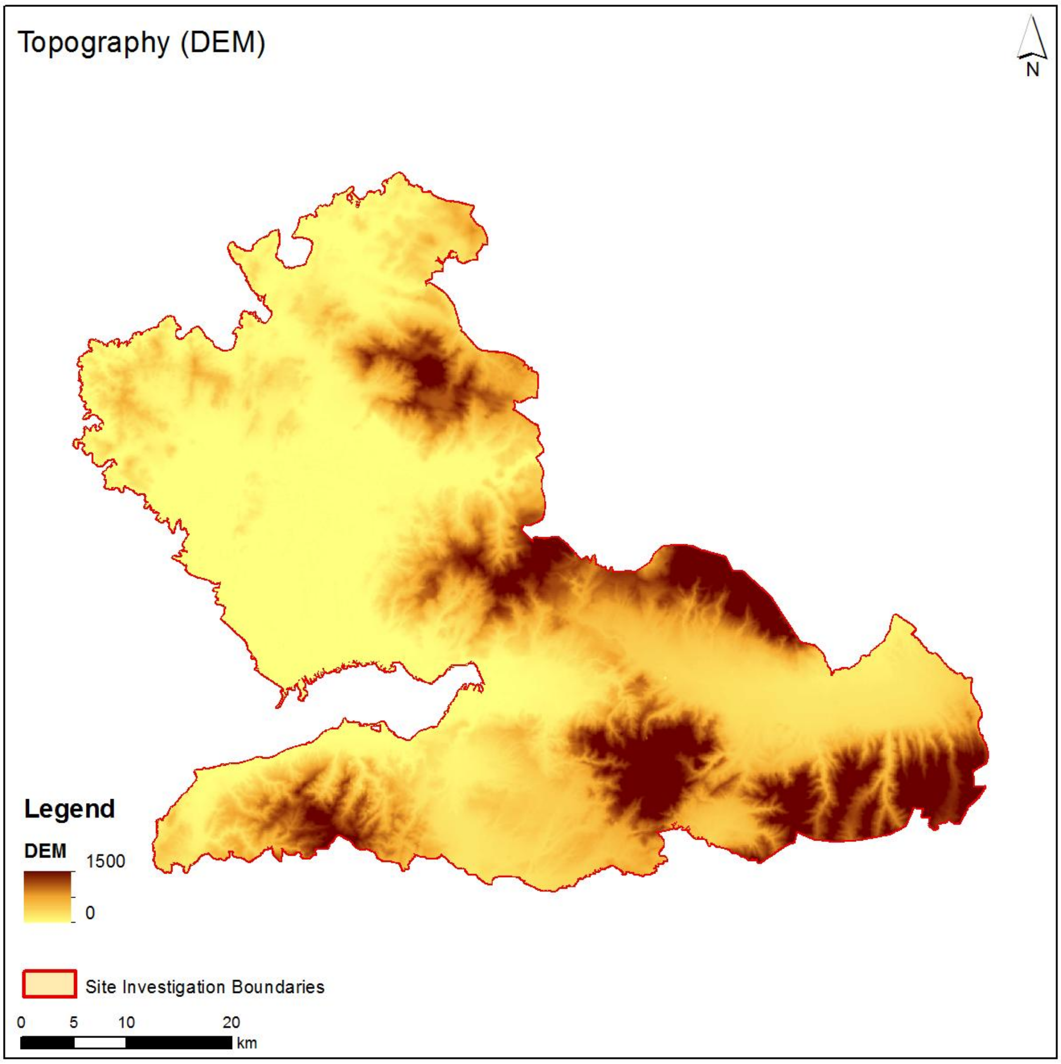


Figure 19: Topography Map

The topography map is obtained from United States of America Geological Survey (USGS). For conformity to the other maps, 25m.resolution is used (Shuttle Radar Topography Mission (STRM) data). Figure 19 shows this map. The main reason for using this map is because we don’t want to choose the location of landfill site on high areas. We employ two various levels of height restrictions, each depicting one scenario.

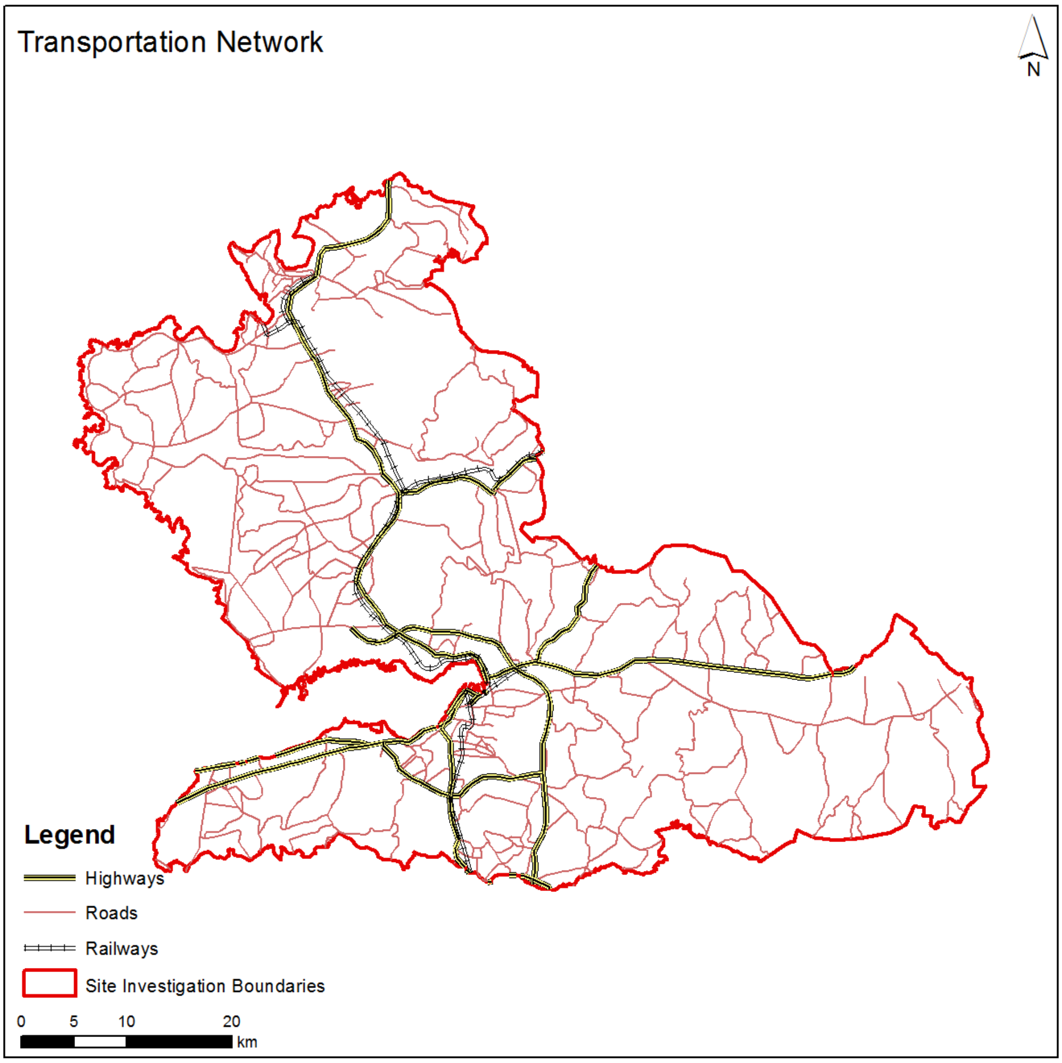


Figure 20: Transportation Map

Transportation map: Figure 20 shows the transportation map of İzmir. The main information provided in this map are the highways, roads and railways in our research area. These maps provides from Ministry of Environment and Forest. We further distinguish between highways and secondary roads since we use different buffers of proximity to highways and secondary roads. Moreover, closeness to both is separated criteria in AHP.

Next, we present the two scenarios, in other words two settings of constraints are used in our analysis.

5.2 Scenario 1:

5.2.1 Constraint Setting and Implementation

This is the more stringent scenario, where we use tighter constraints for criteria. To explicitly define Scenario 1, we now name the criteria and constraints used to result in the site suitability map.

Research Area: The research area cover covers a distance of 50 km. from the city center. Based on the prior information on the planned landfill site in Torbalı, we mark that on the map. To lessen the time and effort in data collection and analysis, we identify an area of coverage for Torbalı facility is use identify those areas that for sure will be served by the Torbalı facility, no matter where the second facility is located. This is an apriori allocation of areas to one facility. The remaining areas may be served by Torbalı facility or the new facility; based on the location of the new facility. Note that we do not exclude the areas allocated to Torbalı facility from demand and cost calculations, we just fix the allocation.

Classified Maps	Criteria	Scenario 1 Constraints and Evaluations
Land Use Map	Agricultural Areas	Not on Areas with LUCCs of I,II,III and IV
	Forest	Unsuitable
	Proximity Olive Areas	>3000m
	Meadow	Unsuitable
	Brush	Suitable
	Pasture	Suitable
	Proximity Industrial Areas	>500m
	Proximity Residential Areas	>1000m
	Proximity Airports	>3000m
Surface Water	Proximity Wetlands	>300m
	Proximity to Dams	>2000m
	Proximity to Lakes	>300m
	Proximity to Rivers	>300m
Protection Areas	Proximity to Historical Areas	>500m
	Fault Line	Unsuitable
	Proximity to Environmental Protected Areas	>500m
	Disaster Areas	Unsuitable
	Geological Unsuitable Areas	Unsuitable
Slope	Topography	<20%
Existing Road Network	Proximity to Highways	>300m
	Proximity to Roads	>100m
	Railways	>100m

Table 4: Criteria used in Scenario 1

Explanations of classifications and constraints that used:

○ Surface Water: We used dams, wetlands, lakes maps for this criterion and buffer tool used in GIS because of protection the surface water. Generally used 300m buffer accordance to “Wetlands Protection Act Regulations” only for dams we want to use minimum 2000m distance because of the water source usage of dams.

○ Transportation Network:

As mentioned before transportation related criteria are important due to high operational transportation costs and their share in total logistics and cost considering the life time of facility. We used two different offset values for roads, we separated in to two. One of them is highways (main roads) and used 300m distance and the other is secondary roads with 100m distance. Following the GIS implementation, we go through on AHP to finalize to decision. This AHP takes as input the candidate locations from GIS software and non-GIS criteria. Within that AHP, we use easy road access as one other additional criterion related with the transportation network.

- Land Use Map:

• Agricultural Areas: Agricultural areas are classified into 8 types. As listed in Table 1 among these area types V, VI, VII, VIII are suitable for landfill site location. Therefore we exclude area types I, II, III and IV consideration. The related maps are provided from Ministry of Agriculture and Rural Affairs maps.

• Forest: Forests are not suitable for landfill site location so we took of them out of the suitability map.

• Olive Areas: According to Olive Production (Law #3573) there cannot be a facility except olive oil factory within 3.000 metres distance of olive areas. Therefore, we used minimum 3.000 metres buffer tool for suitability.

• Meadow: On these areas generally water grades are high so building landfill site on this area can be dangerous for environmental health.

○ Topography: Based on expert opinion and evidence from literature areas with a maximum slope of 20% are suitable for being landfill site (Australia Department of Health and Community Services (ADHCS), 1995; Laeo et. al. 2001; Şimşek et. al., 2006; Sarptaş,2006). We use this value in Scenario 1.

Figure 21 presents a snapshot of the buffet tool implementation in GIS software.

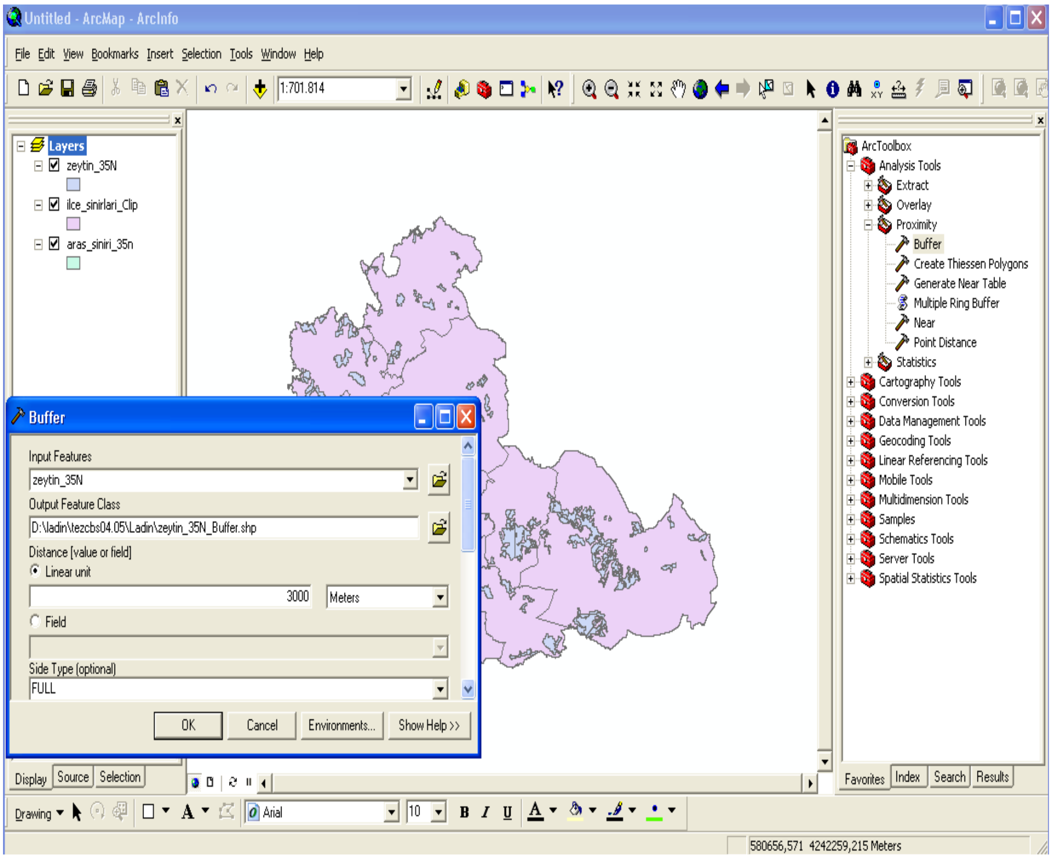


Figure 21: Buffer Tool of GIS

5.2.2 Findings of Scenario 1

Upon GIS implementation all related criteria with relevant maps together with overlay tool in GIS.

We obtain the suitability map as shown in Figure 22. We can identify 7 suitable areas as a result.

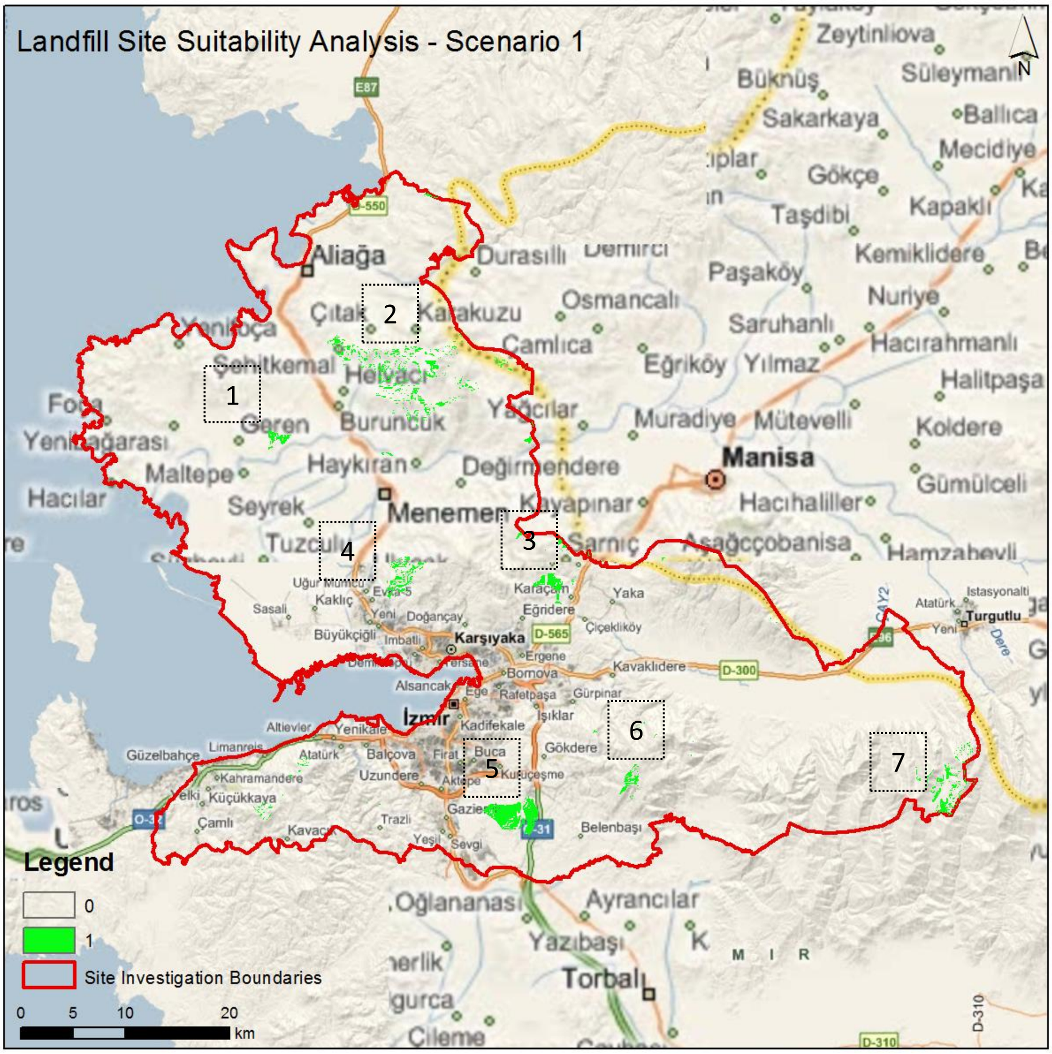


Figure 22: Suitability Map in accordance to Scenario 1

These candidate locations shown on the map numbers from 1 to 7. Alternate location 1 is located nearby Geren, alternative 2 is located near Helvacı. Number 3 is Çamiçi. Alternative 4 is Koyundere, alternative 5 is close to Kaynaklar, alternative 6 is close to Kırıklar and finally alternative 7 is in Bayındır.

We note that Alternative 4 is close to the existing (to be closed) disposal site in Harmandalı.

Base on the output on the GIS implementation, the 7 regions are suitable and they all have the same priority in GIS level of desirability for landfill facility location.

Although there is a tool in GIS for ranking alternatives, we did not use it. This tool denotes suitable areas with color differentiation. Since it provides various colors for very pixel, it is not practical to use in our research where we need information about alternative region. Moreover, this color information is not quantifiable.

We also need a ranking of logistics costs of alternative areas or information on which one has most open to changes to occur in the future, which is not available by the built in coloring of GIS. We therefore go with applying a secondary AHP following the GIS analysis. In this way, we can get the scores of the alternatives according to various important criteria such as developing possibility, logistics costs, economical structure, both educational and cultural structure, price of land in that area, wind potential and distance to waste production centers.

A further look at the suitability map for Scenario 1 shows that there are 3 suitable areas in the south and 4 in the north of İzmir. Feel that it is more appropriate to focus on north part of İzmir. This is because Torbalı region is in the north of İzmir and the new facility is more likely to be closer to the opposite site of İzmir.

Along with the suitability of the alternative areas for facility location with respect to GIS related criteria, we need also to account for the capacity of the potential site. As a long term facility, there should be enough capacity for wastes to cover the future life of the facility. The lieterature has several methods for calculating landfill site area requirement. This is more in the scope of environmental engineering discipline. Based on previous study, we end up with an estimated 100 hektars (1.000.000 m^2) (Sarptaş, 2006).

A benchmark would be the Harmandalı disposal site. It has an area around 900.000 m^2 (90 hectares) and it has in operation since 1992. This means 90 hectare was enough to meet the demand, although Harmandalı is one disposal site of İzmir. Considering the increase amount of waste generated and the landfill site plans in Torbalı, the sum of two capacities should be complementary. Therefore, the 100 hectares constraint seems reasonable. With this in mind, we now take a look at the areas of the alternative suitable locations:

We measure the areas using “draw” tool of GIS software.

Location 1.Geren: Nearly 2,293,356 $m^2 \approx$ 230 hectares

Location 2.Helvacı: We can separate this alternative area in two different areas, and one of them is nearly: 8,000,700 $m^2 \approx$800 hectares; the other is around 5,140,410 m^2 $\approx$ 515 hectares

Location 3.Çamiçi: Around 1,674,710 $m^2 \approx$170 hectares

Location 4.Koyundere: Around 6,461,989 $m^2 \approx$650 hectares

Location 5.Kaynaklar: We can again separate this alternative area in two different areas because of there is an unsuitable area in the middle of the region (because of the elimination of meadow area). One part of the location 5 is nearly 6,568,200 m^2 $\approx$660 hectares and the other part is nearly 3,500,000 $m^2 \approx$350 hectares.

Location 6.Kırıklar: Nearly 2,455,284 $m^2 \approx$245 hectares

Location 7.Bayındır: Nearly 2,503,800 $m^2 \approx$250 hectares

We can then conclude that capacities of all alternative regions are sufficient for İzmir. Clearly, the actual size, shape structure of the landfill site will be identified following more detailed studies on a specific area. This should be multi disciplinary, well researched and well analyzed decision.

Next, we look at the problem with a set of more relaxed constraints. In doing so, we first want to see how this 7 areas are sensitive to constraints. We change constraints and see have alternatives locations behaved in result. (See 4.3 part). After this sensitivity analysis we also use different models to examine different criteria that affect the waste management system in a city.

We now define that setting Scenario 2.

5.3 Scenario 2:

5.3.1 Application and Used Constraints of Scenario 2

In this scenario we used more relaxed versions of three of the criteria. We go with changing three criteria because, others are usually based on legal restrictions based on environmental and public health and health and are not flexible.

Table 5 provides an overall look at Scenario 2 with criteria and their evaluation constraints to determine the second site suitability map:

Classified Maps	Criteria	Scenario 2 Constraints and Evaluations
Landuse Map	Agricultural Areas	Not on Areas with LUCCs of I,II,III and IV
	Forest	Unsuitable
	Proximity Olive Areas	>1000m
	Meadow	Unsuitable
	Brush	Suitable
	Pasture	Suitable
	Proximity Industrial Areas	>500m
	Proximity Residential Areas	>1000m
	Proximity Airports	>3000m
Surface Water	Proximity Wetlands	>300m
	Proximity to Dams	>2000m
	Proximity to Lakes	>300m
	Proximity to Rivers	>300m
Protection Areas	Proximity to Historical Areas	>300m
	Fault Line	Unsuitable
	Proximity to Environmental Protected Areas	>500m
	Disaster Areas	Unsuitable
	Geological Unsuitable Areas	Unsuitable
Slope	Topography	<40%
Existing Road Network	Proximity to Highways	>300m
	Proximity to Roads	>100m
	Railways	>100m

Table 5: Criteria used in Scenario 2

We now state the criteria that differentiate Scenario 1 and Scenario 2.

Olive areas: We decrease the buffer boundaries to 1000m. Construction of a facility or factory is subject to permission of Ministry of Environment and Forest. Relaxing this constraint may show which areas are eliminated due to olive areas buffer.

Proximity to Protected Areas: There is no exact legal restriction in terms of distance to protected areas such as historical and environmental restricted areas. We applied 500m for both of them in Scenario 1 according to evidence from the literature review. In Scenario 2 we relaxed the environmental restricts area buffer.

Slope: Suitable area for be a landfill site, should be have low slope. If not so, related costs (construction of building, construction of road- if it is need-, transportation costs) will be high. In literature there are different points of view on this constraint (Lin and Kao, 1998; Lin and Kao, 2005; Sarptas, 2006; Guiqin, 2009). Moreover, in topography maps for measure the slope of area, random points are collected and their average write on the regions slope. So it should be more sufficient to see on site of the candidate area at the end of all research. Increasing of the suitable value of slope may show which area are eliminated due to slope constraint. We accept areas as suitable for landfill site location that are up to 40% slope in Scenario 2. This value is also acceptable in literature for landfill site location (Lin and Kao, 1998; Lin and Kao, 2005; Guiqin, 2009).

5.3.2 Findings of Scenario 2

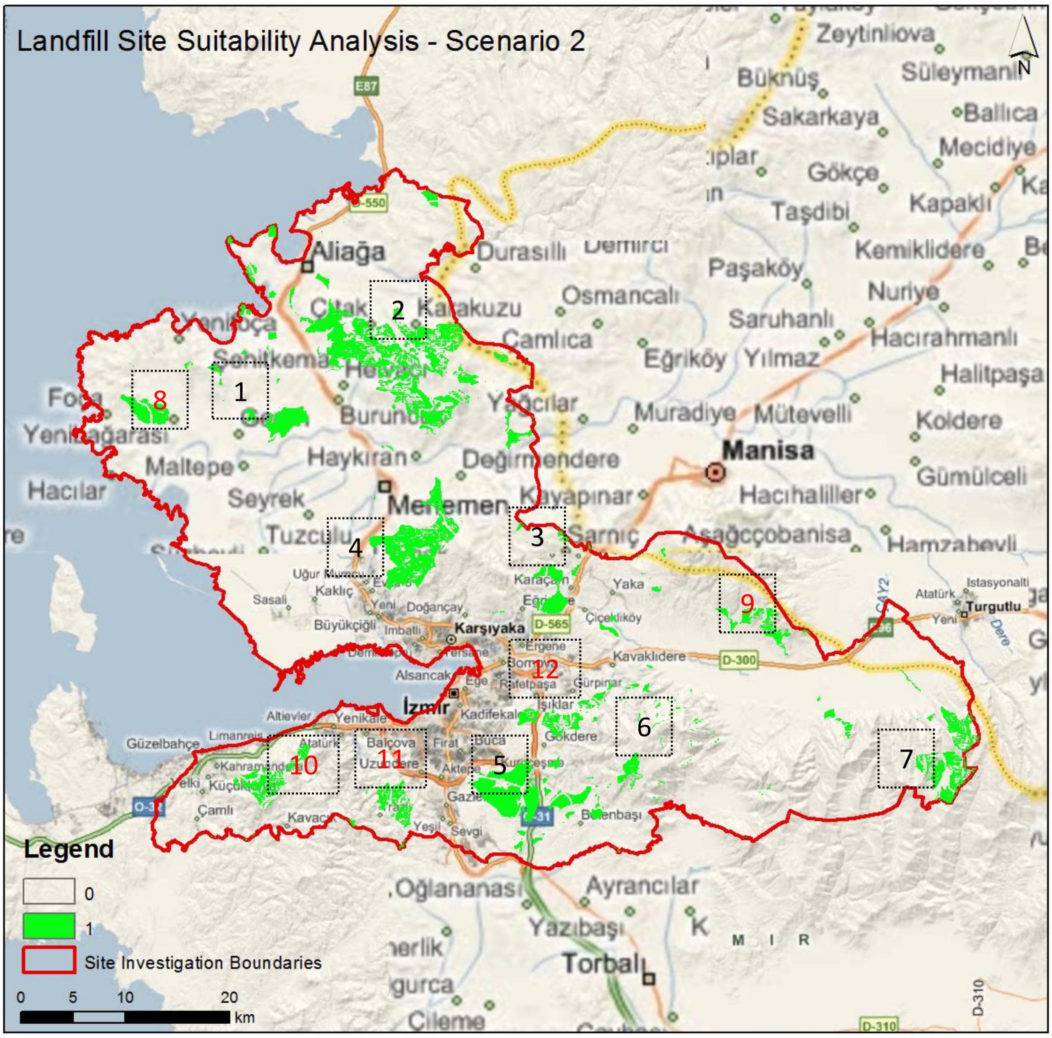


Figure 23: Suitability Map in accordance to Scenario 2

Figure 23 demonstrates the suitability map with respect to Scenario 2. We can observe that there are 12 alternative areas. This is almost double as compared to the 7 alternative areas in Scenario 1. In other words we have an additional 5 candidate areas. A side-by-side analysis of the suitability maps for Scenario 1 and Scenario 2 shows that the 7 suitable areas of Scenario 1 have larger total areas in Scenario 2. This difference demonstrates the answer to one main question to be answered by carrying out the sensitivity analysis using two scenarios. We tried to reveal which constraints resulted in removal of sub-areas from the suitable areas of Scenario 1. In result, we can conclude for instance that the 'slope' constraint as well as the 'olive areas' constraint is a binding constraint for majority of the alternative areas.

A further look at the suitability maps of Scenario 1 and Scenario 2 shows that the additional 5 suitable areas are very close to the boundaries of the research area. We then conclude that these additional areas will perform inferior in terms of logistics considerations (e.g. total transportation cost, proximity to waste production centers, service lead time). Therefore, we decide to leave these areas out of consideration and carry the rest of the analysis based on the outputs of Scenario 1.

Before proceeding to a more detailed review of results, we wish to point out that the GIS implementation study may seem to disregard possible constraints that are implied by regions out of the boundaries of the research area. For instance, a river passing from a neighboring area may cause parts of the research area to be infeasible for locating the landfill site, due to the 300m buffer. We do ignore such possibilities; however we would like to remark that such areas will surely be within the boundary of the research area, and will not be suitable for locating a facility anyway. Moreover, the final decision for landfill site location needs to be given following a very detailed analysis on candidate areas. This analysis may certainly cause alternative areas to become smaller or larger than the GIS analysis proposes.

5.4 Review of Results of GIS Software Implementation

The GIS implementation shows that with increasing demand and sophisticated structure of the problem, finding a site is becoming more complex and difficult analysis. Constraints used in GIS software application are generally related with environmental issues so they particular importance. Although the new technology used in landfill sites make them less harmful and irritant, the environmental constraints are still important. Location the landfill site should be far enough to public life and social areas, protecting rivers, dams for public health along with many other considerations.

When we consider all GIS-related constraints we end up with 7 alternative areas Scenario 1. These alternatives emerge put of the analysis because of their current structure. Generally natural specifications make them suitable for environmental constraints. Clearly there are additional considerations that should be involved. For instance, example 4th alternative is close to the existing disposal site in Harmandalı. The location of the Harmandalı facility was chosen by the municipality. Our analysis shows us the location is really has desired specifications regarding constraints related to environment. However this, existing facility has some important problems nowadays. The site is now nearly the center of the residential areas. In case any problem occurs in the site, public health can be easily affected from this problem. Therefore, the future behavior of the alternative areas in terms of social environment is also important as much as the environmental specifications. To this end, we further evaluate the alternatives with respect to social and demographic considerations. We do this through the AHP (Analysis Hierarchy Process). The details are given in Chapter 7.

Following the GIS implementation, we process economical constraints, based on current and projected data.

CHAPTER 6

LOGISTICS POINT of VIEW for ALTERNATIVE AREAS

In this chapter, we take the locations in the alternative areas obtained after the GIS implementation as inputs. We then employ and analyse from the logistics point of view. This new point is usually not very much considered in the literature.

6.1 Research and Findings about Alternatives

We use several important criteria based on the logistics point of view. These are “Existing Road Network”, “Slope”, and “Distance from Existing Facilities” and “Distance from Waste Production Centers”.

For the slope criteria, we quantify the associated using the GIS map data. In other words we assume that the component of the logistics costs for an alternative areas associated with slope is proportional its slope. Further analysis of the 7 alternative locations however shows that each location has a very much similar slope.

As mentioned earlier, we placed separate importance on waste production centers such as free zones or industrial parks. In analysing these, we denote a collection of such centers as clusters. Therefore, “Distance to Waste Production Centers” criterion is processed according to proximity to clusters and also the result of the General Algebraic Modelling Systems (GAMS) solutions for each alternative.

For “Existing Road Network Criterion” we consider the logistics cost to be inversely proportioned to ease of access. We obtain scores for this criterion by manual analysis over each alternative location and the transportation map. In doing so, we identify regions in the city and compute the most convenient route between each region and each alternative area. We then investigate each road closely to identify lengths of travel passing through in-city residential areas and from major high ways.

The transportation distances are not sufficient to calculate logistics costs. We need to also identify waste producing amounts of population centers. We take both population and socio-economical structures of regions. Socio-economical structure effects amount of waste, produced per person. This in turn means that the waste amounts are related with the current and future populations and socio-economical structures of the regions. Therefore, we further estimate future values populations, development scores for each region and multiply them with amount of waste per person.

We obey the general rule of thumb from the literature and assume there is 0.4 kg waste per person in developing areas and 1.8 kg waste per person in developed areas of the city (Zerbock and Candidate, 2003; Zamorano et. al., 2009). We also need a prepossessing of the transportation map to distinguish highway and roads that passing close to residential areas. We use a scale of 2 in terms of contribution of to logistics costs for roads passing through residential areas. For instance, we compute the road distance between Balçova region and alternative location 3 using Google Maps. The total distance is km. We then analyze the route to identify the highway and urban roads. In this example, we have km. of highway and the remaining km. of urban roads. We therefore calculate the modified distance to be used in our mathematical model as 20+21.8*2=63.6km. The resulting table of calculated distances can be seen in Appendix 2 and Appendix 3.

In summary, for processing logistics criteria we need to compute:

- Identify current populations of regions
- Future projections for population for year 2020 and 2036 (for basis in waste production amount)
- Regional development score (for calculating amounts of waste per person),
- Classifying the road network as highways or urban roads (to calculate transportation costs)
- The distance between the alternative locations and regions as demand points (for calculate total transportation costs).

This processing allows us to conveniently account for logistics criteria.

6.2 Use of Mathematical Modelling and GAMS Software for Logistics Cost Calculation

Following the processing, we now have a base line for computing the logistics cost for each alternative location. For the base calculation, we use projections regarding year 2020. We also consider the 25-years projections. We use the data for 2020 in calculations because the construction costs and to operation within few years after starting facility will be realised prior to 2020.

For this purpose we use mathematical programming modelling with the aid of GAMS Software. This helps us the compute the costs for each alternative, the difference from the optimal costs of alternative locations as well as various sensitivity analysis. Below, we give a statement of the GAMS code of the formulation. What follows is a typical facility location- allocation formulation, with restrictions on demand satisfaction and number of facilities.

$$\min \sum_{i,j} d(i,j) p_i x_{ij} \qquad (1)$$

$$\sum_{j} x_{ij} = 1 \qquad \forall \forall i \qquad (2)$$

$$x_{ij} \leq y_j \qquad \forall \forall i,j \qquad (3)$$

$$\sum y_j \leq 2 \qquad (4)$$

$$y_{L8} = 1 \qquad (5)$$

$$x_{ij}, y_j \in \{0,1\} \qquad \forall \forall i,j \qquad (6)$$

(1) the objective function

(2) allocate each region to a facility

(3) do not assign regions to unopened facilities

(4) limit on number of facilities

(5) open facility in Torbali

(6) integrality.

```
SETS

i population centers /C1*C21/

j candidate facility locations /L1*L8/

;

table d(i,j) weighted total distance between one population center and one candidate
location (Appendix 2)

parameter p(i) weighted demand of population center i (Appendix 2)

variable

objval objective function value

binary variable

x(i,j) 1 if population center i is assigned to candidate location j

y(j)   1 if facility at candidate location j is opened

*positive variable

*z(i) maximum (weighted) coverage distance for population center i

*z    maximum (weighted)coverage distance (over all population centers)


equations

objective

assignment assign each population center to one facility

capacity  assign population centers to openede facilities only
```

```
limitonfacilities limit the number of facilities to open
existingfacility torbali facility is already open
torbali
*coverage calculate maximum coverage for each population center
*coverageall calculate overall coverage
objective    .. objval=e=sum((i,j), d(i,j)*p(i)*x(i,j))
;
assignment (i) .. sum(j,x(i,j))=e=1;
capacity (i,j) .. x(i,j) =l= y(j);
limitonfacilities .. sum(j,y(j)) =e= 1;
*existingfacility .. y('L3')+y('L4') =e= 0;
torbali .. y('L8')=e=1;

Model waste /ALL/;
waste.optfile=1;
option optca = 0;
option optcr = 0;

option iterlim=10000000;
solve waste using MIP minimizing objval      ;
display x.l;
```

6.3 Findings of Mathematical Model

The mathematical programming model aimed at finding the optimal location of the second landfill site given to the first site in Torbalı. In doing the model identifies the best allocation of regions to facility. The objective function is the total cost associated with serving all regions. Therefore it also covers costs of serving from to Torbalı facility.

We differ the discussion of the optimal location of the second facility since the sole location decision will be based on other (e.g. GIS related criteria and a ranking of alternative locations with respect to logistics criteria. Therefore, at this point we are more concerned about the actual values of the cost considering each alternative. Considering alternative location 1 as the location of the new facility: Aliağa, Foça, Menemen, Çiğli, Karşıyaka, Bayraklı, Bornova, Buca, Konak regions are allocated to the new facility (in Locaiton 1) and the objective function is 239.255.208.

For Alternative 2: Aliağa, Foça, Menemen, Çiğli, Karşıyaka, Bayraklı, Bornova, Buca, Konak send their wastes to wate to the new facility (in Loction 2) and the objective function is 238.481.377.

For Alternative 3: Aliağa, Foça, Menemen, Çiğli, Karşıyaka, Bayraklı, Bornova, Balçova, Buca, Güzelbahçe, Karabağlar, Konak, Narlıdere, Seferihisar, Urla regions send their wastes to Location 3 and the objective function is 168.470.427.

Alternative 4: Aliağa, Foça, Menemen, Çiğli, Karşıyaka, Bayraklı, Bornova, Buca regions send their wastes to Location 4 and the objective function is 209.631.006.

Alternative 5: Aliağa, Foça, Menemen, Çiğli, Karşıyaka, Bayraklı, Bornova, Balçova, Gaziemir, Buca, Güzelbahçe, Karabağlar, Konak, Menderes, Narlıdere, Seferihisar regions send their wastes to Location 5 and the objective function is 167.611.204.

Alternative 6: Aliağa, Foça, Menemen, Çiğli, Karşıyaka, Bayraklı, Bornova, Kemalpaşa, Balçova, Buca, Güzelbahçe, Karabağlar, Konak, Narlıdere, Seferihisar, Urla regions send their wastes to the new facility in Location 6 and the objective function is 204.953.381.

Alternative 7: Only Bayındır region sends its wastes to Location 7 and the objective function is 275.999.209.

Table 6 summarize the objective functions of the alternatives. These are the results of mathematical model.

Alternative No:	•Objective Function
Alternative 1	•239.255.208
Alternative 2	•238.481.377
Alternative 3	•168.470.427
Alternative 4	•209.631.006
Alternative 5	•167.611.204
Alternative 6	•204.953.381
Alternative 7	•275.999.209

Table 6: Objective Functions of The Alternative

Now, consider running the model for only Torbalı landfill site not opening as secondary landfill site. The objective function terms out to be 276.424.025. This result points to the reasonability of the decision of opening a second landfill site.

The enumeration of alternatives shows that Alternative 5, 3 the best location for the second landfill site in terms of transportation cost. Alternative 3 gives an objective function very much closer to that of the best alternative, Alternative 5.

We use the objective function values actually the percent deviation from the optimal costs as scores as for the “logistics” criterion in the AHP model.

6.4 Sensitivity Analysis using the Mathematical Programming Model

Recall from section 5.1 used that in mathematical programming model was:

- Populations for regions,
- Future populations for regions,
- Developing Factors for regions,
- Distances between alternative locations and regions
- Separation of distances as highways (main roads) and urban roads

Populations in 2010 based on actual data however others are subjective estimates. Since population is a critical determinant of the problem, we wish to know how sensitive respect to this subjective data is. We therefore examine our findings with respect to:

- Changing the formula used for population estimation: In Turkey there are two main methods for population projection. One of them is Iller Bankası Method (DPT, 2002) and the other is Exponential Function Model (Sarptaş, 2006; State Planning Organization, 2002). Use both to calculate population projections. Evidence from the literature suggests that the second method is more suitable for short term local projections. We chose the Exponential Function Model because of the locality of the projection area. The State Planning Organization (DPT,2002) announced a correction factor for rearranging the gap between the projection of an area in overall and the sum of projections of its subregions.

- Varying development scores of the regions: When we consider the regional development scores, we used the Development Projection Map (İzmir Metropolitan Municipality, 2011). Support to the Solution of Economic and Social Integration Problems in Istanbul, İzmir, Ankara and Bursa as Major in-Migrant Destinations Project (IGEP) Unemployment Map of İzmir (2010), Population according to education Map (İzmir Development Agency, 2010), Socio-economic development order of the regions map, (DPT,2004) (Appendix 4,5,6). Even when based on this data the scores we gave to regions in terms of the developing level were subjective. This data is in term used for calculating the demand. We decided the regional high socioeconomic and low socio economic rates then multiplied them by 0.6 for developing regions and 1.1 for developed regions. (Zerbock and Candidate, 2003;

Zamorano et. al., 2009; TÜİK, 2008) These are further multiplied with each region's population. We varied these rates and observed changes in regional developing scores and thus demands.

- Varying two travel distances for urban roads: As the bases we gave a factor of 2 for urban road we then variable as 3 and rerun the model to see how much sensitive to this factor. (Appendix 7)

With all these changes in data, we observe that the ranking of the alternatives do not change. There are slide changes in terms of variations from optimal costs.

We now decide to rely on the outputs on the mathematical model and utilize AHP to decide on the landfill facility location.

CHAPTER 7

MULTI CRITERIA DECISION ANALYSIS with ANALYTICAL HIERARCHY PROCESS

7.1 Prepossessing for the AHP Analysis

Recall that the suitability map points to seven alternative locations that are suitable for the landfill site. Criteria applied in GIS software are quantitative. However, in result, it provides no quantity rank. Landfill site location problem has both quantitative and qualitative aspects and affects citizens, especially residential areas that located close to landfill site. We clearly need to examine social and demographical criteria with GIS and logistics costs.

The AHP methodology requires a group of experts. We identify these first. This group will score each criterion with respect to one another. This will result the weights for each criterion. After doing this we need to identify score for each alternative, based on each criterion. The weighted a sum of these individual scores results in the total score for each alternative location.

The focus group to rate the criteria involves 9 people. Four of them are environmental engineers; one of them is topographical engineer, two of them are industrial engineers, one of them is an economist, and one of them is a mathematician. The areas of expertise of these people are chosen to be close with the research topic.

7.2 AHP Implementation

We first go for determining the importance of criteria with respect to each other. Table 7 demonstrates the results of this evaluation.

Criteria	GIS	Logistics Costs	Developing Possibility	Educatinal-Culturel Structure	Price of Land	Wind Potential	Distance to Clustered High Waste Potential Areas
GIS	1	1,482785	4,25337987	3,95135382	6,140025	3,38571	2,810332094
Logisitcs Costs	0,672452	1	0,76578121	1,34625102	3,556161	1,748587	2,678135606
Developing Possibility	0,233798	1,296269	1	3,62079911	2,677516	3,058055	3,277658888
Educational-Culturel Structure	0,22957	0,737518	0,30394471	1	0,738011	0,951677	1,260572586
Price of Land	0,162285	0,2802	0,37049064	1,34715153	1	0,255559	0,658103331
Wind Potential	0,292732	0,811781	0,32533026	1,04586299	3,599557	1	0,738000156
Distance to Clustered High Waste Potential Areas	0,353454	0,371481	0,2853181	0,78781899	1,510048	1,346874	1

Table 7: Scores of Criteria

This table constituted by calculating geometrical means of given scores by 9 experts. Table 8 presents a normalization of scores in Table 7.

Criteria	GIS	Logistics Costs	Developing Possibility	Educatinal-Culturel Structure	Price of Land	Wind Potential	Distance to Clustered High Waste Potential Areas
GIS	0,33964	0,247956	0,58231617	0,30164762	0,319438	0,288232	0,226223677
Logisitcs Costs	0,228392	0,167223	0,10484057	0,10277324	0,185011	0,148861	0,215582239
Developing Possibility	0,079407	0,216766	0,13690669	0,27641297	0,139299	0,260338	0,263842144
Educational-culturel Structure	0,077971	0,12333	0,04161206	0,07634032	0,038395	0,081018	0,101472479
Price of Land	0,055119	0,046856	0,05072265	0,10284198	0,052026	0,021756	0,052975431
Wind	0,099424	0,135749	0,04453989	0,07984152	0,187269	0,085132	0,059406897
Distance to Clustered High Waste Potential Areas	0,120047	0,06212	0,03906196	0,06014236	0,078561	0,114662	0,080497133

Table 8: Normalized Scores of Criteria

Finally we obtain the weights of the criteria as specified in Table 9.

Weights of Criteria	Criteria
0,329	GIS
0,164	Logistics Costs
0,196	Developing Possibility
0,077	Educational-cultural Structure
0,054	Price of Land
0,098	Wind Potential
0,079	Distance to Clustered High Waste Potential Areas (Dis.to CHWPA)

Table 9: Weights of Criteria

A rounding of the weights as denoted by percentage values is depicted in Table 10.

Percentage	Criteria
33%	GIS
20%	Developing Possibility
16%	Logistics Costs
10%	Wind Potential
8%	(Dis.to CHWPA)
8%	Educational-Cultural Structure
5%	Price of Land

Table 10: Percentages of Criteria Weights

To conclude to AHP analysis we now need to determine the scores for each alternative with regard to each criterion.

We do this as follows:

- GIS score is obtained from GIS software it actually involves a combination of criteria such as proximity to rivers or residential areas. The evaluation of decision makers point that GIS score is an important criteria for deciders.

Criteria	Constraint	Alt.1	Alt.2	Alt.3	Alt.4	Alt.5	Alt.6	Alt.7
		Distance						
		Score						
Agricultural Areas	>300 m	620	800	1600	600	1100	4700	365
		3	4	9	3	6	10	1
Olive Areas	>3000m	3500	3100	3400	3150	3050	3050	8400
		10	2	8	3	1	1	10
Industrial Areas	>500m	2600	10000	8000	10700	9100	8700	18000
		6	5	5	5	5	5	5
Residential Areas	>1000m	3000	2000	1200	1100	1360	1200	3400
		10	8	2	1	3	2	10
Airports	>3000m	12000	16900	17500	3370	3300	15000	40000
		10	10	10	3	2	10	10
Wetlands	>300m	7500	17500	17700	5200	32000	>20000	>20000
		10	10	10	10	10	10	10
Dams	>2000m	18000	4600	5900	3300	6900	2300	6000
		10	6	8	3	10	1	8
Lakes	>300m	8000	19700	31500	17700	45500	>20000	>20000
		10	10	10	10	10	10	10
Rivers	>300m	500	1700	2500	3500	800	2600	15000
		2	10	10	10	4	10	10
Historical Area	>500m	2750	50000	2700	4700	4270	1900	19600
		9	10	9	10	10	6	10
Environmental Protected Area	>500m	>20000	>20000	>20000	>20000	>20000	>20000	>20000
		10	10	10	10	10	10	10
Topography	<20%	2%	8%	4%	10%	6%	5%	10%
		10	7	9	6	8	8	6
Highways	>300m	5400	2350	1000	1600	320	8000	13000
		1	1	6	2	10	1	1
Roads	>100m	158	900	142	1850	163	137	770
		9	1	10	1	9	10	1
Railways	>100m	6200	2100	8700	2100	2700	17300	>20000
		1	1	1	1	1	1	1
Score of Alternatives:		7,40	6,33	7,80	5,20	6,60	6,33	6,87
		Alt.1	Alt.2	Alt.3	Alt.4	Alt.5	Alt.6	Alt.7

Table 11: GIS Scores of the Alternatives (Legend of Scores in Appendix 8)

- Logistics Costs scores of alternatives were determined as the deviation of objective function value of each alternative from the optimal, based on the mathematical model

- Developing possibility scores were determined with respect to Master Plan of İzmir (Appendix 9) and expert opinions.

- Educational- Cultural Structure Scores were determined with respect to Poverty Map (IGEP, 2010), Unemployed Population Map, Educational Level Map (İzmir Development Agency, 2010) and Survey recommendations about the socio-demographical structure of some regions in İzmir.

- Scores for Price of Land Criterion was taken from experts who is work on related areas.

- Wind Potential Scores were determined with respect to Wind Map of Turkey and Wind Map of İzmir (Appendix 10; Appendix 11)

- Scores of Distance to Clustered High Potential Waste Areas were determined as regards to proximity to Industrial Areas, Free Zones and the number of companies in these areas.

Here, we assume that the number of firms is indicative of the amount of waste generated. The related calculation is given in Table 12 and the results are in Table 13.

Alternative	Cluster Weighted Distance	IAOIZ		Aliağa		Torbalı I.Z.	
		Distance (km)	Number of Firm	Distance (km)	Number of Firm	Distance (km)	Number of Firm
Alt. 1	12.747	19	526	12	184		37
Alt. 2	17.433	28	526	7	184		37
Alt. 3	23.510	27	526	34	184		37
Alt. 4	9.282	6	526	25	184		37
Alt. 5	35.235	41	526	50	184		37
Alt. 6	45.963	48	526	57	184		37
Alt. 7	30.724		526	82	184	26	37

Alternative	Cluster Weighted Distance	KOSBI		Aegean Free Zone		Menemen Free Zone	
		Distance (km)	Number of Firm	Distance (km)	Number of Firm	Distance (km)	Number of Firm
Alt. 1	545		319		236	5	109
Alt. 2	1.417		319		236	13	109
Alt. 3	3.052		319		236	28	109
Alt. 4	1.526		319		236	14	109
Alt. 5	4.469		319		236	41	109
Alt. 6	10.227	16	319		236	47	109
Alt. 7	14.674	46	319		236		109

Table 12: Calculation of Distance to Clustered High Potential Waste Areas

Alternative	Cluster Weighted Distance
Alt. 1	12,747
Alt. 2	17,433
Alt. 3	23,510
Alt. 4	9,282
Alt. 5	35,235
Alt. 6	45,963
Alt. 7	30,724

Table 13: Results of the Distance to Clustered High potential Waste Areas

Table 11 gives an overall view of the scores and Table 14 demonstrates the final score of each alternative location with respect to each criterion.

	GIS	Logistics Costs	Developing Possibility	Educational-Cultural Structure	Price of Land	Wind Potential	(Dis. To CHWPA)
Alt. 1	7.4	5.7	5	4	9	6.5	8.72
Alt. 2	6.33	5.7	3	5	9	6.5	8.26
Alt. 3	7.8	9.9	7	7	4	7	7.65
Alt. 4	5.2	7.4	5	6	2	7.5	9.08
Alt. 5	6.6	10	7	5	3	7	6.48
Alt. 6	6.33	7.7	6	3	9	7.5	5.4
Alt. 7	6.86	3.4	8	2	8	6	6.93

Table 14: Scores of the Alternatives as to each Criterion

Finally, Table 15 demonstrates the scores and the weighted sum (total score) for each alternative:

	GIS	Logistics Costs	Developing Possibility	Educational - Cultural Structure	Price of Land	Wind Potential	(Dis. to CHWPA)	Total Scores
Alt. 1	2.4372	0.9386	0.9807	0.3087	0.4915	0.6420	0.6915	6.4901
Alt. 2	2.0848	0.9386	0.5884	0.3858	0.4915	0.6420	0.6550	5.7861
Alt. 3	2.5689	1.6302	1.3730	0.5401	0.2185	0.6914	0.6066	7.6287
Alt. 4	1.7126	1.2186	0.9807	0.4630	0.1092	0.7407	0.7200	5.9449
Alt. 5	2.1737	1.6467	1.3730	0.3858	0.1638	0.6914	0.5139	6.9483
Alt. 6	2.0848	1.2680	1.1768	0.2315	0.4915	0.7407	0.4282	6.4215
Alt. 7	2.2593	0.5599	1.5691	0.1543	0.4369	0.5926	0.5495	6.1217

Table 15: Total Scores of the Alternatives

These results give us important information because the first sites' score is high by far. The percentages of the alternatives total scores as follows:

Alternative	Percentage
Alt. 1	14,3%
Alt. 2	12,8%
Alt. 3	16,8%
Alt. 4	13,1%
Alt. 5	15,3%
Alt. 6	14,2%
Alt. 7	13,5%

Table 16: Percentages of the Alternatives as to Total Score

7.3 Sensitivity Analysis for AHP Analysis

AHP is a common method for multi decision analysis. We also preferred this method. Surely the scores and resulting decisions are subjective based on perceptions of the experts. We now vary the weights of criteria and see how much sensitive the results are.

We changed the percentages of criteria given by deciders in a range as given in Table 17.

Criteria	Original Weights of Criteria	Changed Weights of Criteria
GIS	33%	27%
Logistics Costs	20%	22%
Developing Possibility	16%	20%
Educational-Cultural Structure	10%	8%
Price of Land	8%	5%
Wind	8%	10%
Distance to Waste Production Centers	5%	8%

Table 17: Changed Percentages of Criteria Weights

Changes in GIS score by increasing by 6% and fewer changes in other criteria.

The resulting score are given in Table 18.

	GIS	Logistics Costs	Developing Possibility	Educational - Cultural Structure	Price of Land	Wind Potential	(Dis. to CHWPA)	Total Scores
Alt. 1	1.9980	1.2769	0.9807	0.3087	0.4915	0.6420	0.6915	6.3892
Alt. 2	1.7091	1.2769	0.5884	0.3858	0.4915	0.6420	0.6550	5.7488
Alt. 3	2.1060	2.2178	1.3730	0.5401	0.2185	0.6914	0.6066	7.7534
Alt. 4	1.4040	1.6577	0.9807	0.4630	0.1092	0.7407	0.7200	6.0754
Alt. 5	1.7820	2.2402	1.3730	0.3858	0.1638	0.6914	0.5139	7.1500
Alt. 6	1.7091	1.7250	1.1768	0.2315	0.4915	0.7407	0.4282	6.5029
Alt. 7	1.8522	0.7617	1.5691	0.1543	0.4369	0.5926	0.5495	5.9164

Table 18: Total Scores of the Alternatives with Changes

These results that show Alternative 3 and Alternative 5 have strong suitability score for landfill site location.

And both results show scores of the Alternative 1 and Alternative 6 are very close to each other.

Alternative	Percentage
Alt. 1	14,0%
Alt. 2	12,6%
Alt. 3	17,0%
Alt. 4	13,3%
Alt. 5	15,7%
Alt. 6	14,3%
Alt. 7	13,0%

Table 18: Percentages of the Alternatives as to Changed Total Score Table

7.4 Comments on AHP Analysis

Although each criterion has a further look at the suitability map shows that each alternative has different advantages. For instance the Alternative 1 is far away from the urban area, but this means high transportation costs at the same time. Alternative 3 is close to the urban area but this means public can be uncomfortable about the landfill site location. Some of the alternatives posses more advantage about the land characteristic. When we look at the suitable areas in detail, Alternative 3 has an unsuitable area at its central part. This results from a buffer in GIS. Building Harmandali landfill area nearly cost 13.5 billion TL and nearly 8.6 billion TL (60%) expenses were for road construction. If the alternative is favourable in terms of road access, this may result in considerable lower construction costs. Although some alternatives have disadvantages about the distance to population centers, building intermediate transfer stations can decrease the cost as mentioned earlier.

Therefore all alternatives should be analysed from a multi directional viewpoint. If the alternatives scores are close (as in our research) then the decision would more likely be a managerial decision.

CHAPTER 8
CONCLUSION

The era we live in brings us face to face with environmental problems. Unfortunately, the dimensions and impacts of these problems are growing every day. Particularly due to public awareness on these adverse impacts, nowadays environmental issues are becoming overemphasized. Coupled with rising responsibility of public and authorities, activities and projects planning related with environment are increasing. On the other hand we observe scarcity of resources along with increases on life standards and consumption:

Within this setting, one of the most important problems of countries, especially of developing countries is waste management. It is primarily environmental experts who are concerned with this matter a lot. Pollution has an important role on environmental changes in world and public health. As one component of this pollution, waste has a special importance. From another perspective, this is an important cost item. Especially in developing countries most of the local public expenses are made on waste management. Nevertheless, it is not easy to state that the overall process of waste management is conducted properly. We focus on this significant issue, particularly on the problem of locating a landfill site for İzmir. In doing so, we touch upon the other components of waste management.

We first layout the similarities and differences of the traditional supply chain and supply chains with the explicit consideration of waste. We then analyze the problem of locating a landfill facility, providing insides to the problem structure and the criteria used for such problems. Upon identifying and defining the problem explicitly we develop a novel methodology to solve the problem. We also emphasize the importance of the overlook logistics point of view to the problem.

The methodology we utilize in this thesis utilizes available information associated with the research area. Within the process of data management, it became evident that there is no particular information system that may possibly supply all the data required for such a study. It was then an important set of decisions to identify which data (e.g. maps, populations, industrial structure, agricultural structure) are to be used, where these can be obtained, and how all data from different sources will be integrated within the analysis. The data obtained from different sources was usually in various formats, various scales and sometimes inconsistent. Therefore, we would like to point out that the rapid growth in GIS software and in the use of GIS tools is not managed appropriately in terms of data processing, reporting and standardization. Considering the importance of these steps and their effects on strategic, operational, and tactical decisions, the issue becomes more significant. We need to admit that the research and the conclusions drawn out of this research relies heavily on the available information. In other words, we might have reached to different results with different data (with more data available/processed or with less data available/processed). To this end, we emphasized throughout the thesis that the actual decisions on, say, the size, location, technology, lifetime of the landfill site have to be given following more detailed analysis on alternative locations in the suitability map.

Within this setting, the main contribution provided by this thesis is the development of a methodology to process the available data and identify alternative locations that need further analysis for the final landfill siting decisions. In doing so, we integrate both more traditional and logistics criteria. We identify the difficulty of processing the two types of criteria, whereby we also propose a multi-stage approach that enhances the analysis. We make use of GIS software and analytical methods (mathematical programming) within the analysis.

The environment that defines the problem under consideration is highly dynamic. To begin with, the amount of waste generated by residents in a specific area is growing every day, and changing in terms of composition. Moreover, cities are becoming more populated, certain regions are being opened to industrial processes or to agriculture. This dynamic nature of the problem research will most probably undermine the validity of any conclusion drawn with static data. On the other hand, natural uncertainty involved in many of the data, as well as the data variability call for a decision making framework that is capable of handling the dynamic and uncertain nature of the problem. The techniques that we apply within this thesis also recognize this dynamics and uncertain structure. We incorporate future projections into the analysis wherever possible. For instance, we explicitly utilize population projections and developing plans of the municipality in the analysis. In several other steps of the research, we utilize robustness/sensitivity analysis. In this way, we make sure that we can proceed to the next step without worrying about data uncertainty or, say, changes in population. This sensitivity analysis also provides insights to the problem such as the significance of each criterion on the decision. We apply robustness/sensitivity analysis to many problem parameters such as distances, travel times, populations of regions, restrictions on slope, restrictions on olive areas. We also include a sensitivity analysis that demonstrates the contribution of the decision on building a second landfill site in terms of logistics related criteria. For such project, this is a very important evidence for deciding whether or not to go ahead with the implementation. Other than the above mentioned parameters, we determine one other key point where the subjectivity of expert evaluations may significantly affect the location decision. We also apply sensitivity analysis on criteria weights to observe the effects on the ranking of alternative candidate locations in the suitability map.

This thesis research provides suggestions for the location of a second landfill site using a sound and robust methodology. It also demonstrates the fact that such a decision is not a straightforward decision; it involves a multiplicity of classes of criteria, dynamic nature, and uncertainty. We suggest a specific methodology to solve this problem. We believe that this study will serve as a decision support tool for governments in solving similar problems. We also hope that this thesis helps draw more attention to the incorporation of logistics and supply chain perspectives to such problems that are traditional accepted to be in the domain of environmental sciences researchers.

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APPENDIX

Appendix 1:

Map	Institution
Master Plan of İzmir	İzmir Metropolitan Municiplaity
Site Investigation Boundaries	İzmir Metropolitan Municiplaity
Rivers Map	Ministry of Environment and Forest
Dams Map	Ministry of Environment and Forest
Lakes Map	İzmir Metropolitan Municiplaity
Wetlands Map	Ministry of Environment and Forest
Agricultural Areas Map	Ministry of Environment and Forest
Forest Map	Ministry of Environment and Forest
Olive Areas Map	Ministry of Environment and Forest
Meadow Areas Map	Ministry of Environment and Forest
Brush Areas Map	Ministry of Environment and Forest
Pasture Areas Map	Ministry of Environment and Forest
Industrial Areas Map	Ministry of Environment and Forest
Residential Areas Map	Ministry of Environment and Forest
Airports	İzmir Metropolitan Municiplaity
Fault Lines Map	İzmir Metropolitan Municiplaity
Historical Protected Areas Map	İzmir Metropolitan Municiplaity
Environmental Protected Areas Map	Directorate of Agricultural Production and Development
Disaster Areas	İzmir Metropolitan Municiplaity
Geologically Unsuitable Areas Map	İzmir Metropolitan Municiplaity
Topography Map	United States of America Geological Survey
Transportation Map	Ministry of Environment and Forest

Appendix 2:

	Distances (km)							
Alternatives	Al.1	Al.2	Al.3	Al.4	Al.5	Al.6	Al.7	Al.8
Aliağa	29,8	15,3	63,2	29,7	77,6	81	140	99,2
Urban Roads	6	2,5	24	2,6	38	39,4	50	45
Highways	23,8							
Foça	18,1	30,2	72,2	40	86,7	90	149	108
Urban Roads	2	6	23	3,2	46,3	47,7	58,3	53,3
Highways	16,1							
Menemen	23,6	15	37,1	7	51,6	55	114	73,1
Urban Roads	3,5	5	21	1,2	36,4	37,8	48,4	43,4
Highways	20,1							
Çiğli	29,6	29,3	26,1	6,2	40,5	42	103	62,1
Urban Roads	7	21	13	1,8	30,5	30,9	42,5	37,5
Highways	22,6							
Karşıyaka	48,5	48,1	28,2	30,4	42,7	45,7	105	64,3
Urban Roads	15	39	8	15	28,7	29,1	40,7	35,7
Highways	33,5							
Bayraklı	42,1	41,8	10	29	27,7	26,5	90,5	49,3
Urban Roads	11	31	6	17	21,3	22,7	33,3	29,3
Highways	31,1							
Bornova	46,2	45,8	6,5	36,5	24,6	23,3	87,4	46,2
Urban Roads	20	34,8	2,5	15,5	14,5	15,9	26,5	22,9
Highways	26,2							
Kemalpaşa	67,4	67	35,8	49,3	37,3	27,5	53,7	32,5
Urban Roads	38	41	23	36	18	19,6	30,2	26,6
Highways	29,4							
Bayındır	130	129	94,7	111	81,6	53,7	15,1	42,5
Urban Roads	42	60	41	54	66,5	32	5	74,9
Highways	88							
Balçova	72,6	76,3	41,8	58,6	25,5	39,9	93,4	52,2
Urban Roads	28	43	21,8	34,8	2,7	4,1	14,7	11,1
Highways	44,6							
Gaziemir	70,1	69,7	35,2	52	19	41,6	72,8	31,6
Urban Roads	37	23	20,5	33,5	5,6	7	17,6	14
Highways	33,1							
Buca	48,9	51,9	18,9	35	31,1	31,8	99	57,8
Urban Roads	29	38	9	22	11	12,4	23	19,4
Highways	19,9							
Güzelbahçe	97,9	97,6	63,1	79,3	46,8	59,9	115	73,5
Şehir içi geçiş Km	45	46	17	30	4	5,4	16	12,4
otoban	52,9							
Karabağlar	78,6	78,2	43,7	60	27,5	50,4	95,4	54,2
Urban Roads	33	25	20	33	5	6,4	17	13,4
Highways	45,6							
Konak	48,5	48,2	18,6	38,1	24,2	31,4	92,2	51
Urban Roads	27	36	15	28	15,2	16,6	27,2	23,6
Highways	21,5							
Menderes	175	74,6	40,1	48,1	23,9	46,5	71,3	30,1
Urban Roads	30	38,6	21	34	7,6	9	19,6	16
Highways	145							
Narlıdere	82,2	81,9	47,3	63,7	31,1	44,1	99	57,8
Urban Roads	33	32	27	40	3	4,4	15	11,4
Highways	49,2							
Seferihisar	114	113	78,7	95,2	62,5	75,5	130	89,2
Urban Roads	51	34	37	50	8	9,4	20	16,4
Highways	63							
Selçuk	118	118	83,3	97,2	70,3	65,1	60,6	33,8
Urban Roads	39	43	15	28	4	5,4	16	12,4
Highways	79							
Torbalı	88,2	87,9	53,4	68,6	40,4	32,5	42,5	13,2
Urban Roads	35	39	13	26	2	3,4	14	10,4
Highways	53,2							
Urla	106	106	71,2	88,1	62,5	70,7	123	81,7
Urban Roads	52	57	28	41	8	9,4	20	16,4
Highways	54							

Appendix 3:

table d(i,j) weighted total distance between one population center and one candidate location

	L1	L2	L3	L4	L5	L6	L7	L8
C1	30	15	63	30	78	81	140	99
C2	18	30	72	40	87	90	149	108
C3	24	15	37	7	52	55	114	73
C4	30	29	26	6	41	42	103	62
C5	49	48	28	30	43	46	105	64
C6	42	42	10	29	28	27	91	49
C7	46	46	7	37	25	23	87	46
C8	67	67	36	49	37	28	54	33
C9	130	129	95	111	82	54	15	43
C10	73	76	42	59	26	40	93	52
C11	70	70	35	52	19	42	73	32
C12	49	52	19	35	31	32	99	58
C13	98	98	63	79	47	60	115	74
C14	79	78	44	60	28	50	95	54
C15	49	48	19	38	24	31	92	51
C16	175	75	40	48	24	47	71	30
C17	82	82	47	64	31	44	99	58
C18	114	113	79	95	63	76	130	89
C19	118	118	83	97	70	65	61	34
C20	88	88	53	69	40	33	43	13
C21	106	106	71	88	63	71	123	82

;

parameter p(i) weighted demand of population center i

/

C1 76391

C2 91672

C3 131880

C4 105985

C5 511036

C6 241875

C7 577497

C8 94726

C9 15172

C10 105012

C11 664301

C12 439125

C13 228599

C14 392477

C15 241464

C16 73173

C17 833715

C18 84238

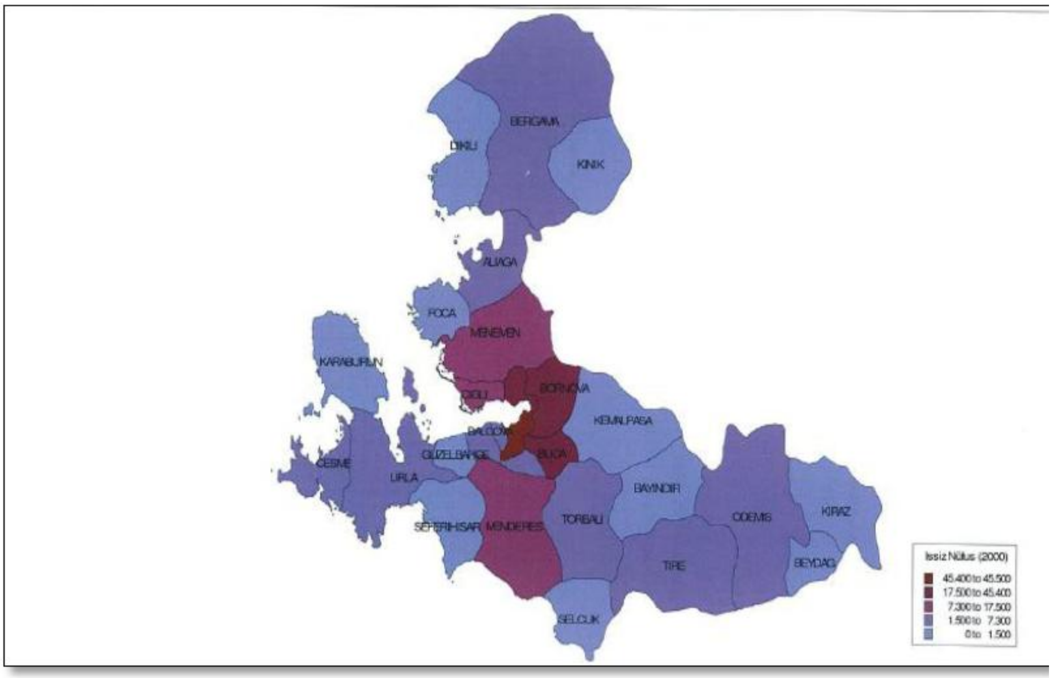
C19 21942

C20 134161

C21 57449

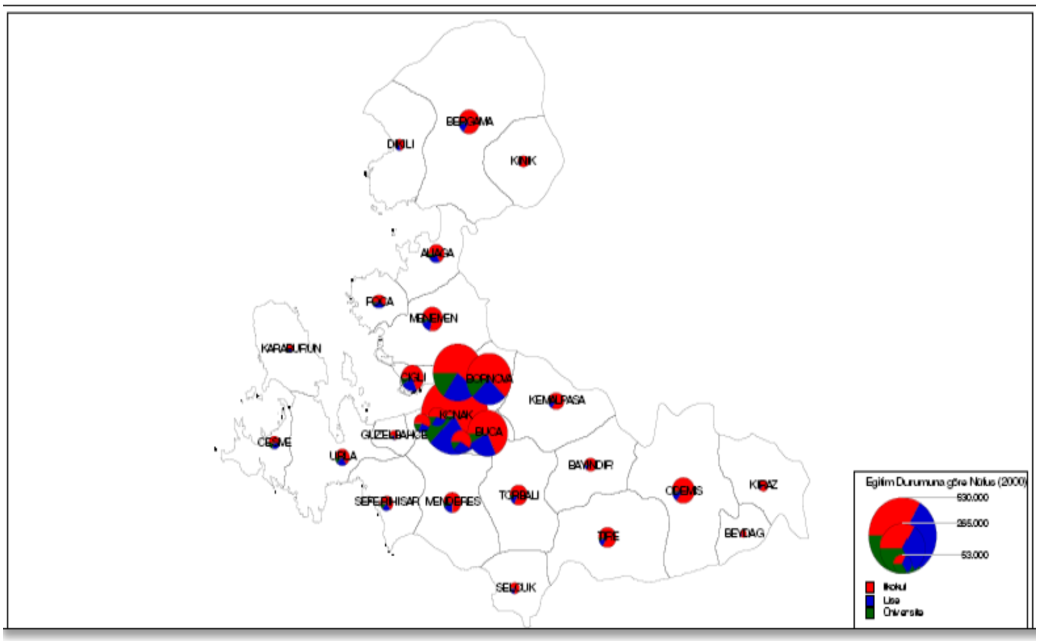
/

Appendix 4:



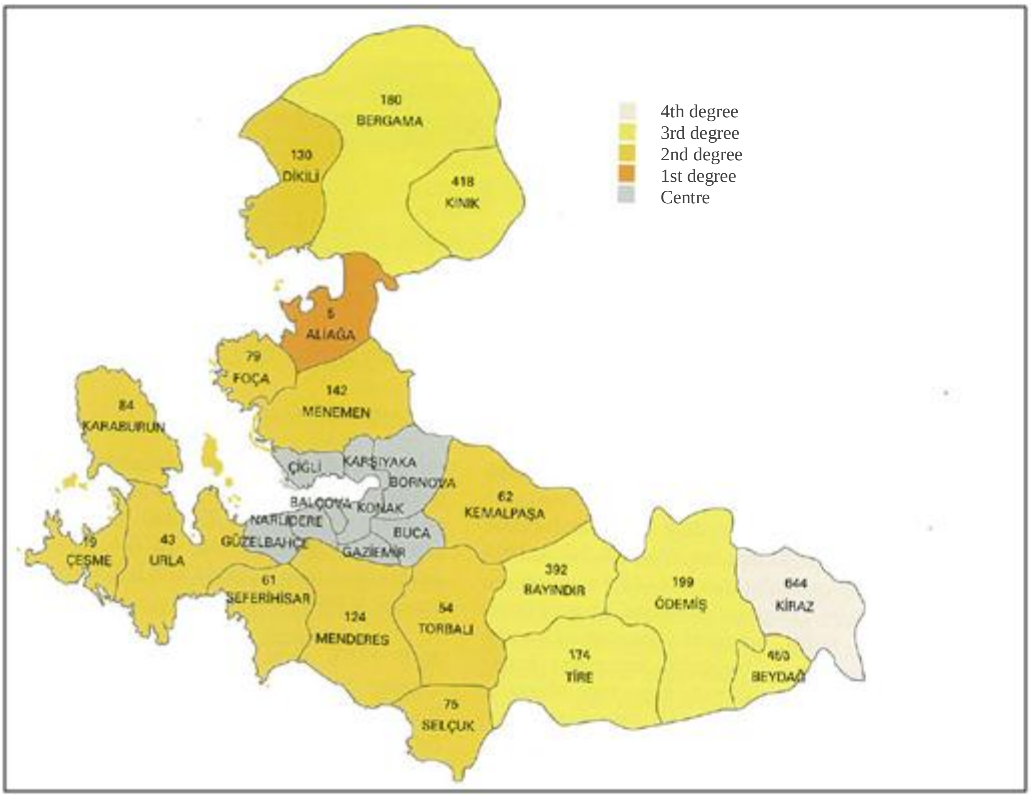
Unemploymnet, İGEP,2009

Appendix 5:



Population according to Education, İZKA,2009

Appendix 6:



Sosio Economic Development Order of Regions, (DPT,2004)

Appendix 7:

Regions	Estimated Population	High Socioeconomic %	Low Socioeconomic %	Overall	1fst score	2nd score
Aliağa	76.587	0,4	0,6	0,8	0	61269,71
Used Data	0	0,6	0,4	0,9	68928,42	0
Foça	57.080	0,5	0,5	0,85	0	48517,96
Used Data	0	0,35	0,65	0,775	44236,96	0
Menemen	156.188	0,4	0,6	0,8	0	124950,1
Used Data	0	0,3	0,7	0,75	117140,7	0
Çiğli	159.587	0,4	0,6	0,8	0	127669,4
Used Data	0	0,3	0,7	0,75	119690,1	0
Karşıyaka	402.930	0,6	0,4	0,9	0	362637,3
Used Data		0,8	0,2	1	402930,4	0
Bayraklı	326.572	0,3	0,7	0,75	0	244929
Used Data		0,4	0,6	0,8	261257,7	0
Bornova	520.702	0,5	0,5	0,85	0	442596,3
Used Data		0,65	0,35	0,925	481648,9	0
Kemalpaşa	110.050	0,4	0,6	0,8	0	88040,27
Used Data		0,3	0,7	0,75	82537,76	0
Bayındır	33.063	0,3	0,7	0,75	0	24797,21
Used Data		0,3	0,7	0,75	24797,21	0
Balçova	96.278	0,6	0,4	0,9	0	86650,57
Used Data		0,7	0,3	0,95	91464,49	0
Gaziemir	277.599	0,5	0,5	0,85	0	235959,3
Used Data		0,5	0,5	0,85	235959,3	0
Buca	505.557	0,4	0,6	0,8	0	404445,2
Used Data		0,35	0,65	0,775	391806,3	0
Güzelbahçe	65.564	0,75	0,25	0,975	0	63925,11
Used Data		0,75	0,25	0,975	63925,11	0
Karabağlar	512.592	0,4	0,6	0,8	0	410074
Used Data		0,3	0,7	0,75	384444,3	0
Konak	398.779	0,4	0,6	0,8	0	319022,9
Used Data		0,3	0,7	0,75	299084	0
Menderes	85.522	0,3	0,7	0,75	0	64141,69
Used Data		0,3	0,7	0,75	64141,69	0
Narlıdere	202.431	0,6	0,4	0,9	0	182187,5
Used Data		0,7	0,3	0,95	192309	0
Seferihisar	53.512	0,5	0,5	0,85	0	45485,15
Used Data		0,3	0,7	0,75	40133,96	0
Selçuk	33.659	0,5	0,5	0,85	0	28609,96
Used Data		0,4	0,6	0,8	26927,02	0
Torbalı	152.646	0,35	0,65	0,775	0	118300,4
Used Data		0,35	0,65	0,775	118300,4	0
Urla	58.949	0,7	0,3	0,95	0	56001,6
Used Data		0,65	0,35	0,925	54527,87	0
Total Demands with 1st scores and 2nd scores:					3.566.192	3.540.211

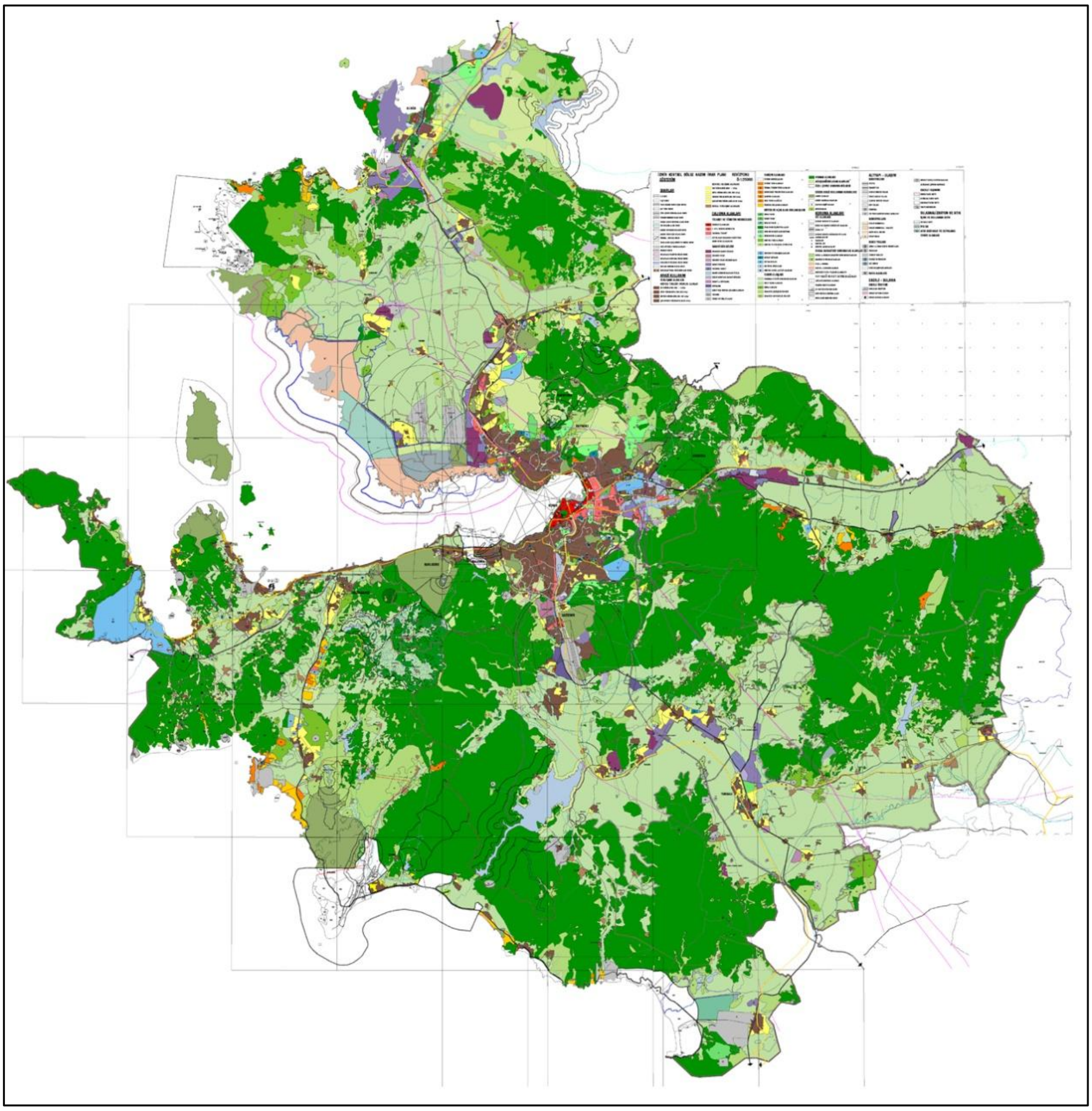
Appendix 8:

Criteria	Constraint		Alt.1	Alt.2	Alt.3	Alt.4	Alt.5	Alt.6	Alt.7
Agricultural Areas	>300 m	Distance	620	800	1600	600	1100	4700	365
		Score	3	4	9	3	6	10	1
Olive Areas	>3000m	Distance	3500	3100	3400	3150	3050	3050	8400
		Score	10	2	8	3	1	1	10
Industrial Areas	>500m	Distance	2600	10000	8000	10700	9100	8700	18000
		Score	6	5	5	5	5	5	5
Residential Areas	>1000m	Distance	3000	2000	1200	1100	1360	1200	3400
		Score	10	8	2	1	3	2	10
Airports	>3000m	Distance	12000	16900	17500	3370	3300	15000	40000
		Score	10	10	10	3	2	10	10
Wetlands	>300m	Distance	7500	17500	17700	5200	32000	>20000	>20000
		Score	10	10	10	10	10	10	10
Dams	>2000m	Distance	18000	4600	5900	3300	6900	2300	6000
		Score	10	6	8	3	10	1	8
Lakes	>300m	Distance	8000	19700	31500	17700	45500	>20000	>20000
		Score	10	10	10	10	10	10	10
Rivers	>300m	Distance	500	1700	2500	3500	800	2600	15000
		Score	2	10	10	10	4	10	10
Historical Area	>500m	Distance	2750	50000	2700	4700	4270	1900	19600
		Score	9	10	9	10	10	6	10
Environmental Protected Area	>500m	Distance	>20000	>20000	>20000	>20000	>20000	>20000	>20000
		Score	10	10	10	10	10	10	10
Topography	<20%	Distance	2%	8%	4%	10%	6%	5%	10%
		Score	10	7	9	6	8	8	6
Highways	>300m	Distance	5400	2350	1000	1600	320	8000	13000
		Score	1	1	6	2	10	1	1
Roads	>100m	Distance	158	900	142	1850	163	137	770
		Score	9	1	10	1	9	10	1
Railways	>100m	Distance	6200	2100	8700	2100	2700	17300	>20000
		Score	1	1	1	1	1	1	1
Score of Alternatives:			7,40	6,33	7,80	5,20	6,60	6,33	6,87
			Alt.1	Alt.2	Alt.3	Alt.4	Alt.5	Alt.6	Alt.7

Legand

1	2	3	4	5	6	7	8	9	10
301-450	451-600	601-750	751-900	901-1050	1051-1200	1201-1350	1351-1500	1501-1650	>1650
3001-3050	3051-3100	3101-3150	3151-3200	3201-3250	3251-3300	3301-3350	3351-3400	3401-3450	>3450
501-750	751-1000	1001-1250	1251-1500	>2750	2501-2750	2251-2500	2001-2250	1751-2000	1501-1750
1001-1125	1126-1250	1251-1375	1376-1500	1501-1625	1626-1750	1751-1875	1876-2000	2001-2125	>2125
3001-3150	3151-3300	3301-3450	3451-3600	3601-3750	3752-3900	3901-4050	4051-4200	4201-4350	>4350
301-450	451-600	601-750	751-900	901-1050	1051-1200	1201-1350	1351-1500	1501-1650	>1650
2001-2500	2501-3000	3001-3500	3501-4000	4001-4500	4501-5000	5001-5500	5501-6000	6001-6500	>6500
301-450	451-600	601-750	751-900	901-1050	1051-1200	1201-1350	1351-1500	1501-1650	>1650
301-450	451-600	601-750	751-900	901-1050	1051-1200	1201-1350	1351-1500	1501-1650	>1651
501-750	751-1000	1001-1250	1251-1500	1501-1750	1751-2000	2001-2250	2251-2500	2501-2750	>2751
501-750	751-1000	1001-1250	1251-1500	1501-1750	1751-2000	2001-2250	2251-2500	2501-2750	>2751
19-20%	17-18%	15-16%	13-14%	11-12%	9-10%	7-8%	5-6%	3-4%	0-2%
>1650	1501-1650	1351-1500	1201-1350	1051-1200	901-1050	751-900	601-750	451-600	301-450
>550	501-550	451-500	401-450	351-400	301-350	251-300	201-250	151-200	101-150
>550	501-550	451-500	401-450	351-400	301-350	251-300	201-250	151-200	101-150

Appendix 9:



Master Plan of İzmir, İzmir Metropolitan Municiplality, 2010