FUZZY MULTI-CRITERIA DECISION MAKING IN SOLID WASTE COLLECTION SYSTEM IN TURKEY

(TÜRKİYE KATI ATIK TOPLAMA SİSTEMİNDE BULANIK ÇOK ÖLÇÜTLÜ KARAR VERME)

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In today's solid waste management, the disposal process is critically important owing to limited storage area and the precautions taken for the human health. Another aspect is the fast exhaustion of natural resources. A new notion appeared over the last decades through these motivations: the recovery of solid waste. Or the recovery process necessitates many new arrangements and revisions in the conventional solid waste management system because the recovery is possible only when the waste is collected properly.

This study is a wide and detailed analysis of the solid waste collection system in Turkey and the new methods existing. A fuzzy goal programming model and a fuzzy TOPSIS model are used to decide which collection method is the best and what are the motivations of acceptance of this method.

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Yeşim KOP
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LIST OF SYMBOLS

TOPSIS	Technique for Order Preference by Similarity to Ideal Solution
EECS	Electric and Electronic Component Scrap
EC	European Community
SIS	State Institute of Statistics
ELECTRE	ELimination Et Choix Traduisant la REalite
MAUT	Multi Attribute Utility Theory
DM	Decision Maker
MCDM	Multi Criteria Decision Making
MODM	Multi Objective Decision Making
GP	Goal Programming
LP	Linear Programming
FLP	Fuzzy Linear Programming
FGP	Fuzzy Goal Programming
MEF	Ministry of Environment and Forestry

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ABSTRACT

Over the last decades, the waste disposal is widely discussed and has become one of the major problems of the world proportionally to the population and technology growth. Governments allocate a larger budget to handle this problem and adopt new strategies as recycling, energy production from waste, etc. These new waste disposal strategies necessitate new transportation and collection technologies.

There is an analogy between an industry and an ecological system according to Ayers. (1989). The manufacturer isn't interested only in product design, costs and economic benefits but also in energy expense, waste formation after the manufacturing. Ayers affirm that all kind of living necessitates food to produce energy and release waste as by-product. Then, it is a ring of the food chain. The circumstance changes in industrial environment where a huge amount of waste is produced [6].

Today many public or private industrial institutions are faced to new management disciplines as environmental protection, responsibility for solid waste collection and recovery [7]. The recovery of solid waste is economically and environmentally worthwhile. Instead of land filling materials as glass, plastic, metal, ceramic and paper, we can assess them as secondary raw materials. Thus, it is possible to decrease the raw material need of the industry and also possible to decrease energy consumption for the raw material production. Moreover, as the density of these materials is low, they compose a huge volume of waste. The recovery of exploitable waste decrease the volume of the waste going to land filling area, with important grades. But the percentage of recovery and the expenses varies for different collection method of solid waste. For example the collection with one pail incur large losses on exploitable waste because it is collected smudged by the biologic waste or can be more expensive over the long term owing to the expenses on the separation facility. But it is more admissible as method for the public.

The exploitation of the solid waste involves a collection process as clean as possible. There are many methods of collection. The general collection method in Turkey is the system operated by one garbage pail. In this system, the garbage is separated in a separation

facility. And then each material is transported to the facility where they are recycled or recovered. Another method is the separate collection at source. This method is used in many way but we can define the system on the whole by ‘collection with many trash bag’. In Turkey there is also another system more practiced actually: it is the collection of each material which can be recycled from the point where they are produced or where people use only this kind of material. For paper, these points are paper manufacturers or schools and offices. But in this system, domestic waste isn’t exploited and this may be an important loss.

This study will help us to understand which collection method is the best for the current situation. Since the paper and the carton paper are the most produced exploitable solid waste in Turkey, it seemed adequate to observe this system. Based on the data received from an institution executing the system of collection from manufacturers we will illustrate the current situation. Then, we will observe other alternatives by using data received from Ministry of Environment and Forestry (MEF) of Turkey. The application part of the study includes the selection of the best collection method by using a multi-objective decision making method named fuzzy goal programming (FGP) approach and then a multi-criteria decision making method named fuzzy TOPSIS.

Whatever is the system and its complexity, an essential function waits to be debated in each problem: The Decision. In the real life of organizations, we are faced with difficulties due to the paradox created by diverse contradictory situations and attributes. The decision maker has several points of view often contradictory in the decision making process. Multi-criteria decision making is one of the most well known branches of decision making. Many authors [Zimmermann,1996] divide multi-criteria decision making into two branches: Multi-objective decision making and multi-attribute decision making [4]. Whereas we use the term multi-criteria decision making instead of the term multi-attribute decision making. In this study the usage of the two decision making model engender a comparison of multi-objective methods with multi-criteria methods.

Reverse logistic process are complex systems where decision making is complicated by multi conflicting objectives and imprecision of data. The algorithms proposed in this paper are useful for solving a method selection problem. They handle effectively the imprecision of data with fuzzy set theory. The optimal selection process is a resource allocation decision and the selection affects ultimately the recovery amount. The method is illustrated by the waste paper collection system selection in Istanbul. This example demonstrated us that the current collection method in Istanbul is not the best suitable neither for the budget target nor for the recovery rate. The separate collection at source is a better method with his low cost and high recovery rate.

RESUME

De nos jours, la disposition des déchets est largement discutée et est devenue le problème principal du monde, proportionnellement à la croissance de la population et de la technologie. Les gouvernements assignent un budget plus important pour manipuler ce problème et adopte de nouvelles stratégies en tant que recyclage, la production énergétique à partir des déchets etc. Ces nouvelles stratégies de disposition de déchet nécessitent de nouvelles technologies de transport et de collection.

Il y a une analogie entre une industrie et un système écologique selon Ayers (1989). Le fabricant n'est pas intéressé seulement à la consommation des produits, aux coûts et aux avantages économiques mais également aux dépenses d'énergie, à la formation de rebut après la fabrication. Ayers affirment que tout le genre de vie doit manger pour produire l'énergie et pour libérer du déchet comme sous-produit. Il est un anneau de la chaîne alimentaire. Les conditions changent dans l'environnement industriel où une quantité énorme de déchet est produite [6].

Aujourd'hui plusieurs établissements industriels privés sont face à de nouvelles disciplines de gestion comme protection environnementale, responsabilité de collection de déchets solides et de recyclage [7]. Le recyclage des déchets solides est économiquement valable. Au lieu d’enterrer les matières en plastique, en métal, en céramique et en papier, nous pouvons les évaluer comme des matières secondaires. Ainsi, il est possible de diminuer le besoin de matière première de l'industrie et aussi possible de diminuer la consommation d'énergie pour la production de matière première. D'ailleurs, comme la densité de ces matériaux est basse, on a un énorme volume de perte. Le recyclage pour des déchets exploitables diminue le volume de la perte à cause de l’enterrage ou de l’accumulation des déchets. Mais le pourcentage du recyclage et les dépenses sont différents pour cahque méthode de collection de déchets solides. Par exemple la collection avec un seau encourent de grandes pertes de déchets solides exploitables, parce qu'elle est ramassée mêlée aux déchets biologiques et peut être plus chère au long terme dû aux dépenses du service de séparation. Mais elle est plus admissible comme méthode pour le public.

L'exploitation des déchets solides comporte un processus de collection aussi propre comme possible. Il y a beaucoup de méthodes de collection. La méthode générale de collection en Turquie est le système actionné par un seau. Dans ce système, les déchets sont séparées dans un établissement de séparation. Et alors chaque matériel est transporté à l'établissement où ils sont réutilisés ou récupérés. Une autre méthode est la collection séparée de la source. Cette méthode est employée de différentes manières mais nous pouvons définir le système dans l'ensemble par “la collection avec plusieurs sac”. En Turquie il y a également un autre système plus pratiqué réellement : c'est la collection de chaque matériel qui peut être réutilisée du point où elles sont produites ou du point où les gens emploient seulement ce genre de matériel. Pour le papier, ces points sont les fabriques de papier ou les écoles et les bureaux. Mais dans ce système, le déchet domestique n'est pas exploité et ceci peut être une perte importante.

Cette étude nous aidera à comprendre quelle méthode de collection est la meilleure pour la situation actuelle. Puisque le papier et le carton sont les déchets solides exploitables les plus produits en Turquie, il est raisonable d'observer ce système au nom de toutes sortes de déchet. Basé sur les données reçues d'un établissement exécutant le système de collection de papier des fabricants nous illustrerons la situation actuelle. Puis, nous observerons autres alternatives en employant des données reçues du ministère de l'environnement et de la sylviculture de la Turquie. La partie d'application de l'étude inclut le choix de la meilleure méthode de collection en employant une méthode multi-objective de prise de décision appelée la programmation de but floue et puis une méthode multi-critères de prise de décision appelée TOPSIS floue.

Quelque soit le système et sa complexité, une fonction indispensable attend à être débordée à chaque procès: La Décision. Dans la vie courante, comme celle des organisations on est face à des difficultés car on est écartelé entre plusieurs situations et attributs contradictoires. Le décideur a plusieurs points de vue souvent contradictoires dans le processus décisionnel. La décision multicritère est une des plus connues branches de la prise de décision. Selon plusieurs auteurs comme Zimmermann, 1996, la décision multicritère est divisée en la décision multi-objective (DMO) et la décision multi-attribut (DMA). Bien que les méthodes de DMC sont largement diverses, elles ont certains aspects communs comme la notion d'alternatives et la notion d'attributs. Dans cette étude l'utilisation de la prise de décision de deux modèle engendrent une comparaison des méthodes multi-objectives avec des méthodes multi-critères.

Le processus logistique renversé est un système complexe où la prise de décision est compliquée par des objectifs et l'imprécision multi contradictoires des données. Les algorithmes proposés dans cet étude sont utiles pour résoudre un problème de choix de méthode de collection. Ils manipulent efficacement l'imprécision des données avec la théorie des ensembles floue. Le procédé de choix optimal est une décision d'allocation de ressource et le choix affecte finalement à la quantité de recyclage. La méthode est illustrée par le choix de système de collection de papier déchet à Istanbul. Cet exemple nous a démontrés que la méthode courante de collection à Istanbul n'est pas la meilleur appropriée à la cible de budget ni à la cible de taux de recyclage. La collection séparée à la source est une meilleure méthode avec son coû bast et son taux élevé de recyclage.

ÖZET

Her canlı türü enerji üretmek için besine ihtiyaç duyar ve yan mamul olarak çöp üretir dolayısıyla besin zincirinin bir halkasıdır. Ancak çok büyük miktarlarda çöp üretilen endüstriyel çevrelerde şartlar değişmektedir. Bugün birçok özel ve kamu endüstri kuruluşu çevre koruma, çöp toplama ve geri kazanma sorumluluğu gibi birçok yönetim düzenlemesiyle karşı karşıyadır [6].

Bu çalışmada Türkiye'de mevcut olan atık yönetimi mevzuatı ve süreci, bu sürecin dünyadaki örnekleri ve Türkiye'nin bu konuda dünyadaki konumu incelenmiştir. Depolama sahalarının kıtlığı ve gittikçe artan nüfusun buna bağlı olarak süratle artan çöp üretimi göz önünde bulundurulduğunda geri kazanım ve geri dönüşüm gibi süreçlerin önemi açıkça ortaye çıkmaktadır. Bu bağlamda, bu çalışmada, bu süreçlerin etken ve etkin yönetimi amaçlanmış ve süreçlerin bir aşaması olan çöp toplama sistemlerinin karşılaştırılması ve seçimi hedeflenmiştir. Bunun yapılabilmesi için mevcut ve benimsenmesi öngörülen toplama sistemleri hakkında çeşitli özel şirketlerden ve belediye, çevre ve orman bakanlığı gibi kamu kuruluşlarından veri toplanarak, bu veriler ışığında bugün uygulanması en uygun çöp toplama sistemi seçilmiştir. Bu çalışma için Türkiye'nin en kalabalık dolayısıyla en çok çöp üreten şehri olan İstanbul şehri çalışma bölgesi olarak seçilmiştir.

Geri kazanılabilir katı atık, cam, seramik, kağıt, plastik, metal, deri ve tahtadan oluşmaktadır. Türkiye Devlet İstatistik Enstitüsü'nden alınan bilgiye göre 2004'te tüm katı atıklar içinde geri kazanılabilir katı atık yüzdesi ortalama %30 civarındaydı. Bu rakam farklı bölgelere ve farklı tüketim alışkanlıklarına göre değişkenlik göstermekte, örneğin kırsal alanda %15'lere kadar inebilmektedir. Bu oranlar her geçen yıl, nüfusun artışıyla birlikte artmaktadır [9,10].

Bütünün içindeki oranına bakılırsa, kağıt en önemli geri kazanılabilir katı atıktır. Nüfusun artışı, yaşam koşullarının gelişmesi, şehirleşme, okuma alışkanlığının artması, matbaanın gelişmesi, kağıt tüketimini arttırmaktadır. 1980'de, Türkiye'de kağıt tüketimi yılda yaklaşık 600 000 tondu. 2004'te bu yılda 1 900 000 ton seviyelerine kadar artmıştır.

2004’ten bugüne kadar ise yılda ortalama % 7’lik bir artış gözlemlenmiştir. 2003 yılında İstanbul’da katı atık içeriği üzerinde yapılan bir araştırmaya göre evsel katı atık, brüt olarak %9,71 oranında atık kağıttan oluşmaktadır (4,47% kuru kağıt). Bu oran okullarda ve ofislerde çok daha yüksektir. Dolayısıyla kuru kağıt, katı atığın ortalama olarak %7,5-9’unu oluşturmaktadır. Devlet İstatistik Enstitüsü’nün verilerine göre, kağıdın geri kazanılabilir katı atık içindeki oranı ise %46’dır [9,10].

Katı atığın geri kazanılması süreci atığın oldukça temiz toplanmasını gerektirmektedir. Her katı atık geri kazanılamaz. Geri kazanılabilecek katı atıktan yüksek verim alınabilmesi için varolan toplama sistemlerinin gözden geçirilmesi, bunalara gerekli yeniliklerin eklenmesi veya yeni sistemlerin kurulması gerekebilir. Toplama ve taşıma geri kazanımın en maliyetli süreçleridir.

Antik Yunan’da, milattan önce 5. yüzyılda, insanlar kendi çöplerini, çöplüğe kendileri taşırdı. Roma İmparatorluğu’nda ise çöpler sokağa konulur, oradan atlı arabalara toplanır ve şehir dışında üstü açık bir çukura atılırdı. Tüm bu uygulamalar Orta Çağ ve Rönesans süresince sekteye uğradı. Bu dönemde çöp bir sisteme bağlı olmaksızın ve insan sağlığı göz ardı edilerek ortaya atılmaktaydı. 1950’lere kadar insanlar çöplerden yakarak kurtuluyorlardı. 1950’lerin ortalarında, yakarak bertaraf etmenin çevreye ve insan sağlığına zararlı etkilerinin olduğu, ayrıca çöpün depolanması sonucunda yeraltı sularının kirlendiği anlaşılmıştır. 1959 yılında, Amerika Birleşik Devletleri’nde çöplerin sıhhi bir şekilde gömülmesi benimsendi. Ayrıca toplama sistemleri de gözden geçirildi. Katı atığın geri kazanılması mümkün olduğunca temiz bir toplama gerektirmektedir [8].

Türkiye’de, bu sistemlerin hepsi farklı bölgelerde ve farklı durumlarda uygulanmaktadır ancak en yaygın olanı çöplerin tek bir çöp arabasıyla toplanmasını, sadece bir kısmının ayrıştırılmasını, bazı tesislerden de geri kazanılabilen atığın ayrı toplanmasını içeren entegre bir toplama sistemidir. Ancak bu yöntemde evsel atık yeterince değerlendirilememektedir. Uygulanabilecek bir başka yöntem de çöpün tek bir çöp kovasıyla toplanıp, geri kazanılabilen katı atığın ayrıştırma tesisinde ayrıştırılarak geri kazanım tesisine gönderilmesi süreçlerini kapsayan yöntemdir. Bu yöntemde de ayrıştırma maliyetlerinin eklenmesiyle toplam maliyet diğer yöntemlerin maliyetlerine oranla yüksektir. Bir diğer yöntem de kaynaktan ayrı toplamadır. Bu yöntemde, toplanan katı atık ayrı ve temizdir, dolayısıyla geri kazanım oranı çok yüksektir. Ancak ayrı toplama, evlerde farklı poşetlemeyle başladığı için, uygulaması zor bir yöntemdir [9,10].

Bu çalışma, hangi toplama sisteminin en etkin sistem olduğunu belirlemeyi amaçlamıştır. Kağıt ve karton kağıt en çok tüketilen katı atık olduğu için, kağıt geri dönüşümü sisteminin incelenmesi uygun görülmüş, çeşitli özel kuruluşlardan ve İstanbul Belediyesi'nden bu sistemin verileri toplanmıştır. Birçok etkene bağlı olarak değişkenlik gösteren bu veriler kesinlik taşımadığı için bulanık kabul edilmiştir. Bu nedenle en etkin toplama sisteminin seçimi, bulanık çok amaçlı karar verme tekniklerinden biri olan bulanık hedef programlama tekniğiyle ve bulanık çok ölçütlü karar verme tekniklerinden biri olan fuzzy/bulanık TOPSIS tekniğiyle yapılmıştır. Bu iki uygulama en etkin çöp toplama sisteminin belirlenmesini sağladığı gibi, iki farklı karar alma tekniğinin karşılaştırılmasına da olanak sağlamıştır.

1. INTRODUCTION

In our world, the resources and the capacities are finite, or as the world population is increasing continuously, the resources are exhausting rapidly. So the recovery of used products is becoming more important. As the storage areas are limited, another problem appears: the waste reduction. It is a major concern of industrialized or densely populated countries because of the huge amount of waste produced after manufacturing or consumption [1].

For a long time, product recovery has been considered as an engineering function, but recently, it has been recognized that it is a logistic function. The process begins with the goods flows from users to producers. So the process works in the reverse direction that is why we call the system as reverse logistics [1]. Reverse logistics notion includes many activities as return to supplier, remanufacture, resell, reuse, recycle etc.

In this study we observe a special subsystem of reverse logistics: the solid waste recovery system. This reverse logistic configuration is called green logistics. The study focuses especially on a specific function of this subsystem: the collection of solid waste. This function includes collection of waste from houses and diverse facilities and its transportation to a land filling area or to a facility where it will be separated or recycled. The schema below elucidates the obscure points of the collection system:

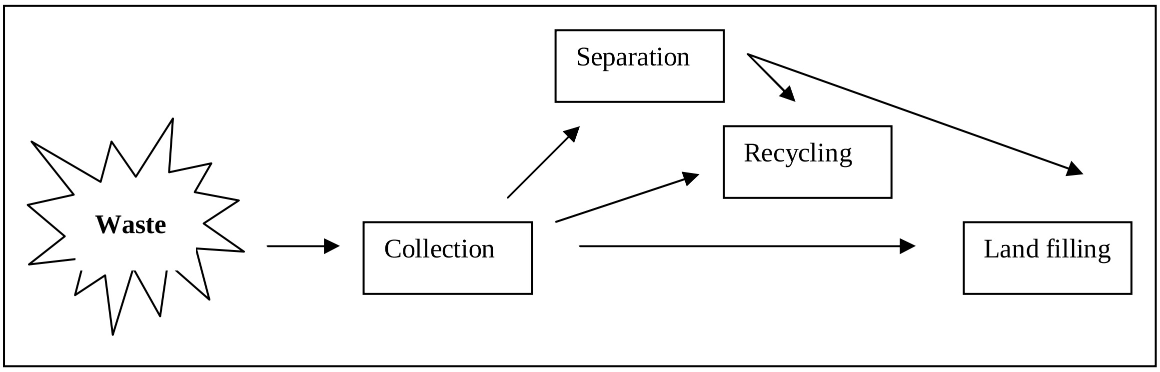

Figure 1.1 : Solid waste collection and recovery system

After the collection, the waste can go ahead through diverse process, related to his collection manner. Generally it is collected mixed from the source, so the next step can be the land filling process or the separation process if we want to recover exploitable waste. Another option is the separate collection from the source which provides a clean collection adequate for recycling.

Considering the information on the collection system and the recovery need of the world, the study focuses on deciding which collection method is the most efficient for our world. As it is almost impossible to execute the study for the entire world, we will choose Istanbul as pilot region. First because it is not realistic to believe that we can obtain reliable information for the entire world and secondly the data obtained from different countries can't be compatible because of different monetary standards and different environmental goals. To make a realistic decision, we have to use realistic and comparable data and also a proved decision method.

Whatever is the system and its complexity, an essential function waits to be debated in each problem: The Decision. In the real life of organizations, we are faced with difficulties due to the paradox created by diverse contradictory situations and attributes. The decision maker has several points of view often contradictory in the decision making process.

Decision has inspired reflection of many thinkers since the ancient times. The great philosophers Aristotle, Plato, and Thomas Aquinas are some of these philosophers who discussed the capacity of humans to decide and in some manners claimed that this possibility is what distinguishes humans from animals [2].

For many years, it has been believed that the only way to state a decision problem was the definition of single criterion. This is very reductive, and in some sense also unnatural. It amalgamates the multidimensional aspects of the decision into a single scale of measure [2]. We can assign three major elements to the decision making process: (1) finding occasions for making a decision, (2) finding possible courses of action, and (3) choosing among courses of action [3]. Each course of action constitutes the alternatives which will be rated according to different points of view contradictory that we call criteria. Given these basic elements, multi-criteria decision making is an activity which helps making decisions mainly in terms of choosing, ranking or sorting the actions [3].

Multi-criteria decision making is one of the most well known branches of decision making. Many authors [Zimmermann, 1996] divide multi-criteria decision making into two branches: Multi-objective decision making and multi-attribute decision making. Whereas we use the term multi-criteria decision making instead of the term multi-attribute decision making. Multi-objective decision making is generally used to make decision when the decision space is continuous and discrete decision spaces are generally subject to multi-criteria decision making problems [4].

In the first part of this study, we deeply analyze the recovery of solid waste by touching upon the reverse logistic system and by defining the green logistics and its importance. This part is concluded by the detailed portrait of paper recycling system in Turkey. The portrait includes the information on the collection methods of solid waste and the paper consumption. As we are faced to make a decision, a second part is dedicated to the decision making process where we introduce methods that we use; these are: Fuzzy goal programming, Fuzzy TOPSIS. In real world applications, we are vis a vis uncertain data, namely we cannot express the data by absolute numbers but by approximate values or linguistic variables. To handle such problem we use fuzzy extension of each decision making model. In the final part we choose the most efficient collection method for paper recycling system in Istanbul by using two methods mentioned before.

Thus, this study brings about the answers to these questions:

(1) Which is the efficient collection method and what are his yields?
(2) What are the arguments confirming the usage of these decision making methods?
(3) What are the strengths and weaknesses of these decision making methods?

2. SOLID WASTE MANAGEMENT SYSTEM

2.1 Reverse Logistic

The Council of Logistics Management defined Logistics as the process of planning, implementing, and controlling the efficient, cost effective flow of raw materials, in-process inventory, finished goods and related information from the point of origin to the point of consumption for the purpose of conforming to costumer requirements [5]. The term “logistic” drift from the Greek "logos" which means "word" or "order". For the Greeks in fact the two concepts were closely connected and expressed with the same writing "graphical sign". That is from logos that derives also "logic" the study of the reasoning. Other etymology interpretation comes from the French "loger" which means "to locate", "to allocate". Logistics is a function whose purpose is the satisfaction of the expressed or latent needs, in the best economic conditions for the company and for a level of service determined. The needs are of internal nature (provisioning of goods and services to ensure the operation of the company) or external (customer satisfaction). Logistics makes call to several branch of business and know-how which contribute to the management, to the physical flow of information and to the financial flows. Initially, logistics came into being in the military field, in particular military engineering. It is the whole of the techniques introduced to ensure the provisioning, and the maintenance in operational conditions of the troops. Generally, logistics indicates the instruments enabling the consistency between the delivery of a product and its request at lower cost. (In a given place, at a given moment) But today, the term sticks more to the tools, the methods, the management of the flows of products etc [6].

Reverse logistics includes all of the activities and characteristics that are mentioned above. But the difference is that all of these activities are executed in reverse. So we can change the definition of The Council of Logistics Management as the process of planning, implementing, and controlling the efficient, cost effective flow of raw materials, in-process inventory, finished goods and related information from the point of

consumption to the point of origin for the purpose of recapturing value or proper disposal. More precisely, reverse logistics is the process of moving goods from their typical final destination for the purpose of capturing value, or proper disposal affirms Rogers and Tibben-Lembke [5]. This discipline consists in managing and optimizing flows coming from the consumer in direction of the manufacturer. Its most known form is that of the Service After Sale but it tends to develop towards recycling and more particularly that of the EECS (Electric and electronic component scrap). The return of the defective products, the overstocks and the articles at the end of the lifetime are also topics which are closely dependent for him. Typical reverse logistic activities would be the processes a company uses to collect used, damaged, unwanted (stock balancing returns), or outdated products, as well as packaging and shipping materials from the end-user or the reseller [5]. Some of these activities are summarized in Table 2.1.

Table 2.1: Common Reverse Logistics Activities

Material	Reverse Logistics Activities
Products	Return to Supplier Resell Sell via Outlet Salvage Recondition Refurbish Remanufacture Reclaim Materials Recycle Landfill
Packaging	Reuse Refurbish Reclaim Materials Recycle Landfill

2.2 Green Logistics

In this study we are handling “Green Logistics” which is a system of distribution and friendly efficient transport for the environment. Green logistics is more than reverse logistics because it seeks to save the resources, to eliminate the waste and to improve the productivity. It must have the smallest trace on the environment. This definition also takes up the idea of eco-design of the products (manufacturing without using toxic materials) allowing an easier reprocessing of waste at a lower cost.

Many companies first focused on reverse logistics issues because of environmental concerns. And it seems evident that environmental considerations will have greater impact on many logistics decisions as:

- Landfill costs have increased steadily over recent years and are expected to continue to rise;
- Many products can no longer be land filled because of environmental regulations;
- Economics and environmental considerations are forcing firms to use more reusable packaging, totes, and other materials;
- Environmentally motivated restrictions are forcing firms to take back their packaging materials;
- Many producers are required by law to take back their products at the end of their useful lifetime [7].

2.2.1 Why Recycling?

Recycling and reuse have been key issues around the globe since the 1980s because there is a growing interest in environmentally conscious manufacturing and the consumers expect environmental improvements from producers. The new trend brings these new notions: How much energy is expended in unit product manufacturing? How much resources are used? How much waste is created? What are the product requirements for transportation and distribution? These are not issues that product designers are accustomed to considering. Their traditional role has been to look at the product by itself and design products that meets specific guidelines and may be environmental pollution laws. Today's focus is different. Manufacturers must take a product stewardship approach and this will predict their survival in today's competitive environment [7].

There is an analogy between an industry and an ecological system according to Ayers (1989) [7]. The manufacturer isn't interested only in product design, costs and economic benefits but also in energy expense, waste formation after the manufacturing. Ayers affirms that all kind of living necessitates food to produce energy and release waste as by-product. Then, it is a ring of the food chain. The circumstance changes in industrial environment where a huge amount of waste is produced. Industrial societies are increasingly faced with the problems of hazardous waste management, locating new landfills, and depletion of raw materials. Rather than continuing with this cycle of waste and extravagance, Ayers (1989) proposed that industrial economies should find better ways to convert wastes from one industry into input in another industry [7]. Today many public or private industrial institutions are faced to new management disciplines as environmental protection, responsibility for solid waste collection and recycling [8]. The recovery of solid waste is economically and environmentally worthwhile. Instead of land filling materials as glass, plastic, metal, ceramic and paper, we can assess them as secondary raw materials. Thus, it is possible to decrease the raw material need of the industry and also possible to decrease energy consumption for the raw material production. Moreover, as the density of these materials is low, they compose a huge volume of waste. The regain of exploitable waste decrease the volume of the waste going to land filling area, with important grades.

We all know that we generate waste and when we stop to think about it, we feel that something could and ought to be done to reduce or recycle what we discard. The European Community (EC) Strategy for Waste Management (SEC (89) 934) which was adopted in May 1990, established a hierarchy of preferred waste management approaches which has now been universally adopted. In descending order of preference this hierarchy is [9]:

1. waste minimization;
2. material reuse;
3. material recycling;
4. energy recovery from waste;
5. safe disposal.

The first step is to reduce the amount of waste that we produce by minimizing the quantities of natural resources that we convert into products and then discard. But our society has a "*consumer culture*" which forces him to consume as many products as he can buy. Therefore, the waste minimization notion does not seem realistic. It also necessitates a high educated and conscious population.

On the other hand a product reuse system is not applicable for all kind of product. So we come to the third waste management option, that of material recycling, which is important for three reasons [9]:

1. The recycling of waste to recover useful materials reduces our need for virgin raw materials. This has two benefits in that many raw material reserves are finite and

the extraction or harvesting of such resources can in itself be extremely destructive to the environment. For example, the production of plastics from naturally occurring oil uses finite resource. Aluminum is produced from bauxite, an abundant but finite resource and the mining of which is extremely destructive to the environment.

2. The reprocessing of waste materials can generate significant energy savings compared with the production of the equivalent virgin material. For example, producing new glass from cullet (broken, discarded glass) uses 25 per cent less energy than producing glass from raw materials of silica sand.
3. Recycling reduces the amount of waste that requires disposal, thus reducing the environmental damage that waste disposal creates. Land filling of waste can create ground water contamination and air pollution. The incineration of waste gives rise to carbon dioxide [9].

Even the intend is to maximize environmentally conscious recycling, there will always be some waste materials that we cannot recycle because they are too contaminated or it is too expensive to recycle these materials. The disposal process begins at that point. According to EC waste management hierarchy, next option is energy recovery from waste. For example the waste is burned to produce heat which is directly used to provide heating to buildings or indirectly used to produce electricity [9].

Before we can decide which elimination method we will adopt; how we can increase the current level of recycling, we need to know what materials there are in the household waste streams which are capable of being recycled and for each of these materials, how much is available. There is, however, quite detailed information available on the composition of household waste. Such waste is collected both directly from the household in the form of dustbin waste and indirectly through householders taking their waste to civic amenity sites. Clearly it is very important to know what materials are present in the waste stream and in what proportions, before any plans are made to introduce recycling [9].

Table 2.2: Usage area of exploitable waste (Ministry of Environment and Forestry)

Waste Type	Usage Area
Glass	Secondhand glass, after thawing, can be used for all kind of glass product. But there is some delimitation for white glass.
Metal	Secondhand metals, after thawing, can be used for initial intended use. Due to the characteristic of alloy, cross applications (as using bins after thawing to produce window bar) may not be always possible.
Plastic	The reuse of plastic products is limited. The mechanical separation of plastics is very difficult when we take into account the diversity of various kinds of plastics. So it is almost impossible to obtain high quality secondary product. Secondary plastic materials must not be in contact with food. It can be used only for external hull, pipe, flower pot, plastic furniture.
Paper	It is added to the pulp of new paper, provided that it does not exceed a specific proportion. Papers produced from waste paper in the ratio of 100%, cannot reach the quality of paper produced from wood, in color and configuration.
Textile	It can be used for paper production, filling material, insulation material and cord production.
Wood	It can be used in paper production and as fuel.
Bone	It can be used in the production of gelatin and similar materials.

2.2.2 Background Information on Waste Management in Turkey

The exploitable solid waste is composed of glass, ceramic, paper, plastic, metal, leather and wood. Considering the data received from State Institute of Statistics (SIS) of Turkey, the exploitable solid waste weight percentage was around 30% in 2004. This rate shifts for different allocation units related to different consumption habits. In rural area it decreases to 15% ranks. These rates increase every year proportionally with population growth. General waste characterization of Turkey is given in the subjacent figure [[10],[11]].

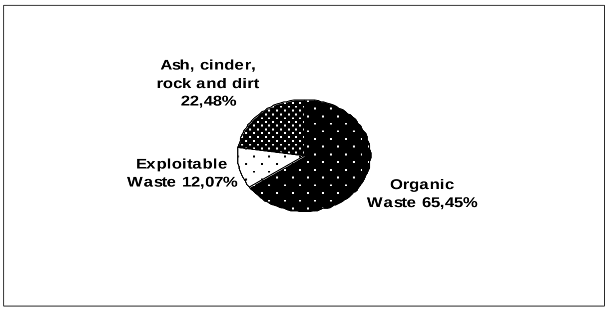

Figure 2.1: General waste characterization of Turkey

2.3 Paper

Paper is the most important exploitable solid waste due to his proportion in the whole. Upsurge in population, development of living conditions, urbanization, rise of reading habits, development of the print, increase the paper consumption. The paper consumption of countries depends on their revenues. Paper consumption unit is paper/person/year. Table 2.3 includes the data about the paper consumption of different countries.

Table 2.3: Paper consumption per person

COUNTRIES	PAPER CONSUMPTION (Kg/person/year)
USA	332
GERMANY	187.7
JAPON	239
UK	163.5
EUROPEAN UNION	190
ASIA (Average)	26
AFRICA (Average)	5.5
WORLD (Average)	50.4
TURKEY (Average)	42.0
ISTANBUL	53.0

In 1980 paper production in Turkey was around 600,000 ton per year. In 2004 it became 1,900,000 ton per year. Average proportion of annual increment is at 7% order. Especially in Istanbul, a study on solid waste in 2003 demonstrates that household solid waste is consisted of 9.71% of gross paper (4.47% dry paper). This rate is higher for schools and offices. In the aggregate, paper constitutes approximately 7.5-9% of the solid waste.

The subjacent table shows the waste paper rate in different cities of Turkey.

Table 2.4: Waste paper proportion in each city

City	Paper proportion (%)
Ankara	7.9
Izmir	12
Bursa	10
Antalya	19
Denizli	7.2
Gaziantep	5.2
Diyarbakır	8
Trabzon	5
Rize	4
Istanbul	7.5-9
Touristy Regions	11.55

But this entire amount isn't available for regaining or recycling. The data of SIS illustrate largely the composition of exploitable solid waste. Turkey is the 28th largest paper and carton paper producer, 23rd largest paper and carton paper consumer in the world [10,11].

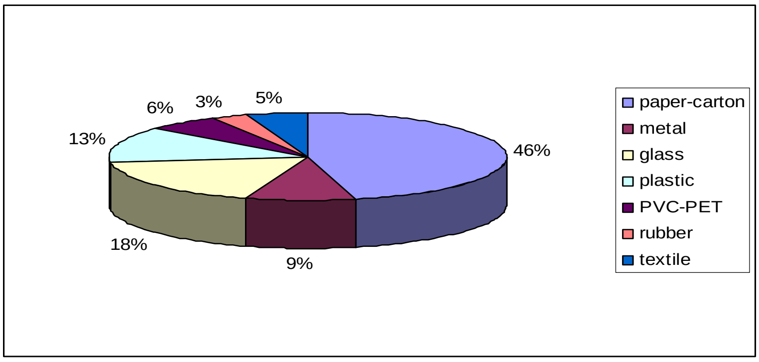

Figure 2.2: Composition of exploitable solid waste

2.3.1 The Production Process of Paper

The production process of paper from wood is composed of several steps. The process begins with woodcutting. Woods are transported to an appropriate point. Cutting tool equipments and means of transportation are considerably large-size. So it is inevitable to cut some of trees and this affects negatively the natural life of animals and vegetation. And this act is irreversible. Every year, 1.3% of world forests are used in the paper production and this is approximately the equal area of Paraguay or Switzerland [12].

The wood is kept waiting in water 10-15 days because the wood must involve 20-25% water. The next step is the separation of the bark from the wood. The turnout of the raw material is very low as it seen. After the separation step, the wood is converted to the wood pulp. There are two methods for this conversion: mechanical paper production and chemical paper production. With the first method we obtain a low grade pulp. The second one is harmful for the nature because chemical solutions are used to ensure the abrasion of wood [12]. In this pulp production process, waste paper can be used as raw material if a lower quality is acceptable. This will reduce wood cutting and energy dissipation. The graphic below demonstrates the difference between the production from wood and the production from waste paper.

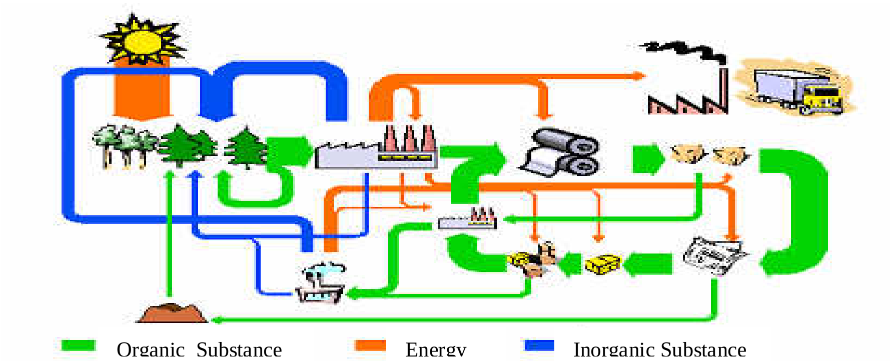

Figure 2.3: Paper Production process

2.3.2 The Advantages of Waste Paper Recycling:

In 1985, the usage of waste paper in paper production was 31.6% and this rate increase to 41.9% in 1995. It is still growing as the environmentally conscious manufacturing outpaced all manufacturing conventions. Forests are oxygen producers as a tree growing 1000 gr. absorbs 765 liters of CO_2 and produces 770 liters O_2. The CO_2 concentration increased 30% in the twentieth century. We know that 57% of CO_2 is absorbed by forests and seas. The usage of waste paper will reduce the wood cutting and also the greenhouse gas and methane formation in storage facility. In paper production facility, waste paper is separated into small pieces. The material obtained after this separation is soaked. So, the remanufacturing of fibers causes 10-15% loss [12].

In the paper production process a huge quantity of energy is used. The quantities of energy used during the paper and the pulp production process are mentioned in the table below [12].

Table 2.5: Different energy consumption

Type of Pulp	Paper Production (GJ/t)	Pulp Production (GJ/t)
Wood Pulp	30-37	15-25
Kraft Pulp	35-54	26-45
Waste Paper Pulp	13-17	5

On the other hand, for paper production from wood, 20-50 tons water is required. Or 5 tons are sufficient for paper production from waste paper. The table below makes a comparison between paper production from wood and from waste paper. The amounts are for 1 ton paper production [12].

Table 2.6: Comparison of paper production from wood and waste paper

Resources	1 ton Paper from Wood	1 ton Paper from Waste Paper
Usage of Wood (ton)	2.4	-
Usage of Waste Paper (ton)	-	1.2
Usage of Water (ton)	440	1.2
Usage of Electrical Energy (kWh)	7600	2800

When the waste paper is chucked out, it is decomposed 3 months from-to five years. Or when 1 ton paper is recycled instead of throwing, we can prevent:

- The cutting of 17 mature pines
- The emission of 36 tons of CO_2 in the atmosphere
- The dissipation of 4100 kWh of electrical energy
- The emission of 267 kg of pollutant gas in the atmosphere
- The dissipation of 1750 liter of fuel-oil
- The dissipation of 3-4 m^3 of warehouse area
- The destruction of 85 m^2 of forest area
- The dissipation of 38.8 tons of water [12]

In Turkey the solid waste amount going to waste storage area is 65000 tons per day, it is 13000 tons per day in İstanbul as mentioned before. So the reuse or the regain of waste paper reduces the solid waste amount which will go to storage area. The regain of waste paper creates new jobs and lengthen the life of waste storage area. 1 ton paper regained releases 3-4 m^3 waste storage area. In Istanbul the proportion of waste paper going to waste storage area is 7.5- 9% which means 975 tons of paper. The regain of the half of this amount will lengthen the life of waste storage area in Istanbul in the proportion of 7.5-10.7% and will reduce the waste elimination cost 2373000-2555000 $/year.

2.3.3 Efficient Recycling

In order to realize this regaining potential, the existing methods of waste collection need to be changed and new techniques of material collection need to be implemented. However, as we seen, not all waste is recyclable, so that there will be a continuing need for the existing waste collection and disposal services. It is therefore vital that any new arrangements for recycling are integrated with the existing methods of refuse collection and disposal, in order to ensure that we maximize the efficiency and effectiveness of both methods of waste management [9].

To collect cleanly is important as much as to find the efficient collection method. It is extremely important to constitute a separate collection system in first-degree paper producers as schools, offices and then in secondary producers as houses. Because the collection and the transportation of waste paper constitute the maximum cost. Germany, Austria, Norway, Finland and Sweden are the countries where the regaining percentage reaches the highest value.

Each waste collection authority is responsible for organizing the collection of waste for its area and the delivery of this waste to a point of disposal [9].

In United Kingdom, waste collection authorities prepare each period a waste recycling plan which requires to:

1. Decide what arrangements are appropriate for dealing with the waste by separating, baling or otherwise packaging it for the purpose of recycling it.
2. Decide which collection method will be the most effective for increasing the amount of waste reserved for recycling, by considering also the cost of each method.
3. Plan which instruction program will be managed to inform the public.

2.4 Collection Methods

The exploitation of the solid waste involves a collection process as clean as possible. There are many methods of collection. In ancient Greece, in the fifth century before J.C., people were responsible for carrying their own garbage to the town dump. Then, in Roman Empire, people used to depose their garbage into the streets, where it was collected by horse-drawn wagons, and taken to a centrally located open pit. These habits were broken during the Dark Ages and also during the Renaissance. During these times, trash was generally discarded without much thought given to its effect on people and the environment [5].

Until the 1950's, waste disposal still consisted primarily of burying waste in a large pit. But by the mid-1950's people began to recognize the harmful effect of burying trash without control and the need to analyze groundwater down gradient from landfills. And by 1959, the sanitary landfill was the primary waste disposal system used in USA. In a sanitary landfill, also known as controlled tip, trash is sealed in cells from earth or other materials. For a number of years, there has been a perception of an impending shortage of landfill space [5].

The exploitation of the solid waste involves a collection as clean as possible. There are many methods of collection and there is a list below containing some of these methods and the percentage of waste regained by each method [10 ,11].

Table 2.7: Different Collection methods

COLLECTION METHOD	THE PERCENTAGE OF WASTE REGAINED
System operated by one garbage pail	15-20
Multiple pail system	10-15
Trash bag system	13-19
Separate garbage pail for biologic waste	20-25
Central collection container for each material	< 8
Collection from houses by commercial organizations	5-8

The general collection method in Turkey is the system operated by one garbage pail. In this system, the garbage is separated in a separation facility. And then each material is transported to the facility where they are recycled or recovered. Another method is the separate collection at source. This method is used in many way but we can define the system on the whole by ‘collection with many trash bag’. In Turkey there is also another system more practiced actually: it is the collection of each material which can be recycled from the point where they are produced or where people use only this kind of material. For paper, these points are paper manufacturers or schools and offices. But in this system, domestic waste isn’t exploited and this may be an important loss. The costs grow out of regular collection from every houses, factories, offices etc. Except the separate collection at source we can observe other two methods in Turkey. In Istanbul, the separate collection is recently implemented in pilot regions but it is still in the pipeline.

Before 1996, waste paper and packaging waste were collected through garbage in unhealthy conditions. This inconvenient collection process brought extra cost to the Istanbul Municipality. Another inconvenience in this collection process was that paper and all other recyclable materials were greasy and dirty.

2.5.1 Current Collection Method

This is the regular collection system which focuses only on throwing off the waste and does not have environmental senses. This unsystematic collection does not necessitate special containers or bags because it is not a subject to any standard. These systems can be seen more advantageous to municipalities with lower cost and the easiness of organization. But the facts that the waste is leftover in the open air, trash bags are torn, serious hygienic problems may occur. Haphazard bag usage causes waste water leakage. Other negative effects are putrefaction, general pollution, insect attraction etc. To reduce these effects municipalities may have to account for more often collection which will increase costs. It is impossible to obtain noteworthy recyclable material and there is no separation activity after the collection. There are some unregistered junk collectors whose health is under serious danger. The income is unregistered as the quantity of material regained.

2.4.2 System Operated by One Garbage Pail

This system relies on the regular collection system. The unique difference is the separation process executed by the municipality after the collection. There are extra costs as separation facility investments, separation employee's fees, and transportation costs after separation. This method increase the efficiency of regain but there are still negative aspects as the lower quality having as reason the mixed collection with organic waste.

2.4.3 Separate Collection at Source

The efficiency of this system is very high but it is very hard to implement this system whether because of the different segments of the society whether because of the disorganization of responsible waste collection institution. The separate collection of recyclable waste provides high quality last products after recycling as the recyclable waste isn't mixed with organic waste. This collection system requires extra costs for new containers, new trash bags to each segment of material as paper, plastic, metal etc. The discharge of these containers is effectuated exactly same as the discharging process in the regular collection system, that is to say by ash carts.

The vehicles used to collect household waste, namely ash carts, have become increasingly sophisticated and are known collectively as waste collection vehicles. Most waste collection vehicles are rear-ending loaders, that is, the waste is loaded into the rear of the vehicle. In order to maximize the payload of the vehicle and hence its collection efficiency, all such vehicles have compaction devices which compress the loose refuse, normally in a ratio of about 3:1 [9].

When a waste collection vehicle is full, it is driven to the point of discharge (a landfill site, incinerator or transfer station), the rear section of the vehicle body is raised and the compacted waste ejected using the hydraulic ram which forms part of the compaction system. The type of waste collection container and the arrangements for its collection determine the size of the collection vehicle crew required. For example, a collection system based on waste sacks being collected by the crew from the rear of a household, factory, office (called 'back-door' collection) will typically require a crew of two or three operators plus a driver. In Turkey, the average number of operators is three with the driver [9].

2.5 Research of Literature

The costs of waste collection vary considerably with the methods used and the area being serviced. The costs for different waste collection methods in Istanbul are given in the application part of the study.

The waste disposal is vital for human health and the environment so it has been subject to many studies. As we are interested in making decision by using goal programming and TOPSIS, this literature research focuses on the usage of goal programming and TOPSIS in solid waste management.

In this study, we observe the logistical aspects of waste systems. Closer studies are those of Alidi [13] who treats hazardous waste systems planning; of Sudhir et al. [15] who propose a planning for urban solid waste management considering renewable and nonrenewable sources, and also environmental impacts of waste disposal; of Chang and Wang [17] who evaluate the compatibility between municipal solid waste management systems and incineration. The Chang’s study is very close to our study where we are trying to evaluate the compatibility between the current waste disposal method and the recycling target.

As TOPSIS study we can quote that of Cheng et al. [21] on selection of an optimal landfill site.

Table 2.8: Literature Research on Goal Programming in Solid Waste Management

GOAL PROGRAMMING IN SOLID WASTE MANAGEMENT				
	Year	**Article Title**	**Author(s)**	**Journal Title**
1	1992	An integer goal programming model for hazardous waste treatment and disposal [13]	Abdulaziz S. Alidi	Applied Mathematical Modeling, Volume 16, Issue 12, December 1992, Pages 645-651
2	1992	Indian urban solid waste management systems—Jaded systems in need of resource augmentation [14]	A. V. Shekdar, K. N. Krishnaswamy, V. G. Tikekar and A. D. Bhide	Waste Management, Volume 12, Issue 4, 1992, Pages 379-387
3	1996	Integrated solid waste management in Urban India: A critical operational research framework [15]	V. Sudhir, V. R. Muraleedharan and G. Srinivasan	Socio-Economic Planning Sciences, Volume 30, Issue 3, September 1996, Pages 163-181
4	1997	Value analysis of disposal strategies for automobiles [16]	Surendra M. Gupta and Jacqueline A. Isaacs	Computers & Industrial Engineering, Volume 33, Issues 1-2, October 1997, Pages 325-328
5	1997	Integrated analysis of recycling and incineration programs by goal programming techniques [17]	Ni-Bin Chang and S. F. Wang	Waste Management & Research, Volume 15, Issue 2, April 1997, Pages 121-136
6	1997	A fuzzy goal programming approach for the optimal planning of metropolitan solid waste management systems [18]	Ni-Bin Chang and S.F. Wang	European Journal of Operational Research, Volume 99, Issue 2, 1 June 1997, Pages 303-321
7	2006	Disassembly to order system under uncertainty [19]	Elif Kongar and Surendra M. Gupta	Omega, Volume 34, Issue 6, December 2006, Pages 550-561
8	2007 (to appear)	A goal programming model for paper recycling system [20]	Rupesh Kumar Pati, Prem Vrat and Pradeep Kumar	Omega, Volume 36, Issue 3, June 2008, Pages 405-417

3. DECISION MAKING PROCESS

In the real life, as mentioned before we are faced with difficult choices emanating from the diversity of the factors which influence the decision. For example, the price and solidity are two criteria which are in conflict. If the decision is taken according to price, we are likely to buy a not very solid good. In addition, if we want to buy a rather solid good, it is strongly probable that we will pay more. Thus we can lead to a result only by the compromise of decisions. In the majority of situations, the risk also, is a criterion which goes in the contrary direction of the other criteria. It intervenes in fact practically in all decisions.

3.1 History of Decision

In fact, the concept of contradictory criteria exists in the popular culture since ages, but appears on the scene of scientific research only at the end of the 19th century. At that time the economists started to seek the bonds between the behavior of the economic agents and the economy. But at that time the economic behavior was explained like the maximization of the function of utility. The concept of distinct criteria did not exist. It is Pareto who proved that all the agents could not obtain their maximum satisfaction at the same time. The situation where the agents cannot maximize their profit any more all at the same time calls "the Pareto's optimum". Thus in a group made of several agents, each one with different preferences, we are faced with the multi criteria problems [22].

In addition two judges brought together in a jury, who must give a single judgment whereas they have two different criteria, make the multi criteria analysis without the knowledge. These problems were studied by the Marquis de Caritat de Condorcet around 1780 and he published it in 1785 in its book “Essai sur l’application de l’analyse à la probabilité des décisions rendues à la pluralité des voix ". Condorcet was a precursor of the scientific reflection in the field of the social sciences. He knew very well that the context of the judges was extending to the problem of vote since, when n voters must choose, each one with its own criteria or motivations, only one elected among n

candidates; it is the problem of social choice. Chevalier de Borda (1733-1799), spirit less theoretical than Condorcet, proposed a simple method of social choice, less known than one of Condorcet. The method of Borda was adopted by the Academy for the election of the new members [22].

After the Second World War, the economist current and the political current converge to become the social choice theory, the theory of the vote and of the multi criteria analysis whose basic elements are common. The synthesis of two currents was carried out within the general framework of micro economy, under the impulse of many economists like Hicks, Bergson and Samuelson founders of "the new economics of welfare". Emanating from the micro economy, the need to look further into the bond between the individual behavior of the agents and the results observed in the company was felt. From another point of view, the relation between choice and relation of order are fundamental in the theory of the consumer. It is the theory of the revealed preferences initialized by Samuelson (1938) which will be studied by the American school with the problem of the choice of a group of agents or social choice. For this field we can note moreover fundamental theoretical contributions of Savage (1954), and Debreu (1960) [22].

From 1960, the multi criteria decision analysis adopts its current problems: problem of choice of an action in the presence of multiple criteria. We can quote works on the "goal programming" of Charnes and Cooper (1961) who solve the problem of multi criteria decision, in linear programming, by the search of a solution remotely minimal of a multi criteria objective (goal), generally unrealizable, fixed by the decision maker. In 1968, appeared, the concept of outclassing (Roy, 1968) and the method of associated discrete multi criteria decision, ELECTRE [22].

In 1970 was held in The Hague (Netherlands), within the framework of the seventh mathematical congress of programming, the first scientific meeting devoted to the multi criteria analysis. In the United States, in the years 1970, the reflexion on the multi criteria decision was dominated by the discussions over the additivity of the preferences. The most durable result between those of Leontief in 1947, Debreu in 1960, Fishburn in 1965 and others was method MAUT popularized by the book of Keeney and Raïfa (1976). From 1975, a French school explored the discrete multi criteria decision, the relations of outclassing and the preferences of the decision maker. And in 1985, the multi criteria methods knew world diffusion. The most outstanding element of the Eighties is the introduction of data processing into the reflexion on the multi criteria decision. The interactive methods could consequently be established very easily and the possibilities of the machines, in particular of the microphones, are an important element of reflexion in the design even of the methods. Finally data processing brings its own methods like the artificial intelligence [22].

3.2 Common Aspects of Decision Making Methods

As we mentioned before, the multi-criteria decision making is divided into two branches: Multi-objective decision making and multi-attribute decision making [4].

Whatever is the decision making method used; the primary concern for the decision aid is the following:

1. choosing the most preferred alternative to the decision maker (DM)
2. ranking alternatives in order of importance for selection problems, or
3. screening alternatives for the final decision [23].

Although the methods of multi-criteria decision making are largely varied, they have certain common aspects like the concept of alternatives and the concept of attributes [4]:

Alternatives: In general, the alternatives represent the different choices of action available to the decision maker. The series of alternatives is supposed to be limited [4].

Multiple Attributes: Each multi-criteria decision making problem is associated with multiple attributes. We can also name the attributes like the goals or the decision criteria. They represent various dimensions of the alternatives. In the situations where the number of criteria is large, the criteria can be classified in a hierarchical manner. In this case, certain criteria can be the major ones. Each major criterion can be associated with several sub-criteria [4].

The Conflict between Criteria: Since the various criteria represent various dimensions of the alternatives, they can be in conflict with each other [4].

Disproportionate Units: The various criteria can be associated with various measuring units. The fact of being obliged to consider the various units makes the multi-criteria decision problems harder to solve [4].

The Weight: Several methods of multi criteria decision making require that the criteria be associated weights of importance. In general, these weights are standardized to swell to 1 [4].

The Decision Matrix: A multi criteria problem of decision can be easily represented in a matrix form. A matrix of decision A is a matrix $(m*n)$ in which element a_{ij} represents the performance of the alternative A_i when it is considered under the existence decision criteria C_i $(i = 1, 2, ..., m \;\; and \;\; j = 1, 2, ..., n)$. In other words the matrix (a_{ij}) is called the matrix of decision or performance table. Each line of this matrix expresses the performances of the action or alternative i relative to n criteria considered. Each column j expresses the evaluations of all the actions (alternate) made by the decision maker, relative with the criterion j [4].

3.3 General Formulation of a Multi-criteria Decision Making Model

In multiple criteria decision making (MCDM) problems, there does not necessarily exist the solution that optimizes all objectives functions as mentioned before, and then the concept which is called Pareto optimal solution (or efficient solution) is introduced. Usually, there exist a number of Pareto optimal solutions, which are considered as candidates of final decision making solution. We can express a MCDM problem in matrix form as:

$$\begin{array}{c|cccc} & C_1 & C_2 & \cdots & C_n \\ \hline A_1 & x_{11} & x_{12} & \cdots & x_{1n} \\ A_2 & x_{21} & x_{22} & \cdots & x_{2n} \\ \vdots & & & & \\ A_m & x_{m1} & x_{m2} & \cdots & x_{mn} \end{array} \qquad (3.3a)$$

(3.3b)

$$W = [w_1, w_2, ..., w_n]$$

Here, $A_1, A_2, ..., A_m$ are the alternatives among which we will choose the best alternative considering the criteria $C_1, C_2, ..., C_n$. x_{ij} is the rating of alternative A_i with respect to criterion C_j, w_j is the weight of criterion C_j [23].

3.4 Decision Making under Uncertainty

The distinction between good decisions and good results is important in the case of uncertainty. It puts the point at the case of decision-making. If it is difficult to judge the quality of a decision, how can we get out of the decision-making process before the results are known? To better include/understand this problem, we have to consider the choices in general [24].

When the results of the alternatives are known and the consequences are described by only one measurement, then to make a decision is an easy task.

Or uncertainty involves the intervention of a new element called "risk". The complications coming from uncertainty extend to all phases of the process of decision-making. Sometimes it happens that we are unaware of uncertainty. The insurance and the banking investment are the examples of industries created to surmount the uncertainty and the risk.

Under uncertainty, we do not seek to maximize any utility function but to achieve satisfactory levels of utility based to our past experience. This means that single-objective mathematical programming models using certain data are inappropriate and weak in this situation [25].

Due to the high degree of imprecision of real world situations, it is unrealistic to make exact definition of these situations in decision making process. Zadeh [26],[27] proposed fuzzy set theory to handle this imprecision. Fuzziness is a type of imprecision which may be associated with sets in which there is no sharp transition from membership to nonmembership claimed Zadeh and Bellman [28] [4].

The solid waste disposal system involves many imprecision as it is a reverse logistic function. The reverse logistic is the reverse process of production which is rather appraisable. Or the production of waste is completely indeterminable. So the transportation costs and recycling rates can be appraised roughly. To handle this problem we use fuzzy extensions of each decision making method.

3.5 Goal Programming

The classical formulation of an operations research model is based on minimization or maximization of an objective function. But we have to recognize that it is impossible to represent all the points of view of a decision maker by only one objective function. This lack of representation leads us to adopt a new formulation of decision making problem where a set of objective functions representing different criteria have to be optimized. In general, the multi-objective optimization problem can be defined as finding a feasible alternative that yields the most preferred set of values for the objective functions [29].

Keeny and Raiffa propose a method to determine the utility function of the decision-maker in mathematical form. This utility function then represents a decision-maker's level of satisfaction with different alternatives. Mathematical programming is basically a static optimization problem, consisting of different models such as linear programming, goal programming, dynamic programming and game theory. Goal Programming (GP) is designed to deal with problems involving multiple conflicting objectives. This is a multi-objective technique [30].

Applications of decision analysis with multiple objectives have been summarized in several publications. Corner and Kirkwood (1991) have more than one hundred applications including applications in energy, manufacturing, services, public policy and health care sectors. Before these applications we must also cite the work of Bell, Keeney and Raiffa (1977) on the multi-objective decision making (MODM). Another application of MODM including personal decisions is found in Keeny (1992). Many of the descriptive concepts and ideas used in perspective analysis are discussed in Kahneman, Solvic, and Tversky (1982), von Winterfeldt and Edwards (1986), Bell, Raiffa and Tversky (1988), and Edwards (1992) [31].

Goal Programming (GP) has been used in diverse applications as Christmas tree optimization (Hansen, 1978), the pricing of alcoholic beverages (Korhonen and Soismaa 1988), the rationing of pregnancy (Minguez, Romero and Domingo 1988). But we can announce that the basic idea of GP has been traced by Romero (1992) to a study by

Charnes, Cooper and Ferguson (1955) on executive compensation. In the Charnes and Cooper (1961) book, GP was suggested for use in solving unsolvable Linear Programming (LP) problems [31].

It is very likely that objectives will conflict with each other in that the improved achievement with one objective can only be accomplished at the expense of another. Minimize costs and optimize the service quality are in conflict since the quality can only be obtained for a price. An objective generally indicates the direction in which we should strive to do better (by minimizing or maximizing according to the case). A goal is different from an objective. Goals identify a level of achievement to strive. Goal programming is a technique applied to linear programming problems in the presence of multiple objectives or goals [30].

In linear programming problems the objective function can be represented only by one measure as benefit, as productivity or as cost. Yet, organizations have many objectives or goals that cannot be represented by one measure. These objectives are often in contradiction. For example, in a firm, maximization of benefit measured by YTL (new Turkish lira) and maximization of production measured by unit coexist. In a firm, we can introduce also the problem of minimization of costs measured by YTL which is contradictory with the maximization of production [30].

In case there are many goals in a firm's management, we must rank them. In other words, we can associate an importance range to each one. And finally, minimization of the sum of deviations (positive and negative) will be the single objective [30].

A starting point for the GP model can be found by restating the LP model, its assumptions and modeling notation. The canonical form of the LP model permits the possibility of positive deviation from the right-hand-side (RHS) coefficients in the model, since the sum of the products in the left-hand-side can be greater than any bi. The mathematical requirements represented by the constraints must be satisfied in order to have a feasible solution [30]. For a LP model, optimization of the objective function is secondary to finding a feasible solution set of the x_j that will satisfy all of the constraints in a model. When one or more constraints in an LP model finds itself outside or in conflict with the area of feasible solutions; we have an infeasible solution. Each constraint that makes up an

LP model is separate function, called a functional. These functionals are viewed as individual objectives or goals to be attained. In effect, b_i are a set of objectives or goals that we must satisfy in order to have a feasible solution. If we subtract bi from both sides of an equality constraint, we can express the functional as the absolute value of an LP constraint [30].

Minimize: $Z = \sum_{j=1}^{n} c_j x_j$

subject to: $\sum_{j=1}^{n} a_j x_j \geq b_i, \quad for \quad i = 1,\ldots,m$

$$x_j \geq 0, \quad for \quad j = 1,\ldots,n \tag{3.5a}$$

$$f_i(x) = \left| \sum_{j=1}^{n} a_j x_j - b_i \right|, \quad for \quad i = 1,\ldots,m \tag{3.5b}$$

Charnes and Cooper (1961) referring to these functionals as goals, suggested that goal attainment is achieved by minimizing their absolute deviation. In this way it is possible to obtain a kind of solution where constraints are in conflict with one another [30].

Charnes and Cooper illustrated how that deviation could be minimized by placing the variables representing deviation directly in the objective function of the model. This allows multiple goals to be expressed in a model that will permit a solution to be found. A generally accepted statement of this type of GP model was presented in Charnes and Cooper (1977) [30]:

Minimize: $Z = \sum_{i \in m} \left(d_i^{+} - d_i^{-} \right)$

$$\text{subject to: } \sum a_j x_j - d_i^{+} + d_i^{-} = b_i, \quad for \quad i = 1,\ldots,m \tag{3.5c}$$

$$d_i^+, d_i^-, x_j \geq 0, \quad for \quad i = 1, \ldots, m; \quad j = 1, \ldots, n \tag{3.5d}$$

Where d_i^+ is called a positive deviation variable and d_i^- is called a negative deviation variable. The substantially useless value of Z is the summation of all deviations [30].

Ijiri established the assigning of relative weights to goals in the same priority level. Charnes and Cooper (1977) stated the weighted GP model as:

$$\text{Minimize: } Z = \sum_{i \in m} \left(w_i^+ d_i^+ - w_i^- d_i^- \right) \tag{3.5e}$$

In this study, we have to make a resource allocation decision, we have to choose one of the collection method. 0-1 goal programming is a strong method for resource allocation. Since the first introduction of goal programming in 1950's, many various type of goal programming solution methodologies have been appeared in the literature. There is a list below including various goal programming algorithms and methodologies used to generate integer goal programming and 0-1 goal programming solutions.

Table 3.1: Integer Goal Programming Studies [30]

Integer Goal Programming Studies					
	Year	**Article Title**	**Author(s)**	**Journal Title**	**Subject**
1	1976	Solving Multi criterion Integer Programming Problems [32]	M. Sharif, R.L.Agarwal	Industrial Management, Vol. 18, No.1	classical introductions to the subject
2	1977	Integer Goal Programming Methods [33]	Lee, Sang M. And Morris R.L.	Management Sciences, Vol. 6, pp. 273-289	classical introductions to the subject
3	1980	A Branch-and-Bound Algorithm with Constraint Partitioning for Integer Goal Programming Problems [34]	Arthur J.L., Ravindran A.	European Journal of Operational Research, Vol. 4, No. 6, pp.421-425	introduction of branch-and-bound method
4	1980	On Mixed Integer Solutions to Goal Programming Problems [35]	Sharma J.K., Sharma M.M.	Indian Journal of Pure and Applied Mathematics, Vol. 11, No. 3	all discuss of integer programming
5	1983	GP-GN: An Approach to Certain Large Scale Multi objective Integer Programming Models [36]	Ignizio James P.	Large Scale Systems, Vol.4, pp. 177-188	all new methodologies
6	1985	Fuzzy Multi criteria Integer Programming via Fuzzy Generalized Networks [37]	Ignizio james P., Daniels S.C.	Fuzzy Sets and Systems, Vol. 10, pp. 261-270	a combined methodology with fuzzy GP
7	1986	An Interactive Heuristic Approach for Multi-Objective Integer Programming Problems [38]	Gabbani D., Magazine M.	Journal of the Operational Research Society, Vol. 37, No. 3, pp. 285-291	a combined methodology with heuristics
8	1986	Multi-Stage Lot Sizing in a Serial Production System [39]	Vickery, Shawnee K., Markland Robert E.	International Journal of Production Research, Vol. 24, No. 3, pp. 517-534	all new methodologies
9	1988	A Critical Comment on Integer Goal Programming [40]	Hallefjord A., Jornsten K.	Journal of the Operational Research Society, Vol.39, No. 1, pp. 101-104	all discuss of integer programming
10	1989	Integer Quadratic Goal Programming [41]	Gupta A. K., Sharma J. K.	Journal of the Institution of Engineers (India), Vol.70, No.2, pp. 43-47	a combined methodology with quadratic programming

Table 3.2: 0-1 Goal Programming Studies

0-1 Goal Programming Studies					
	Year	**Article Title**	**Author(s)**	**Journal Title**	**Subject**
1	1978	An Implicit Enumeration Algorithm for Solving Zero-One Goal Programming Problems [42]	Garrod N. W., Moores B.	Omega, Vol. 6, No.1, 374-377	An implicit enumeration method
2	1986	Zero-One Programming with Multiple Criteria [43]	Rasmussen L. M.	European Journal of Operational Research, Vol. 26, No.1, pp. 83-95	All provide new methodologies or innovations
3	1987	A Zero-One Goal Programming Algorithm Using Partitioning and Constraint Aggregation [44]	Lee, Sang M. Luebbe Richard L.	Journal of the Operational Research Society, Vol. 38, no.7 pp. 633-641	A methodology utilizing a partitioning method
4	1988	A Comparison of A Constraint Aggregation and Partitioning Zero-one Goal Programming Algorithm with the Lee and Morris Algorithm [45]	Lee, Sang M. Luebbe Richard L.	Computers and Operations Research, Vol. 15, No. 2, pp.97-102	A comparative evaluation of a variety of methods
5	1988	An Approach to Postoptimality and Sensitivity Analysis of Zero-One Goal Programs [46]	Wilson G. R., Jain H. K.	Naval Research Logistics, Vol.35, No.1, pp. 73-84	All provide new methodologies or innovations
6	1990	A Computational Algorithm for Solving 0-1 Goal Programming with GUB Structures and Its Application for Optimization Problems of a System Reliability [47]	Gen M., Ida K., Lee J. U.	Electronics and Communications in Japan, Part 3, Vol.17 pp. 525-530	All provide new methodologies or innovations

3.5.1 Fuzzy Goal Programming

To deal with uncertainty, many attempts have been made but the most fruitful was the theory of Zadeh. In 1965 Zadeh invented the fuzzy set notion to represent the real world imprecise data [48]. This notion gives us the opportunity to represent mathematically some real world expressions as ‘very high temperature’. The criteria of membership of these expressions are not defined precisely. In other words the adjective ‘high’ is fuzzy because his meaning isn’t fixed by precise numbers. In 1970 Bellman and Zadeh represented some case of decision-making in fuzzy environment. Since the single objective fuzzy linear programming (FLP) study made by Zimmermann in 1976 and multi objective fuzzy linear programming in 1978, the fuzzy theory has been applied to many decision making problem. One of these applications is the fuzzy goal programming (FGP) study of Narsimhan in 1980 with imprecise aspiration levels of fuzzy goals. There are many studies involving different kinds of FGP method to deal with uncertain data about a certain parameter (fuzzy alternatives, fuzzy objective functions, fuzzy deviation functions etc.). The study of Hannan in 1981 represent a fuzzy logic based method where decision maker satisfaction in goal attaining are represented by piecewise linear functions [49]. In 1991, nonlinear membership functions are used in FGP by Yang, Ignizio and Tiwari et al. (1987) proposed a method similar to lexicographic GP where the problem is decomposed into n sub problems. Here, n is the number of preemptive priority levels [50].

To solve our fuzzy goal programming model we use the algorithm proposed by Huey-Kuo Chen which is a modified version of the method developed by Tiwari, Dharmar and Rao in 1993 [51]. The optimal selection process is a resource allocation decision and the selection affects ultimately the recovery amount. 0-1 FGP is a strong method for resource allocation in presence of several objectives and imprecise data. So we manipulate the algorithm by extending it to 0-1 FGP by adding a 0-1 constraint [30].

We consider the special type of fuzzy values, namely, triangular fuzzy numbers with piecewise linear membership functions [52].

A set of goals G is a set of triangular fuzzy numbers, G = $\tilde{T}$, where :

$$\tilde{T} = \left\{ \tilde{g}; \tilde{g} = \left(g, \underline{g}, \overline{g} \right), \underline{g} \geq 0, \overline{g} \geq 0 \right\} \tag{3.5f}$$

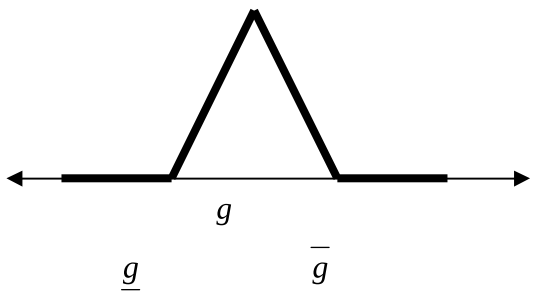

Figure 3.1.Fuzzy Goal

Our solving algorithm uses symmetrically triangular membership functions of fuzzy goals [4]. This means that

$$\left(\overline{g_i} - g_i\right) = \left(g_i - \underline{g_i}\right) = \Delta_i \tag{3.5g}$$

We can represent m imprecise fuzzy goals and membership functions as follows:

$$\begin{aligned}
&G_1 : a_{11}x_1 + a_{12}x_2 + \ldots + a_{1n}x_n \simeq g_1 \\
&G_2 : a_{21}x_1 + a_{22}x_2 + \ldots + a_{2n}x_n \simeq g_2 \\
&\vdots \\
&G_m : a_{m1}x_1 + a_{m2}x_2 + \ldots + a_{mn}x_n \simeq g_m \\
&x_j \geq 0, \;\; j = 1, 2, \ldots, n
\end{aligned} \tag{3.5h}$$

The symbol $\approx$ refers to the fuzzification of the aspiration level. The triangular membership function of this FGP is [49]:

$$\mu_i\left(AX\right) = \begin{cases} 1 & if\,(AX)_i = g_i \\ 0 & if\,(AX)_i \leq \underline{g_i} \\ \dfrac{\left(AX\right)_i - \underline{g_i}}{\Delta_i} & if\ \underline{g_i} \leq (AX) \leq g_i \\ \dfrac{\overline{g_i} - (AX)_i}{\Delta_i} & if\ g_i \leq (AX)_i \leq \overline{g_i} \\ 0 & if\,\overline{g_i} \leq (AX)_i \end{cases} \tag{3.5i}$$

The aim of the method proposed by Tiwari et al. is to find the maximum membership value by enumerating all possible combinations which cover the entire feasible region. As we mentioned before the membership functions are in the form of triangular shape so we must consider two subsets which are left and right hand sides intersecting at the point having the highest membership value equal to 1. Therefore, there will be 2m sub problems taking into account of different combinations of membership functions. Different combinations of membership functions of fuzzy goals can be constructed as [51]:

$$\max_{x\geq 0} \lambda = \left[\min_i \left\{ \frac{(AX)_i - \underline{g}_i}{\Delta_i} \right\} \right]$$

$$\underline{g}_i \leq (AX)_i \leq g_i \qquad i = 1, 2, ..., m \tag{3.5j}$$

and

$$\max_{x\geq 0} \lambda = \left[\min_i \left\{ \frac{\overline{g_i} - (AX)_i}{\Delta_i} \right\} \right]$$

$$g_i \leq (AX)_i \leq \overline{g_i} \qquad i = 1, 2, ..., m \tag{3.5k}$$

As the sub problems are linear with a single objective function, the FGP method has the advantage that a commercially available software as LINDO may be used for solving it. The solution of the original FGP problem is derived from the sub problem which has the highest membership value (λ). In Tiwari et al.'s method membership functions are assumed triangular and symmetric. Symmetrically triangular membership function becomes a linear line within the feasible region which reduces computational load for solving the FGP problem [51].

Chen proposed in his model to render linear the original triangular membership function by using a single line function instead of a piecewise linear function. By minimizing the largest deviation to the highest membership value equal to 1, the best solution is then easily derived [51].

The new formulation of the model is:

$$\max_{x\geq 0} \lambda' = \left[\min_i \left\{ \left| \frac{(AX)_i}{\Delta_i} - 1 \right| \right\} \right],$$

subject to

$$\underline{g}_i \leq (AX)_i \leq \overline{g}_i \qquad i = 1, 2, ..., m \tag{3.5l}$$

or,

$$\max_{x \geq 0} \lambda = 1 - \lambda'$$

subject to

$$\lambda' \geq \frac{(AX)_i}{\Delta_i} - 1, \quad i = 1, \ldots, m$$

$$\lambda' \geq 1 - \frac{(AX)_i}{\Delta_i}, \quad i = 1, \ldots, m$$

$$\underline{g_i} \leq (AX)_i \leq \overline{g}_i \qquad i = 1, 2, \ldots, m \tag{3.5m}$$

3.6 TOPSIS Method

TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) method was developed by Hwang and Yoon (1981) as an alternative to the ELECTRE method. The basic concept of the method is that the selected alternative should have the shortest distance to the ideal solution and the farthest distance to the negative-ideal solution. The Euclidian distance approach was proposed to evaluate the relative closeness of the alternatives to the ideal solution [4]. It solves the dilemma of the choice between ideal and anti-ideal by using an idea that Dasarathy (1976) applies to the data analysis. The TOPSIS method evaluates the decision matrix which refers to m alternatives which are evaluated in terms of n criteria [22].

<u>Stage 1:</u> The standardized values are calculated:

$$r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} x_{ij}^2}} \quad (i = 1, \ldots, m; \ j = 1, \ldots, n) \tag{3.6a}$$

<u>Stage 2:</u> The balanced values are calculated:

$$V_{ij} = w_{ij} * r_{ij} \tag{3.6b}$$

Stage 3: The positive and negative ideal solutions are identified:

$$A^* = \left\{V_1^*, \ldots, V_j^*, \ldots, V_n^*\right\} = \left\{\max V_{ij}, \min V_{ij}\right\} \tag{3.6c}$$

$\max V_{ij}$ for the benefit and $\min V_{ij}$ for the cost.

Stage 4: Separation measures are calculated:

The separation of each alternative of positive ideal solution A^* is given by:

$$S_i^* = \sqrt{\sum_{i=1}^{m}\left(V_{ij} - V_j^*\right)^2} \quad i = 1, \ldots, m \tag{3.6d}$$

The separation of each alternative of negative ideal solution A^- is given by:

$$S_i^- = \sqrt{\sum_{i=1}^{m}\left(V_{ij} - V_j^-\right)^2} \quad i = 1, \ldots, m \tag{3.6e}$$

Stage 5: Relative closeness to the ideal solution is calculated:

$$C_i^* = S_i^- / \left(S_i^- + S_i^*\right), \quad i = 1, \ldots, m \tag{3.6f}$$

Stage 6: Ranking of the preference order

The best alternative can now be decided according to the preference rank order of C_i^*. Therefore, the best alternative is the one that the shortest distance to the ideal solution [4].

3.6.1 Fuzzy TOPSIS Model

In real-world situation, because of incomplete or non-obtainable information, (for example, human judgments including preferences are often vague and cannot estimate his preference with an exact numerical data, the data are often not so deterministic, there for they usually are fuzzy/imprecise, so, we try to extend TOPSIS for fuzzy data [23]. The main advantage of fuzzy formulation compared to the crisp formulation is that the decision maker is not forced to give a precise formulation, for the sake of mathematical reasons, even though he or she might be able or willing to describe the problem in fuzzy terms [53].

The extension of TOPSIS to fuzzy TOPSIS provides a new multi-criteria decision making method compatible with the real world decisions. There are diverse applications of this method in the literature as the evaluation of airline service quality of Sheng-Hshiung Tsaur et al. (2002) [56], selection of expatriate host country of Mei-Fang Chen et al. (2004) [57], bridge risk assessment of Ying-Ming Wang et al. (2006) [60], new product introduction of Cengiz Kahraman et al. (2007) [67], industrial robotic system selection of Cengiz Kahraman et al. (2007) [69] etc. There is a list below including the studies of fuzzy TOPSIS.

Table 3.3: Fuzzy TOPSIS Studies in the literature

FUZZY TOPSIS STUDIES				
	Year	**Article Title**	**Author(s)**	**Journal Title**
1	1994	TOPSIS for MODM[54]	Young-Jou Lai, Ting-Yun Liu and Ching-Lai Hwang	European Journal of Operational Research, Volume 76, Issue 3, 11 August 1994, Pages 486-500
2	2000	Extensions of the TOPSIS for group decision-making under fuzzy environment[55]	Chen-Tung Chen	Fuzzy Sets and Systems, Volume 114, Issue 1, 16 August 2000, Pages 1-9
3	2002	The evaluation of airline service quality by fuzzy MCDM [56]	Sheng-Hshiung Tsaur, Te-Yi Chang and Chang-Hua Yen	Tourism Management, Volume 23, Issue 2, April 2002, Pages 107-115
4	2004	Combining grey relation and TOPSIS concepts for selecting an expatriate host country [57]	Mei-Fang Chen and Gwo-Hshiung Tzeng	Mathematical and Computer Modeling, Volume 40, Issue 13, December 2004, Pages 1473-1490
5	2005	Extensions of TOPSIS for multi-objective large-scale nonlinear programming problems [58]	Mahmoud A. Abo-Sinna and Azza H. Amer	Applied Mathematics and Computation, Volume 162, Issue 1, 4 March 2005, Pages 243-256
6	2006	An interactive algorithm for large scale multiple objective programming problems with fuzzy parameters through TOPSIS approach [59]	Mahmoud A. Abo-Sinna and Tarek H.M. Abou-El-Enien	Applied Mathematics and Computation, Volume 177, Issue 2, 15 June 2006, Pages 515-527
7	2006	Fuzzy TOPSIS method based on alpha level sets with an application to bridge risk assessment [60]	Ying-Ming Wang and Taha M.S. Elhag	Expert Systems with Applications, Volume 31, Issue 2, August 2006, Pages 309-319

8	2006	Extension of the TOPSIS method for decision-making problems with fuzzy data [61]	G.R. Jahanshahloo, F. Hosseinzadeh Lotfi and M. Izadikhah	Applied Mathematics and Computation, Volume 181, Issue 2, 15 October 2006, Pages 1544-1551
9	2007	Multiple attribute decision-making methods for the dynamic operator allocation problem[62]	Taho Yang, Mu-Chen Chen and Chih-Ching Hung	Mathematics and Computers in Simulation, Volume 73, Issue 5, 10 January 2007, Pages 285-299
10	2007	Extensions of TOPSIS for large scale multi-objective non-linear programming problems with block angular structure[63]	Mahmoud A. Abo-Sinna, Azza H. Amer and Ashraf S. Ibrahim	Applied Mathematical Modeling, In Press, Corrected Proof, Available online 31 January 2007
11	2007	Multiple-attribute decision making methods for plant layout design problem [64]	Taho Yang and Chih-Ching Hung	Robotics and Computer-Integrated Manufacturing, Volume 23, Issue 1, February 2007, Pages 126-137
12	2007	Group decision-making based on concepts of ideal and anti-ideal points in a fuzzy environment [65]	Ming-Shin Kuo, Gwo-Hshiung Tzeng and Wen-Chih Huang	Mathematical and Computer Modelling, Volume 45, Issues 3-4, February 2007, Pages 324-339
13	2007	A note on group decision-making based on concepts of ideal and anti-ideal points in a fuzzy environment [66]	Ying-Ming Wang, Ying Luo and Zhong-Sheng Hua	Mathematical and Computer Modeling, In Press, Corrected Proof, Available online 14 February 2007
14	2007	A two phase multi-attribute decision-making approach for new product introduction [67]	Cengiz Kahraman, Gülçin Büyüközkan and Nüfer Yasin Ateş	Information Sciences, Volume 177, Issue 7, 1 April 2007, Pages 1567-1582
15	2007	Generalizing TOPSIS for fuzzy multiple-criteria group decision-making [68]	Yu-Jie Wang and Hsuan-Shih Lee	Computers & Mathematics with Applications, In Press, Corrected Proof, Available online 26 April 2007
16	2007	Fuzzy multi-criteria evaluation of industrial robotic systems [69]	Cengiz Kahraman, Sezi Çevik, Nüfer Yasin Ates and Murat Gülbay	Computers & Industrial Engineering, Volume 52, Issue 4, May 2007, Pages 414-433
17	2007	Compromise ratio method for fuzzy multi-attribute group decision making [70]	Deng-Feng Li	Applied Soft Computing, Volume 7, Issue 3, June 2007, Pages 807-817

Table 3.3: Fuzzy TOPSIS Studies in the literature

Let $A_1, A_2, ..., A_m$ be m alternatives among which we will make the selection, $C_1, C_2, ..., C_n$ be the criteria that are under consideration during the decision making process. $\tilde{x}_{ij}$ is the fuzzy rating of alternative A_i according to the criterion C_j and $\tilde{w}_{ij}$ is the fuzzy weight of each criterion. Fuzzy data used here is triangular fuzzy number. We can express this fuzzy multi criteria decision making problem in matrix format [23]:

$$\begin{array}{c|cccc} & C_1 & C_2 & \cdots & C_n \\ \hline A_1 & \tilde{x}_{11} & \tilde{x}_{12} & \cdots & \tilde{x}_{1n} \\ A_2 & \tilde{x}_{21} & \tilde{x}_{22} & \cdots & \tilde{x}_{2n} \\ \vdots & & & & \\ A_m & \tilde{x}_{m1} & \tilde{x}_{m2} & \cdots & \tilde{x}_{mn} \end{array} \tag{3.6g}$$

$$W = \left[\tilde{w}_1, \tilde{w}_2, \ldots, \tilde{w}_n \right] \tag{3.6h}$$

It is necessary to make comparable the numerical and not-numerical criteria and for this reason we must normalize the decision matrix [55]:

$$\begin{aligned} \tilde{r}_{ij} &= \left(\frac{a_{ij}}{c_j^*}, \frac{b_{ij}}{c_j^*}, \frac{c_{ij}}{c_j^*} \right), \quad j \in benefit \quad criteria \\ \tilde{r}_{ij} &= \left(\frac{a_j^-}{c_{ij}}, \frac{a_j^-}{b_{ij}}, \frac{a_j^-}{a_{ij}} \right), \quad j \in \cos t \quad criteria \end{aligned} \tag{3.6i}$$

Here, $c_j^* = \max_i c_{ij}$, $a_j^- = \min_i a_{ij}$

Thereby, the normalized fuzzy decision matrix $\tilde{R} = \left[\tilde{r}_{ij} \right]_{m \times n}$ is constituted. In decision making process each criterion can have a different importance for the decision maker who will assign different weights to each criterion. A second operation waits to be performed: multiplication of the decision matrix by the weight vector, $\tilde{v}_{ij} = \tilde{r}_{ij} \otimes \tilde{w}_j$ [55].

$$\tilde{V} = \left[\tilde{v}_{ij} \right]_{m \times n}, \quad i = 1, \ldots, m, \quad j = 1, \ldots, n \tag{3.6j}$$

As the elements of the decision matrix and weight vector are triangular fuzzy numbers, the elements of the weighted matrix are also triangular fuzzy numbers. We will define the positive ideal solution A^* and the negative ideal solution A^- [55]:

$$A^{*} = \left(\tilde{v}_1^{*}, \tilde{v}_2^{*}, ..., \tilde{v}_n^{*}\right) \quad (3.6k)$$

$$A^{-} = \left(\tilde{v}_1^{-}, \tilde{v}_2^{-}, ..., \tilde{v}_n^{-}\right) \quad (3.6l)$$

Then, we have to calculate the distance of each alternative to A^{*} and A^{-}, by using the formula of distance between two fuzzy numbers [55].

$$d_i^{*} = \sum_{j=1}^{n} d\left(\tilde{v}_{ij}, \tilde{v}_j^{*}\right), \quad i = 1, ..., m \quad (3.6m)$$

$$d_i^{-} = \sum_{j=1}^{n} d\left(\tilde{v}_{ij}, \tilde{v}_j^{-}\right), \quad i = 1, ..., m \quad (3.6n)$$

The distance between two fuzzy numbers is calculated as:

$$\tilde{x} = (a_1, b_1, c_1), \quad \tilde{y} = (a_2, b_2, c_2),$$

$$d(\tilde{x}, \tilde{y}) = \sqrt{\frac{1}{3}\left[\left(a_1 - a_2\right)^2 + \left(b_1 - b_2\right)^2 + \left(c_1 - c_2\right)^2\right]} \quad (3.6o)$$

A relative closeness index between d_i^{*} and d_i^{-} is calculated to determine the ranking order of alternatives [54,22]:

$$R_i = \frac{d_i^{-}}{d_i^{*} + d_i^{-}}, \quad i = 1, ..., m \quad (3.6p)$$

3.6.2 Fuzzy Membership Function

During the decision making process in the presence of fuzzy data, decision makers use the linguistic variables to evaluate the ratings of alternatives according to various criteria [64]. Each rank is assigned to a membership function. A transformation table is below [64]. The linguistic variables are classified from extremely low to extremely high [55]. For example, the fuzzy variable Low to Medium is associated with triangular fuzzy number

(0,3; 0,4; 0,5); where 0,3 is the minimum, 0,4 is the mode and 0,5 is the maximum. Fig 3.1 illustrates the fuzzy membership functions [64].

Table 3.4: Linguistic Variables [54]

Extremely Low (EL)	(0; 0; 0,1)
Very Low (VL)	(0; 0,1; 0,2)
Low to Very Low (LVL)	(0,1; 0,2; 0,3)
Low (L)	(0,2; 0,3; 0,4)
Low to Medium (LM)	(0,3; 0,4; 0,5)
Medium (M)	(0,4; 0,5; 0,6)
Medium to High (MH)	(0,5; 0,6; 0,7)
High (H)	(0,6; 0,7; 0,8)
High to Very High (HVH)	(0,7; 0,8; 0,9)
Very High (VH)	(0,8; 0,9; 1)
Extremely High (EH)	(0,9; 1; 1)

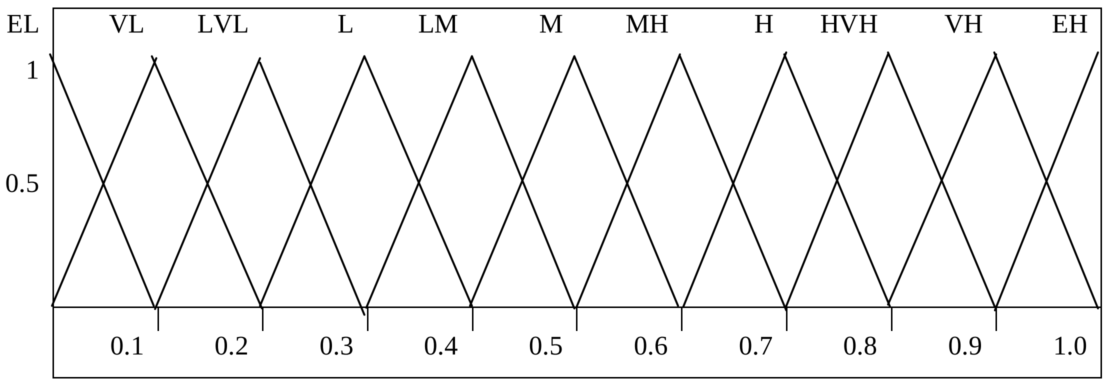

Figure 3.2: Fuzzy Triangular Membership Functions

The fuzzy linguistic variable is transformed into a fuzzy triangular membership function following the assignments of table 3.4

4. APPLICATION

This study will help us to understand which collection method is the best for Turkey. Since the paper and the carton paper are the most produced exploitable solid waste in Turkey, it seemed adequate to observe this system. Based on the data received from an institution executing the system of collection from manufacturers we will illustrate the current situation. Then, we will observe other alternatives by using data received from Ministry of Environment and Forestry (MEF) of Turkey. The application part of the study includes the selection of the best collection method by using fuzzy goal programming (FGP) approach and then fuzzy TOPSIS approach.

These two applications will allow us to find out which collection method is most effective under the present circumstances and also to take together a multi-objective decision making model and a multi-criteria decision making model. The examination of two different segments of decision making will reveal the strengths of each method to solve such problems.

This part is also the terminal stage of the solid waste collection system analysis of Turkey. It will strengthen the theoretical information and the data obtained by an extensive observation. For a product reuse system, to achieve an environmental performance that is essential to optimize all parts of the system. As mentioned before the collection and the transportation constitute the most expensive part of the system. They are also extremely important for the recycling rate.

4.1 Usage of Fuzzy Goal Programming

4.1.1 Decision Variables

We express the variables as x_i ($i = 1, 2, 3$) which correspond to 3 waste paper collection methods. We define x_i = 1 if method i is selected and 0 otherwise. The collection methods mentioned are collection by one garbage pail and separation, separate collection at source, current situation which are described at the second part of the study. The study enclose whole Istanbul city with his 33 districts. The selection process involves 3 fundamental objectives: Cost objective, Recovery objective and land-filling objective. Minimization of cost and maximization of material recycled are two conflicting objectives. On the other hand maximization of material recovered and minimization of material going to land-filling are two objectives parallel. Under the assumptions of MEF, we will construct the problem by considering these two objectives as one. All data used in this study is the data of year 2007.

4.1.2 Cost Objective

Collection by one garbage pail and separation method requires additional cost to current situation for labor cost of separation facility. Collection cost of this method is identical with current situation. Separate collection at source requires additional cost of collection because we need specific garbage pail for every category of waste like paper; glass etc. and we also need specific garbage cart which is able to transport different kind of waste without mixing them. Or in that case, there is no additional labor cost for separation. As separation cost we only consider the paper separation.

Table 4.1: Cost item for different collection methods

NTL(New Turkish Lira)	**Separate Collection at source**	**Collection by one garbage pail and separation**	**Current Method**
Container Cost	17 183 430	10 312 500	10 312 500
Gasoline Cost	19 958 364	39 916 728	19 958 364
Labor Cost	14 795 784	36 390 492	22 245 423
TOTAL	51 937 578	86 619 720	52 516 287

The labor costs for collection are identical for each collection method but in the first collection method there is extra costs for transportation because each material is transported separately which means that there are many waste collection vehicle and many garbage man. On the other hand second collection method namely collection by one garbage pail and separation requires a separation process which means extra costs for the separation facility laborer. The table below detail the labor cost for each collection method:

Table 4.2: Detailed Labor Costs

NTL(New Turkish Lira)		**Current Method**	**Collection by one garbage pail and separation**	**Separate Collection at source**
Labor Cost	***Collection***	14.795.784	14.795.784	14.795.784
	Separation	-	16.662.780	-
	Transportation	7.449.639	4.931.928	-
TOTAL		22.245.423	36.390.492	14.795.784

Generally, municipalities determine approximately 10 NTL/ton as budgetary target of waste collection. Considering the reports of Ministry of Environment and Forestry about waste composition, collection and recovery in Turkey and the data of municipality of Istanbul, the quantity of waste collected in Istanbul is 4 745 000 ton per year.

We are seeking to minimize all deviations of our goal. This means that all of our spending to collect the waste must be equal to the budget determinated by the Ministry of Environment and Forestry. The uncertainty in determining the budget is handled by the fuzzy data $\left(g, \underline{g}, \overline{g}\right)$. The experts give us a nearly value for the budget: Budget allocated to the waste collection in 2007 $\approx$ 52,195,000 NTL (New Turkish Liras)

4.1.3 Recovery Percentage Objective

According to data of MEF of Turkey the waste recovery of Istanbul in 2006 with current collection method is 30%. The recovery amount increase 10% with the collection by one garbage pail-separation method and 15% with the separate collection at source method. They become 33% and 34.5% respectively. Even though the five-year plans are made for the recovery target, the expectations of recovery percentage are uncertain. So the expected recovery percentage for 2007 is also a fuzzy number: the expected recovery percentage $\approx$ 32.5 %.

4.1.4 Solution Procedure

The mathematical model of our collection method selection problem is constructed using the equation (3.5h)

$$G_1 : 51,937,578x_1 + 86,619,720x_2 + 52,516,287x_3 \approx 52,195,000$$

$$G_2 : 0,33x_1 + 0,345x_2 + 0,3x_3 \approx 0,325$$

$$x_1, x_2, x_3 \geq 0$$

We will find the solution for the goals above by using the revised algorithm of Tiwari et al. by Huey-Kuo Chen. The membership function of recovery percentage objective is below:

$$\mu_1(G_1) = \begin{cases} 1 & , if\; 0.33x_1 + 0.345x_2 + 0.3x_3 = 0.325 \\ 0 & , if\; 0.33x_1 + 0.345x_2 + 0.3x_3 \leq 0.3 \\ \dfrac{0.330x_1 + 0.345x_2 + 0.300x_3 - 0.300}{0.025} & , if\; 0.3 \leq 0.33x_1 + 0.345x_2 + 0.3x_3 \leq 0.325 \\ \dfrac{0.350 - (0.330x_1 + 0.345x_2 + 0.300x_3)}{0.025} & , if\; 0.325 \leq 0.33x_1 + 0.345x_2 + 0.3x_3 \leq 0.35 \\ 0 & , if\; 0.33x_1 + 0.345x_2 + 0.3x_3 \geq 0.35 \end{cases}$$

As mentioned in the membership function above the expected recovery percentage is expressed as $(0.300, 0.325, 0.350)$.

The membership function of budget objective is below:

$$\mu_2\left(G_2\right)=\begin{cases} 1, if\ 51{,}937{,}578x_1+86{,}619{,}720x_2+52{,}516{,}287x_3=52{,}195{,}000 \\ 0, if\ 51{,}937{,}578x_1+86{,}619{,}720x_2+52{,}516{,}287x_3\le 47{,}450{,}000 \\ \dfrac{51{,}937{,}578x_1+86{,}619{,}720x_2+52{,}516{,}287x_3-47{,}450{,}000}{4{,}745{,}000} \\ if\ 47{,}450{,}000\le 51{,}937{,}578x_1+86{,}619{,}720x_2+52{,}516{,}287x_3\le 52{,}195{,}000 \\ \dfrac{56{,}940{,}000-\left[51{,}937{,}578x_1+86{,}619{,}720x_2+52{,}516{,}287x_3\right]}{4{,}745{,}000} \\ if\ 52{,}195{,}000\le 51{,}937{,}578x_1+86{,}619{,}720x_2+52{,}516{,}287x_3\le 56{,}940{,}000 \\ 0, if\ 51{,}937{,}578x_1+86{,}619{,}720x_2+52{,}516{,}287x_3\ge 56{,}940{,}000 \end{cases}$$

As mentioned in the membership function above the budget is expressed as $\left(47{,}450{,}000;52{,}195{,}00;56{,}940{,}000\right)$.

By solving the 2^2 = 4 sub problems by using the data given above we obtain the results in the table 4.3. The optimal choice is the first collection method which is the separate collection at source. As the sub problems are linear with a single objective function, the FGP method has the advantage that a commercially available software as LINDO may be used for solving it. The sub problem 1 is given below as an example.

Sub problem 1:

$\max \lambda$

st.

$\lambda \leq 13.2x_1 + 13.8x_2 + 12x_3 - 12$

$\lambda \leq 10.95x_1 + 18.26x_2 + 11.07x_3 - 9$

$0.300 \leq 0.330x_1 + 0.345x_2 + 0.300x_3 \leq 0.325$

$9 \leq 10.95x_1 + 18.26x_2 + 11.07x_3 \leq 10$

$x_1, x_2, x_3 \in \{0,1\}$

Table 4.3: Results

Results / Sub problems	Optimum Membership Value	Collection Method Selected
1. sub problem	Infeasible	-
2. sub problem	0.9999	X1
3. sub problem	Infeasible	-
4. sub problem	0.9460	X1

The method is illustrated by the waste paper collection system selection in Istanbul. This example demonstrated us that the current collection method in Istanbul is not the best suitable neither for the budget target nor for the recovery rate. The separate collection at source is a better method with his low cost and high recovery rate.

4.2 Usage of Fuzzy TOPSIS

An expert has evaluated tree collection methods according to six criteria which are:

C_1: Recovery rate; the amount of waste recovered / the amount of exploitable waste produced for each collection method alternative.

C_2: Costs; labor, transportation and container costs of each collection method

C_3: Difficulty of application; the difficulty of application related to laborers and to the public

C_4: Environment Consciousness; the cleanliness and sensibility of each collection method

C_5: Extra costs; for example cost of instruction and presentation, and many other costs

C_6 : Compatibility to legal arrangements; compatibility to new legal arrangements emanates from the European Union Law.

The alternatives are:

A_1 : Separate collection at source

A_2 : Collection by one garbage pail and separation

A_3 : Current method

The table below is the evaluation matrix of the expert made according to the linguistic variables of Table 3.3:

Table 4.4: Evaluation Matrix of the Expert

	C1	C2	C3	C4	C5	C6
A1	VH	MH	EH	EH	VH	EH
A2	EH	VH	EL	LM	EL	HVH
A3	M	H	EL	LM	EL	EL

Then the tables below are respectively the decision matrix constituted by the fuzzy values of each linguistic variable assigned by the expert to evaluate each alternative according to each criterion, the normalized decision matrix, the tables of weight of each criterion determined by the expert and the normalized weighted decision matrix:

Table 4.5: Decision Matrix

rij	C1			C2			C3		
	a1	b1	c1	a2	b2	c2	a3	b3	c3
A1	0,90	1,00	1,00	0,50	0,60	0,70	0,90	1,00	1,00
A2	0,80	0,90	1,00	0,80	0,90	1,00	0,00	0,00	0,10
Â3	0,40	0,50	0,60	0,60	0,70	0,80	0,00	0,00	0,10

rij	C4			C5			C6		
	a4	b4	c4	a5	b5	c5	a6	b6	c6
A1	0,90	1,00	1,00	0,80	0,90	1,00	0,90	1,00	1,00
A2	0,30	0,40	0,50	0,00	0,00	0,10	0,70	0,80	0,90
Â3	0,30	0,40	0,50	0,00	0,00	0,10	0,00	0,00	0,10

Table 4.6: Normalized Decision Matrix

rij	C1			C2			C3		
	a1	b1	c1	a2	b2	c2	a3	b3	c3
	BENEFIT			COST			COST		
A1	0,83	1,00	1,00	1,00	0,80	0,60	0,10	0,00	0,00
A2	0,67	0,83	1,00	0,40	0,20	0,00	1,00	1,00	0,90
Â3	0,00	0,17	0,33	0,27	0,60	0,40	1,00	1,00	0,90
rij	C4			C5			C6		
	a4	b4	c4	a5	b5	c5	a6	b6	c6
	BENEFIT			COST			BENEFIT		
A1	0,86	1,00	1,00	0,20	0,10	0,00	0,90	1,00	1,00
A2	0,00	0,14	0,29	1,00	1,00	0,90	0,70	0,80	0,90
Â3	0,00	0,14	0,29	1,00	1,00	0,90	0,00	0,00	0,10

Table 4.7: Weights of Each Criterion

Criteria	C1			C2			C3		
Weight	EH			EH			H		
Weight	0,90	1,00	1,00	0,90	1,00	1,00	0,60	0,70	0,80
Criteria	C4			C5			C6		
Weight	MH			M			H		
Weight	0,50	0,60	0,70	0,40	0,50	0,60	0,60	0,70	0,80

Table 4.8: Weighted Normalized Decision Matrix

	C1			C2			C3		
	a1	b1	c1	a2	b2	c2	a3	b3	c3
A1	0,750	1,000	1,000	0,540	0,800	1,000	0,000	0,000	0,080
A2	0,600	0,833	1,000	0,000	0,200	0,400	0,540	0,700	0,800
A3	0,000	0,167	0,333	0,360	0,600	0,267	0,540	0,700	0,800
	C4			C5			C6		
	a4	b4	c4	a5	b5	c5	a6	b6	c6
A1	0,429	0,600	0,700	0,000	0,050	0,120	0,540	0,700	0,800
A2	0,000	0,086	0,200	0,360	0,500	0,600	0,420	0,560	0,720
A3	0,000	0,086	0,200	0,360	0,500	0,600	0,000	0,000	0,080

The positive and the negative ideal solutions are determined:

$$A^{*} = \{(0.75,1.00,1.00);(0.54,0.80,1.00);(0.54,0.70,0.80);$$
$$(0.43,0.60,0.70);(0.36,0.50,0.60);(0.54,0.70,0.80)\}$$

$$A^{-} = \{(0.00,0.17,0.33);(0.00,0.20,0.40);(0.00,0.00,0.08);$$
$$(0.00,0.09,0.20);(0.00,0.05,0.12);(0.00,0.00,0.08)\}$$

Now we calculate the distance of each alternative to A^* and A^- (3.6m), (3.6n) by using the equation (3.6o):

$$d_1^* = \sqrt{\frac{1}{3}\left[(0.75-0.75)^2+(1.00-1.00)^2+(1.00-1.00)^2\right]}+$$
$$\sqrt{\frac{1}{3}(0.54-0.54)^2+(0.80-0.80)^2+(1.00-1.00)^2}+$$
$$\sqrt{\frac{1}{3}(0.00-0.54)^2+(0.00-0.70)^2+(0.08-0.80)^2}+$$
$$\sqrt{\frac{1}{3}(0.43-0.43)^2+(0.60-0.60)^2+(0.70-0.70)^2}+$$
$$\sqrt{\frac{1}{3}(0.00-0.36)^2+(0.05-0.50)^2+(0.12-0.60)^2}+$$
$$\sqrt{\frac{1}{3}(0.54-0.54)^2+(0.70-0.70)^2+(0.80-0.80)^2}$$

Where,

$d_1^* = 1.092$

$d_2^* = 1.309$

$d_3^* = 2.345$

$$d_1^- = \sqrt{\frac{1}{3}\left[(0.75-0.00)^2+(1.00-0.17)^2+(1.00-0.33)^2\right]}+$$
$$\sqrt{\frac{1}{3}(0.54-0.00)^2+(0.80-0.20)^2+(1.00-0.40)^2}+$$
$$\sqrt{\frac{1}{3}(0.00-0.00)^2+(0.00-0.00)^2+(0.08-0.08)^2}+$$
$$\sqrt{\frac{1}{3}(0.43-0.00)^2+(0.60-0.09)^2+(0.70-0.20)^2}+$$
$$\sqrt{\frac{1}{3}(0.00-0.00)^2+(0.05-0.05)^2+(0.12-0.12)^2}+$$
$$\sqrt{\frac{1}{3}(0.54-0.00)^2+(0.70-0.00)^2+(0.80-0.08)^2}$$

Where,

$d_1^- = 2.473$

$d_2^- = 2.287$

$d_3^- = 1.417$

A relative closeness index between d_i^* and d_i^- is calculated with the equation (3.6p):

$$R_1 = \frac{2.473}{(1.092 + 2.473)} = 0.69$$

$R_2 = 0.64$

$R_3 = 0.38$

The ranking of decision are mentioned in the table below. As it seen, the seperate collection at source is the best collection method and the current method is the worst. The best collection method selected in this application is compatible with the result of the fuzzy goal programming application.

Table 4.9 : Ranking of Alternatives

	d_i^*	**Ranking**	d_i^-	**Ranking**	R_i	**Ranking**
A1	1,092	1	2,473	1	0,694	1
A2	1,309	2	2,287	2	0,636	2
A3	2,345	3	1,417	3	0,377	3

5. CONCLUSION

Reverse logistic process are complex systems where decision making is complicated by multi conflicting objectives and imprecision of data. Reverse Logistic, the process of planning, implementing, and controlling the efficient, cost effective flow of raw materials, in-process inventory, finished goods and related information from the point of consumption to the point of origin for the purpose of recapturing value or proper disposal. More precisely, reverse logistics is the process of moving goods from their typical final destination for the purpose of capturing value, or proper disposal [5].

Reverse logistics is a new and emerging area consisted of many activities as collection, separation, reprocessing, disposal etc. The estimation of the size of reverse logistic is hard because it is a reverse process where the providers are consumers. The huge amount of providers and the lack of production plan render this process hard to handle. The algorithm proposed in this paper handles effectively the imprecision of data with fuzzy set theory.

The specific steps of the reverse logistics process begin with the collection of finished goods. Collection refers to all activities rendering used products available and physically moving them to some point where further treatment is taken care of [1]. The purpose of this study is to find the best collection method in as solid waste recovery system. Since the paper and the carton paper are the most produced exploitable solid waste in Turkey, it seemed adequate to observe this system. The application part of the study includes the selection of the best collection method by using two different decision making methods: fuzzy GP and fuzzy TOPSIS.

Fuzzy goal programming method (FGP) is a multi-objective decision making method effective in resource allocation problem solving. The optimal selection process is a resource allocation decision and the selection affects ultimately the recovery amount. 0-1 FGP is a strong method for resource allocation in presence of several objectives and imprecise data. In this study we extended the FGP method of Huey-Kuo Chen to 0-1 FGP and we observed that the method succeeded to select the best collection method in other words to allocate the waste collection budget to one of the collection methods. Goal programming derives a unique solution by specifying goals or preferences. GP is generally utilized where there are a number of competing goals or objectives. The overall aim is to meet all the criteria or goals to the greatest extent possible, to choose the most desirable plan from a set of possible options. GP is a very effective method when the decision maker rather knows his targets. Because GP model is a multiple objective model it requires additional assumptions regarding the decision process employed by the decision maker [29]. Sometimes, this characteristic can be the weak side of GP. Because in the real life decisions there are also criteria or goals to what we cannot assign exact numbers, namely qualitative criteria. At that point a multi-criteria decision making method can be stronger. We could extend this study with a GP model involving also the system constraints, and then the usage of GP would have been more meaningful. In this study, considering the attainable data, it is more convenient to make a decision with a multi-criteria decision making method.

TOPSIS, developed by Hwang and Yoon (1981), is a flexible decision making method, which is useful in the resolution of complex multiple criteria decision making problems when quantitative and qualitative data are implied. So we could insert new qualitative criteria in the decision making problem. The weaknesses of TOPSIS method is the need of an expert which interrupts and complicates the decision making process.

The two method compromise at the same alternative: the separate collection at source. This is the waste collection strategy adopted by many other country related to his cleanliness and environment consciousness. This example demonstrated us that the current collection method in Istanbul is not the best suitable neither for the budget target nor for the recovery rate. The separate collection at source is a better method with his lower cost and higher recovery rate. Furthermore the fuzzy TOPSIS method requires us a ranking of all alternatives. This ranking does not only demonstrate that the current collection method is not the best method but also that it is the worst. So we can conclude that the waste collection system in Turkey needs serious revisions.

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